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# Iran Conference on the TRANSFER OF NUCLEAR TECHNOLOGY

Persepolis/Shiraz

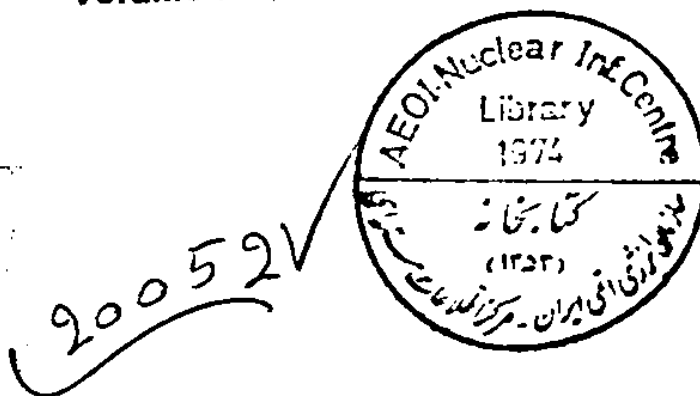
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# **EXPERIENCE IN MANPOWER TRAINING**

## **PARALLEL SESSION**

**Co-Chairmen: E. Perryman (*AECL/Canada*)  
P. Saeedi (*INECO/Iran*)**



## IS NUCLEAR ENERGY ACCEPTABLE<sup>1</sup>

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That the acceptability of nuclear energy is shadowed by doubt is painful to those of us who have devoted our careers to peaceful nuclear energy. Twenty-five years ago we were hailed as harbingers of a new and more abundant age based upon nuclear energy; today many of us feel like Horatio at the bridge. Often we find ourselves subjected to abuse, to accusations of dishonesty or cowardice, because we continue to insist, despite noisy protests, that nuclear energy is a good thing, not a bad thing; and that it is man's great good fortune to have come upon this miracle at the same time we began depleting fossil fuels at an alarming rate.

The opposition to nuclear energy is hardening. These words are being written as the voters of California are preparing to decide whether or not to impose a moratorium on nuclear energy. Similar actions are at various stages in more than twenty other states. Ralph Nader, among others, has committed himself to abolition of nuclear energy. There is a non-zero chance that the public will turn away from nuclear energy, that those who are intent on abolishing nuclear energy may succeed in so doing. Indeed, what began as a debate on nuclear energy has taken on the aspect of a war of annihilation.

It is, as Senator John O. Pastore of Rhode Island is alleged to have said, easier to scare people in describing nuclear energy as a Faustian bargain<sup>2</sup> - that is, an arrangement in which man promises meticulous and persistent attention to detail in exchange for an inexhaustible and, in principle, a non-polluting energy source.

My purpose here will be twofold. First, I shall try to unscare people - that is, to place the hazard of nuclear energy in perspective. For unless we unscare the public, I believe the chance of losing the nuclear option is real. My second purpose is farther-reaching. It is to set forth proposals for the future development of nuclear energy that might serve as the basis for compromise between the opponents and proponents of nuclear energy.

### - Is Nuclear Energy Desirable ? -

If none of the products of fission were radioactive, or if plutonium were neither radioactive nor capable of sustaining a fast neutron chain reaction (and therefore were not a nuclear explosive), there would be little question about nuclear energy being at least as desirable as fossil-based energy. The most recent estimates of the costs of electricity generated in large plants completed in the late 1970's are about 22 mills/kWhr for nuclear and coal-fired plants, about 28 mills for oil-fired plants. These numbers are based on 70 percent plant

capacity factors, coal at \$20 per ton, oil at \$12 per barrel. For plants completed in 1985 the average costs during the first ten years of plant life are 38, 42, and 55 mills/kWhr, respectively.<sup>3</sup>

Estimates of capital costs of coal and nuclear power plants built in 1985 are hardly reliable. Barry Commoner,<sup>4</sup> for example, asserts that nuclear plants by then will be too expensive to compete with fossil plants. But in his estimates he forgot that coal plants using high sulfur Eastern coal will require expensive scrubbers, and that low sulfur Western coal, burned in the East, is expensive. It appears that nuclear plants will continue to be competitive in the 1980's, though this could change if scrubbers prove unnecessary or if the price of coal falls.

Over the long term, we hardly have an alternative to a non-fossil fuel. The overwhelming squeeze that we face is the shortage of oil and gas. Even if our energy demand to the year 2000 increases by only 70 percent (to 120 quads\* or 20 billion barrels of oil equivalent), i.e., at an average increase of 2 percent per year, we shall seriously deplete our oil and gas by the early 21st century. We shall turn first to synthetics from coal and shale; but by the early 21st century, assuming, say, 100 quads come from coal, we shall be using more than 4,000,000,000 tons of coal per year. At this rate, our coal reserve of, say, 600,000,000,000 tons begins to look not so large - quite apart from the environmental damage that would result from so much coal mining.

An alternative to fossil fuel is almost surely needed, even with the conservation that is implied in reducing our growth of energy from 4.5 percent per year to 2 percent annually. The alternatives we visualize now are geothermal, fusion, solar, and fission. Geothermal will surely be used more extensively, but it is a relatively small source of energy; fusion has yet to be shown to be feasible; solar and its children (wind, waves, ocean thermal gradients, bioconversion) as sources of electricity are in many cases intermittent and appear to be either very expensive (electricity from a solar-driven steam system would cost 80 mills per kilowatt-hour according to Minneapolis Honeywell)<sup>5</sup> or small (wind). Only fission seems to have been demonstrated both technically and economically. It is, I believe, irresponsible and dangerous for nuclear abolitionists to imply that solar electricity is clearly a tenable alternative - and one that would not cost the society very heavily - should we turn away from fission as they advocate.

What about the environmental impacts of fission? Properly operating reactors and their supporting subsystems damage the environment far less than do conventional coal-fired power plants. The routine emissions - now limited to 5 millirem per year to individuals at the plant boundary - represent less than 5 percent of the natural background radiation. Mining and milling of uranium is, per unit of energy extracted, far less dangerous to health than is conventional coal mining;<sup>6</sup> and, because uranium is a concentrated fuel, its extraction does less damage to the environment than does strip mining of coal. It

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\* 1 quad =  $10^{15}$  BTU

is true, on the other hand, that light water reactors, operating at 30 percent thermal efficiency, throw out 50 percent more heat than does a fossil plant operating at 40 percent efficiency.

To summarize, nuclear reactors when properly operating represent a superb long-term source of prime energy: they are probably as cheap as if not cheaper, and do less violence to the environment, than does any other large-scale prime source of thermal energy.

#### - The Hazards of Nuclear Energy -

But nuclear reactors do produce immense amounts of radioactivity: plutonium is an explosive; and reactors will not always operate properly. Thus, we are assuming certain risks when we opt for nuclear power. Are the risks worth the benefits?

The major argument against nuclear energy by the nuclear abolitionists is that the meticulous attention to detail that is demanded by nuclear energy is beyond man's capability. If a serious accident should occur, or if fissile material were diverted to a bomb, the nuclear enterprise would very possibly be terminated. Therefore, say the critics, it is better to halt the enterprise now when it is relatively small and not risk a shut-down of a major source of energy than to become too dependent on what some consider an undependable source of energy.

The issue, then, is twofold: would an accident be likely to shut down the industry, and what indeed are the probabilities of a major accident?

To first question, I would say yes: a very serious reactor accident, one that caused many people to die, would probably shut down the industry at this time, especially with such escalated concerns. Thus the aim of the nuclear enterprise must be to avoid, at all costs, a really serious nuclear accident, one that affects many people adversely. In a way, the situation is rather like nuclear war: the strategy is to avoid rather than "win" a nuclear war. Our whole military posture has failed if we get into a nuclear war; analogously, our reactor strategy has failed if we allow a serious accident.

The second question, what is the probability of a major accident, is by its very nature unanswerable in a strict scientific sense. The most serious attempt to quantify the risk of accident from a light water reactor (LWR)<sup>7</sup> has been made by Professor Norman Rasmussen of MIT in an extensive study sponsored by AEC.

First, however, let me provide some background. An LWR operating 1000 MW electric has an inventory of 10,000,000,000 curies of radioactivity. Because of the afterheat caused by radioactive decay, it is necessary to continue cooling of the reactor even after the chain reaction has stopped. Normally, this energy is taken care of by the regular cooling system. Suppose the cooling system is lost? In that event, the so-called emergency core cooling system (ECCS) springs into action to keep the reactor cool until the residual heat decays.

But suppose the ECCS fails - an unlikely, though not impossible, contingency. It had

been generally assumed that the failure of emergency core cooling following a loss-of-coolant accident would automatically lead to the China Syndrome: the fuel might slump into a molten mass that would eat through the containment and spread catastrophic radioactive contamination.

The main result of the Rasmussen study is to dispel this oversimplification. Even if the ECCS should fail, aboveground containment usually is not breached, at least in the PWR; moreover, even if containment is breached, the large majority of cases lead to an accident that is far less serious than that predicted in the old WASH-740 report.<sup>8</sup> More specifically, Rasmussen predicts that the probability of a meltdown in a pressurized water reactor is one in 20,000 per reactor per year, and most of these meltdowns would not breach the main containment above the reactor. The risk to an individual of being fatally injured by an accident in 100 light water reactors is not greater than one in 5,000,000,000 per year. This is to be compared with the risk of fatality from hurricanes in the U.S. (one in 2,500,000 annually) or from motor vehicles (one in 4000 per year). The worst accident, which Rasmussen estimates might happen once in 1,000,000,000 years per reactor, might cause 3300 immediate fatalities, about 10 times that number of early illnesses, some additional genetic effects and long-term cancers, and perhaps \$14,000,000,000 in property damage.

The Rasmussen study has been praised and criticized - mainly on the grounds that uncertainties of unknown origin are inherent in any such estimates, and that the dangers may be underestimated by a large factor. Rasmussen himself states that the uncertainty in estimating the frequency of nuclear events lies between 1/5 and 5, the uncertainty in estimating consequences between 1/4 and 4. One again can never totally refute such arguments: what is, in principle, unknowable is unknowable; and there is no way to settle the issue scientifically. We are dealing here with trans-science, not with science.<sup>9</sup> But this much is essential and has been proved by Rasmussen: the oversimplified view that failure of ECC automatically spells catastrophe - i.e., that containment and ECCS are really in parallel, not in series, was wrong. Yet it was precisely this point that underlay the lengthy and controversial hearings on emergency core cooling systems. Was ECCS absolutely necessary to prevent catastrophe? The answer of Rasmussen is no; even if ECCS should fail, most of the time the damage to the public would be relatively minor.

Two points are illustrated here. First, is that we are still learning things about nuclear reactors; and indeed, the nuclear community is committed to increasing the safety of its devices. Rasmussen's results strongly suggest that reactors already are "safe enough" in the sense that the likelihood of something serious happening with those reactors that are now deployed is so small as to make it unnecessary to go back and extensively re-fit those we already have on line.

But what about the inherent conflict between our desire to make reactors as "cheap as possible" (a desire that is independent of whether the reactor is built in a socialist or capitalist country) and the requirement to make the reactor as "safe as possible"? Again, this is not an issue that can be resolved scientifically; this is a trans-scientific matter that is

inherently adjudicable only by the interplay of conflicting social forces. It is because of this inherent conflict that I generally favor the recent modification of the Price-Anderson Indemnity provisions of the Atomic Energy Act.<sup>10</sup> The original law limited the liability that can arise from a nuclear accident. This liability was set at \$560,000,000, of which the Government now provides \$440,000,000. In exchange for limit of liability, the insurance is no-fault - i.e., claimants are not required to sue for redress.

Price-Anderson in some respects is now an anachronism. I see no reason why the industry itself should not pay for the entire insurance - and indeed, the new Price-Anderson law calls for retroactive premiums of \$2,000,000 to \$5,000,000 per reactor, to be paid after an accident that causes damage that exceeds what is covered through regular insurance.

But this is still not good enough. I believe we should recognize that in nuclear energy we have an almost unique situation: very small probability of very great damage. The Rasmussen report suggests that the probability of an accident in 100 present-day reactors causing \$1,000,000,000 property damage is about one in 1,000,000 (though there is considerable uncertainty in both of these numbers). I would argue that up to some number such as this, the industry accept the entire risk - say by retroactive assessment of premiums on all reactors after an accident has occurred. Beyond this - say for accidents that cost more than \$1,000,000,000 damage, I propose that the Government assume responsibility, as it now does in the case of floods and other natural disasters. By placing large, but not bankrupting, liability on the utility, one certainly places pressure on the utility to weigh the safe-as-possible-cheap-as-possible balance on the side of safety. On the other hand, by explicitly making the Government the insurer of last resort, one protects the public in those accidents that might bankrupt the reactor operator. Of course, the utilities would pay insurance to the Government for this ultimate protection; what this premium should be would be determined actuarially. According to Rasmussen's calculations and standard actuarial procedures, to insure against an accident that caused \$14,000,000,000 property damage and 3300 fatalities (at \$1,000,000 per fatality) would cost only a few thousand dollars per year per reactor.

What I propose here amounts to placing extremely unlikely accidents in the category of Acts of God. This flies against judicial tradition that holds the owner of a device responsible, regardless of the improbability of an accident. Yet reactors do pose an almost unprecedented situation, and I would think new principles of jurisprudence are needed to handle the very-small-risk-very-great-damage situation. Moreover, this proposal makes the Government the insurer of last resort; it could be viewed as a natural extension of present disaster insurance policy, modified for the almost unique risk posed by nuclear energy.

I have been careful to qualify my description of reactor risks as almost unique. Nuclear energy poses a risk because so much energy is concentrated in a reactor. But this is true of other power plants, most notably large dams. The gravitational energy contained in Hoover Dam is enormous, some 10,000,000,000 kilowatt-hours, i.e., equal to the



energy generated in a 1,000,000-kilowatt reactor operating for a year. It has been estimated by David Okrent et al. at UCLA<sup>11</sup> that the failure of the Folsom Dam on the American River above Sacramento would cause the death of 260,000 people; the probability of this happening is one in 100 per year - an immensely greater probability than the probability of a nuclear reactor grossly malfunctioning. Failure of dams is something to which we have somehow become accustomed. The Johnstown flood, which resulted from a dam failure, and the Vajont disaster, which resulted from the slide of a mountain into the reservoir which then gushed over the dam, each killed 2000 people, in addition to causing considerable property damage.

The risks associated with coal-fired power plants are, of course, large; B.L. Cohen<sup>12</sup> has estimated that a 1000-MW coal-fired power plant might kill, each year, some 70 people by emission of SO<sub>2</sub> and other noxious fumes. This is in addition to the damage done as the result of underground coal mining. Several hundred thousand coal miners now receive compensation for black lung disease.<sup>13</sup> I mention also the spectre of a climatic change caused by accumulation of CO<sub>2</sub> in the atmosphere. This possibility is hard to assess, though some climatologists believe it to be a real danger.

The other potential hazards of nuclear reactors - low-level radiation, diversion of fissile material, sabotage, plutonium toxicity, and even disposal of wastes - I would judge to be less important as far as public perception of nuclear risks is concerned. I shall touch upon them rather briefly.

#### 1. Low-level Release of Radioactivity:

Low-level radioactivity release has become essentially a non-problem since the Atomic Energy Commission reduced the permissible release levels from reactor facilities to some five milliroentgens per year. As noted earlier, this represents less than five percent of the natural background dose; it is a level at which no biological effects can be detected. Most critics of nuclear energy now concede that - at this level of release - the biological danger, if any, is extremely small.

#### 2. Diversion of Fissile Material; Sabotage:

I include diversion and sabotage together since both involve willful acts by individuals or groups of individuals. Because no such acts have occurred this far - in particular, no fabricated nuclear weapons have been stolen despite their very wide deployment - it is again hard to assess the seriousness of such possibilities. However, the Energy Research and Development Administration, in response to these contingencies, now requires additional guarding, including armed convoys for trucks transporting fissile or radioactive materials.<sup>14</sup>

### 3. Radioactive Waste Disposal:

The problem of radioactive waste disposal is not that wastes cannot be sequestered in places - such as salt mines - that are almost certainly safe; it is rather that one cannot prove with total mathematical certainty that such disposal will forever keep the wastes sequestered and away from the biosphere. If the effluents from reactors remain dangerous for many years, then in a sense we are imposing on future generations a burden that may have to be dealt with far in the future. What this generation can do is to dispose of the radioactive wastes in a manner which we conceive to be totally safe. But, short of rocketing wastes to outer space (and even rockets abort), it is hard to ensure totally that the wastes can, under no circumstances, return to the biosphere. Any waste management scheme, whether it be storage in aboveground vaults or sequestering in geologic formations such as salt, probably implies some small degree of human surveillance over very long periods. In this almost hypothetical sense, nuclear energy commits future generations to maintain the security of its effluents. But to put this in perspective, we must recognize that other actions by one generation commit future generations: our depletion of fossil fuels places a burden on future generations. Moreover, one must remember that after 10,000 years the ingestion hazard of the wastes is less than the hazard of the uranium that underwent fission to produce those wastes. Fission eventually cleanses the earth of radioactivity.

### 4. Toxicity of Plutonium:

Much is said today about the toxicity of plutonium, as though this were a new problem. What may be new is that certain scientists have rediscovered what we have known for 25 years - namely, that alpha-emitting "hot" particles deposited in the lung, for example, will expose cells in the immediate vicinity of the particle to very large doses of radiation. But is there any evidence that the number of manifest cancers actually produced is greater than if the same amount of radiation is uniformly distributed in the lung or other tissue? Many experiments that bear on this question have been performed over the past decade; but to date no unequivocal effect has been found. Moreover, some two dozen workers at Los Alamos now carry enough plutonium in their lungs, probably in the form of hot particles, to have developed cancer, but no cancers have appeared though 30 years have elapsed.

But none can deny that plutonium and its related transuranic elements, such as americium or curium, are very dangerous materials. It was partly on this account that most of the world gave up atmospheric testing of nuclear weapons. To the nuclear technologists, this means that these materials must be handled carefully and with great respect; it does not mean that we must forego the benefits of abundant energy that use of these materials confers upon our society.

## **- Can The People Be Unscared ? -**

Despite the reassurances that I and other nuclear proponents give, portions of the public remain unconvinced. The threat to the nuclear option remains real. What is there about the nuclear risk that is somehow different, and causes the distrust that undoubtedly exist?

To say that there is general distrust of big technology and of proponents of big technology is true, but this is only part of the difficulty. Nuclear energy began as a military enterprise; man first handled radioactivity on a very large scale with the building of Hanford. That mistakes were made - for example, the use of ground disposal for low-level liquid wastes or the use of tanks that can leak for liquid storage - is not surprising. All one can say to this is that standards are much more rigid now than they were during the war. Wastes will be solidified, and in fact are being solidified at Arco and, on a smaller scale, at Hanford. To the accusation that the nuclear community cannot be trusted, I can only say that the nuclear community is much more open than it previously was. The separation of the regulatory and development functions of nuclear energy in the Energy Reorganization Act of 1974 will help keep us, and those who follow us, honest.<sup>15</sup>

As for the intrinsic hazards to life of nuclear energy - with one exception (the persistence of radioactivity) - they are no different, and in some respects are much smaller than the intrinsic hazards of other energy-producing systems. As for actually killing people, the numbers seem to favor nuclear by a large margin. If we compare nuclear reactors with automobiles, the comparison is striking. The dangers from autos are real and stark; 50,000 people will die on the road every year. By contrast, the dangers from nuclear energy are presumptive - no one has been killed by radioactivity from a commercial nuclear power reactor.

Nor can it be the idea that a sudden, large catastrophe is much less acceptable than a series of small catastrophes spread over time and over very many people. A dam represents a potential sudden catastrophe that again is a real, not a presumptive danger - yet no one really worries about the 10,000,000,000 kilowatt-hours of gravitational energy impounded behind Hoover Dam. To be sure, the property damage that could conceivably be caused by a reactor failure might exceed that caused by failure of any other man-made device, but certainly not by orders of magnitude, and the probability of this happening, according to Rasmussen, is almost infinitesimal - one in 10,000,000 per 100 reactor years for a \$14,000,000,000 catastrophe.

There are four essential elements that I suspect are responsible for the peculiar concern over nuclear energy. First is the possibility of diversion, which is not shared by other energy technologies, but is something we have lived with since the advent of the nuclear bomb. In that case we accepted the risk in return for something we felt very worthwhile: Victory in World War II, mutual deterrence that has staved off World War III despite the predictions of many Cassandras. I should think we would be prepared to accept the smaller risk of diversion from nuclear power plants in the interest of maintaining our energy system.

Second is the newness of the radiation hazard. Though radiation is part of our natural environment, many of us are terror-stricken by the idea of being harmed by radiation. In a way, it is reminiscent of early fears over the possibility of electrocution when electricity became widespread. By now most have made psychological peace with the hazard of electricity. We would expect that as man lives with radiation he will acquire the same attitude toward it: one does not deal with radiation carelessly, but neither does one panic over it.

The most unique part of the nuclear hazard is its persistence. Land interdicted by widespread contamination could be difficult to clean up, so that it might be interdicted for a very long time. It is this aspect of the nuclear hazard that prompts me to urge cluster siting<sup>16</sup> - to put only a few spots on the planet at risk of persistent contamination. This was the underlying idea of placing reactors at Hanford in an isolated area so that, come what might, the effluents would not cause much damage.

Finally, people are worried about the meticulous attention to detail demanded by nuclear energy. In a sense, nuclear technology is the most demanding, and possibly the most unforgiving, of technologies. All one can say is that as the technology improves, the demands on people diminish. For example, the CANDU reactors are now operated by computer. I would expect this trend to continue; as the technology matures the demands on people diminish. But again, this will always be a price we pay for such an inexhaustible source of energy.

If we ask why people are scared about nuclear energy, it is not because the magnitude of the danger is much greater than that from other energy-producing devices - and certainly not when compared to natural disasters. Rather, people are scared because of the persistence of the radioactivity and the newness of the hazard. Most of us are not used to living near a reactor, though many million Californians live below large dams or in San Francisco where earthquakes are rather common.

But are nuclear fission reactors in fact very new? Until 1972 we believed that the first chain reaction on earth occurred on December 2, 1942, when Fermi's reactor went critical. But we were mistaken. In 1972 French scientists discovered that in a uranium mine in Oklo, Gabon, several natural reactors had operated some 1,800,000,000 years ago, when the concentration of  $^{235}\text{U}$  was 3.0 - not 0.7 percent.<sup>17</sup> The reactors operated intermittently over 500,000 years; they produced as much energy as a 1000 MW (e) PWR operating for 3 years; and they produced five tons of fission products, about two tons of  $^{239}\text{Pu}$ . What is the significance of the "phenomene d'Oklo", as the French call it? I believe it has two significances: scientific and metaphysical.

Scientifically, the studies to date suggest that the Pu (which has long since decayed) and the rare earth fission products remained in place. Thus, we do have some evidence as to what occurs over very long periods when fission products and  $^{239}\text{Pu}$  are placed in the earth as insoluble oxides: not very much happens, at least as far as the rare earths and Pu are concerned, and possibly the  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$ , though the evidence here is less certain. The metaphysical significance, I believe, is greater. I find it somehow reassuring

ing to realize that chain reactors are not a new thing - that the earth has seen them before December 2, 1942, and that the earth has survived this event. Fermi rediscovered a phenomenon that occurred naturally two billion years ago. In this sense, nuclear reactors present less foreign intrusion on the earth than do some of the new chemicals which the earth has never seen before.

#### - Is Nuclear Energy Acceptable ? -

Let me return now to my original question: Is nuclear energy acceptable ? In answering this question we must recognize that nuclear energy based on fission reactors will very probably go through two phases. Phase I is the present period. It is based on burner - mainly light water - reactors. Each such 1000 MW(e) reactor requires about 5000 tons of uranium over the 30 years of its operation. The United States' reserve of uranium sufficiently cheap to fuel light water reactors is estimated to be about 3,000,000 tons. If we accept these estimates, then Phase I, if based on light water reactors of more or less present type, can support about 20,000 reactor years of 1000 MW(e) LWR's - roughly 600 reactors operating for 30 years. Thus Phase I of nuclear energy is rather transitory; and indeed if nuclear energy were of such small dimension, it would hardly be worth all the trouble and effort that have been devoted to it.

But more than that, because Phase I is a relatively short episode, the risks that we can afford to take per year are higher than if Phase I were to last very much longer. We are, after all, speaking of risk probabilities. The actual hazard is the product of the risk per year and the number of years the risk lasts. Thus, if we take Rasmussen's figure of a meltdown once in 20,000 reactor years, we would place the hazard of a single meltdown during the 30 or so years of Phase I at about unity; and the most probable consequences of this incident would be no fatalities or injuries, and less than \$1,000,000 off-site property damage. Rasmussen warns against such extrapolation since he asserts, with reason, that reactors will be improved as time goes on. But these estimates illustrate the point that Phase I is very likely to pass without a serious reactor accident. Moreover, the other dangers we have listed also are matters of probability, not certainty. The strong probability is that during Phase I none of the dangers we have discussed will actually eventuate.

Thus I argue that nuclear energy substantially in its present form is acceptable during the limited period of Phase I. This does not mean that improvements are not desirable; but neither does it mean that every improvement need be back-fitted to every existing reactor. These improvements might include better containment (the issue of undergrounding vs. strengthened aboveground containment is still an arguable point), more highly automated control, better in-service testing of components; as well as strengthening of the Nuclear Regulatory Commission, and further modification of Price-Anderson so that the Government becomes the insurer of last resort. But these are incremental improvements, the sort that one expects from a developing technology. Thus to the question, "Is nuclear energy acceptable ?" I would answer "Yes, nuclear energy, largely in its present form, is accept-



able during Phase I."

But Phase I will end, say in 50 years. At that time, assuming that no other inexhaustible and convenient source of energy has been developed, we shall turn to the breeder. If the breeder is successful, it would be the basis for the ultimate nuclear energy system. Since the raw material for the breeder is practically inexhaustible, the ultimate breeder-based system might well last indefinitely. This is Phase II of the age of nuclear energy: based on breeders, lasting, in principle, as long as technological man endures - and correspondingly, carrying the immense social commitment that is implied in a quantum change in man's way of living.

Is nuclear energy acceptable for Phase II? My answer to this is, "Nuclear energy as the ultimate energy source in Phase II is acceptable, but only if it is substantially modified." The small probabilities that seem innocuous when viewed in a short time frame must be reduced even further when we view the matter over the very long term.

Can we identify the elements of the system that should be modified so that man can live with fission comfortably over very long times - i.e., during Phase II? I assert that in Phase II three essentials must be achieved: physical isolation, social isolation, dedication of the nuclear cadre.

Physical isolation is to a good degree already achieved with the containment systems we now have. But, in the long run, I would espouse further isolation by clustering breeders and their chemical support in more or less isolated areas. The asymptotic U.S. nuclear energy system I visualize would consist primarily of 1000 breeders, each generating 2000 MW(e), confined to 100 nuclear parks. Each park would contain 10 reactors, chemical and fabricating plant; these 100 sites, along with half a dozen waste disposal areas would constitute the entire land area committed to nuclear fission - in all, perhaps 5000 square miles.

The advantages of such clustering over the long term seem compelling to me. Stability of work force, strength of cadre, elimination of plutonium transport, possibility of guarding against sabotage and terrorism - these seem to outweigh the disadvantages - more expensive transmission, possible heat island effects, possibility of common mode failure. The recent NRC study on energy centers concluded that centers up to this size were indeed feasible;<sup>18</sup> I hope our Government will take this finding very seriously and indeed, adopt as national policy the siting of breeders in nuclear energy centers.

Such a change in siting policy would rather automatically achieve social isolation. It seems clear, unfortunately, that if modern man is to live comfortably with fission, he will have to come to terms with the growing possibility of sabotage and terrorism. This means, eventually, that the nuclear facilities will have to acquire the same sort of security as was imposed on Hanford and Oak Ridge during the war. I cannot conceive of this happening without, in some degree, giving to these nuclear energy centers an atmosphere of security that we do not and cannot impose on the rest of society. It is in this sense that I think of the Phase II nuclear energy system as being socially isolated: those whom it would be prepared to give up some freedoms, such as we in Oak Ridge gave up during World War II

in the interest of maintaining the security of the system. But the entire cadre thus affected would be relatively small - ultimately perhaps 100,000 people - and the norms of security imposed on them would affect the rest of the society as little as the norm of security imposed on, say, the Strategic Air Command, affects the basic freedoms of most Americans.

The final requirement for Phase II is the dedicated cadre. Let me explain by recalling the Browns Ferry fire where the control room filled with smoke and respirators were required - yet the idea of jumping ship simply did not occur to anyone. Staff operators were needed to keep things from getting out of control - for example, to relieve pressure when the condensate pumps tripped out - and the operators were equal to their responsibility.

The nuclear system, as I have said, is benign, probably our most benign thermal energy system when it is operating properly. To keep it operating properly, and to deal with malfunction, requires a dedicated, knowledgeable cadre that is fully aware of its heavy responsibility. The possibility, however remote, of serious harm from a reactor is something all associated with the nuclear enterprise must be aware of and must be prepared to deal with. The responsibility that is borne by the operator of a large nuclear energy plant is at least as great as that of the Captain of a 747, and in some ways it is much greater. I assert that the integrity of Phase II - and this may be a phase that continues very far in the future - depends more heavily on the dedication and sense of responsibility of the cadre than on any other single element.

Those of you who are here this afternoon will be part of this cadre, mostly during Phase I, but also during the transition from Phase I to Phase II. Each of you must recognize the full weight of the responsibility that you have accepted in entering nuclear technology. It is your responsibility to assure the continued acceptability of Phase I of nuclear energy, and to help establish the ultimate acceptability of Phase II. I believe each of you understands this commitment and will honor it: all our futures may well depend on such commitment and understanding.

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## MANPOWER DEVELOPMENT FOR THE NUCLEAR POWER PROGRAM IN INDIA

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### ABSTRACT

Transfer of technology invariably involves training of scientific and technical manpower. The programme of manpower planning and development in a developing country for the introduction of high technology is a complicated problem. It is connected with the industrial base and the infra-structure available in the education sector, in addition to other socioeconomic factors. Introduction of a nuclear program in a developing country very often symbolises introduction of modern science and technology in both its fundamental and applied aspects. This paper deals with the Indian experience of training of manpower for the nuclear energy program.

In India manpower training for the nuclear power program started several years before the introduction of nuclear power plants. The setting up of the research organization viz. Atomic Energy Establishment Trombay, now named the Bhabha Atomic Research Centre and design and construction of research reactors and their utilization formed the backbone of manpower development. This enabled the first batch of engineers and scientists to be trained on design and operation in programs connected with research reactors, use of isotopes in industry, agriculture and medicine and development of nuclear instrumentation. The introduction of nuclear power plants required the stepping up of this manpower development program. The next step was therefore to establish a Training School in the Bhabha Atomic Research Centre in which fresh graduates from the Universities could be given courses both in their own disciplines and in other inter-connected disciplines of nuclear sciences. About 150 to 200 such graduates have been trained every year since 1957. Approximately 3000 graduates from this Training School are involved in various capacities in India's nuclear power program at present.

With the commissioning of the first power reactors, it became necessary to conceive of training engineers, scientists and technicians particularly for operation and maintenance of such systems. For this purpose a separate Training Institute at Rajasthan Atomic Power Project near Ranapratapsagar was set up. Models, simulators and courses particularly emphasising the heavy water system of reactors were introduced in order to train operating personnel and power station equipment maintainers.

The Isotope School at Trombay provides training in radiography techniques and in the handling of radioisotopes for users in the fields of industry, medicine, agriculture and

research. A one year post-graduate course in the uses of radioisotopes is also conducted in BARC for graduates in science and engineering.

In developing countries manpower training has to be a continuous activity not only from the point of view of augmenting the required manpower, but also to minimise the effects of brain drain.

The unique power of "Science and Technology" to foster economic growth and social and cultural progress has long been realised by the developing countries. Among the various technologies leading to industrial growth, nuclear technology occupies a unique position, for it encompasses many other technologies and by its exacting standards helps to develop new technologies for the future.

The problems faced by the developing countries in adopting nuclear technology are however different from those in the developed countries. It is possible for some of the developing countries to adopt a black box approach in this field which may be adequate or even beneficial in the immediate short run. However such a course by itself does not provide for a sustained growth necessary for meeting the needs of a rapidly changing technology like nuclear technology. With several choices for the future, for example, in fuel cycle, waste management etc. which are dependent on natural resources of the concerned country, a broad based R & D program is necessary to sustain a growth rate in nuclear power. The Indian atomic energy program is therefore very broad-based both in its R & D activities and manpower development.

Efforts in nuclear technology started in India around the late forties. Though the modern educational system was 80 years old at that time and the society in general was ready to accept modern science and technology, the needs of a rapidly growing nuclear technology were very different. The way this technology was acquired by the Indian scientific community is an interesting study not only from the technical point of view but also from the sociological point of view, because very often it is said that a pre-condition for technological growth is the existence of an industrial infrastructure which was not available in adequate measure at that time. In the beginning a limited program was initiated in the shape of mineral surveys, setting up of rare earth and thorium plants etc. As a part of the manpower development program in basic nuclear sciences, research groups were set up at the Tata Institute of Fundamental Research. In 1954 with a view to stepping up the scale of activities, the Atomic Energy Establishment, now renamed Bhabha Atomic Research Center was established at Trombay. Programs in several scientific and engineering disciplines required to fulfill the long term objectives were started at the Center.

One of the first tasks undertaken by the Center was the construction of a Swimming Pool type reactor APSARA in 1955. An R & D group was set up to design, fabricate and construct the reactor and all its equipment including the control electronics excepting the fuel elements. Following APSARA, the 40 MW heavy water reactor CIRUS was constructed with the assistance of Atomic Energy of Canada Ltd. Although external assistance was involved in this project, the experience and the manpower developed in the APSARA project helped

to undertake the major construction activities locally. CIRUS thereafter acted as powerful catalysing agent to R & D effort in general and for gaining experience in the natural uranium - heavy water system on which our power reactors were to be based. The other reactors built later were ZERLINA and PURNIMA. The latter is the first fast reactor built to gain experience in our fast reactor program. More important than the reactors themselves is the manpower trained in these research reactor projects which is being utilised for planning, designing and constructing power reactors at a number of centers in the country.

Closely linked to the reactor program, the Center undertook several allied projects calculated to build up skills in ancillary nuclear technologies which were to be expanded to full-scale facilities later. Among these may be mentioned fuel fabrication, reprocessing, heavy water production, radioactive waste disposal plants, instrumentation for reactor control etc. Many of these activities which were started on a pilot plant scale have now provided enough training and design data to build large sized plants. Several new production organizations like Electronics Corporation of India Ltd., Nuclear Fuel Complex, Uranium Corporation of India Ltd., Indian Rare Earths Ltd. etc. have been set up. Basic research in various disciplines like physics, chemistry and biology are also encouraged in order to develop adequate expertise in support of applied research. Radiation safety, materials research and research in biological mutations and food preservation using ionisation radiation form other major activities. The most significant offspring of BARC is the new Reactor Research Center started at Kalpakkam near Madras. This Center will specialize in all activities related to fast reactor technology. Here again a Fast Breeder Test Reactor under construction will form the nucleus for all related technologies leading to design and construction of commercial fast reactors.

## 1. BARC TRAINING SCHOOL

To ensure the successful execution of such a broad-based program where multi-disciplinary teams working in an integrated manner are necessary, special training programs were undertaken from the initial years. Before the multi-disciplinary teams could be built on actual projects, training in different disciplines was necessary. Generally there are three sources from which manpower may be obtained; mobilization of resident scientists and technicians in the country, recalling scientists settled abroad and training fresh scientists and technicians. It was obvious from the point of view of developing coherent multi-disciplinary teams in adequate numbers that further training of fresh graduates from universities was to be the main source of manpower. Thus in the BARC Training School established in 1957, graduates in Physics, Chemistry and Engineering subjects, totalling about 200 per year are selected and given training for one year. Here trainees are given courses in radiation physics, health physics, reactor physics, electronics etc. In addition to courses in their basic disciplines to orient them to the specific nature of the atomic energy program. Laboratory work, projects and on the job training are included

as a part of the course to make the trainees familiar with radiations and radiation measuring instruments. A detailed summary of the courses is given in a paper by Ramanna et al. (1)

In addition to such formal training, courses are organized for specialized areas like reactor operations, safety in the use of radioactive sources in industry, medical research, etc.

## 2. TRAINING IN NUCLEAR POWER STATIONS

With the expansion of the nuclear power programme, it became necessary to evolve an additional training program primarily for the technicians and craftsmen and specialist engineers required for the operation and maintenance of the nuclear power stations. A training center was therefore started at the Rajasthan Atomic Power Station to train the operation and maintenance staff. The training program is designed so that a person acquires the competence required to fill a particular position. Emphasis is laid on the nuclear safety and reliability aspects. The training at the center is programed at different levels to cater to the needs of power stations. A description of these programs in the Nuclear Training Institute at the Rajasthan Power Station is given in Table 1 and also described in a paper by Iyengar et al (2).

In the entire training program, fresh graduates or those with diploma or certificates, or high school education are recruited for training at the appropriate levels rather than experienced personnel. The success of this approach has vindicated the policy that atomic energy should not and need not grow at the cost of depleting experienced manpower from industry or other organizations. In fact a time has come when we are in a position to send out our trained scientists to universities for research and teaching in order to improve the standards of scientific education in Indian universities. Also as a part of our policy of improving science education in the universities from which we obtain our manpower, summer schools are organized for university teachers. In addition, scholarships and research grants are also given. Besides training our own personnel, we have also trained many scientists and engineers from other countries, especially from the South East Asian region.

It would be interesting to see how the manpower training and development programs with pilot plants and small research reactor facilities have resulted in large scale sophisticated plants and facilities in a few typical areas.

As mentioned, we have been designing and constructing research reactors since 1955 with a view to developing self reliance and breeding new skills. When economic studies showed that in many parts of the country remote from coal fields, nuclear power would be competitive, we started a nuclear power program first by constructing power stations with foreign collaboration to be replaced later indigenously. The successful indigenisation of power stations presently being built in India has shown the rightness of our approach for manpower development in this complex and modern technology. This example stands in

contrast to what is generally experienced in other conventional technologies. Though the steel industry in our country is fairly old, it is not in a position to diversify and produce new products like alloy steel etc. without foreign collaboration. It shows that unless powerful scientific and engineering groups are established during the construction and operation of plants, either full scale or prototypes, as a matter of deliberate policy, dependence on foreign technical assistance will continue. Large efforts put in at BARC in establishing pilot plants for fuel fabrication, heavy water production, waste management facilities and carrying out design and fabrication of instruments have resulted in their expansion on a commercial scale with the formation of units like Nuclear Fuel Complex, Electronics Corporation of India Ltd. and other large scale industrial operations. Another area where we are developing manpower for the future is in fast reactor technology. It is known that in view of the fact that the supply of uranium is limited, future power reactors will be based on fast breeders. Since the technology is new and it will take about a decade before it can be established firmly, we have undertaken construction of a prototype fast breeder at RRC with a view to developing manpower in this new technology. Another area where we have generated expertise is in the area of particle accelerators. As a result of the expertise developed in technical physics over a period of two decades, we have been able to construct a 60 MeV Variable Energy Cyclotron at Calcutta which is being commissioned.

These and other examples given earlier have been the result of deliberate manpower development planning taken at initial stages of our nuclear program. Our philosophy in manpower development can best be explained by reproducing a sentence from the prophetic letter written by late Dr. Bhabha in 1944 which reads "Moreover, when nuclear energy has been successfully applied for power production, in say a couple of decades from now, India will not have to look abroad for its experts but will find them ready at hand." A comprehensive account of the developments in atomic energy based on this philosophy is given in an address by Dr. Bhabha <sup>(3)</sup>. This is the goal of every developing country with a nuclear program. Since the problems are similar, the developing countries in the region can benefit by sharing our experiences in manpower training and development.

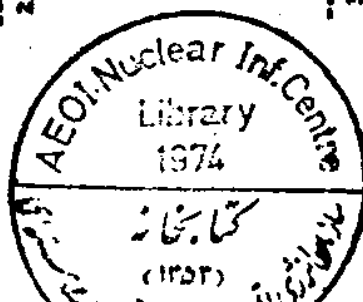
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Table 1. Courses Given at Nuclear Training Center, Rajasthan Atomic Power Station Anushakti, Kota, Rajasthan, India.

S. No.	Description	Length of Course	Eligibility	Frequency	Condensed Syllabus	Language of Training	Remarks
1.	Operational/Maintenance Engineers' Course	2 yrs	Graduates in Mechanical, Electrical, Chemical or Electronics Engineering	Once a year	Advanced level courses in Nuclear Theory; Nuclear Materials; Nuclear Power Plant Engg.; Instrumentation & Control; Radiation Protection; Nuclear Safety; Nuclear Fuel Management; Physics & Chemistry	English	Six months training at Nuclear Training Centre followed by 18 months on-the-job training at Rajasthan Atomic Power Station.
2.	Operator/Maintainer/Technicians	2 yrs	Three years Diploma in Mechanical, Electrical, or Electronics Engg. after 11 years of School	Once a year	Middle level courses in Nuclear Theory; Nuclear Materials; Nuclear Power Plant Engg.; Instrumentation and Control; Radiation Protection Nuclear Safety; Nuclear Fuel Management; Physics and Chemistry; Operational skills or Equipment maintenance skills as appropriate	English	Six months training at Nuclear Training Centre followed by 18 months on-the-job training at Rajasthan Atomic Power Station.
3.	Operator/Maintainer/Craftsmen	2 yrs	11 years of school for Operator, For Maintainer, 10 years school and 2 years certificate course in a tech. school	Once a year	Basic level courses in Nuclear Theory; Nuclear Power Plant Engg.; Radiation Protection; Instrumentation; Operational skills or equipment maintenance skills as appropriate	English	Six months training at NTC with 18 months on-the-job training at RAAPS for Operators. For Maintainer/Craftsmen, 1 year training in NTC with 1 year on-the-job training at RAAPS.



## MANPOWER TRAINING APPROACH IN THE ATOMIC ENERGY ORGANIZATION OF IRAN

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### ABSTRACT

Manpower training approach and philosophy in Atomic Energy Organization of Iran is presented.

The present programs interact extensively with foreign institutions; certain difficulties experienced are mentioned. Local programs and manpower programs under development and planning are discussed.

### 1. INTRODUCTION

Educational activities in the fields of Nuclear Science and Technology in Iran prior to the creation of the Atomic Energy Organization of Iran (AEOI) have been limited to scattered and uncoordinated programs among different universities and institutions of higher learning. Chief among such programs was that which was offered in the Nuclear Science and Technology Center of the Tehran University. This center in collaboration with the Engineering school and the school of sciences of Tehran University offered Master programs in Nuclear Physics and Chemistry, Radiobiology and Nuclear Engineering. This center has access to various Research and laboratory facilities such as a 5MW pool type Reactor, Van-De Graaff Generator and various Irradiation sources and detection equipment. Due to insufficient demand in Iran for the nuclear type personnel the output of the above center in terms of graduates has numbered about 20 students. Also the school of Public Health of Tehran University, in coordination with the World Health Organization and the Tehran Nuclear Center, in 1972 set up an international two year course in Radiation Protection. A total of fifteen persons including eight Iranians were graduated from this course.

## 2. TRAINING & EDUCATIONAL ACTIVITIES IN AEOL (FOREIGN ASSISTED)

The Atomic Energy Organization of Iran, at the start of its activities and considering its rather lofty objectives faced an acute shortage of trained personnel in the nuclear field. It would have seemed more appropriate to direct all initial efforts at this stage on the manpower training program prior to the start of the Nuclear Industrial Development. However, due to various politico-economic considerations it was decided to adopt a head-on approach to the developmental work while simultaneously starting training activities. This predicated a rather unconventional approach to the manpower training program in that a great reliance was placed upon foreign institutions. On one hand this was made necessary because of the insufficient local capabilities in the areas of nuclear science and technology and in graduate Engineering Education in general in Iran. On the other hand, technology transfer by means of taking advantage of the foreign educational and training facilities, though attractive, nevertheless poses a number of problems such as cost, uneven levels of training abroad compared to local needs, and also a retarded rate of development of the local training capabilities, etc. To arrive at an optimum solution to the above multifaceted problem the following training scheme has been adopted. The plan is initially to train a minimum number of qualified personnel through various foreign academic and on-the-job training programs. This will provide sufficient number of personnel to fill the key organizational positions while allowing time for initiation and startup of indigenous training programs which will be assisted later by the above mentioned graduates. A detailed listing of the existing AEOL training program which reflects the above mentioned philosophy is as follows:

### 2.1 Fellowship Program:

Fellowships are granted to outstanding students to pursue academic training in the fields of interest to AEOL in superior Universities either through individual grants or through contracts with universities and sending students in groups. This is a rather short-lived program which will be phased out in the next one or two years. The group type programs allow us access to very fine academic institutions along with certain flexibility such as better student orientation and supervision which is not normally available through individual routines.

The cost figure is usually the most pronounced disadvantage of the group-type programs. Some reputable universities, in submitting proposals for educational collaboration with AEOL have occasionally forgotten the non-profit making nature of their institutions.

In the fellowship program nearly two hundred persons have received scholarships up to this point and nearly a quarter of them have returned and are absorbed by various divisions within AEOL.



## **2.2 Classical-Practical Training Program:**

In another phase of the manpower development program, a theoretical practical approach was adopted in which an on-the-job training program was interspersed with academic course work.

The programs with NJIT in collaboration with Westinghouse Company and the Harwell Program etc. can be cited as examples of this group with an expected student participation of about forty. From experience obtained thus far, It appears that this type of program may be oriented more toward a theoretical learning as opposed to the practical experience which would be easier to implement both administratively and also more suited to the mentality of the Iranian trainees. Some of the training Institutions occasionally have displayed inadequate preparation to handle their training responsibility, which may be attributable to various factors.

## **2.3 Practical-Industrial Program:**

One of the obvious manpower bottlenecks in AEOL currently is a shortage of personnel with practical and/or industrial experience. To overcome this difficulty, a number of different on-the-job training programs in industrial firms and in Research Centers have been undertaken. Generally industrial training programs by a given company are associated with furnishing the needed training for personnel for specific project for which the said company is the prime contractor. Two of the major programs in this category are those with Kraftwerk Union and Technicatom. In these, the responsible personnel for Iran I and II power plants and the Isfahan Nuclear Technology Center are trained respectively. In another variation of this program, agreements are signed or proposals are being considered from Seibersdorf, Karlsruhe, and Bhabha Research Centers for various types of on-the-job training. Some of the proposed areas of training cooperation include Reactor Safety planning and projecting of Nuclear power plants, Reactor Engineering, Isotope Technology, Thermonuclear Fusion, Waste Management and Radiation Protection.

Proper execution of the above programs may provide invaluable assistance to us in the development of our nuclear industry. However, interaction with a number of different training centers with different structures, languages, etc. has produced a number of difficulties for AEOL and its trainees which are summarized as follows:

- a) High training costs.
- b) Language problem especially in non-English speaking centers.
- c) Insufficient industrial experience of some of our trainees giving rise to a reduced absorption rate of the material presented.
- d) A reduced training effectiveness due to social, cultural and environmental factors in a foreign country.
- e) A general lack of coordination between the training material offered as opposed to what is needed or even proposed by the center.

- f) Insufficient previous experience on the part of some of the training institutions in the most effective way of interacting with groups of foreign trainees.
- g) Acquisition of foreign cultural and ethical values by our trainees and interference with the local value systems resulting in lowered performance effectiveness of the trainees later in Iran.

Because of the mentioned difficulties associated with the foreign programs and also in order to achieve national self sufficiency in the areas of educational fields most needed by AEOL, it is intended to implement a sequence of manpower training programs in Iran similar to the current foreign training assistance.

### 3. TRAINING AND EDUCATIONAL ACTIVITIES IN AEOL (LOCAL PROGRAMS):

#### 3.1 University Programs:

In support of the local academic programs, a contract has been signed between AEOL and the Pahlavi University (P.U.). Based on this agreement, students are admitted to the Master's program in the fields of Nuclear Engineering and Radiation Protection. In addition to financial support provided to students, AEOL, also aids P.U. by augmenting their teaching staff. Pahlavi University also has access to all of the AEOL's research and laboratory facilities in connection with our cooperation program. Other Iranian institutions of higher learning such as Tehran University, Arya Mehr University and Tehran Polytechnic are also encouraged to develop programs most useful to AEOL. The arrangements of this nature will replace the core of our foreign fellowship program within the next couple of years. The single most important hindering factor in the development at the Universities of academic programs which are most needed by AEOL is the prevailing competition for the employment of the qualified personnel. This rivalry however, is expected to diminish in a short time with a greater influx of nuclear type personnel.

#### 3.2 Educational Programs Offered by AEOL:

AEOL is also creating in-house potential for implementing educational programs peculiar to its own mission. In this connection it has offered courses in Basic Nuclear Technology. Courses of this type are supported by the personnel and laboratory facilities provided by AEOL's various research centers. This course covers topics in Mathematics, Reactor Physics and Engineering, Health Physics, Nuclear Materials, Laboratory, Reactor Safety and foreign language instruction. This course is pitched at graduate level and is equivalent to ten to twelve hours of university load and is taught during a four months session.

In developing a comprehensive manpower training program, a center for Advanced Studies is planned to start operation next Fall. This center will offer one or two year courses in Radiation Protection, Engineering (Nuclear, Electrical, Electronics, Chemical and Mechanical), Metallurgy, Biology, Physics and Chemistry. It is envisioned for this center

to be able to expand and offer other courses upon demand. This center will act as the main source of supply for providing all senior level technical personnel for AEOI, and will be setup near a research center to facilitate the exchange of ideas among students, teachers, researchers, etc. It is planned to start this center during the fall of 1977 initially with Nuclear Engineering and Radiation Protection options. The nuclear engineer-curriculum will cover topics in Mathematics, Nuclear Physics, Reactor Theory, Reactor Engineering, Nuclear Laboratory, Nuclear Material, Health Physics, Environmental Protection, Numerical Techniques in Reactor Design, Reactor Safety, etc.

The Radiation Protection Course will include topics in Mathematics, Nuclear Physics, Ionizing Radiation Sources, Electronics, Basic Biology, Radiation Dosimetry, Computer Programming and Numerical Analysis, Radiobiology, Basic Nuclear Engineering, Operational Health Physics, Medical Physics, Chemistry, Health Physics Engineering, Environmental Protection Inspection, Methodology, etc. Some joint educational planning is also under consideration between AEOI and some of the Iranian medical institutions. In connection with this program a detailed country-wide personnel requirement survey in areas of Nuclear Medicine, Radiation Physics, Radiopharmacology, Radiotherapy, etc. has been made. On the basis of this information, joint training programs among AEOI and various local and foreign medical institutions are underway.

In order to meet a somewhat larger demand for middle level technical staff and skilled workers, a special technical school was setup by AEOI and started operation in September of 1976 with an intake of a few hundred trainees. This school runs on a two year basis and provides technicians, operators, and maintenance crews, etc. There are also other special short courses which are offered by the various divisions mainly to transmit specific information to their staff members. Some of these courses have been in Radiation Protection, Radiation Application in industry and medicine, Advanced Computer Programming, etc.

# THE NUCLEAR TECHNICIAN TRAINING PROGRAM IN IRAN

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## 1. INTRODUCTION

The sophistication of nuclear power plants requires well trained and reliable personnel at all levels of operation. Special preparation and specific training for the staff of nuclear power plants is necessary even in industrialized countries. To train qualified Iranian personnel for the successful operation of Iran's nuclear power stations, the INECO Training program has to meet the following objectives:

- To prepare skillful and capable professional plant operators and technicians able to successfully operate a commercial nuclear power plant in a safe and efficient manner; to be aware of the short and long range problems; and have the capabilities to solve them through use of their own ingenuity and imagination.
- To successfully qualify the applicants for the examinations conducted by the proper authorizing agencies.

### 1.1 Goals

In order to meet the objectives, INECO has developed its own training program for Iran which is based on the following goals:

- 1 Interchangeability  
The training program must provide the Nuclear power plant owner with an operating staff in which the majority of key personnel can substitute for their collaborator or assistant with a minimum level of effort.
- 2 Training According To The Level Of Responsibility  
The training is performed for different professional fields and at various levels of depth. The degree of knowledge achieved will enable the future power plant owner or authority to determine the eventual assignment and responsibility of the trainee.
- 3 Emphasis On Applied Theory - Theoretical  
Instruction is given having the necessary extent and depth required to meet the trainee's intended position. The program emphasizes only those theoretical considerations that can be justified by direct and immediate application.
- 4 Emphasis On Practical Training  
Practical training will be given in the beginning in Iran in conjunction with the

theoretical instruction. After satisfactory completion of this course of training, further instruction will take place in the country from which Iran's future reactors are to be purchased. This experience will be eventually in plants associated with the nuclear industry in the final stages on actual nuclear power plants with components having a direct relationship to those the specialist will experience in actual site-working in Iran.

5 Coordination With Design And Construction Schedule

The timing of the training activities will be coordinated with specific phases of the design and construction work to enable the trainee to help in the commissioning of Iran's nuclear power plants.

## 2. METHODOLOGY BASIS

In industrialized countries, the normal professional education of a technician begins at an age of 14 to 15 years with practical apprenticeship training in a specific skilled field in a school for this field or perhaps a combination of both. In some countries, such as the United States, the apprenticeship may also be replaced by practical on-the-job training.

After the basic training in one specific field, the future technicians work in a manufacturing plant for power plant components/equipment, or in construction work, or in a conventional (fossil fuel) power plant. Then after a number of years of this experience, a few of the better technicians are chosen for a special training course in Nuclear power plants. Thus, in the major industrial countries, these technicians have to have two levels of education and training before admittance into a special nuclear training course.

This two-level education and training process in the industrial countries is not at the moment available in Iran. A special training program for Nuclear power plant technicians in Iran must, therefore, begin on another premise. The Nuclear power plant training program must be adjusted to allow that, and the manner of training must be generally different from that in the major industrial countries.

### 2.1 Establishment

Because of the circumstances peculiar to Iran, the training program for Nuclear power plant technicians must begin after a successful High School graduation (at 18 years of age) and extend over a two-year time period, subdivided into four semesters. This training period must be followed by an additional year of practical training in operating Nuclear power plants or in respective component/equipment manufacturers work outside Iran. After on-site training in the above Nuclear power plants, it is necessary that the technician work in Iranian Nuclear power plants, during the commissioning period. During the whole of the training period counselling and guidance plays an important part in safeguarding the welfare of the students and ensuring continuity in the organization.

The above mentioned four semesters of training will be held at the INECO Training Center in Tehran, Iran. These semesters will be subdivided into a theoretical part and practical part. The theoretical part of the program is oriented toward better understanding of the practical part of the program.

The mathematical level in all the technical fields in the INECO Training Center will be limited to the use of differential and integral calculus. However differential equations will not be taught and exercised. In addition, no general organic or analytical chemistry should be taught and exercised.

No general conversational English should be taught. The purpose of the English courses should enable the students to understand technical reports concerning their future working fields.

The practical training part, called shops, are divided among the semesters as follows:

First Semester :	Basic Shops
Second Semester:	Shops A
Third Semester :	Shops B
Fourth Semester:	Advanced Shops

The basic Shops are relatively general and represent a combination of practical training and academic training adjusted to the Iranian students' ages and their previous education. They are held for all students. The basic Shops are composed of two parts: Basic craft training and laboratory training.

Shops A, Shops B, and Advanced Shops replace the practical apprenticeship training in the industrial countries, but they are more directed to the future tasks of the student than are the general practical apprenticeships in industrial countries.

The INECO Training Center Shops A and B offer nineteen (19) different fields, each of which will be attended by twenty-five (25) or fifty (50) students.

### **3. COURSE LECTURES**

#### **3.1 First Semester Courses**

The aforementioned nuclear training program for Iranian High School graduates begins with review lectures in general mathematics, general physics, and inorganic chemistry. English and other language courses are given parallel and supplementary to the technical lectures in order to enhance the students' ability to use languages.

Exercises in classroom self-expression are included during the first semester. The subject matter of these courses deal with current topics that are familiar to the student, i.e. national, social, political, and technical current events.

All the courses, except the language courses, are held in the Farsi language. The language courses are based on contents from the specific technical vocabulary used in the technical courses. (for example, the sentence, "The valve is connected to the pipe", will



be substituted for content normally taught in English classes, such as "The dog chases the boy".) In coordination with the language courses, the teachers for the science courses and for the later engineering courses and shops give translations for the various technical terms and expressions used.

The language and self-expression courses are held in small student groups of approximately twenty-five (25) students each. The English classes will be supported by a language laboratory for seventy-two (72) students. Additional languages, besides English, are given depending on the student's ability but in no case will students be expected to take more than two languages in addition to Farsi.

The science lectures and the engineering courses in the later semesters are held in groups of up to two-hundred (200) students. These lectures will be accompanied by numerous demonstration experiments.

The courses for the first Semester, as well as for the second semester, are designed for review, for exercising self expression and for forming a base for the more advanced courses: the courses and shops during first semester are the same for all students regardless of their later specialization. However, during the first Semester, students will be selected for the various professional specialties that are listed under the sub-division given in the second Semester. They will also be selected for linguistic abilities during the first semester.

All students are sub-divided into four groups for the language lectures. These four groups are formed according to their familiarity with the English language. The first group (approximately 25% of the total of the beginning students) are those students who have a very little knowledge of the English language. The other groups are graded accordingly.

### 3.2 Basic (Review) Courses:

(a) Mathematics	(In Farsi)	70 hours
(b) General Physics	(In Farsi)	90 hours
(c) General Organic Chemistry	(In Farsi)	50 hours
(d) Self expression	(In Farsi)	45 hours
(e) Basic English I		220 hours
(f) Craftwork, Industry & Laboratory Technics	(In Farsi)	<u>40 hours</u>
Sub-Total for first Semester Courses:		515 hours

Courses (d) & (e) are in groups of 25 students; the other courses are in groups of approximately 200 students.

### 3.3 Second Semester Courses

The first two semesters are designed for review, for exercising self-expression and

for forming a base for the more advanced courses and shops. For the second semester, the students study the sub-divisions below:

**Courses:** All students enroll in these courses to extend their professional knowledge.

(a) Mechanics	(In Farsi)	35 hours
(b) Materials	(In Farsi)	15 hours
(c) Structures	(In Farsi)	15 hours
(d) Fluid Mechanics	(In Farsi)	60 hours
(e) Basic English II		150 hours
(f) Thermodynamics, Heat & Mass Transfer	(In Farsi)	70 hours
(g) Electricity	(In Farsi)	40 hours
(h) Basic Atomic & Nuclear Physics	(In Farsi)	70 hours
(i) Preliminary survey on PWR-NPP's, its equipment and operations	(In Farsi)	<u>90 hours</u>

**Sub-Total for second Semester Courses:** 545 hours

**Note:** These courses are in groups of approximately 200 students each. Course (e) (is conducted) in groups of approximately 25 students.

### 3.4 Third Semester Courses

The third semester is designed for training the students in nuclear engineering. In this semester, the students apply the basic knowledge that they have learned in the first two semesters. Students continue training in their professional fields in the following courses.

(a) Nuclear reactor principles	(In Farsi)	100 hours
(b) Reactor Instrumentation and Control	(In Farsi)	35 hours
(c) The Components of the Nuclear Island	(In Farsi)	25 hours
(d) Turboset and conventional	(In Farsi)	35 hours
(e) Technical English I		165 hours
(f) Radiation Protection and Health Physics	(In Farsi)	35 hours
(g) Radiological, Meteorological and other environmental programs	(In Farsi)	40 hours
(h) Standards and rules Including conventional		



safety features	(In Farsi)	35 hours
(I) Electrical power generation, transmission and distribution systems	(In Farsi)	<u>35 hours</u>
Sub-Total for third Semester Courses:		505 hours

### 3.5 Fourth Semester Course

The fourth semester courses are designed to complete the students' formal training. All instruction is given in the English language.

The training in this semester will prepare the students in their professional specialties so that they can continue the training program overseas in an actual nuclear power plant.

**Courses:** All students enroll in these courses to complete their theoretical professional knowledge.

(a) Reactor fuel, transportation loading and start-up	(In English)	50 hours
(b) The nuclear island and its auxiliary and ancillary systems	(In English)	70 hours
(c) The overall nuclear power plant, systems, functions and protection	(In English)	70 hours
(d) Nuclear safety and related features, the safety report	(In English)	50 hours
(e) Technical English II		130 hours
(f) Plant operating methods and organization	(In English)	70 hours
(g) Quality assurance, inspection, maintenance and repairs	(In English)	70 hours
(h) Plant documentation manuals and their use	(In English)	<u>50 hours</u>
Sub-Total for fourth semester courses:		560 hours

### 3.6 Compilation of Courses

A compilation of courses on chart I shows the relationship of the courses throughout the four semesters. It can clearly be seen that the basic technical courses form a foundation for the more advanced applied technical training.

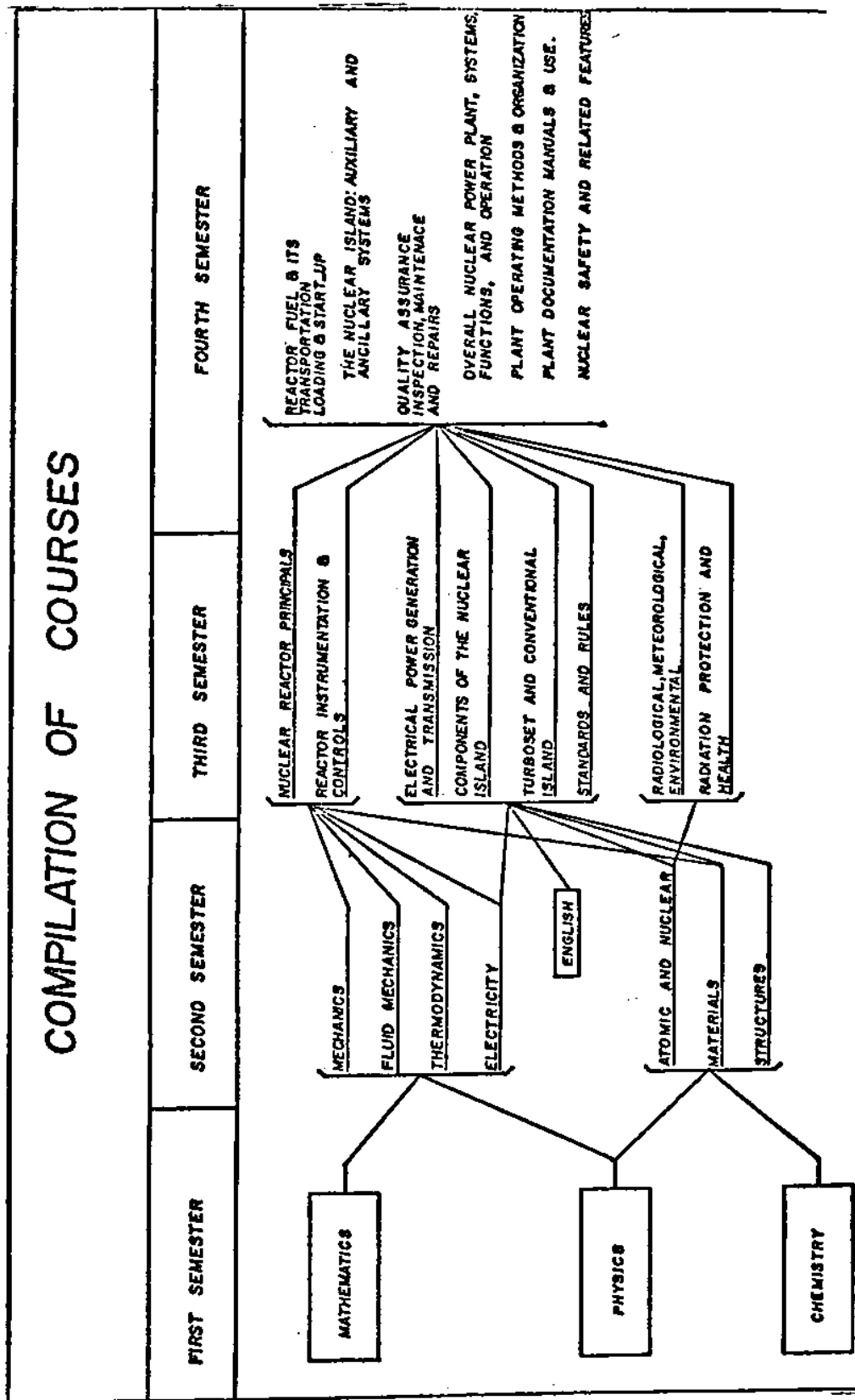


Chart I

## 4. SHOPS

Shops are provided within the INECO training program for the students's practical training. A description of the shops and their credit hours are given below.

### 4.1 Basic Shops

The first Semester Shops are designed for familiarizing the students with tools and workmanship. They are designed to create the theoretical and practical background of basic knowledge for the apprenticeships that begin in the second Semester. These Shops, as well as the first semester courses, are the same for all students regardless of their later specializations.

The Basic Shops are subdivided into two main groups:

First Group - Crafts Apprenticeship

Second Group - Laboratory Apprenticeship

The purpose of the first group is to give a feeling for manual work in wood, metal, glass, ceramics, plastic and electrical crafts. The second group gives the students a feeling for the deeper influence of the basic sciences in the plant processes as a whole. The students should get a feeling for physical methods in measuring, control, working and handling plant components, their layout and design. The outline for the sub-topics and their hours for the crafts Apprenticeship and laboratory Apprenticeship are given below:

1. <u>Crafts Apprenticeships</u>		
(a) Woodwork by hand and by machine	(in Farsi)	15 hours
(b) Metalwork by hand and by machine	(in Farsi)	15 hours
(c) Electrical work	(in Farsi)	10 hours
(d) Glass, ceramics and plastic work	(in Farsi)	10 hours
2. <u>Laboratory Apprenticeships</u>		
(a) Mechanical	(in Farsi)	30 hours
(b) Electrical	(in Farsi)	30 hours
(c) Optical	(in Farsi)	20 hours
(d) Radioactivity	(in Farsi)	<u>20 hours</u>
Sub-Total		150 hours

The total number of hours for the first Semester are as follows:

First Semester Courses	515 hours
First Semester Basic Shops	<u>150 hours</u>
Total First Semester Hours	665 hours

The Crafts Apprenticeship activities are held outside of the training center in suitable workshops. This program is structured for groups of 25 students for each sub-topic.

The laboratory Apprenticeship Involves experiments to be performed by the individual students in groups of two or three students.

The Apprenticeship itself is subdivided into four parts which are as follows:

1. Mechanical, Acoustic and Caloric Experiments.  
Each student will carry out a total of ten (10) experiments for this subject.
2. Electricity and Magnetism.  
Each student will carry out a total of ten (10) experiments for this subject.
3. Optics.  
(Experiments in optical measuring processes, vernier dials, remote sensing, etc.)  
Each student will carry out a total of seven (7) experiments for this subject.
4. Radioactivity.  
A portion of this section of the laboratory Apprenticeship consists of special lectures (extracted from the general physics and general chemistry courses) on the phenomena and laws related to radioactivity.  
Each student will carry out a total of seven (7) experiments for this subject.

#### 4.2 Shops A: Special Apprenticeships

As stated earlier, students need complete training to execute the different kind of craft work corresponding to the craft apprenticeships in industrial countries.

In accordance with the requirements for specialization of technicians in Nuclear power plants, the training in Shops A and Shops B are carried out in the necessary professional fields. The selection of students for these different professional fields must be made during the first semester by the teaching staff in accordance with the students' abilities and desires.

After the completion of the first semester, a total of 550 students will be allocated into the following groups for professional specialization:

- |  |       |
|--|-------|
| 1. <u>Mechanical Works</u>   |       |
| (a) Metal Works  | 25    |
| (b) Precision instrument makers  | 25    |
| (c) Welders  | 25    |
| (d) Installators and repairmen for pipes and valves, etc.                              | 25    |
| (e) Machine specialists (turbines, pumps, fans, diesels, etc.)                         | 25    |
| (f) Universal Mechanical repairmen (vessels, heat exchangers, auxiliary boilers, etc.) | 25    |
|  | <hr/> |
|  | 150   |
| 2. <u>Electrical And Electronic Works</u>  |       |
| (a) Electric fitters:  |       |

particularly installators of wires, cables (power, telephone, measurements, etc.), circuits, equipment, systems, etc.	50
(b) Rotating electrical machines, transformers and other equipment specialists	25
(c) Communication systems specialists	25
(d) Specialists in digital electronics (logic systems, computers, etc.)	25
(e) Specialists in measuring and control (M & C) equipment, including mechanical M & C equipment	50
	<hr/> 175
<b>3. <u>Measuring, Maintenance And Other Services Technicians</u></b>	
(a) Analytical Water Chemists	25
(b) Radiochemists	25
(c) Environmental radiological measurement specialists	25
(d) Meteorologists (climatologists) specialists	25
(e) Health physics and radiation protection specialists	25
	<hr/> 125
<b>4. <u>Operators (Technicians)</u></b>	
(a) Measuring and control technicians for overall plant and main components	25
(b) Technicians for computers and programming, including process computers	25
(c) Plant components and overall plant specialists	50
	<hr/> 100
Total Number of Students: 550	

Second semester training denoted as shops A conducted in Farsi with 120 hours for each selected group. Shops A will be followed by Shops B in the third semester (160 hours) until this training is complete. Shops A and Shops B comprise a total of 280 hours.

#### **4.3 Shops B: Special Apprenticeship**

Shops B are a continuation of Shops A. The professional groups and sub-groups of Shops A

are identical in Shops B.

#### **4.4 Advanced Shops**

All groups of Shops A and B will participate fully in the advanced Shops in the third semester. The language will be entirely in English.

The Advanced Shops are characterized by the following topics:

1. Exercises in reading related technical descriptions and manuals.
2. Exercise in radiological protection.
3. Execution planning for repair work.
4. Practical mock training of special repair work (i.e. main heat exchanger, etc.)  
(Eventually, simulator training for operators will be established.)

The advanced Shops are the final preparation in Iran before the practical third-year training in actual operating Nuclear Power Plants in an industrial country.

A compilation of shops is shown in chart II.

#### **5. MASTER PLAN**

The Master Plan encompasses the complete listings of all of the courses and shops for four semesters at the INECO training program for Nuclear Power Plant Technicians and Operators. The Master Plan is exhibited on chart III. It is to be noted that the number of hours allocated to the individual courses and shops may be determined more accurately in the future after the room for lectures and laboratories and the travel time from the various locations have been properly scheduled. It is planned that the travel time by bus between classroom and laboratory buildings and to workshops will occur only once per day during the noon hour for, say, each student.

INECO staff personnel who are specialists in the individual courses and shops will actively participate as advisors to the Training Center.

Chart II

COMPILATION OF SHOPS			
BASIC SHOPS SEMESTER I (IN FARSI)	SHOPS A SEMESTER II (IN FARSI)	SHOPS B SEMESTER III (IN FARSI)	ADVANCED SHOPS SEMESTER IV (IN ENGLISH)
<u>CRAFT APPRENTICESHIPS</u> <div>WOODWORK</div> <div>METALWORK</div> <div>ELECTRICAL WORK</div> <div>GLASS, CERAMICS, AND PLASTICS WORK</div>	<div>MECHANICAL WORKS</div> <div>LOCKSMITHS</div> <div>INSTRUMENT MAKERS</div> <div>WELDERS</div> <div>INSTALLATORS</div> <div>MACHINE SPECIALISTS</div> <div>UNIVERSAL MECHANIC</div> <div>REPAIRMEN</div> <div>ELECTRICAL AND ELECTRONICAL WORKS</div> <div>INSTALLATORS</div> <div>ELECTRICAL EQUIPMENT SPECIALISTS</div> <div>COMMUNICATION SYSTEMS SPECIALISTS</div> <div>DIGITAL ELECTRONICS SPECIALISTS</div> <div>MEASURING AND CONTROL SPECIALISTS</div> <div>MEASURING AND MAINTENANCE TECHNICIANS</div> <div>ANALYTICAL WATER CHEMISTS</div> <div>RADIO CHEMISTS</div> <div>ENVIRONMENTAL RADIOLOGICAL SPECIALISTS</div> <div>METEOROLOGICAL SPECIALISTS</div> <div>HEALTH PHYSICS AND SAFETY SPECIALISTS</div> <div>OPERATOR TECHNICIANS</div> <div>MEASURING AND CONTROL TECHNICIANS</div> <div>COMPUTER AND PROGRAMMING TECHNICIANS</div> <div>PLANT COMPONENTS AND OVERALL PLANT SPECIALISTS</div>		<div>READING TECHNICAL DESCRIPTIONS AND MANUALS</div> <div>RADIOLOGICAL PROTECTION</div> <div>PLANNING REPAIR WORK</div> <div>MOCK TRAINING OF REPAIR WORK</div> <div>(SIMULATOR TRAINING FOR OPERATORS)</div>
<u>LABORATORY APPRENTICESHIPS</u> <div>MECHANICAL</div> <div>ELECTRICAL</div> <div>OPTICAL</div> <div>RADIOACTIVITY</div>			



Chart III

# **INECO TRAINING PROGRAM COURSE MASTERPLAN**

SEMESTER I Basic Science and English (in Farsi)	SEMESTER II Advanced Science and English (in Farsi)	SEMESTER III Applied Technics and Technical English (in Farsi)	SEMESTER IV Advanced Technics (in English)
a Mathematics 70 h	a Mechanics 35 h	a Nuclear reactor principles 100 h	a Reactor fuel transportation, loading and start-up 50 h
b General Physics 90 h	b Materials 15 h	b Reactor instrumentation and control 35 h	b The nuclear island and auxiliary & ancillary systems 70 h
c General Chemistry 50 h	c Structures 15 h	c Nuclear island components 25 h	c The overall nuclear power plant, systems, functions and operation 70 h
d Self expression (Farsi) 45 h	d Fluid mechanics 60 h	d Turbostat and conventional island 35 h	d Nuclear safety and related features: safety reports 50 h
e Basic English I 220 h	e Basic English II 150 h	e Technical English I 165 h	e Technical English II 150 h
f Technology, Industries, Laboratory-technics 40 h	f Thermodynamics, Heat and Mass transfer 70 h	f Radiation protection and health physics 35 h	f Plant operating methods and organization 70 h
g Basic Shops 150 h	g Electricity 40 h	g Radiological, meteorological & environmental programs 40 h	g Quality assurance, inspection, maintenance and repairs 70 h
	h Basic atomic and nuclear physics 70 h	h Standards and rules: incl. conventional safety features 35 h	h Plant documentation manuals and their use 50 h
	i Preliminary survey on pressure water-reactor nuclear power plants: equipment & operation 80 h	i Electrical power generation, transmission and distribution systems 35 h	i Advanced shops 105 h
	j Shops A 150 h	j Shops B 180 h	
<b>TOTAL HOURS 665 h</b>	<b>665 h</b>	<b>665 h</b>	<b>665 h</b>

SHOP TRAINING: Separate courses will be held for radiation measuring and monitoring, health physics, welding, water chemistry, maintenance and repairing of equipment, etc.

## SOME THOUGHTS ON NUCLEAR POWER TRAINING IN JAPAN

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### ABSTRACT

The educational aspect of the transfer of nuclear power technology to Japan is described for the purpose of introducing our practical experiences to those countries which are going to make exertions in the field of nuclear power. In the first place, the transfer of nuclear power technology over the past two decades is historically reviewed as a part of our efforts to transfer the fruits of modern Western scientific knowledge over the past century. In the next place, our practical experience with the training of LWR operating personnel and also the training aspects of our first commercial nuclear power plant, Tokai GCR, are described.

Then an attempt is made to evaluate the training effect based on the plant productivity which will be yielded by better personnel with improved training to meet consumer demand and to save oil consumption for years to come. The nuclear electricity generation of one of our plants is compared with that of the model plant, applying the comparative method proposed by the author at the ANS 1976 Annual Meeting. This method enables us to indicate graphically time lags and level gaps in the process of technology transfer. In analyzing this process, the reduction of time delays demands better training and education of a higher quality. Finally the possibility of achieving a higher technology level through international cooperation is emphasized.

### 1. INTRODUCTION

What is the transfer of nuclear technology? This term appears to mean more than the installation of nuclear facilities which are imported from advanced countries to developing countries. The original objectives of such facilities can not be deemed to have been achieved unless they are successfully operated and maintained by educated and trained personnel. The educational and training aspects of our experience with the transfer of nuclear technology are described in this paper. Here we wished to concentrate on nuclear technology, presuming this conference is more concerned with nuclear power.

First of all, the historical review of nuclear power training in Japan is described, and then, current activities and achievements in this field are presented hoping that this information might be helpful for those countries which are going to make exertions in the field of nuclear energy. Finally some thoughts on human factors affecting the efficiency of technology transfer are discussed.

## 2. HISTORY

It is nearly twenty years since we started learning nuclear technology. At that time the feasibility of nuclear power generation had been demonstrated successfully in the world. As these very successful demonstrations led to the nuclear power programs of the British GCR around 1960 and of the American LWR in the mid 1960s, our utilities, in cooperation with our heavy industries, imported them as models of our nuclear power program. This necessarily called for the training of our key personnel, engineers and prospective reactor operators, in the exporting countries, i.e. Great Britain and the United States.

Behind this scene of the transfer of nuclear technology over the past two decades, there existed in our country a group of eminent nuclear scientists, and also a pool of engineers and technicians who were well educated and experienced in the field of steam power and electric power. The base technology of steam-electric power has been well established in Japan as a result of the successful transfer of western technology, since Japan became firmly committed to introducing western civilization nearly a century ago.

Even in our feudalistic age which preceded the so-called "Opening of Japan"<sup>(1)</sup> in 1853, our people maintained an excellent tradition in education and respected teachers.<sup>(2)</sup> We are thankful for teachers from the West, who devoted themselves to transfer the fruits of modern Western scientific knowledge to our relatively small islands in the Far East.

Particularly since the Meiji Revolution<sup>(1)</sup> of 1868 which followed the "Opening of Japan", most emphasis has been placed on "education" as our national policy. Thus the basic education system was established in Japan to enhance the transfer of nuclear technology in later years.

## 3. BASIS FOR NUCLEAR POWER TRAINING

The existence of the basic education system and the base technology of steam-electric power made it possible for us to introduce a nuclear power training system<sup>(3)</sup> which assumes certain minimum requirements for our trainees. They are:

- a) Several years of conventional plant experience in steam and electrical system,
- b) A basic training in mathematics and physics either at high school or later.

Here the question is raised of the maturity of conventional base technology which is a must for nuclear power training. Without this maturity some difficulties may be found initially in recruiting supervisors who are not only experienced in modern technology but also have deep understanding of the souls of native workers.

However we have to pay attention to the major difference which distinguishes nuclear power technology from conventional power technology: radiation. In some cases it is hard for those experienced in a non-radioactive area to visualize the difficulties involved in radioactive maintenance works, until hard lessons are learned through experience. In this respect, it might be more desirable to train younger flexible people rather than to introduce the concept of radiation to old experienced people.

From this point of view, the infancy of the base technology may turn out to be an advantage in the long run, since it means more flexibility for the evolution of a nuclear power industry. Therefore it has been left for the young developing countries to take advantage of the infancy in base technology.

#### 4. TRAINING OF NUCLEAR OPERATING PERSONNEL

Some practical experience with the training of operating personnel for our nuclear power plants is described. Usually a nuclear power plant is operated with a staff of about 100 - 200, and round-the-clock operation is carried out by four shifts, each of which consists of about 10 operators. In addition to the plant personnel, the plant operation is supported by staff at headquarters and subcontractors. The effective training of this supporting staff is also of importance as will be discussed in section 6.

The training of each employee may be considered to continue through his professional career or even through his life, but we will focus our attention on a particular phase of the training, which is carried out at an educational institution such as our nuclear power training center.

##### 4.1 Training of LWR Operating Personnel

As previously mentioned, in regard to the training of operating personnel of our LWRs, which were imported or started commercial operation before the mid 1970s, the senior members of operating staff were sent to the United States. However, as our LWR nuclear power program has expanded and the importance of training has been recognized, nuclear power training centers were established in mid 1972 and training was commenced in spring 1974. The PWR training center (JNTC) was established in a joint venture by Mitsubishi Heavy Industries and our nine utilities. The BWR training center was established jointly by Hitachi and Toshiba.

As an example, the PWR course is described as follows:

##### (a) The Training Course

The PWR Initial Training Course is split into the following three phases:

- 1) Nuclear fundamentals
- 2) System descriptions and plant observations
- 3) Simulator training<sup>(4)</sup>, <sup>(5)</sup>

Since we imported training materials and a simulator from the United States, the course is similar to that of Westinghouse Zion nuclear training center (WNTC) in the early 1970s<sup>(3)</sup>. Assuming that the American Simulator Training has already been presented in other sessions, only those aspects which are different from the American course will be described.

For the purpose of plant familiarization, Mihama Station (3 units), which is located about 10 miles from JNTC, is made available by the Kansai Electric Power Company. De-

pending on the background experience of trainees, some special lectures on operating experience are given by managers or engineers of the station, and found extremely useful for trainees.

In addition to the aforementioned initial training which lasts for about 20 weeks, a two-week re-training course is becoming increasingly popular. Since nuclear power plants are intended for base load operation, which means less chance for operating personnel to exercise plant start-up and shut-down operation, some exercises with the simulator are found useful for such purpose.

#### (b) Achievements with Our PWR Training

In the last three years, since we started our training in spring 1974, a total of about 200 personnel have been trained at JNTC in various programs. Out of 200 trainees, a total of about 100 have completed the initial training, and been assigned to a specific plant for start-up tests and subsequent commercial operation. They are now furthering their training on the job. Thus the feel of the plant will be obtained with their own plants and the jobs are learned best by executing responsible duties. In addition, a total of about 100 students attended a two-weeks retraining course.

### 4.2 Training of Operating Personnel of Our First Commercial Nuclear Power Plant (Tokai GCR)

With respect to the type of power reactors, LWRs are playing a dominant role in the 1970s in our country. However in presenting the educational aspects of the transfer of nuclear power technology, the description of our experience with our first commercial nuclear power plant, British type Tokai GCR, may be of some interests for those who are going to make an effort in nuclear power.

In regard to our Tokai plant, the training of operating personnel was carried out in accordance with the British standard<sup>(6)</sup>. Our key personnel attended the Calder Operation School, and then were allowed to get some practical experience with Calder Hall Atomic Power Station. In this case the major part of the training was carried out by the plant owner, U.K. AEA. In addition to the above standard training, some of our people were allowed to attend nuclear generating stations owned by British Electricity Generating Boards (CEGB or SSEB) in their commissioning stages.

As described in the case 4.1 and 4.2, there are some variations in the course for the transfer of nuclear power technology, depending on commercial arrangement and social system involved. In both cases, mutual respect and full participation by those concerned are of vital importance, since the technology transfer is an exercise in human relations, patience and understanding.

## 5. EVALUATION OF THE TRAINING EFFECT

### 5.1 Indices for the Evaluation of Training Effect

Now, an attempt is made to evaluate the effect of the training. As it is recognized that better personnel, with improved training, will yield increased productivity<sup>(7)</sup>, plant productivity may be considered to indicate the effect of the training, and furthermore to indicate the technology level aimed at producing more nuclear electricity at a given nuclear power plant, not only for today but for years to come, in order to meet consumer demand and to save oil consumption.

### 5.2 An Example of the Technology Transfer

Since our achievements in regard to the transfer of LWR technology are being presented by our representatives in other sessions and the technology transfer is an exercise of patience one of the actual examples of the transfer of nuclear power technology over the past decade is shown in Fig. 1 (a). This is the case of our first commercial nuclear power plant, Tokai CCR, of which the training aspect has already been described in section 4.2.

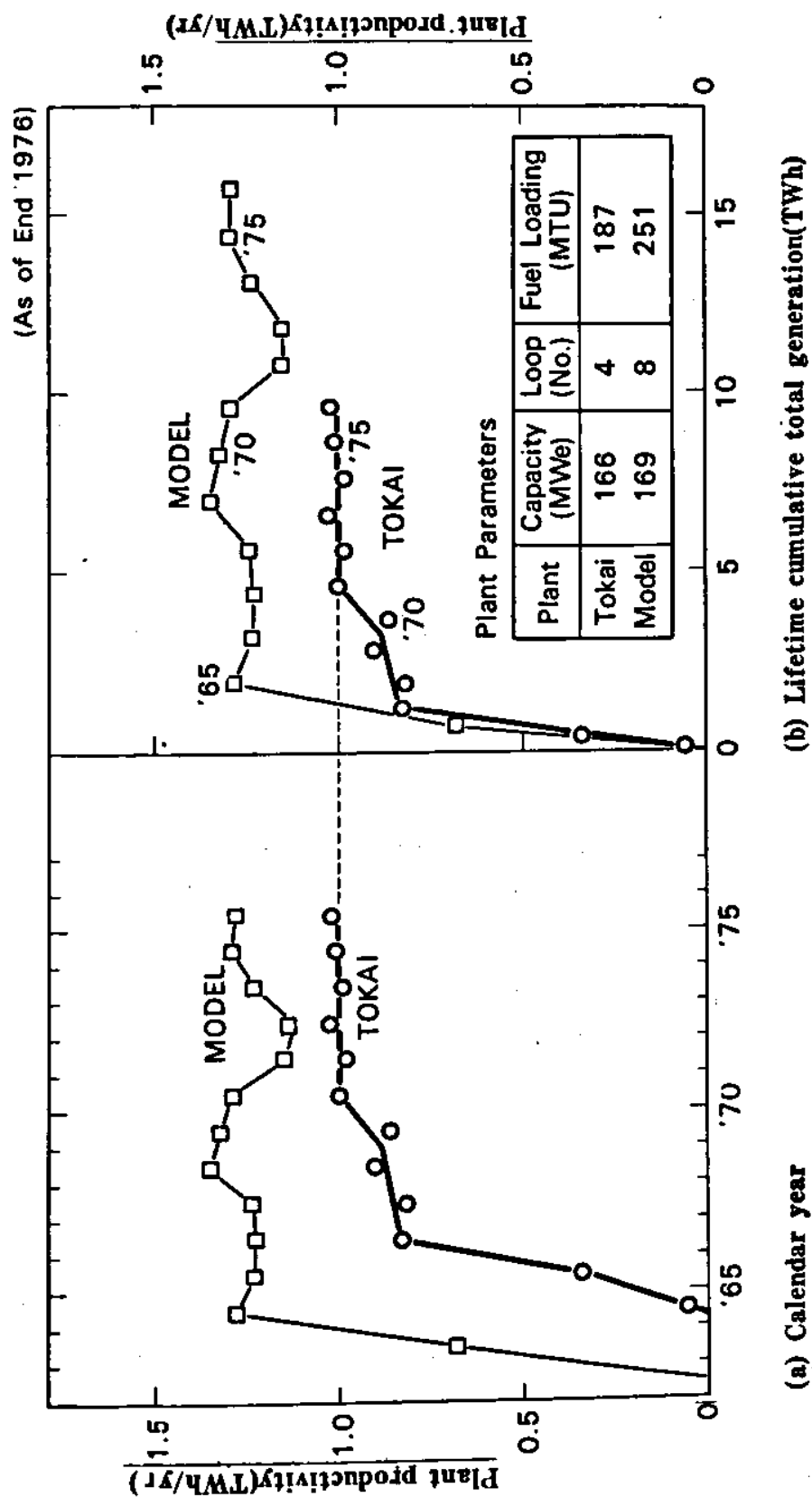
The level gap in productivity is obvious from this drawing, but the time delays in recent years are not clearly indicated. One method of evaluating the time delay would be to count the number of years from the commencement of commercial operation<sup>(8)</sup>. But a more straightforward and simple method<sup>(9)</sup> would be to adopt the cumulative generation as indices of effective plant ages as shown in Fig. 1 (b). In comparing plants of different size, it is customary to use the Capacity Factor (CF), but an alternative method<sup>(10)</sup> of normalizing them in terms of the nuclear fuel was adopted as shown in Fig. 2.

Thus our achievement with our first commercial nuclear power plant is found on a similar locus as the British model plant in terms of the technology level which is aimed at getting as much power as possible out of a given amount of nuclear fuel loaded (MWh/MTU per year)<sup>(10)</sup>. Our plant is found on a similar level, but is about 2 years behind, as compared with the British model plant.

## 6. LEVEL GAPS AND TIME DELAYS IN THE TECHNOLOGY TRANSFER

Generalization of our experience in the previous section leads us to Fig. 3 (a) & (b). To analyze this figure, some efforts, both in quantity and quality, in reducing gaps and delays may be indicated as in Fig. 3 (c).

In order to achieve a higher level, more investment and ingenuity for development works is required. The amount of the investment may be dependent on the number of plants to be built, and more investment may be justified through international co-operation. Furthermore unique ideas from both sides should be effective in resolving technical problems. Development works at the transferring side have to be respected.



Notes: Gen. Data : Nucleonics Week  
Plant Data: IAEA Operating Experience with Nuclear Power Stations.

Fig. 1. An Example of the Transfer of Nuclear Technology



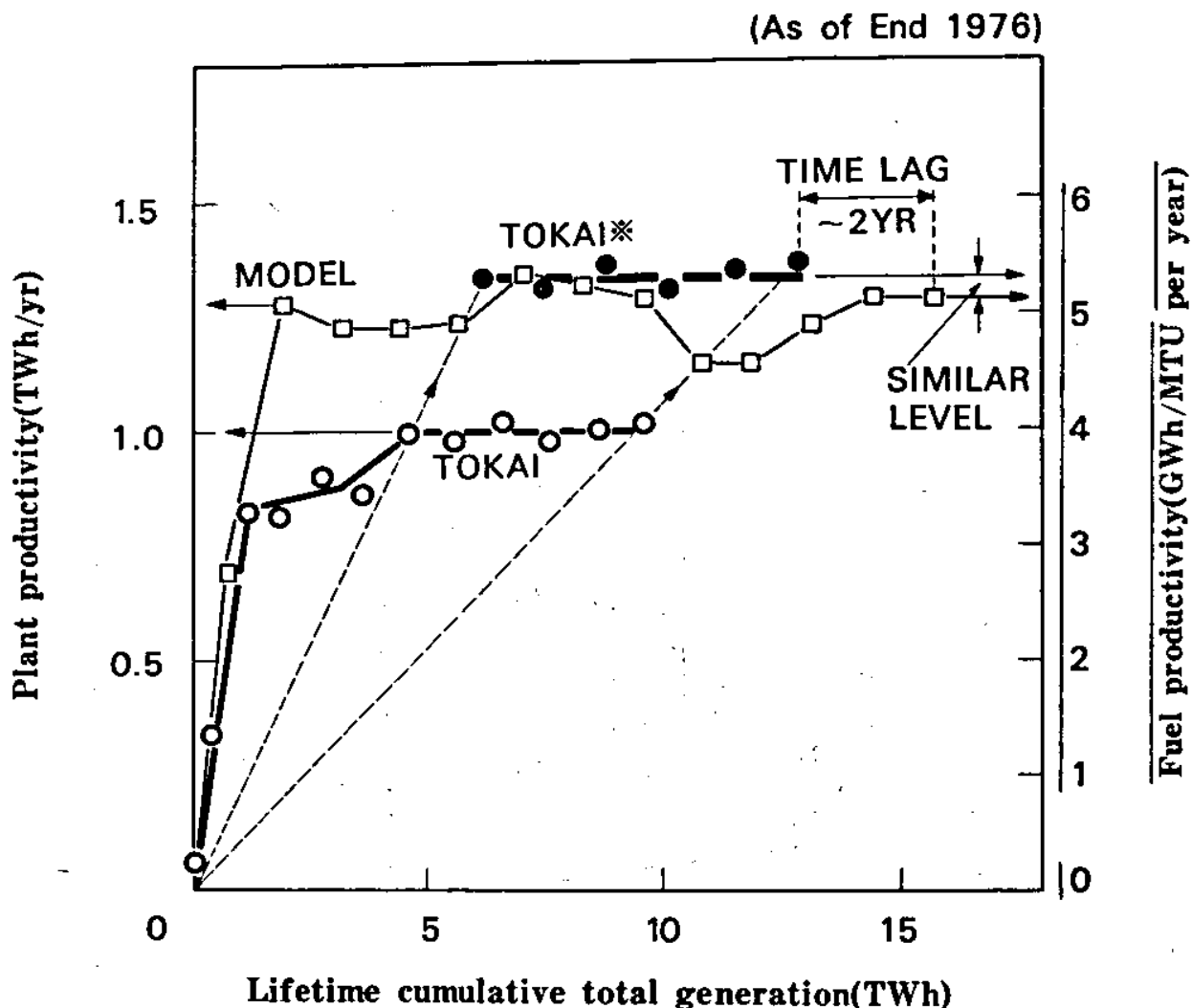
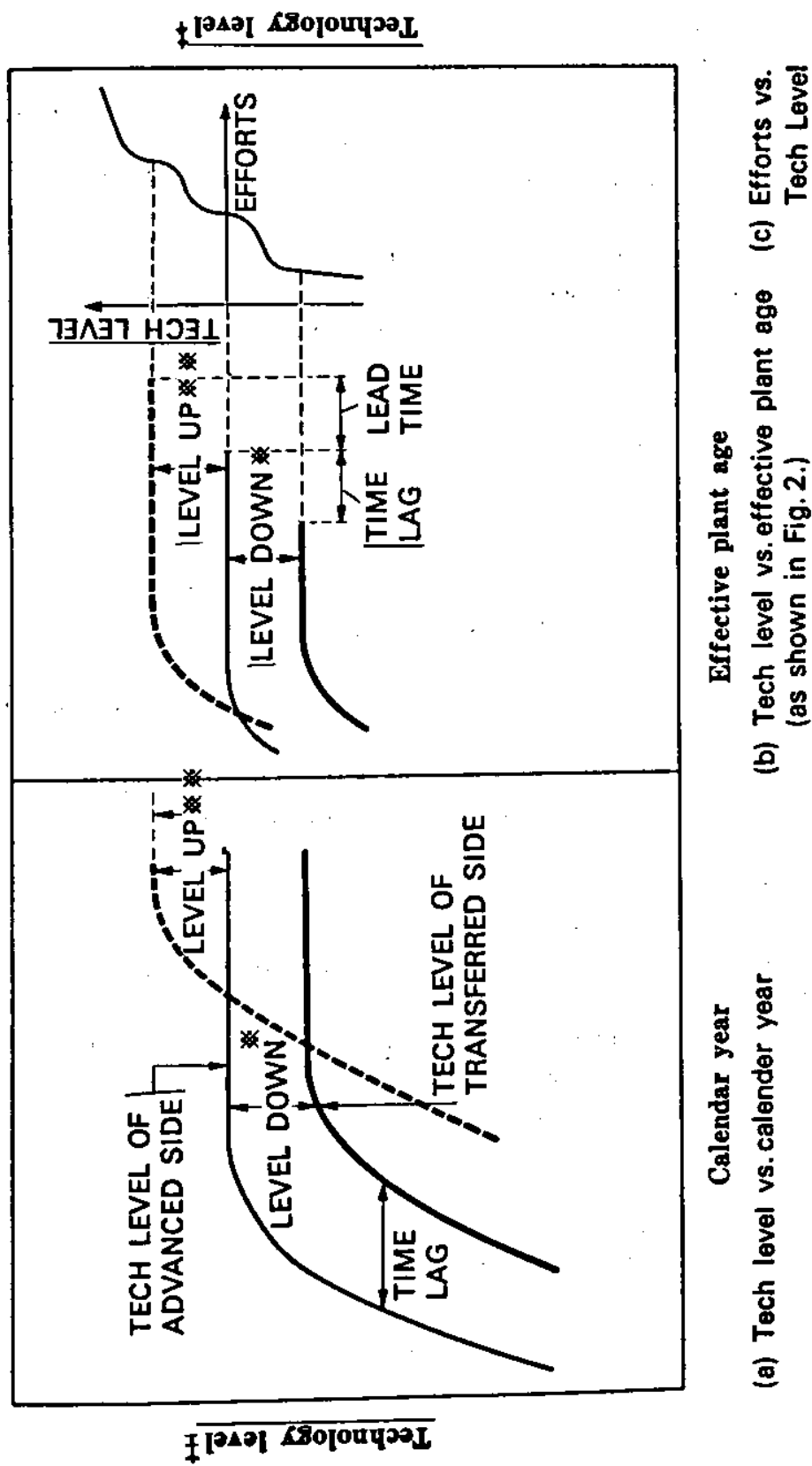


Fig. 2. Comparison of Tokai GCR and a British Model Plant

\*Tokai projected on a Model Plant  
(Fuel loading ratio of Fig. 1, 251/187, multiplied)

Such a triumphant attitude to enjoy the higher level without such active efforts at the transferred side may not be allowed. Some informal information on potential problems in the developing area may be helpful for the operator, based on very good human relations of mutual respect and trust.

Then, how is it possible to reduce the time delay? In analogy to the technology of servomechanism, in which "the transfer function" is widely used, the reduction of time delay demands a better control system for technology transfer and effective feed-back loops for operating experiences. However the improvement of this time response may be restricted by the chronic nature of such potential problems as corrosion.



- \* Passive Transfer: Less participation of the transferred side
- \*\* Active Transfer: With own creative efforts at the transferred side

Technology level may be represented by plant productivity as proposed in Ref. 9.

Since it is not unusual for the resolution of some potential problems to take a longer time for development work, the time relationship is apt to be changed. Some quantitative change in time delays may demand qualitative improvements in training and education. As the time delay is reduced, the following aspects of training or education may be required:

- 1) A powerful maintenance force to cope with unprecedented incidents or repair work,
- 2) An independent design capability to resolve modification works,
- 3) Research and development capability, e.g. in the field of material testing or fuel irradiation.

Since this system of technology transfer involves not only the technical problems but also such social factors as response time of a particular society which is dependent on the flexibility or rigidity of an organization or individual, the subject of technology transfer may have to be analyzed in cooperation with social or political scientists on a national or even international basis<sup>(11)</sup>. The evaluation of our achievements in the transfer of nuclear technology may be left to historians of future generations.

## 7. CONCLUSIONS

In summarizing my presentation, the following conclusions can be derived:

- (1) For the enhancement of the transfer of nuclear technology, a greater emphasis has to be placed on basic education.
- (2) The base technology of steam-electric power makes it possible for us to introduce nuclear power training systems in advanced countries.
- (3) The task of taking advantage of infancy in base technology is left to the young developing countries, since it means more flexibility for the evolution of nuclear power industry.
- (4) Without independent-minded active participation from the transferred side, some difficulties might be experienced in keeping the technology level as transferred.
- (5) The efficient technology transfer with a shorter time delay demands qualitative improvements in education and training.
- (6) It is possible to achieve a higher technology level through international cooperation, since combined efforts by well educated and trained people will justify greater investment in development work in resolving technical problems.

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## EDUCATION AND TRAINING IN NUCLEAR TECHNOLOGY IN LIBYA

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### ABSTRACT

For a rich developing country like Libya, one of the major problems encountered in the implementation of nuclear technology is, without doubt, the formation of the required number of qualified technicians and research people necessary for the running of future nuclear power stations and all the connected projects. The aim of the paper is to discuss the program of education in nuclear technology actually followed for undergraduate and graduate students and also to indicate what is actually done for the training of Libyan technicians. Recommendations are made in order that other developing nations may take advantage of our experience.

### 1. INTRODUCTION

#### 1.1 Why Going Nuclear ?

The answer was given by Dixie Lee Ray, the former president of the United States Atomic Energy Commission, stating that it is foolish to cast suspicions on developing nations if they are looking for nuclear energy: the cost explosion on the oil market, the fact that oil reserves will be exhausted in the not too distant future (we are dealing with capital and not with income: fossil fuels are not made by men, they cannot be recycled and once they are gone, they are gone for ever), the nonsense of burning oil instead of processing it, .... all these reasons compel many nations to go nuclear.

Also from the pure economic point of view, it seems now that, for very large power stations, the nuclear ones with an expected life time much greater than twenty years,

might be cheaper than conventional units, under some circumstances, in the long run. The actual oil price situation has greatly improved the economic outlook for nuclear power in general and small and medium nuclear plants in particular.

Last, but not least, it should be good for oil producing countries like Libya to know or at least have a good idea of the technology of to-morrow, not only to prepare technicians for the future but also to maintain the oil price at a competitive level with respect to other sources of energy.

## **1.2 Difficulties Facing Programs of Nuclear Implementation in Libya**

Libya is actually a developing nation and consequently has to face problems related to the implementation of any industry in young, developing countries such as the lack of adapted technical structures, the difficulties in recruiting capable local technicians, the hesitations in taking the responsibility for technical decisions, etc... <sup>(1)</sup>

Another paper presented in the session on General Aspects of Nuclear Technology Transfer III will consider in detail the problems facing nuclear research in developing countries <sup>(2)</sup>. But we must not forget that Libya is a rich developing country and consequently its major problem in nuclear implementation is not money but rather the formation of the required number of qualified technicians and research people.

## **2. EFFORTS IN EDUCATION**

### **2.1 Missions to Developed Countries**

So far, about 250 young Libyans have been sent abroad by the Libyan government in two main consecutive waves for undergraduate studies. This experience is now two years old and it is time to analyze the results.

Many problems were encountered: the language obstacle, the difference in education systems from one country to another, the decrease in educating efficiency with an increase in the number of our students at the same teaching place (five seems to be an upper limit for reasonable studying efficiency), the difficulty to oblige the students to study certain specialities that the country is in absolute need of, the forced orientation of student towards fields of little interest to them by the host organization or country, ...

However we estimate the percentage of successful students to be about 70% and we think that this campaign will reach the principal aim which was to constitute a first human reservoir of high level capability.

The same scheme was retained for graduate students but for far fewer people (about fifty) and for a much shorter time abroad. Before leaving Libya, these graduate students received local training in different laboratories of the El Fateh Faculty of Science, the Agricultural Research Center and the Industrial Research Center. The main problems encountered were of course very close to the ones mentioned for the undergraduate group.

In particular the duration of the mission was too short (one month to six months only) to take full advantage of. Also it is extremely difficult to cover the whole spectrum of nuclear specialities due to the external constraints imposed by the receiving organizations, universities, research centers or specialized laboratories.

## **2.2 Universities Response**

The two Libyan Universities have responded to the need for technical manpower in the nuclear industry by the following:

### **2.2.1 Courses in Nuclear Science Topics in the First two University Years**

Naturally the science curricula of upper secondary education touch on the structure of the atom in physics or chemistry courses in more or less detail; also the applications of nuclear science in biology or agriculture and the genetic effects of radiation are mentioned.

But the representative experiments in nuclear science recommended by the Buenos Aires International Atomic Energy Agency & Unesco Joint Panel on nuclear science teaching<sup>(3)</sup> for secondary schools are really done as physics experiments in the second university year. For example the following experiments: Characteristics of a Geiger-Muller detector, the inverse-square law, the absorption of  $\gamma$ -rays, density and thickness determination, half life calculation, are given to the second-year students in all departments of the Petroleum Faculty and in the Mechanical, Electrical and Civil departments of the Engineering Faculty.

Because of the increasing peaceful uses of nuclear energy and their applications for man's welfare, we think that attempts should be made to increase the nuclear science aspects taught in physics courses at the second year university level. Opportunities should be fully given to students in their early years at the university to understand the role of nuclear science in the world today and to share in the excitement of using radiation science techniques, (according to reference<sup>(3)</sup>, approximately one-fifth of the laboratory physics exercises should be in the sector of nuclear physics).

### **2.2.2 Creation of the nuclear department at the El Fateh Faculty of Engineering**

The decision was taken to create an independent nuclear department at the Faculty of Engineering of the El Fateh University and the overall supervision of everything concerned with this department was entrusted to a senior Professor with a wide experience in the formation of engineering departments.

The syllabus contains the following nuclear courses, the number in brackets indicating the weekly number of hours of lectures and quiz sections or laboratories.

- a) for second year students: Survey of nuclear engineering (2) Modern physics (5).
- b) for third year students: Fundamentals of nuclear engineering (3) - Transport



phenomena (3) .

- c) for fourth year students: Nuclear reactor analysis (5) - Nuclear heat transport (3) - Nuclear engineering lab. (3) - Nuclear reactor materials (4) - Electrical lab. for nuclear engineers (3) - Introduction to plasmas (4) - Radiation damage (3)
- d) for fifth year students: Nuclear power systems (3) - Reactor dynamics (3) - Reactor laboratory (3) - Shielding (2) - Health physics and environmental aspects (3) - Project in nuclear reactor plant design (4) .

It should also be noted that the mathematical subjects of the syllabus put emphasis on all forms of numerical computation in order to familiarize our future nuclear engineers with the use of both large and small computers.

### 2.2.3 Cooperation Between the El Fateh University, the Different Research Centers and the Libyan Atomic Energy Establishment

There is close cooperation between the Faculty of Engineering and the Faculty of Science of the El Fateh University, the Agricultural Research Center, the Industrial Research Center and the Atomic Energy Establishment. Some of the professors of the above two faculties work part-time for the Atomic Energy Establishment.

### 2.3 Nuclear Research Center

In order to achieve the following three objectives: complementarity of specialities, proper balance of staffs, team spirit, it was decided in 1975 to create a nuclear research center within five years. This center will be equipped with all modern scientific means in order to cover the main lines of nuclear activities development:

- . neutron physics - neutron generator & associated electronics
- . fission reactor - highpower research reactor
- . fusion reactor - Tokamak
- . isotopes - radio chemical laboratories

This project which should take from four to five years for completion is coordinated with an education and training program extending over about the same period of time.

It is hoped that the existence of such a research center will contribute to solving the "brain drain" question, not only to foreign countries but essentially in Libya to other industries which are in very bad need of qualified Libyan personnel.

After proper selection of the graduate student he will be assigned to one of the four main sections of the research center. He will probably in this stage go abroad to get deeper formation in his field of assignment. He should then participate in the erection of his future equipment and collaborate in the start-up of his facility.

Finally, after about four years, the appropriate teams can be set up to run the facilities of the nuclear center with the required level of knowledge and integration. This

should be achieved without any heavy support to the Libyan center from outside the country.

Naturally in the long run, the educative role of this nuclear research center will decrease in importance due to the increased efficiency of the nuclear department of the El Fateh University but there will be still then a very strong link between the nuclear center and the local industry through research itself.

#### 2.4 International Cooperation

As far as multilateral cooperation is concerned, we possess in the International Atomic Energy Agency a very efficient tool and connecting link. We are convinced that the Agency's way of dealing with scientific and technical assistance is an excellent approach to the problems of technology transfer and consequently Libya supports IAEA activities without any reservation. One of the Agency's governors is Libyan; the Agency has organized expert assistance for Libya in the following fields: radio isotopes applications, protection from radiations, nuclear electronics. However we think, in agreement with the IAEA technical cooperation activities report <sup>(4)</sup>, that these activities are rather modest in scope. Until August 1975, the Agency has involved the provision of only 199 fellowships while the recipient countries themselves have provided 57 experts in support of the Agency's technical assistance program and accepted 39 Agency fellows for training. There are indications that in the Middle East region at least Kuwait, Saudi Arabia and Libya are studying the possibilities of "going nuclear". The foremost need in all these cases will be for massive technological staff training and experts' advice and the IAEA can play a very important role in assisting our countries in furthering their plans.

Bilateral cooperation is also very fruitful, with many countries and mainly takes the form of exchange of scientists in both directions, exchange of information, mutual assistance, joint use of research facilities, fact-finding missions, consultants and last, but not least, training at universities and technical colleges and "on-the-job" training of graduates.

Unfortunately bilateral cooperation is always very sensitive to fluctuations in the domain of foreign policy.

### 3. EFFORTS IN TRAINING

The final objective of the Libyan nuclear program is to set up the human resources able to work consistently on the nuclear industry and research development. This implies complementarity in the nuclear specialities developed in this human reservoir. It means also that, as in any other field, there be a proper balance between the different levels of knowledge. We are fully aware that many more technicians are needed than Ph.D.s or D.Sc.s and that technicians have to be trained not only in nuclear science but also in related supporting areas. Also nuclear technology needs people working in teams. Consequently our Libyan Atomic Energy Establishment tries to give as much importance to train-

ing teams as to training individuals.

### 3.1 Teacher Training

According to the recommendations of the Athens panel on Nuclear Science Teaching III<sup>(5)</sup> there are efforts to update the content background of the secondary schools teachers because they are the people directly involved in influencing the thinking and attitudes of thousands of students each year. This is done mainly in collaboration with the Faculty of Education.

### 3.2 Short Missions to Developed Countries

For a few staff members of the Libyan Atomic Energy Establishment short-term visits to centers outside Libya are made for training purposes. These short missions are undertaken through the granting of fellowships sponsored by appropriate national and/or international organization. Such fellowships are aimed at making available a core staff in Libya with more advanced knowledge in the field.

### 3.3 Local Training

The main problem facing local training is the lack of skilled people to repair the existing instruments. The training of technicians which did not receive particular attention up to now will begin to be much more effective with the opening of specialized institutes such as those of Ben Walid, Hon, Garabully, etc. The three year period after finishing high school will provide an adequate formation basis plus some specialization to many technicians. A complementary education in nuclear technology could be given either in parallel, for example during the last year, or by a few months course with a short stay abroad. It is today recognized that nuclear training is much more fruitful when given to technicians with a good basic knowledge, the education being supplemented by practical work in a nuclear laboratory. It is hoped that local training will gain more importance with the opening as soon as possible of the above specialized institutes besides the creation of the Nuclear Research Center. Under the auspices of the Middle Eastern Regional Radioisotope Center for the Arab Countries two training Programs in radioisotope applications were carried out in 1976 and 1977. Each program took three months with two courses weekly and was attended by more than 25 members. The courses were given by lecturers from the above Center, the El Fateh University and the Libyan Atomic Energy Establishment. It is our intention to increase the number of such programs in the future and diversify their subject.

## **4. RECOMMENDATION**

We would like to stress the following points according to our experience in this field:

- Too young people should not be sent abroad for training; i.e. it is a must to try to

develop local training as much as possible at least in its early stages.

Strong incentives should be created for training in disciplines of particularly high importance such as nuclear technology <sup>(6)</sup>.

The necessity for developing nations to have as soon as possible one or more low power training plant.

The creation of close connections between universities and atomic energy establishment and/or nuclear research center (s) in order to ensure that all engineering capabilities are fully used for economic growth <sup>(6)</sup>.

The necessity of developing all types of regional cooperation such as on the applications of radioisotopes, on the solution of pollution problems, on the struggle against diseases (human, agricultural, ...).

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## **NUCLEAR SCIENCE TRAINING IN SRI LANKA**

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### **ABSTRACT**

The Nuclear Science Program in Sri Lanka is designed to meet the need for isotope and radiation techniques and for power. The main training center in Sri Lanka at present is the Radioisotope Center. A Department of Applied Nuclear Science at the Radioisotope Center and a Department of Nuclear Engineering at the Katubedde Campus will be established in the near future. The aim of these training centers will be to borrow already developed and tested technology and transfer this technology to those who are expected to handle nuclear science activities in our Country.

### **TEXT**

Sri Lanka is a small developing country with a land area of 25,000 square miles and a population of 14 million. Her total electricity generating capacity at present is about 400 MW, most of which is hydro power. The total economically exploitable hydro capacity in Sri Lanka is about 1,500 MW with an energy content of 5700 GWH per annum. This includes about 900 MW that is made available as a result of the recent diversion of the longest river, Mahaveli ganga, towards the north central region of the country. The electrical power demand in the country is rising steadily at a rate of about 11% per annum and it is estimated that the total exploitable hydro capacity will be tapped by the year 1990 for generation of electricity.

However some of the hydro power stations that are already in operation have begun to be unavailable from time to time due to shortages of water; and present indications suggest that this seasonal nature of hydro power will make it necessary for the country to think of nuclear power even before 1990. This has made it necessary to prepare the infrastructure required to incorporate nuclear power into our national grid.

Further, the realization by scientists, engineers and doctors of the vast potential in nuclear techniques for solving research, industrial and medical diagnostic and therapeutic problems has made it necessary for them to acquire know-how of these techniques.

The Atomic Energy Program in Sri Lanka started in 1958 when the Government appointed a Committee on Atomic Energy. To facilitate the function of this committee which was to draw up a program on the peaceful uses of atomic energy suitable to Sri Lanka, a mission was invited from the International Atomic Energy Agency (IAEA). The main recom-

recommendation of the IAEA mission which visited Sri Lanka in 1959 were:

- a) The establishment of an Atomic Energy Authority, which should be responsible for the control, importation, allocation and distribution of radioactive material and for the formulation and enforcement of atomic energy regulations in Sri Lanka.
- b) Carrying out training, development and research programs and applications of radioisotopes in various fields of science in a Central National Laboratory (The Radioisotope Center).

Following these recommendations the Radioisotope Center was established in 1961 whereas the establishment of the Atomic Energy Authority was achieved in 1969.

The Radioisotope Center was designed as a self supporting center able to provide laboratory, library, advisory and training facilities to all departments of the University and the Government and other organizations and institutions. The main functions of the Radioisotope Center are:

- a) Teaching and Training
- b) Undergraduate and post graduate research
- c) Collaboration with other institutions in research work involving radiation and radioisotopes.
- d) General advice on matters related to atomic energy and
- e) Providing services to other institutions.

Before the Radioisotope Center was set up, training in the uses and handling of radioisotopes was available only to those who could obtain a fellowship or a scholarship to go abroad and the number who could do this was very small.

The Atomic Energy Authority of Sri Lanka established in 1969, handles policy matters and national legislation on atomic energy. It also promotes and assists peaceful applications of atomic energy in Sri Lanka, organizes and supports coordinated research programs among different institutions in the country and channels IAEA assistance where ever necessary.

Uses of radioisotopes and radiation for diagnostic and therapeutic purposes is handled at the Cancer Institute in Colombo and the Nuclear Medicine Unit in Kandy. The Nuclear Medicine Unit also instructs medical students on the uses of nuclear techniques in medicine.

Nuclear technology is extremely sophisticated and has been developed up to the present state at an enormous cost to many developed countries. Further development is still more costly. A small developing country like Sri Lanka cannot afford to develop any such technology on her own. Therefore we have to depend on borrowed technology that is already well proven.

The enormous potential of nuclear technology to help solve many problems of mankind, such as power generation, food production, industrial development and quality control, medical diagnosis and treatment and environmental quality has made it a sine qua non of the modern epoch for the survival and progress of all nations, particularly the countries of the third world.



Our training program on atomic energy is geared to achieving the objective of transferring nuclear technology from wherever it is available to our scientists, engineers and technicians so that these techniques can be exploited to their fullest capacity for the upliftment of our nation.

The basic plans for the transfer of nuclear technology from abroad to Sri Lanka are as follows:

- 1) Sending scientists, engineers and technicians to countries which are advanced in nuclear technology for advanced training.
- 2) Drawing experts and teachers from abroad for initial organization of programs and training groups of workers in specialized projects.
- 3) Conducting regional training programs with the assistance of international organizations and with teachers from abroad, wherever necessary, to obtain know-how in specialized fields.
- 4) Organizing training and research programs with the help of local persons who have already undergone advanced training abroad.
- 5) Making available an advisory service for scientists and industrialists who need the help of nuclear techniques.

Item 1 is achieved mainly through the IAEA fellowship scheme. A few years ago we had to use these fellowships to train our people even in the basics such as the handling of isotopes. Now, as our own training ability in these is growing, we are using fellowships to train them in more specialized fields such as isotope hydrology, repair and maintenance of nuclear electronic equipment and also in power technology. Fellowship schemes other than the IAEA scheme have also been useful to a small extent.

Item 2 is also achieved through IAEA assistance. For many projects which require a certain amount of organization and on-the-spot training of many people it has been found that the services of an expert, who is experienced in such work is extremely useful. For this type of work we prefer professional experts. Obtaining the services of experts in this manner overcomes the lack of experience of a freshly trained person. In Sri Lanka this scheme has been very successful.

Item 3 is also achieved through the support of the IAEA. This enables a wide spectrum of scientists or technicians to be trained in specialized fields. The first such course was held in Sri Lanka in 1963 at the Radioisotope Center. The second one on "Nuclear Techniques for Chemical Residue and Pollution Problems" was held at the Radioisotope Center last month. This course was very successful and 11 Sri Lankan scientists received training. With this number trained we are now in a position to start a program on environmental pollution problems. For this project the IAEA will supply an expert and some equipment this year. Organization of such courses has the advantage that the host laboratory gets some equipment which can support the continuation of such work without delay.

Items 4 and 5 are achieved by our own efforts. Advisory services such as guidance in the use of isotopes and safety considerations, a radiography service and a service for repairing nuclear electronic equipment are being made available at the Radioisotope Center.



Training programs at the Radioisotope Center, which is the main center for nuclear science training in Sri Lanka have been expanding since its inception. The courses conducted at the Center are:

- a) Nuclear Chemistry Course for Chemistry students,
- b) Radioisotope Course for Chemistry students,
- c) Radiochemistry Course for General Science students,
- d) Radiobiology Course for Zoology and Botany students,
- e) Nuclear Physics Course for Physics students,
- f) Course in Nuclear Measurements to Industrial Electronics students,
- g) Radiochemistry Course for Applied Science students,
- h) Radioisotope Course for scientists and
- i) Radioisotope Course for technicians.

As the training requirements are expanding the University has proposed to establish a department of Applied Nuclear Science at the Radioisotope Center. Once this is established it will be possible to train annually a small number of undergraduates with a greater emphasis on Nuclear Science.

In addition to formal training courses the Radioisotope Center allows technicians from other departments to work at the Center for two to four week periods to gain experience in handling radioisotopes.

For training requirements in Nuclear Engineering it is hoped to start the department of Nuclear Engineering at the Katubedde Campus, which is the Campus closest to the Radioisotope Center, which has an engineering faculty. Already IAEA has offered two fellowships to train the staff required for this department. In the future all training in Nuclear Sciences in Sri Lanka is to be handled by these two departments, the Department of Applied Nuclear Science (presently Radioisotope Center) and the Department of Nuclear Engineering.

Apart from these, the physics curricula in all Campuses contain a component of nuclear physics. The Peradeniya Campus Physics Department is at present organizing a specialized section in neutron physics which the IAEA have kindly agreed to support.

The development of nuclear know-how in Sri Lanka depends on the expansion of the Radioisotope Center, establishment of the Department of Nuclear Science and also on the success of the course in nuclear engineering. This can be achieved only with the assistance of the IAEA and friendly countries. Assistance is required especially, to obtain the necessary equipment and experts.

## NUCLEAR RESEARCH AND EDUCATION IN SPAIN

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### 1. INTRODUCTION

The aim of the National Electric Plan established in Spain is to increase the electro-nuclear power installed in the Country from the present 1100 MWe to 21000 MWe in 1985, by setting up 12 PWR and 8 BWR generator units.

Overall participation of Spanish engineering and industry in building and installation of nuclear power plants will have been 66% for the units which will start operating in 1977. This participation should increase to 80% for the plants to be put in service in 1980. This increase will be possible because of the establishment of new industries for the manufacture of heavy components for nuclear power plants as well as for activities related to the fuel cycle.

The use of radioisotopes and ionizing radiation generator devices has extended considerably in Spain. Spanish regulations in this field make it necessary to obtain operator's or supervisor's licenses for all persons responsible for the installation and handling of such devices. These individuals are submitted to suitable tests to prove that they have the required knowledge. Up to 1976, more than 1200 such licenses have been granted.

All this has been made possible due to a great effort in research and education which has been carried out over 28 years, since the first Commission for the study of nuclear energy was founded in Spain. However, it will be necessary to intensify these efforts in order to reach the goals established for the next decade.

This paper describes the present activities and the immediate future research and personnel training projects for developing peaceful nuclear energy applications in Spain.

### 2. NUCLEAR RESEARCH

The "Junta de Energía Nuclear" (JEN) is the official agency responsible for development and regulation of nuclear energy in Spain. At the present time, JEN has a staff of over 2000 persons, of which more than 400 are scientists and high-level technicians. Its annual budget is equivalent to about 42 million dollars.

From 1951, the year in which it was created, to 1960, almost all Spanish research in the nuclear field was carried out by JEN. In about 1960, Universities and high-level Technical Schools started showing an interest in carrying out nuclear research and included

courses on nuclear technology in their study programs.

Most of the physics and nuclear technology professors of the universities received their first nuclear training in JEN. This has helped to facilitate collaboration between JEN and the universities. In order to promote this cooperation as well as to intensify personnel training courses, at all levels, on the multiple aspects of nuclear energy, the Institute of Nuclear Studies was created within the JEN.

The Institute is the body responsible for education on matters relating to nuclear energy, as well as for the promotion and coordination of nuclear research across the country. It is governed by a Board formed by representatives of the Ministry of Industry, Ministry of Science and Education, Universities, the JEN itself, the main Research Centers, electrical utilities and industrial companies. The chairman of the Board is the chairman of the JEN.

Due to the lack of experimental facilities, early nuclear research and teaching in the universities was fundamentally based on theory. Although the Institute's funds were also rather limited, it helped in setting-up laboratories and in purchasing equipment for radiation measurement and analysis. Thus, experimental techniques were implemented. Some universities were able to start their own research programs and established fruitful contacts with foreign universities and scientific organizations.

The funds assigned to research in Spanish universities have always been low. The Institute goes on helping, within its limitations, by establishing research contracts on subjects related to nuclear energy, proposed by universities, or on subjects of interest to JEN, related to its own programs. In order to promote research and teaching in reactor physics in Engineering Schools, JEN built and installed Argonaut-type reactors of 10 kW maximum power, in two such schools.

Furthermore, the Institute grants scholarships to post-graduates for extended stays in the JEN laboratories so that they can become specialized in one of the many branches of nuclear technology or prepare a Ph.D. Thesis. Scholarships are also offered to foreign post-graduates for the same purpose, either through the International Atomic Energy Agency or as a result of bilateral agreements with different countries.

The research and development work promoted by JEN includes:

1. Absolute measurement of radioactivity and dosimetry of nuclear radiation and X-rays.
2. Determination of disintegration schemes and energy levels of radionuclides using alpha and gamma spectrometry.
3. Study of solid state physics, especially of radiation effects on ionic crystals.
4. Research on high energy physics by analysis of photographic plates from the bubble chambers of the European Center for Nuclear Research (CERN).
5. Development of methods for carrying out chemical analyses in very low concentrations.
6. Research concerning production and application of radioactive isotopes.
7. Studies concerning ecological impact and safety of nuclear plants.
8. Studies concerning radiation biology, especially the DNA alteration mechanisms

caused by ionizing radiations.

9. Geological prospection of uranium minerals, treatment of minerals and uranium metallurgy. Manufacture of fuel elements for experimental reactors. (Uranium enrichment is carried out in the United States).
10. Treatment of irradiated fuel, with a pilot plant for treatment of MTR type irradiated fuels.
11. Radioactive waste management. Careful geological studies for determining possible permanent deposits.
12. Development of instruments for rapid detection and analysis of weak radioactive contamination.
13. Development of calculation methods for reactor cores to determine critical mass, distribution of neutron flux and fuel burning ratios.
14. Research on liquid sodium technology as a coolant for fast nuclear power reactors.
15. Fundamental studies on plasma physics, especially on macroscopic equations, wave propagation and instabilities.

Nuclear research in the University, mainly theoretical, is related to several of the above-mentioned subjects. Some university departments also carry out experimental nuclear research, with rather limited means, either in collaboration with JEN or with several foreign scientific groups.

### 3. EDUCATION AND TRAINING

The Spanish program for nuclear power plant installations and the wide-spread and growing use of ionizing radiations in many fields poses an important problem in personnel training. This training takes place in the universities and engineering schools, in the Nuclear Studies Institute and also in the electric utilities with nuclear programs.

#### 3.1 Universities and Engineering Schools

In almost all the Spanish faculties of science, Nuclear Physics and Radiochemistry are explained. In the main engineering schools, several subjects directly related to Nuclear Technology are also taught. In the Geological Science Departments, and Mining Engineering School's programs, the fundamentals of Uranium Geology are also included.

Industrial Engineering studies include a specialty called Energy Techniques which deals with the above-mentioned subjects in greater detail. As mentioned before, two of these schools are equipped with Argonaut-type experimental nuclear reactors for teaching and research.

These universities and technical schools also organize special courses on subjects related to nuclear technology, such as Quality Control, Health Physics, Nuclear Safety, Radiolotope Applications in specialized fields, etc. When it is possible and convenient, part of the experimental work of these courses is carried out at JEN laboratories in order

to profit from expensive equipment which it is not advisable to duplicate elsewhere in the country.

### 3.2 Nuclear Studies Institute

For its educational and training purposes, the Institute uses JEN's laboratories, pilot plants and nuclear reactors. Aside from a small full-time staff, professors are JEN experts with teaching talents, who dedicate part of their working time to this task. In this way, the Institute offers the following three types of courses on a regular basis:

- a) Annual Nuclear Engineering Course, lasting ten months, with exclusive and intensive dedication. This course is attended by Spanish and Latin-American post-graduates in engineering and science, many of them being already employed in engineering or electric companies engaged in the nuclear business. Aside from the fundamental disciplines involved in nuclear technology (Nuclear and Reactor Physics, Reactor Technology, Instrumentation and Control, Nuclear Materials, etc.) the course also includes seminars on Nuclear Safety, Health Physics, Shielding Studies and Nuclear Economics, besides a design project, whose subject depends largely on the experience and interest of each group of students. During the course, detailed visits are made to nuclear power plants under construction or in operation, as well as to factories where equipment for such plants is built.
- b) Intensive courses on basic nuclear technology, lasting four months, which provide the second training stage for future nuclear power plant operators. These courses are 4 or 5 months long, depending on the background and previous experience of the students, who are generally designated by the utilities. Main topics on Atomic, Nuclear and Reactor Physics are included, as well as Instrumentation and Control (Reactor and General) and Health Physics. Operation and experimental measurements are performed in two experimental reactors.
- c) Intensive training courses for future supervisors and operators of radioactive installations. After common basic lectures and experimental work, these courses diversify into different branches: Industrial radiography, nuclear medicine, health physics, use of radioisotopes in research and process control, etc. These courses help the participants to obtain the license required to handle or supervise operations with radioisotopes or ionizing radiation generators. In order to attend to the many requests for such licenses the Institute promotes these courses all over the country, in close cooperation with universities, technical schools and the training services of the Ministry of Labor.

Other courses are held upon request from official organizations or private companies or when the Institute perceives the need to train technicians in a given specialty. As an example, courses for future radiochemists of nuclear power plants, courses on nuclear instrumentation, courses with special reference to particular radioisotope applications and courses on instrumental chemical analysis can be mentioned.

The average number of participants in the above mentioned courses is 15 to 22 per course according to the availability of space and facilities for practical work.

### 3.3 Electric Companies

Utilities with nuclear power plants either in operation, or under construction or even in the planning stage, actively participate in training their nuclear power plant personnel. Generally speaking, this training consists of the following stages:

1. Preliminary stage, during a variable period between 3-8 months, teaching the fundamentals of thermal energy production and active training in a fossil fuel power plant.
2. Basic nuclear technology course (4 months) in the Institute of Nuclear Studies, with practical training in experimental nuclear reactor operation.
3. Training in a nuclear power plant (4 months) of similar type (PWR, BWR) to the future job assignment, with detailed study of the plant's systems and equipment.
4. Simulator operations (3 months) and dynamic plant studies, in normal and varied emergency conditions.
5. Study of the plant to which the person is assigned (12 months) until a detailed knowledge of the plant's systems, equipment and operating procedures is acquired.
6. On-the-job training (12-18 months) to acquire full knowledge of the plant, with detailed study of its operating procedures, and participation in commissioning and testing.

During stages 5 and 6, the future operators participate actively in preparing the operating manuals for normal and emergency conditions. They also receive complementary lectures on nuclear safety, regulations, health physics, quality control, etc.

Stage 1 is carried out in the electric company itself. As indicated, stage 2 is carried out in the Institute of Nuclear Studies, stage 3 either in the Spanish nuclear power plant in Zorita (PWR) or in Santa Maria de Garona (BWR). At present, Stage 4 is carried out in the United States. Stage 5 is usually carried out in the utility itself and stage 6 in the nuclear power plant in which the technician is going to become an operator.

All the training stages indicated above are thus carried out in Spain, except stage 4 as there are not yet suitable nuclear power plant training simulators in our country.

In view of the importance of simulators, both for training new operators and for periodic retraining of senior operators, some large European electric companies have decided to set up their own nuclear power plant simulating centers. So has a Spanish service company in which most of the country's electrical utilities participate.

This company is building in the outskirts of Madrid, a training center for which two large nuclear power plant simulators, of PWR and BWR types, have been ordered. Inauguration of the PWR plant simulator is foreseen for the spring of 1978. The BWR plant simulator will start operating about a year later. A comprehensive agreement has been concluded with JEN by which the Institute of Nuclear Studies will participate in the activities of this training center.



#### **4. CONCLUSION**

Building a nuclear power plant usually takes longer than estimated by the promoters. In any case, it always takes a longer time to properly train the personnel who will have to guarantee the plant's correct operation, maintenance and safety.

Consequently, developing countries looking for a significant national participation in the installation and operation of their nuclear power plants should set up personnel training programs well in advance. Experience has shown that in many cases these programs have been inadequate.

Substantial participation in the planning, construction and operation of a nuclear power plant always requires a certain level of research capability in many different fields. Therefore, a realistic and responsible national nuclear program requires and notably stimulates, the technological development of a developing country.



## **BASIC TRAINING OF OPERATIONAL PERSONNEL FOR NUCLEAR POWER PLANTS**

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### **ABSTRACT**

This paper gives explanations for a basic structure of personnel organization and informs on prequalification and qualification required. Especially on the nuclear power plant Iran 1 and Iran 2 examples are given for the training of management, operators and specialists as well as for the retraining of honarestan graduates.

Furthermore, information is provided on requirements of licensing examinations, and on problems in case of training in a foreign country.

### **1. INTRODUCTION AND PROBLEM DEFINITION**

Besides the three classical production factors, namely: soil (or nature), man (or labor), and capital, there is also a fourth one, to wit: education. Now this fourth production factor "education" is of very great importance, especially in our modern age. In almost all fields of modern technology it will no longer do to-day to employ, say, operating personnel who have received mere basic instructions without any accompanying in-depth training. Personnel must be thoroughly trained so as to acquire the required knowledge on the technology concerned, its internal and external relationships, and its proper handling. This specialized training must go hand in hand with a continuous re-training program. While specialized training serves to acquaint and familiarize the employee with the plant he operates, re-training has the purpose of refreshing and deepening this knowledge.

On account of the complex problems involved, the great variety of fields of work, and the qualification requirements imposed by the public authorities, the training of nuclear power plant personnel is a very difficult matter. Thus, a knowledge not only of general mechanical and electrical engineering but also of some specialized subject, such as e.g. control engineering or turbine construction is required. The subjects mentioned were selected at random from a wide variety of fields which cannot possibly be enumerated here in their totality.

The approach to the training problem as described in the following pertains only to such technical personnel of a nuclear power plant as are immediately required for its operation. Be it remarked here at the beginning that the overall responsibility for the availability and qualification of personnel rests with the owner.

## 2. ORGANIZATION AND TASKS OF POWER PLANT PERSONNEL

Before taking-over a plant, the owner must have a complete, properly qualified staff for its operation and maintenance at his disposal.

In principle it would be possible to train the entire staff of a nuclear power plant. As a rule, however, it is not necessary to put the commercial staff (e.g. book-keepers and members of the financial officer's department), nor the entire administrative personnel through specialized training. Similarly, construction engineers and operators of conventional auxiliary equipment need only be instructed during the actual construction time, or during erection and commissioning on site. Experienced personnel for these tasks is thus normally available on the local labor market.

The technical personnel for the operation of a power plant comprises the higher and lower-level management, the operating personnel proper, and the maintenance and repair personnel.

For each position within the organization a job description with indication of the qualification requirements must be available at a very early point in time already. Only after the tasks and the training objective have been laid down can it be decided what supplementary training is required in the light of the required prequalification at the start of training.

First of all it is necessary to classify the personnel to be trained according to their educational levels and their tasks, with the structure of the various categories thus established to be refined at some later time. A two or multi-category system is possible here. In the following a three-category system will be assumed, with the first category comprising the complete engineer-level management, supervisory personnel and operators, the second category the technicians and foremen, and the third category the skilled workers. Each category can be subdivided further as required by the nature of the plant concerned. The following example of a subdivision of Category I gives an illustration:

- 1.1 May comprise, for example, the entire top management, (Plant Superintendent, Sub-division Manager, Department Manager).
- 1.2 Comprises all persons of Senior Supervisor or Supervisor level.
- 1.3 Comprises e.g. the specialists (process computer engineers, health physicists, chemists, physicists, etc.).
- 1.4 comprises the operators.

In this manner, as mentioned above, each category may be suitably fine-structured. For this personnel the competent authorities usually require an organizational chart prepared by the owner and showing the various areas of responsibility. In Germany such a chart must in particular show which ones, if any, of the functions shown belong to any of the categories mentioned below.

The training of German nuclear power plant personnel is guided by the "Richtlinie für den Fachkundenachweis von Kraftwerkspersonal" (Guideline for the Proof of the Professional Qualification of Nuclear Power Plant Personnel), dated October 8th, 1974, which

calls for a clear-cut breakdown of the personnel concerned into the following groups:

General management	(1.3.1)
Other executives	(1.3.2)
Radiation protection management	(1.3.3)
Shift personnel	(1.3.4)

For good order's sake the relevant definitions are rendered here as follows:

#### **1.3.1 General Management**

General management shall comprise all superiors of shift personnel and their permanent deputies as well as the staff on duty having authority to direct the shift personnel outside normal working hours.

General management shall be responsible for the safe operation of the nuclear power plant and the compliance with licensing requirements. A part of its tasks shall be delegated by written operating instructions which the subordinate personnel shall obey. Direct interference with the course of operations by general management shall be an exception to the rule.

#### **1.3.2 Other Executives**

Other executives within the meaning of this guideline shall be the members of the staff with supervisory powers but not belonging to general management, radiation protection management or shift personnel, in particular, the members of the maintenance, engineering physical and chemical fields.

These other executives shall not be authorized to direct the shift personnel, although there will be a relationship of mutual assignments between these two groups, and they shall assist general management and shift personnel in the fulfillment of their respective tasks.

#### **1.3.3 Radiation Protection Management**

Radiation protection management shall comprise:

- those responsible for radiation protection under Sec. 20, paragraph 1, subpar. 2 of the First Radiation Protection Regulation and
- the other members of the staff of a nuclear power plant, responsible for all necessary actions of radiation protection during specified normal operation and during incidents with the exception of general management.

#### **1.3.4 Shift Personnel**

Shift personnel under this guideline shall comprise:

- all shift working superiors of the entire staff engaged in the shift work, including

their permanent deputies. They are referred to as "shift supervisors" in this guideline;

those control room operators who are authorized to operate and supervise the reactor within the scope established for their shift. They shall be referred to as "reactor operators" in this guideline;

all other control room operators who are authorized to operate and supervise individual systems (such as turbine, cooling water system, ventilation systems) in accordance with given instructions.

The shift personnel's job shall consist of the continuous operation of the nuclear power plant during specified normal operation and during incidents within the scope of the existing operating instructions and the operating schedule provided by general management.

The breakdown of the operating personnel into the above mentioned groups shall be effected by the owner.

A number of variants has evolved for the overall technical organization. It should be assured that the production, planning and maintenance, and supervisory fields will be so coordinated that overlapping interests will not give rise to any conflict.

A nuclear power plant consisting of several units shall be so organized that measures extending to several units are uniformly directed by a coordinating department.

The basic principle of the organization of several German plants, and a draft of the organizational chart of the Iran 1 and Iran 2 nuclear power plant are shown in the following (see Attachments 1-3).

### 3. QUALIFICATION REQUIREMENTS FOR OPERATING PERSONNEL, AND PERSONNEL REQUIREMENTS

As a rule, consideration will have to be given to specific minimum requirements imposed by the competent authority in the owner's or the supplier's country for the training to be given to the personnel. The licensing authority will only then issue an operating license if the personnel is suitably qualified. This qualification comprises in this connection both professional training and practical experience. With respect to the latter, credit can be given for practical experience gathered in similar installations and activities comparable to the future job.

In Germany these minimum requirements are laid down in the above-mentioned guideline; consequently, proof of them must be furnished when a license examination is applied for. The details of the provisions concerned are as follows:

#### 2. Proof of Qualification

Proof of the adequate qualification of the persons referred to in subpar. 1.3.1 to 1.3.4 shall be furnished to the responsible licensing or supervisory authority by:

- the submission of documents verifying sufficient specialized training and practical

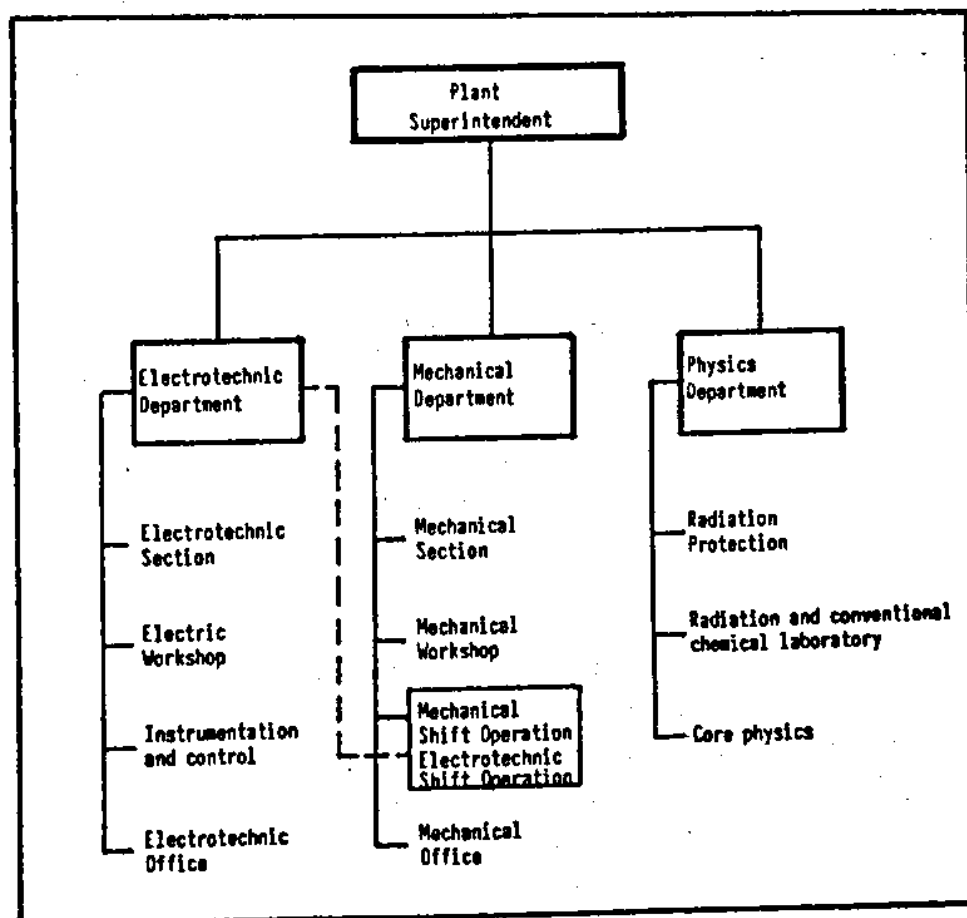
- experience,  
and, for shift supervisors and reactor operators:
- an additional written and oral examination at the plant in accordance with Sec. 3.

## 2.1 Minimum Requirements for Specialized Training and Practical Experience

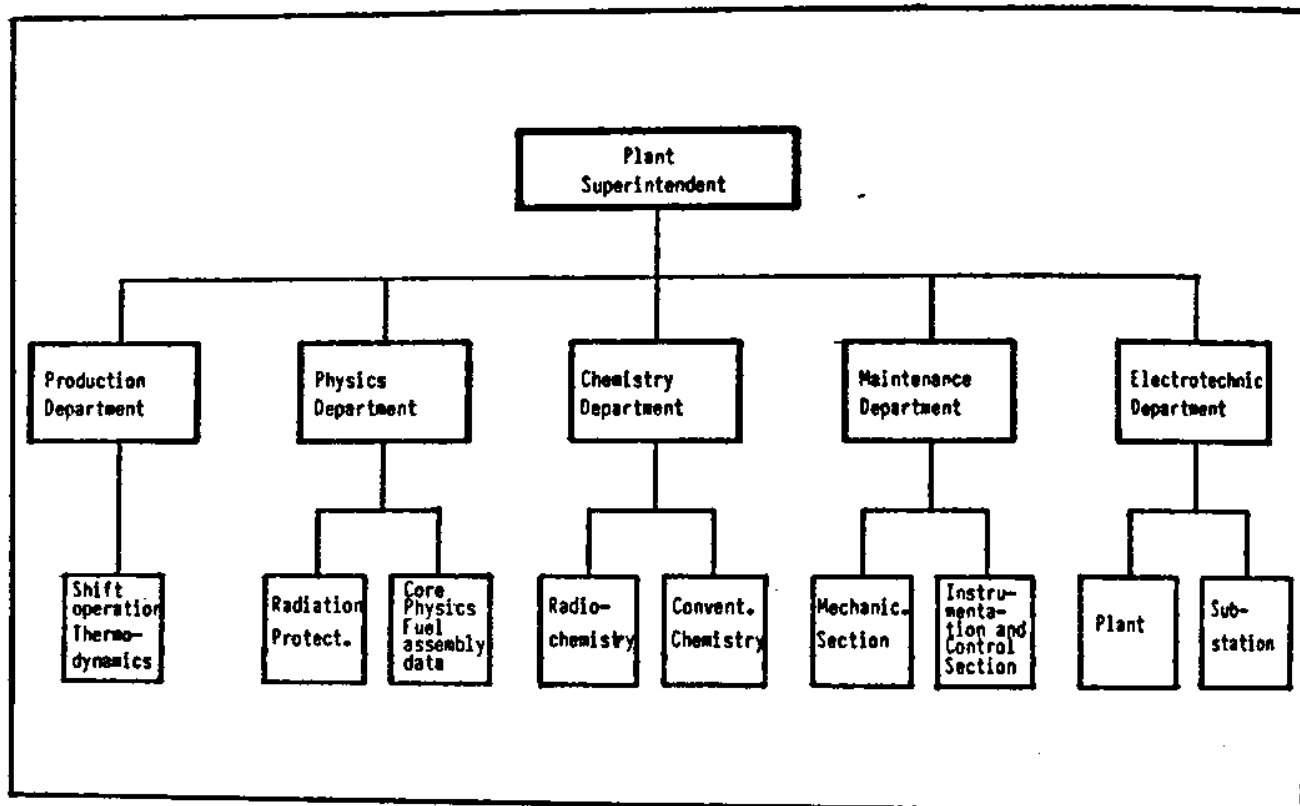
### 2.1.1 General Management

Persons belonging to general management and authorized to give directions relating to the safety of the plant or its operation shall furnish proof of the graduation from a state-operated or state-recognized university or specialized college, of sufficient knowledge<sup>(1)</sup> of reactor physics, reactor engineering, reactor safety, radiation protection and the relevant legal provisions under the Atomic Energy Act and the First Radiation Protection Regulation and shall have acquired at least 24 months' practical experience in a responsible position at a power plant, generally a nuclear power plant.

Attachment 1. Technical Organization Chart Nuclear Power Plant Stade, Germany PWR, 660 MWe



Attachment 2. Technical Organization Chart Nuclear Power Plant Würgassen, Germany  
BWR, 670 MWe



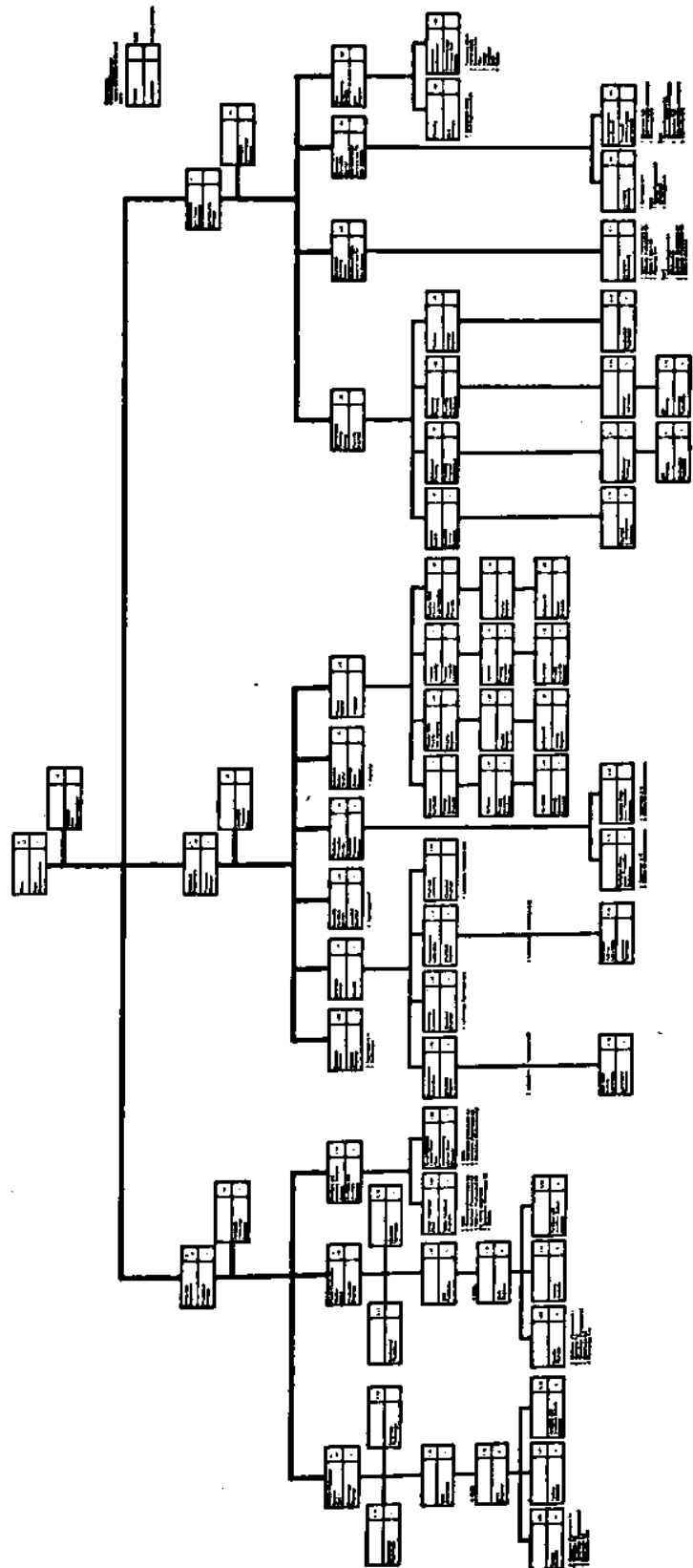
### 2.1.2 Other Executives

Other executives shall furnish proof of the graduation from a state-operated or state-recognized university or specialized college in the special line in which they will take on responsibility, of sufficient knowledge <sup>(1)</sup> of reactor physics, reactor engineering, reactor safety and radiation protection and shall have acquired at least 12 months practical experience at a power plant, generally a nuclear power plant.

### 2.1.3 Radiation Protection Management

Persons belonging to radiation protection management shall at least furnish proof of having passed a final state-operated or state-recognized examination as technicians in a line appropriate to their tasks, of additional training in radiation protection, basic knowledge <sup>(1)</sup> of reactor physics, reactor engineering and reactor safety and shall have at least 12 months practical experience in radiation protection, of which at least 6 months were spent at a nuclear power plant.

# NPP Iran 1 and 2 Technical Organization Chart





#### 2.1.4 Shift Personnel

**Shift supervisors:** Shift supervisors should, as a rule, furnish proof of having passed a final examination at a state-operated or state-recognized specialized college and shall at least furnish proof of passing a state or state-recognized final examination as a master or technician, of an additional specialized nuclear training<sup>(2)</sup> and, as a rule, of 18 months practical experience at a comparable nuclear power plant, of which at least 6 months must have been practical experience as a reactor operator at the plant in question.

**Reactor operators:** Reactor operators should, as a rule, furnish proof of having passed a state or state-recognized final examination as a master or technician and shall at least furnish proof of training in a technical line furnished by an examination as a skilled worker or journeyman, of an additional specialized nuclear training<sup>(2)</sup> and of at least 18 months of work in the operation<sup>(3)</sup> of a nuclear power plant and, in addition, 6 months of shift work at the plant in question.

**Control room operators:** Control room operators shall at least furnish proof of training in a technical line finished by an examination as a skilled worker or journeyman or of equivalent training, shall have received instruction on the interactions between that part of the plant which is controlled by them and the entire plant and, as a rule, shall have operated the particular controls for at least 4 weeks under supervision.

#### 2.1.5 Exceptions

The requirements for specialized training specified in subpars. 2.1.1 to 2.1.4 may be waived if proof is furnished to the responsible licensing or supervisory authority that corresponding knowledge was acquired in some other way (e.g.: the necessary training may have been part of the main training; cooperation in the design construction and commissioning of the plant in question).

Footnotes:

- (1) Proof of sufficient knowledge of reactor physics, reactor engineering, reactor safety and radiation protection may be furnished e.g. by submitting certificates verifying the successful attendance of suitable courses.
- (2) Subjects and scope of such additional specialized nuclear training shall be provided for in a separate guideline.
- (3) Major activities refer e.g. to radiation protection, reactor plant, nuclear and conventional auxiliary systems, turbine and condenser systems, measuring, open-and-closed loop control systems, electrical equipment.

Now these requirements are in general mere minimum demands imposed in a country such as Germany which possesses a solid body of personnel trained in many fields with experience in related areas. It is therefore evident that in a country where the utilization of nuclear energy is still in its infancy far higher demands must be imposed on the qualifications of the engineering personnel. The risks inherent – despite all engineering safe-

guards - in the operation of a large plant suggest the advisability of employing only well trained personnel.

A number of influences must be taken into account when laying down the prequalification requirements before training commences. Thus the title of engineer by no means denotes a roughly equal educational standard everywhere in the world. Nor can a great deal be deduced in first approximation from such job titles as "welder" or "electrician". The existing qualitative differences among educational systems are to be taken into account when laying down a training program. By the same token it is not always possible, in the absence of detailed expert opinions, to make inferences with respect to a person's education and experience on the basis of diplomas/employer's statements and employment records alone.

Other influences follow approximately from the requirements imposed by the plant itself.

Is it a thoroughly proven and "harmless" design or is it a prototype? Is the plant highly automated or does it require frequent intervention by the personnel? Can the personnel - varying with the plant location and the industrialization level of the country concerned - call on assistance from outside, or must they handle all imaginable cases and problems by themselves?

Based on the above considerations it was decided for example with respect to unit 1 of the Iran 1 and Iran 2 nuclear power plant to prescribe an engineering degree (B.Sc. or M.Sc.) as prequalification required before the start of training for all positions from Plant Superintendent to Operator, and to make the filling of all these jobs contingent on the passing of a licensing examination.

In view of the aforementioned differences among the prequalifications in the various countries it is advisable to conduct a preselection among the applicants in the owner's country. Such a preselection includes as a rule a psychological test and a professional qualification test, with the former serving to determine the applicant's ability to concentrate, intelligence, etc. and the latter preferably limiting itself to ascertaining his basic knowledge of mathematics, physics, chemistry and thermodynamics. The preselection also provides an indication of what level the training program should start from. Thus it is sometimes expedient to have one or more preparatory courses precede the training program proper.

These preparatory courses can serve various purposes. First and foremost they are to provide, through the learning of the technical vocabulary of the teaching language and other matters, a starting platform for the subsequent training program. Furthermore each trainee needs a certain period of adjustment to his new work and the unfamiliar conditions awaiting him. A repetition of the basic knowledge makes it possible to proceed more rapidly with the training courses proper as it assures a better and more uniform starting level among the trainees, thus enabling them to concentrate fully on the subject on hand.

To illustrate the description of function and of the minimum prequalification required and to be documented before training starts, the following examples are given here:

**Plant Superintendent:** Function: Direction, coordination and supervision of all activity of the plant, assuming the overall responsibility, head of all departments of the Plant.

**Minimum Prequalification Required:** MSc (mechanical or electrical engineer) with at least 5 years experience in a responsible position in a power plant, preferably a nuclear power plant.

**Maintenance Manager:** Function: Head of all technical departments for planning, maintenance, repair and workshops. **Minimum Prequalification Required:** MSc (mechanical engineer), prequalification same as the Plant Superintendent.

**Reactor Operator:** Function: Entitled to operate and supervise the reactor within the scope of the shift. **Minimum Prequalification Required:** BSc or operator with at least 1 year experience in a power plant.

So that the required strength of the technical operating personnel can be determined it is necessary that the organization chart and the number of shifts have been laid down.

Experience of various nature has led to the organization of a six-shift operating system rotating at 6 week intervals. It can be assumed that a single-unit plant requires some 200 technical personnel, which number can vary somewhat depending on the plant location and the prevailing conditions.

When a plant grows to 2 or 3-unit size its personnel will chiefly increase by the shift personnel for the new units only, as such matters as maintenance and repairs are handled by the central department.

#### 4. TRAINING OBJECTIVE AND TYPE

Once the training objective has been defined, it should not be too difficult to draw up the training program.

The training objective should be to enable the suitably trained personnel to start up and shut down the power plant, to operate the plant in continuous operation at various loads as demanded by the load dispatching center, and to control possible failures, thus averting by their own efforts any hazards to the power plant.

After this general description of purpose, it is of course also necessary to describe the individual training objective for each trainee. As a detailed presentation is impossible here, the above general definition of purpose must suffice. However, the general training program described below takes special training objectives into account as well.

The first question arising is that of the place of training. Each possible training site undoubtedly has its peculiar advantages and disadvantages. Training can take place both in the manufacturer's country and in that of the owner, with the language being one of the most difficult problems to be solved. Conducting the training in the trainee's native language may present the danger of some concepts of modern technology not having an equivalent in this language, thus giving rise to difficulties of communication and expression. Also, of course, the experts available for the training will only in the rarest of cases have a command of this language. It will, moreover, undoubtedly be most difficult to

install in each instructor so good a knowledge of the language concerned as to allow for proper communication and conveyance of knowledge. This is especially valid since the training program will generally comprise several subjects to be covered. The simpler and more promising way is to have training take place in the supplier's country and in his language. As the owner's country will, as a rule, not have enough trainee jobs at nuclear power plants available, the practical training aspects are a further factor speaking in favor of having the trainees learn the language of the supplier's country so that they will be able to understand the instructions of the supplier's personnel, as well as to read literature, information, etc. in the supplier's language.

The next question is that of the program itself. At the outset of this chapter it was remarked that drawing up a training program is not too difficult once the objective has been defined. This is undoubtedly true of training courses in customary - i.e. not too strongly specialized - professions in which an adequate number of training possibilities exists. For example, the training of data processing people does not present much of a problem. Process computer engineers - key employees at a nuclear power plant - can likewise attend generally accessible courses.

Here we have just made an important differentiation, namely between generally accessible courses (i.e. open to the general public) and special courses organized by the supplier. In Germany, for example, there exists a number of institutes and schools offering an extensive program for nuclear power plant personnel, but even the totality of these programs does not suffice to offer a complete training in which the supplier's technology is adequately considered.

The training program in the supplier's country should be preceded by a 1-2 month preparatory course in the owner's country, to be conducted after preselection has been completed.

In this course the trainees should be prepared for their new task, which should include their being familiarized with the customs, transportation systems, traffic conditions, economic inter-relationships, climate, recreational facilities, etc. at the places of their later training. Misconceptions can rapidly jeopardize the hoped-for training success!

Using the Iran project as an example, we will demonstrate in the following what a training project might look like.

In principle, the content and duration of the training program are such that each trainee has the possibility of successfully completing the various courses.

The training program is generally divided into two stages, with the first stage serving to provide the required theoretical knowledge of the field concerned, and the second one consisting of practical training.

Starting out with a 3-4 month basic course, the trainee is gradually prepared for his tasks. The rate of progress of the course is such that any trainee applying himself can successfully complete it. In seminar-like group work, specific tasks are solved and discussed.

This basic course creates the prerequisites for the program proper following it.

Necessary fundamentals in the fields of mathematics, fluid dynamics, turbomachinery, electrical engineering, mechanics, to mention a few, are refreshed and/or taught.

As many trainees have been exercising their professions for years already, a repetition of known subject matter constitutes a meaningful part of the program.

The basic course is followed by a 12-week reactor operating engineer course at the "Schule für Kerntechnik" (Nuclear Engineering School) in Karlsruhe, where the trainee is taught specific subjects. In addition he receives practical instruction and may make his first acquaintance with a reactor, as a training reactor is available. The trainee is furthermore encouraged to perform independent experiments on the basis of descriptions of the processes concerned.

Theoretical instruction provides knowledge in such varied fields as neutron physics, reactor physics, health physics, reactor engineering, etc.

Having by now spent some 6 to 7 months on theoretical matters, the trainee now deserves to be taken to the field, i.e. to a nuclear power plant. While doing practical work at a nuclear power plant or at a construction site of such a plant he is entrusted on the spot with a wide variety of tasks which have a direct bearing on his later field of work.

Depending on the given circumstances he may also be assigned directly to a shift crew so as to broaden his knowledge of the events that may occur in the operation of a plant. The duration of the trainee's stay at the power plant or construction site will be some 9 months.

Having now been supplemented and expanded by practical experience, the trainee's basic theoretical knowledge of his special field is now broadened in a 6-months' training course in specialized subjects with direct reference to the plant of interest in the given case. This means that the instructor will now no longer deal with, say, the ventilation of a power plant in general but will instead discuss in detail the specific systems to be installed in the nuclear power plant in question. In seminars the subject matter, presented either live or audiovisually, is thoroughly treated from every point of view. The trainees have the opportunity to ask questions and to cooperate in the solution of specific problems. As in the other courses, intermediate tests are performed and ratings given to obtain an exact picture of the trainee's learning progress. So that the trainee may get accustomed to independent working and thinking he has to prepare talks from time to time which he must then deliver to the group.

This part of the course is followed by a 4-week preparatory period for an 8-week simulator training course. On the simulator the trainee is confronted with a number of operating conditions which he must handle. The simulator program is so organized that a running program can be stopped at numerous points, enabling the trainee to draw his conclusions from any errors he may have committed and to take the proper measures when the program is run through the next time.

A theoretical licensing examination (see section 5) concludes this first part of the training program.

Having successfully passed this theoretical licensing examination, the trainee returns



to Iran. On the nuclear power plant construction site there, he will now receive on-the-spot training from the supplier's erection and commissioning engineers in the specific technology of the plant. This stage is undoubtedly the most important one with respect to the trainee's acquiring a thorough familiarity with, and understanding of, the plant.

Here the fact that the trainees have learned the language of the erection and commissioning personnel of the supplier will again prove beneficial. Knowledge and experience can now be transferred in direct person-to-person contact.

A 3-months' refresher course on the subjects directly pertaining to the plant in question and, if possible, a brief simulator training course on site are envisaged for a later date.

The complete training program for Category I trainees will end with the successful conclusion of the practical licensing examinations on site. It must be pointed out here that a successfully passed examination is not synonymous with actual licensing, as licenses can only be granted by the competent authorities.

On the basis of the regularly conducted tests and examinations and of the trainees' evaluation by their instructors they can, once the theoretical licensing examination has been passed successfully, be assigned to the positions shown on the organization chart.

For the management and supervisory personnel so assigned, additional courses and familiarization aids are planned.

The specialists mentioned above - chemists, planning engineers, process computer engineers, etc. - are assigned, following completion of the basic course, to practical work at an office, laboratory or nuclear power plant in line with their later functions. This practical work will, as far as possible, be suitably supplemented and rounded off by special courses.

In addition to the above described group of persons of Category I there is also a Category II. This Category II comprises the groups of foremen and skilled workers.

Since there are no nuclear power plant positions as yet for which specific training programs have been established and recognized, the best solution is to conduct allround training programs. Accordingly it was decided to follow applicable German guidelines in training skilled workers for the Iran 1 and Iran 2 nuclear power plants.

Skilled workers trained according to these guidelines, whether in mechanical or in electrical engineering, possess extensive and detailed basic knowledge in their given field. This basic knowledge, supplemented by practical experience gathered at a nuclear power plant, constitutes the most sound basis offered anywhere for the shift, maintenance and repair personnel. The duration of this training is some 3 1/2 years for a mechanic and some 1 1/2 years for an electrical installer, with the latter then being able to take additional specialized training to become e.g. a power plant electronics specialist.

Now the German "Berufsbildungsgesetz" (BBiG = Vocational Training Act) provides for the possibility of training people in a shorter time as well, as is done particularly when persons already skilled and experienced in fields not related to mechanical or electrical engineering are re-trained to become skilled in either of these fields.

Now it is this re-training which is practiced in some similar form for the Iran 1 and Iran 2 units. The persons being so re-trained are Honarestan graduates, i.e. graduates of a vocational school. Even while still attending this school they were trained to exercise one or another of a great variety of crafts. This type of training falls far short, however, of the training required for a later power plant worker.

These Honarestan graduates are first given a 6-month German language course, followed by a 6 month basic course in which they acquire theoretical knowledge and practical skills. Depending on his progress in learning, it is then decided for every trainee how much time he will need to be able to pass the skilled-worker's examination. If it is found that his capabilities are not sufficient for him to follow the theoretical instruction, he can follow instead an assistant's training program without taking a final examination.

The subject matter covered in the courses is basically the same for both skilled workers and assistants.

The knowledge to be imparted in the training of skilled workers is regulated by precise guiding directives.

Having passed the skilled-worker's examination the trainee will go through a job rotation program in which he visits several manufacturers of nuclear power plant components to work there as a temporary trainee. His overall stay in Germany is concluded by an assignment of approximately 3 months' duration to a nuclear power plant where he will perform certain work according to plans prepared in advance, working either with the shift personnel or the erection personnel. Following this assignment he will return to Iran, where he will be assigned suitable duties by the erection and commissioning personnel. Depending on his physical and psychological suitability he will then be assigned either to the maintenance and repair personnel or to the shift personnel.

It will also frequently happen that persons qualified to take further specific training, such as the absolutely essential and qualified foremen, are not at all or only in limited numbers to be found in the country concerned. Since, however, supervisory personnel is required on the skilled-worker level as well, the most expedient solution will consist of training the best men in each field to become foremen.

Besides these skilled workers, chemical personnel for the chemical laboratories are given two years of training at a chemical school to qualify as chemical assistants. This training is followed by six months of practical instruction at laboratories, both at the various research centers and at those of a nuclear power plant. Having completed these six months they, too, will return to Iran to receive on-the-job training for their respective tasks at the plant.

Upon the conclusion of the vocational program, all trainees attend a six-weeks' basic course in which the fundamentals of reactor engineering and reactor physics are explained to them.

The objective and type of the training as described in particular for the Iran 1 and Iran 2 nuclear power plant project can be adopted either in identical or in a somewhat modified form for plants with other reactor types or in other countries. Any interest on



the part of the owner in conducting part of the training himself can furthermore be taken into consideration, in which case the supplier will contribute only specific segments to the overall training program.

## **5. EXAMINATIONS AND TESTS**

Any training must of necessity go hand in hand with examinations and tests, this being necessary in order to:

- keep track of the learning progress, and
- assess the learning speed.

Furthermore, passing the final examination is the goal to be reached in any training. The test marks given during a course are combined with the examination mark to supply a final mark as overall evaluation. Should the trainee fail to pass the final examination he has the opportunity to repeat it.

In Category I all examinations consist exclusively of an oral and a written part. An exception is the licensing examination, which also includes a practical part. Details of the licensing examination are contained in sections 3.3 to 3.3.4 of the "Guideline for the Proof of Professional Qualifications of Nuclear Power Plant Personnel". They read as follows:

### **3.3 Scope and Conduct of the Examination**

The examination shall consist of a written and an oral part.

#### **3.3.1 Written Examination**

The written examination shall serve as a proof of sufficient basic and plant-related knowledge in the following lines:

- basic nuclear physics;
- reactor physics and engineering;
- reactor safety;
- basic radiation protection;
- arrangement and mode of operation of the plant in question; behaviour during incidents;
- conditions of the license insofar as they refer to the operation of the plant;
- existing operating instructions;
- emergency plans.

The detailed scope of the required knowledge shall be specified in a separate guideline taking into account the different requirements for the respective functions and the various reactor types so as to improve the consideration of practical aspects.

The written examination shall be held as an internal examination at the plant; the

responsible licensing or supervisory authority shall be notified of the questions and the result of this examination as provided for in para 3.2. Only candidates successful in the written examination shall be admitted in the oral examination.

### **3.3.2 Oral Examination**

Subjects and scope of the oral examination shall be agreed upon between the licensee and the responsible licensing or supervisory authority on the basis of a separate guideline (cf. 3.3.1).

The oral examination shall consist of a general and a practical technical part.

The general part, as a supplement to the evaluation of the written examination under subpar. 3.3.1, shall serve as a proof of sufficient basic knowledge. The responsible licensing or supervisory authority may admit restrictions in the subjects covered by the general part of the oral examination if the result of the written examination justifies it.

The practical technical part of the oral examination shall serve as a proof of sufficient plant-related knowledge and of the ability to operate the plant safely and to carry out all necessary protective measures during incidents. This part shall include an inspection of the plant during which the candidate shall answer questions as well as the detailed and comprehensive description of selected courses of operation concerning the behaviour of and control measures in the plant.

If possible, an examination shall be carried out at a simulator.

The practical technical part of the oral examination shall be compulsory.

### **3.3.3 Decision on the Result of the Examination**

Following the oral examination the board of examiners shall take a decision on the result of the examination and shall notify the candidate thereof.

The chairman of the board of examiners shall suggest the result of the examination after mutual consultation. The members of the board of examiners shall vote on such result. A positive result shall require an unanimous vote. In the event of a negative result the reasons shall be given.

The minutes of the oral examinations, the result and the reasons therefore shall be submitted to the responsible licensing or supervisory authority.

### **3.3.4 Re-examination**

If an examination is not passed, a re-examination may not be held before the expiration of a 2-month term. The board of examiners shall decide whether such re-examination is admissible and which scope is required. The candidate shall be notified forthwith of the scope of the examination and the probable date.

Category II trainees, on the other hand, shall be required to submit a work sample at

every examination except the language test.

The performance of the trainees of all categories will be judged by different instructors at the various program stages, so that by the end of training it will be possible to have a rather precise impression of each trainee.

These evaluations, together with the marks given, will be of decisive importance when the decisions as to the manning of the various posts are being taken.

Upon the conclusion of a trial period according to German law it would be possible to reject those trainees who do not meet the requirements and whose performance is inadequate.

A vital test to be passed by each trainee is the health check, which, if negative, makes it necessary to reject the trainee.

Especially in a nuclear power plant health is of vital importance, and the fitness test conducted in this connection is one of the most searching examinations imaginable. An eyesight test (clear recognition and color discrimination) is required in particular for Category II personnel.

## 6. TRAINING PROBLEMS

It would be wrong to let the fact go unmentioned that the training of personnel in the supplier's country, possibly extending over several years, may involve considerable difficulties and problems. They start already when suitable personnel is to be made available. As a rule a country about to build its first nuclear power plant cannot supply any personnel having experience in installations of this nature. In many cases it will even be doubtful whether personnel with experience in installations of a similar nature, e.g. conventional plants operating at high steam pressures and temperatures, is available. In such cases the prequalification requirements are extremely hard to fulfill. From these considerations the owner, too, will face problems in connection with recruitment, contracting, payment, separation from the family, etc.

Being sent into a foreign country means a change in the habits of daily life as well. One is suddenly confronted with other customs in the preparation of meals and with other dwelling conditions; conditions imposed by the public authorities must be met; traffic behaviour may be different; etc. A steadily recurring problem is furthermore the taking along of dependents.

Apart from the problems immediately arising here, such as additional language problems, school problems, etc., the trainee loses his flexibility in adjusting to his frequently changing locations. He is obliged to pay a great deal of attention to his family, causing his progress in learning to be far less than that of his colleagues who have no dependents.

If a dependent falls ill, it is generally the trainee who assumes the care of the patient, thus remaining absent from the courses and possibly finding it difficult to catch up afterwards.

Increased living expenses are further problems that suggest the advisability of recommending to the trainees to leave their families in their home country.

It is especially the provision of accommodation that presents the greatest problem. It is certainly easy to find a furnished apartment for one or two families. But if there are 10 to 20 families as a group, an almost unsolvable problem arises at once. There is hardly any housing market offering so much free capacity at reasonable costs.

Of course such a training program also has its human facet. It can hardly be demanded of anyone to separate from his wife or his family for two or more years. The problem of home-sickness like the family problem imposes a burden, too.

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## **SPECIAL TRAINING**

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## FUEL MANAGEMENT TEACHING EXPERIENCE - SUCCESSSES AND PROBLEMS

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Fuel Management given as a Special Course at the Pennsylvania State University for the past nine years is described in detail. The current syllabus is presented together with some history of its development. Both in-core fuel management and out-of-core fuel management are included in the lectures with particular emphasis given to in-core fuel management and fuel economics. The students are assigned a project requiring them to utilize in a practical manner the course material. Many problems and successes have occurred throughout the course's history and these are presented. The importance of using professional computer codes as part of the assigned lessons is explained and the improvements anticipated in the future are outlined.

### I. INTRODUCTION

Fuel management at Penn State has been offered for the past nine years principally as a special topics course each summer<sup>(1)</sup>. During this period the curriculum has been continually modified to make the material more current, to strengthen those portions and methods which are successful in transferring knowledge to the students and to reduce those items which tend to become irrelevant. Both Master's theses<sup>(2,3,4)</sup>, and Ph.D. theses<sup>(5,6)</sup> have been used to develop the nucleonic codes and provide background information for the course. The course has two aspects:

(1) the development of the power distribution, core  $k_{eff}$ , and the important isotopic inventories throughout the fuel cycle and (2) establishing the principles of economics governing the value of these isotopes.

Some important aspects of teaching fuel management are: (1) the students are required to use their knowledge of reactor physics in a practical manner (2) the principles of economics are developed and applied to a relevant nuclear engineering problem and (3) the students are taught system engineering via a practical project assignment. Attempting to inculcate this much information to students during a one-term period is fraught with difficulties. Nevertheless the principal goals of the course are usually attained.

The fuel management course is presented to Nuclear Engineering graduate students who have a basic understanding of reactor physics. Although "out-of-core" fuel management and BWR type core analysis are covered, a principal goal of the course is to determine the core depletion characteristics and fuel costs of a PWR core and verify, where possible, the accuracy of the results by comparing them to the measured data. The students are also required to predict future reload patterns to obtain information to determine fuel costs. To



fulfill these objectives the students are given sophisticated codes capable of accurately determining the depletion characteristics of the cores and providing real fuel costs.

The syllabus is structured to provide quick instruction on the use of the nucleonic codes together with a brief explanation of their internal characteristics. This is done to enable the students to commence analysis of the assigned PWR reactor as soon as possible. Afterwards the important physical concepts and mathematical methods used by the nucleonic codes are covered in some detail to eliminate their "black box" usage. An identical approach is made with the economic code.

The nucleonic codes presented in the course are those originally obtained from the Argonne Code Center and modified under contract to utilities. For the past few years the Metropolitan Edison Co. utility has been providing the support through the GPU Service Corporation; consequently, their reactor power plant, the Three Mile Island Unit 1 core, is studied. The codes developed and being developed for Metropolitan Edison Co. are called the Penn State Fuel Management Package (PFMP)<sup>(6)</sup>. The inculcation of the PFMP to the students is a step by step process that has been developed over the past several years. The method by which this is achieved is a main topic of the paper.

The next section describes the course content covering both the reactor physics aspects and the principles of economics as they are presented to the students. In addition the latest course project is described in some detail because it involves an important part of the course. The last two sections describe the problems and successes encountered in teaching fuel management at Penn State and the conclusions, respectively.

## II. COURSE DESCRIPTION

The first lecture of the course provides an overview of fuel management and explains the course project to the students. The LEOPARD<sup>(7)</sup> code is then introduced via the paper by Strawbridge and Barry<sup>(8)</sup> together with an input instruction manual to enable the students to calculate 2 and 4 group macroscopic constants for multigroup diffusion theory codes. The next set of lectures describe the one-dimensional FOG<sup>(9)</sup> and two-dimensional EXTERMINATOR-II<sup>(10)</sup> multigroup diffusion theory codes, and assignments are given to require the students to calculate the beginning-of-life (B.O.L.)  $k_{eff}$  and power distributions for two core geometries. The EXT-II code calculates the information for a 2-dimensional configuration that has the X-Y geometry of a small PWR core, and the FOG is used to study the same core homogenized<sup>(6)</sup> into annular geometry. All codes have been made operational on Penn State's 370/168 IBM computer.

The first few lectures are easily understood by the majority of students; however, the learning of the detailed input procedures to the various codes causes many difficulties. The students make simple input errors and much of their time is spent in understanding the input format as well as ferreting out their mistakes. Here it is very helpful to have a graduate student assistant, who has experience with these codes, to help those taking the course make the first few successful computer calculations. While learning the use of the

three codes, LEOPARD, FOG, and EXT-II, the students are introduced to depletion calculations. No texts are available on this subject, so that the students must learn the material from the lecture notes and by working with the codes. The amount of hand calculations and computer calculations, at this stage, are kept to an absolute minimum; nevertheless, the work is very time consuming.

The next part of the course is given to eliminate the "black box" use of the LEOPARD code. It is assumed that the students' prior knowledge and the short lectures on FOG and EXT-II removes any "black box" use of these two codes. Slowing down theory and thermalization, as used in LEOPARD is more complex. Sections from textbooks<sup>(11,12)</sup> and a report by Leslie<sup>(13)</sup> are integrated into the lecture notes. Once the LEOPARD lectures are finished, the students are prepared to understand the PFMP and commence work on the project.

The PFMP consists of a modified LEOPARD code which generates macroscopic cross sections as a function of depletion in the form of a library called ADD's. These ADD's are then used as input data to a 2-dimension, 2 group automated depletion code called SCAR<sup>(6)</sup>. SCAR consists of an EXT-II type two-dimensional, 2 group diffusion theory code and many subroutines devised to determine the core reactivity and X-Y power distribution as a function of core burnup. It also has a free reading input format that minimizes difficulties in utilizing the code. The burnup is actually performed in steps, the length of a step chosen to establish a smooth picture of the change in power distribution across the core as it depletes. SCAR contains a "High Speed Model" (HSM) that depletes the core providing 2 dimensional burnup data by performing synthesized one-dimensional calculations. The results with the HSM take 1/10 the time of the more accurate 2 dimensional calculation, and it can be used to determine the critical soluble boron content in the moderator at each depletion step.

Complications arise when depleting a PWR core, because soluble boron is used in the moderator to maintain core criticality. Although such problems are solved by the PFMP, the students must be careful in generating the ADD's.

The course is given at a relatively fast pace making considerable demand on the student's time to insure completion of the project. The project assigned on the first day requires the student to investigate the operation of a nuclear power plant and understand how the core is depleted and refueled. The latest project given requires the students to follow precisely the actual burnup of the Three Mile Island Unit 1 core during the first reactor cycle and compare with the measured data<sup>(14)</sup>. Subsequent cycles are assigned based on cycle lengths as projected by the Metropolitan Edison Co.; the detailed reloading configurations are left to the students to determine. Technical aspects and constraints of reactor operations, i.e. control rod positions, maximum hot channel factors, etc. are identified and incorporated into the project. The students are assigned windows during which time the reactor is not allowed to be shut down. The first reactor cycle for the Three Mile Island Unit 1 reactor operates with a few control rods fully inserted into the core and with burnable boron rods placed in selected fuel assemblies. In addition, the inserted control rod configuration is

changed twice during the first reactor cycle. The project requires as a final task the determination of fuel cycle costs. Because of the nature of the project and the time it takes before the students can successfully deplete the first reactor cycle and learn to reload cores, it is possible to present fuel cycle economics and the out-of-core fuel cycle prior to their need in the project.

The economic lectures commence once the last lecture on the PFMP is given. These lectures present material on the time value of money, amortization of investment, the effect of taxes, indebtedness and financial structure upon the cost of money, marketplace conditions and the annual income required to offset depreciation developed. Concurrent with the project works, the students are assigned economic problems that are first performed by hand calculations. These computations are then repeated using the economic code ZMCOST<sup>(3)</sup>.

ZMCOST is a computer code developed at Penn State to provide accurate nuclear fuel costs, either as fuel cycle costs or batch costs. The code is descriptive of all direct and indirect costs with the exception of insurance premiums and warranty charges. Flexibility is built into the program to vary time of purchase of the fuel at each of the various stages of production prior to placement in the core (the head-end costs). Time value of money, loss of fuel, etc., are determined from the input data. The tail-end of the cycle has many options regarding costs at the various steps, i.e. fuel transport, reprocessing, storage, and recycling of the fuel. As with the head-end costs, time value of money, fuel losses, etc., are accounted for.

The course syllabus ends with presentations on the nodal methods (FLARE)<sup>(15,16,17)</sup>, syntheses techniques,<sup>(18,19)</sup> and optimization approaches<sup>(20,21)</sup>.

### 3. PROBLEMS AND SUCCESSES

The major problem encountered in this course is the attempt to have the students complete the project and learn the subject material presented in one term. The classes are relatively small, only five to ten students. In general, usually two groups are created within the class, and with the smaller classes, the project can become difficult to complete on schedule. Each student must assume a responsibility for various sets of calculations which include every type of calculation. The more students per project group, the fewer the tasks. In general, five students per group is an ideal size.

The project necessitates teaching the students the practical aspects and limitations of a code prior to explaining its theoretical structure. Students with a background in Transport Theory are better prepared for a portion of the course material, but it is not feasible to assign transport theory problems because they are so busy learning in great detail so many different items and performing many time-consuming calculations, both by hand and with the computer.

Nevertheless, at the conclusion of the course, the students are familiar with the literature on the subject, they are capable of performing in-core fuel management as well as fuel costs using professional type computer codes that give good results, the students learn

group participation wherein the efforts of each are important to the success of the group, and they become familiar with problem solving tasks indigenous to the nuclear industry. The course connects the theoretical techniques of reactor physics used in some of the relatively sophisticated nucleonic codes to their practical applications and ties the codes together in a systematic way to produce effective results. The students learn the economic problems, not only those associated with fuel costs, but also with computer costs. Computer costs required for assessing core performance are not small, approximately \$3000 per student in this course. Thus the students become knowledgeable of the essential ingredients which make up a good nuclear engineer.

During the past several years, the support of graduate students to develop these codes has been extremely helpful, both in providing the codes and background material, and in having a knowledgeable student available to help the students. Techniques for improving the course content and syllabus are continuing. Most of the computer codes used by the industry are confidential and unavailable to the Universities. The present set of computer codes used in this course have been developed at Penn State with partial support from the Metropolitan Edison Co. and General Public Utilities. In this regard GPU<sup>(14)</sup> has been very helpful in providing operational codes. The codes are presently being modified for automatic reload and to improve some of their operational characteristics. These latter improvements should also make it easier for the students to learn to use the codes effectively.

Of importance to the future of the course is the work now being supported under NSF and ERDA grants to the Kansas State University (KSU)<sup>(22)</sup>. The KSU contracts are supporting the writing of a set of educational modules to cover the complete fuel cycle. When finished the modules should provide most of the text material needed for the course.

#### 4. CONCLUSIONS

It is possible for students to learn the essentials necessary to perform in-core fuel management and to determine fuel costs from a one term course on the subject. In so doing the students learn the importance of understanding the codes and not using them as "black boxes". It is important to use industrial type nucleonic and economic computer codes to provide the students actual experience in solving the problems. A large IBM or equivalent computer should be available. Of particular importance is having the codes operational prior to the course. In this regard, the success of the course can be insured by having a knowledgeable graduate student assistant assigned to work with the students. In the future, the course contents should be improved by further development on the codes and by the incorporation of the educational modules being effected under a KSU contract.

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## **EDUCATION AND TRAINING FOR REACTOR CORE ANALYSIS AT AEOI**

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### **1. INTRODUCTION**

Iran has a very ambitious nuclear power program. The first power reactor will be in operation 1980-81 and during the following 20 years roughly one new plant will go into operation every year. This development will naturally require a very big staff of experienced people in all related fields. Added to this, the fact that Iran started its large-scale industrial development only recently and has many of the limitations in qualified manpower typical for a developing country makes the personnel training a very important task. In this paper we will discuss the training and development in the special area of reactor core analysis, required for the support of the operation of both power and research reactors, for nuclear fuel management, safety analysis, etc.

AEOI, besides electricity generation facilities, also includes the regulatory body and research activities. Therefore the role of AEOI is more extensive than e.g. a strictly commercial power utility company. This must be taken into account when a philosophy for training and development is adopted.

The goal of our activity is to be able to perform any kind of reactor core analysis that will be required in the organization. This will need first tools for calculations: a basic computer code package treating the neutronics and thermohydraulics of the reactor core and complemented with e.g. plant simulation and economics codes. Both the codes and the data base on which they will work must have been tested to give confident results. The second requirement is experienced personnel who not only know how to use the computer codes but also have the necessary knowledge about the process to be analyzed.

In summary, the area of our activity is analytical work that requires a description of the physical behavior of the reactor core. This means involvement in the following disciplines: fuel management, operational support and safety analysis.

Our efforts are channelled in two directions:

- manpower
- computer codes

which will be described separately below.



## 2. MANPOWER REQUIREMENT

To acquire a staff of people, properly educated and experienced, is probably the most crucial problem for a developing country. We thought that for the long term it is essential that the personnel is mainly Iranian, primarily in order to ensure the continuity and stability of the staff. However, for the initiation of the activities foreign specialists will have to be engaged, preferably for periods of at least a couple of years. Later on it will certainly also be useful to call in foreign specialists for shorter periods to help solve special problems. Hiring foreign experts is in fact a typical example of transfer of nuclear technology. The benefit is manifold: the experts advise on the planning of the future activities and at the same time they start the projects and create a suitable climate for the development of the group.

With this philosophy in mind, we formed a group consisting of Iranians educated abroad plus a few foreign specialists. However, there were insufficient Iranian graduates returning home with a background in nuclear engineering to develop this group. The situation will probably be better in the future, but to meet our immediate needs we found it necessary to start a "tailor-made" education program ourselves. Our idea was the following: we employ a number of fresh graduates in physics or engineering from Iranian universities, we start by giving them some intensive courses and try to get them prepared to start working together with the more experienced staff as soon as possible. This would be a typical example of training on the job - they would learn while working. Possibly, complementary special courses should be given later within our group or at foreign institutions.

Our educational program, which we called the "Reactor Calculation Workshop", is evidently very problem-oriented, you learn enough to solve specific problems in contrast to the more discipline-oriented academic education which gives a broader base of knowledge but obviously takes a much longer time. The lay-out of the educational program will be given below.

## 3. THE REACTOR CALCULATION WORKSHOP

The goal of the "workshop" was to make the students familiar with the problems in reactor core analysis and the methods used to solve them. In reactor calculations it is important to understand the underlying physical theories as well as the approximations necessary to make them applicable and the numerical methods used to solve the problem.

The selected students all had a B.Sc. in physics or engineering and had no work experience and had not been previously exposed to the nuclear field.

The course was divided into three categories of lectures: basic, specialized, and lectures for general information.

- I. The basic lectures included:
  - Elementary Nuclear and Neutron Physics
  - Reactor physics
  - Applied Mathematics
  - Numerical Methods and Computer Programming.
- II Specialized lectures were given in the following fields:
  - Reactor Theory
  - Neutron Slowing Down
  - Neutron Thermalization
  - Computer Codes for Reactor Analysis
  - Numerical Methods in Reactor Analysis
- III The short lectures for general information were given for:
  - The Nuclear Fuel Cycle
  - Description of different reactor types
  - Reactor Shielding
  - Fuel Performance and Modelling
  - Health Physics

The emphasis in all the courses was put on practical exercises and problem-solving. After about six months the lectures of categories I and III were terminated, and it was decided that the students were prepared to start some practical work, while the category II lectures continued. They were grouped together two and two, working on a project under the supervision of a more experienced staff-member.

The experience we gained from this kind of education is to a great extent positive. The following could be pointed out:

The initial phase, consisting only of courses, must be kept as short as possible, in order to keep the students from falling back into the old school habit of learning for the exams rather than for life. The importance of practical exercises and applications must be stressed again.

The students' ability to start working on a project is not so much related to their results in the theoretical courses. More important is the enthusiasm to work and their communication ability.

Even though it will take the students some time before they can work independently, we believe in this kind of education for a developing country in order to increase the staff and complement the more experienced staff members.

### 3. COMPUTER CODES

The need of computer codes for reactor analysis is obvious. For an organization like AEOL, which engages itself in the nuclear power field with a very ambitious program this need grows as follows (time 0 refers to the time of start-up of the first plant) :

<u>Time (years)</u>	<u>Need of Computer Codes for</u>
- (6-8)	bid evaluation
- (3-4)	design evaluation
	safety reports revision
- 2	first core specification
0	support for start-up
	support for operation
	fuel management

However the codes should be available as early as possible for the purpose of personnel training.

Three different approaches are feasible in obtaining the necessary codes:

1. Repeating the nuclear technology development procedure of the industrialized countries, i.e. develop all the codes ourselves.
2. Licensing agreement with a commercial organization (e.g. the nuclear manufacturer or a consulting engineering company) to provide a whole computer code package and training assistance.
3. Making use of the public domain codes available from international organizations.

Obviously alternative 1 is not practically possible, but can be combined with alternative 3 in order to improve the public domain codes.

Alternative 2 has the disadvantage that one has to rely on a code package more or less like a "black box" and make oneself dependent on the supplier. However, it is obviously the only way to obtain usable codes in a very short time.

Concerning alternative 3, the public domain codes, they have to be improved, modified and tested to be useful. This might be a tedious process, but will in the meantime give a lot of experience and knowledge about codes which is a very effective form of technology transfer.

Because of our broad spectrum of applications, we considered the training aspect to be of such importance as to lead us to choose this last approach: to obtain public domain codes, and start working on them in order to implement them on our applications. Still, we leave the second option, buying a code package, open; because we recognize that special problems, that will have to be solved in the future, will require a tested and reliable code package.

The codes initially chosen were for

- Lattice burnup calculation
- Transport theory
- Shielding
- Plant dynamics.

Our ambition is also to develop a national data file as we have acquired ENDL-2 data file.

An example of the improvement and development work will be mentioned: The code ERUPT (2D R-Z geometry code with burnup and fuel shuffling) was modified to be more useful for PWR application. This was done by adding XY-geometry, enable fuel shuffling in the geometry, including thermohydraulic and Xe-feedback routines for load follow simulation etc.

Some new codes have also been developed in the field of fuel cycle economics, fuel pin modeling and a code for control rod calculations.

#### 4. PRESENT STATE OF OUR ACTIVITIES

At present our professional staff consists of Iranians with education from abroad, foreign experts and those who have gone through our "workshop" education. Some of the latter will soon be sent abroad for further training at research institutes.

The work is going on in the following areas in parallel:

- conversion and implementation of public domain codes
- modification of these and development of new codes
- applied calculations to IRAN 1 & 2 power plants and our research reactor.

The applications made so far include core lifetime calculations and fuel management studies. Different sets of codes have been used, compared against each other and the data supplied by the reactor vendor.

For the future we see a continuing need for more codes but expect the activity to shift gradually towards applied calculations. This will hopefully cause increasing technical cooperation and exchange with other groups within AEOL as well as the reactor supplier and foreign organizations working in this field.

# **PROGRAM PLAN FOR TRANSFER OF CORE ANALYSIS TECHNOLOGY TO THE NUCLEAR UTILITY INDUSTRY OF A DEVELOPING COUNTRY**

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## **ABSTRACT**

The functions and the need for an independent core analysis capability are addressed and the objectives of the transfer of core analysis technology to the reactor owner/operator are stated. The technology involved is described. The analysis methodology is briefly summarized and the various computer program modules that comprise a core analysis system are delineated. The activities of the utility staff during the transfer of core analysis technology are summarized. These encompass the time periods prior to startup, during startup and during commercial operation. The computer requirements necessary to implement the core analysis system are tabulated. A schedule and time frame for implementing the transfer of technology consistently with the activities is presented along with the staffing requirements and a brief description of the disciplines and interests required for a viable staff.

## **1. INTRODUCTION**

This paper addresses the transfer of a specialized technology to the owner/operator of the reactor, the Core analysis technology, and will cover

- The need for the technology
- Very briefly the methodology and
- The functions performed during the transfer

NAI was formed 11 years ago with the purpose of providing the utilities an independent source of nuclear technology needed to support plant operations. The key staff came from the Allis Chalmers Manufacturing Company when they withdrew from the nuclear business. NAI specializes in:

- Core analysis systems
- On-line monitoring
- Safety analysis

NAI has transferred core analysis technology by the approach described in this paper to 20 utilities and the system is being used today in the support of 22 operating plants.

There are certain functions which must be performed in the support of operations for

every plant that is built. These relate to the monitoring and evaluation of core performance, verification of core operation within design and license limitations; alternate methods of operation, safety and transient analyses. These tasks are not optional, the option for the owner is who will perform them.

The owner can have vendor, consultant, utility staff or a combination of all three perform these. In the U.S. for many new nuclear utilities, emphasis is on the vendor during early operation and gradually shifting towards the utility in many areas of responsibility as operating experience is gained.

It is our opinion that ultimately all these functions should be performed by the owner.

## 2. THE TECHNOLOGY

### 2.1 Analysis Methodology

It is not possible because of economic and computer limitation constraints to represent explicitly all the inter-related phenomena that occur in a reactor core. The approach, by necessity, is to utilize theoretical considerations, assumptions, approximations and empirical results in a series of computer codes that treat many phenomena semi-independently, and combine the various modular results into a representation of the overall reactor. This type of system can be composed of 6 to 10 major modules and up to 15 support modules depending upon the automation desired. The objective is that this system when used in a consistent manner will produce reliable information as to reactor characteristics and performance.

During our 11 year history, NAI has developed two such systems, and integrated the best of each into a highly refined well-benchmarked engineering tool for Core Analysis. The first such system called LEAHS was developed starting from codes available in the common domain. The second based on LEAHS was developed by NAI for EPRI and is called ARMP. This latter system has been sublicensed by EPRI to some 40 utilities. Such a system, to be practical, must be:

- Technically rational
- Reasonably accurate
- Economically feasible

Figure 1 illustrates the phenomena which must be accounted for by the overall system. A brief summary of all types of considerations in such a system will illustrate the need for procedures and experienced people.

- (a) The neutron density as a function of energy is calculated for every different kind of pin in the core. These detailed neutron spectrums are used to determine cross sections for four energy groups. Simultaneously, a homogenization of the  $\text{UO}_2$ , clad and surrounding coolant is performed where local spatial effects are superimposed upon the energy effects. This process is illustrated in Figure 2.

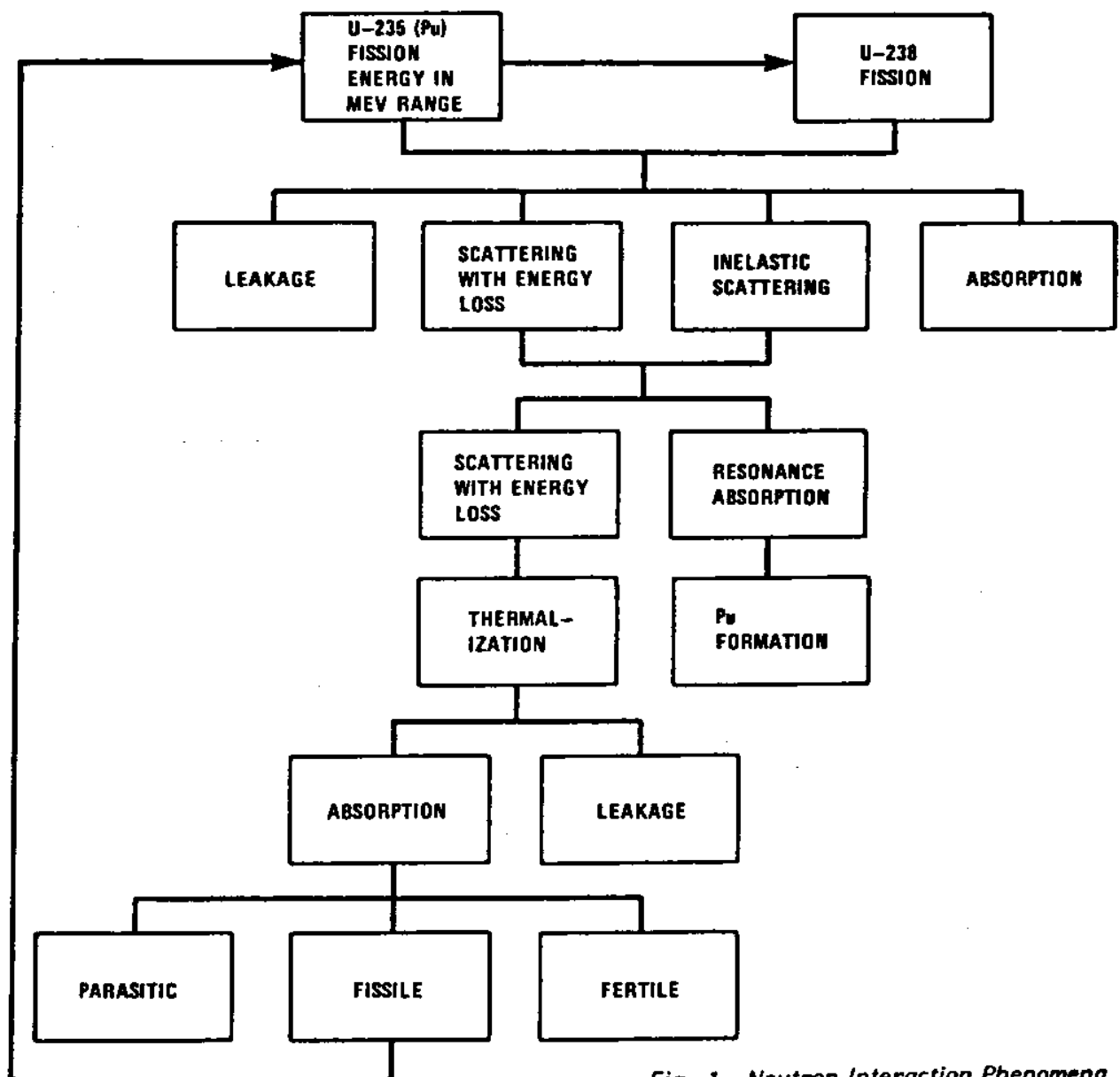


Fig. 1. Neutron Interaction Phenomena

- (b) There are certain features in the reactor design that cannot be treated by conventional means, i.e. the approximation of treating energy and local space effects separately and superimposing the two is not valid. One such is the heavy neutron absorbers such as gadolinia pins, boron pins and control rods. Here space and energy effects must be treated simultaneously and interactively. This is done by using more sophisticated techniques (and consequently greater computer time). The resulting cross sections then are used in the detailed spatial flux calculation. Figure 3 illustrates the GD and Control rod conditions.
- (c) The detailed spatial flux distribution is necessary to obtain pin powers in an assembly and the proper weighting of the various pins and other assembly materials in the determination of  $k_{\infty}$ . This is calculated by representing an assembly



or cluster of assemblies in two spatial dimensions and two to four energy groups. Each fuel pin and its associated coolant is represented explicitly. The Zr structure, water gaps and control rods are also represented explicitly (Figure 3). The two to four group cross sections necessary for input into this detailed spatial flux model come from items a and b. This spatial flux model is then used to determine  $k$  and local power distribution of the assembly for all conditions envisioned. These effects are not treated simultaneously and the effect of each one for a given set of conditions must be determined. The results are then parameterized for input to the 3D model which is the global spatial model for the core.

#### BRIEF SUMMARIES OF SEQUENCE CODES

##### BASIC CROSS SECTION GENERATOR

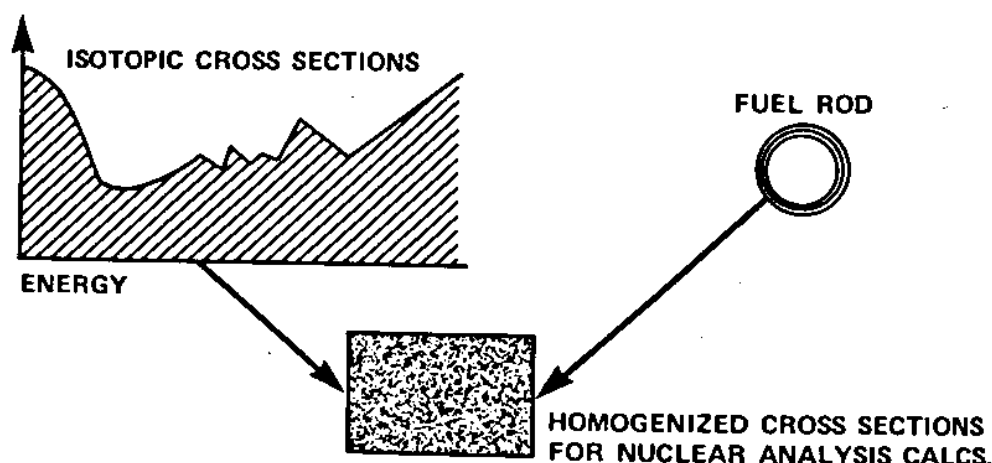


Fig. 2. Energy to Spatial Dependence

## 2.2 Core Analysis System Modules

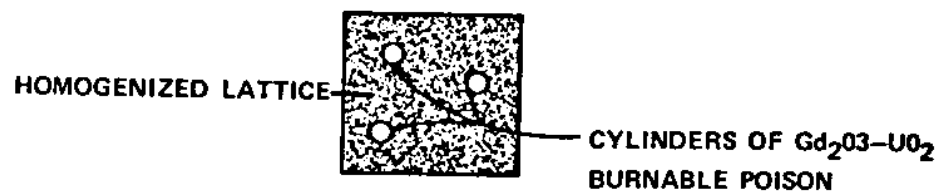
The inter-relationship of the primary codes and the general flow of data through such a system is shown in Figure 4 for a PWR and Figure 5 for a BWR. The main sequence physics codes are briefly described below:

### 2.2.1 Main Modules

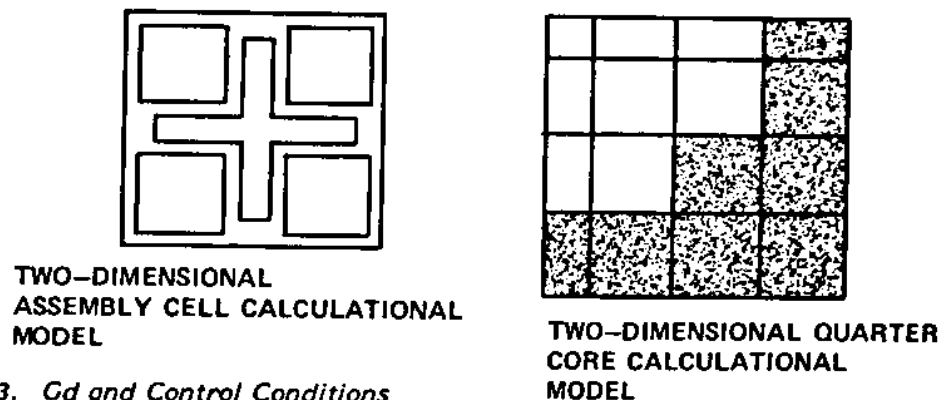
1. **EPRI-CELL:** With due recognition of simplification in the explanation, this code may be said to treat a fuel rod or burnable poison in explicit cylindrical geometry; It approximates less exactly the surrounding environment. Various engineering modifications have been developed to improve this environmental approximation. Depletion of the fuel rod or burnable poison can be conducted and various depletion-dependent quantities can then be edited.

2. PDQ-7/HARMONY: PDQ-7, as generally used in the CAS, geometrically approximates a fuel assembly in X-Y geometry with the lattice components each homogenized in their respective cells. In terms of energy, the neutronics distribution and reaction rates are derived from a representation in 2 to 4 groups with the homogenized group constants derived from EPRI-CELL and various consistent parameterizations.

**LUMPED ABSORBER CROSS SECTION  
GENERATOR WITH DEPLETION**



**MULTI-DIMENSIONAL  
DIFFUSION-DEPLETION PROGRAM**



*Fig. 3. Gd and Control Conditions*

3. NAI-NODE-P and -B: These programs utilize the nodal approximations; i.e., at each of 12 axial positions, each assembly is approximated by a node or point. Associated with each node are a set of predetermined equations which account, in a fashion integrated with the global solution, for the local variations in assembly characteristics due to temperature effects, moderator density, depletion, etc. Given the input parameters for these equations one has a powerful and cost-effective tool available for X-Y-Z LWR core simulation.

The interrelationship among the main sequence codes and the data processing modules is illustrated in Figure 6. The letters A, B, C, D and E on this figure designate specific data transferred between the various modules.

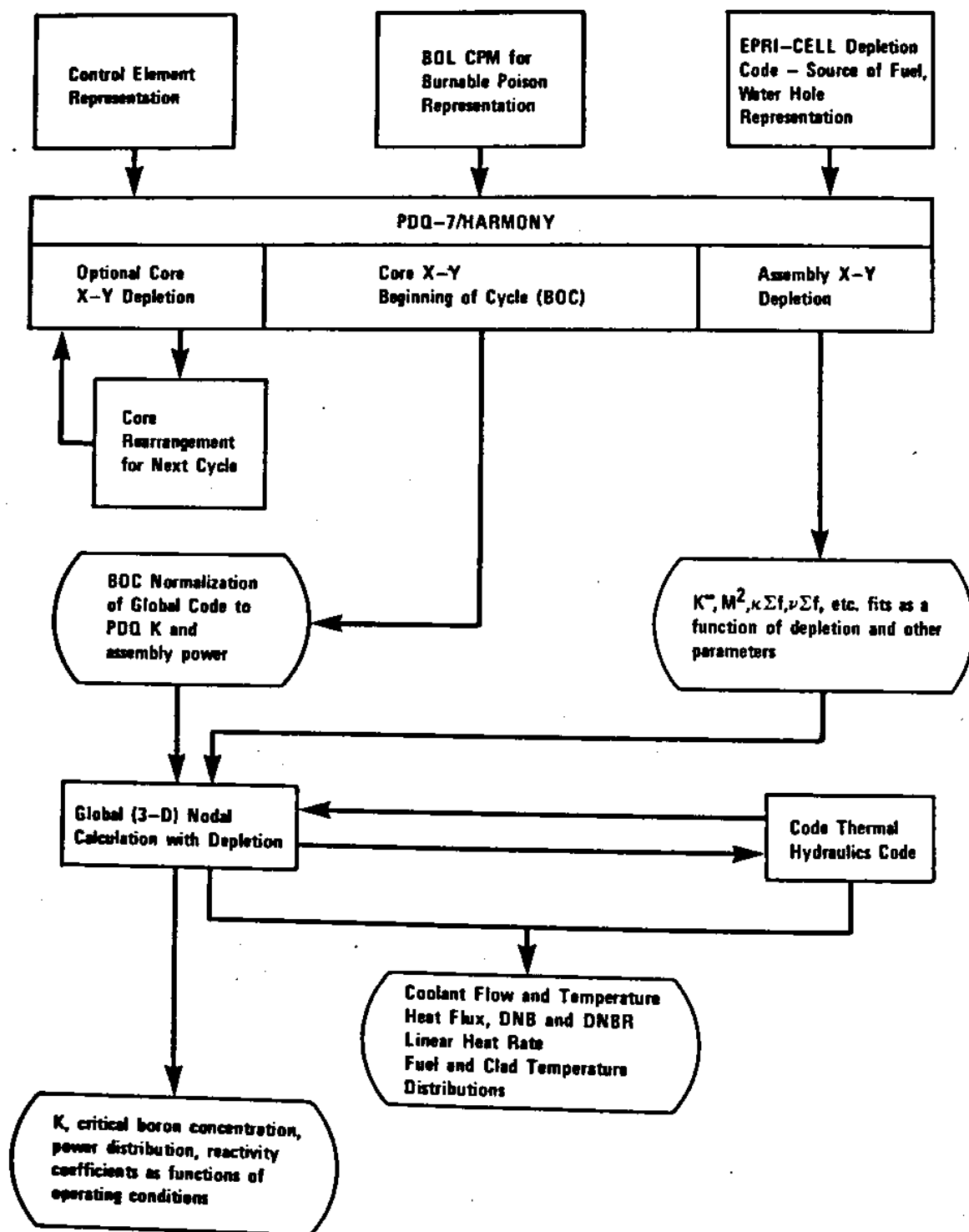


Fig. 4. Outline of PWR Data Flow

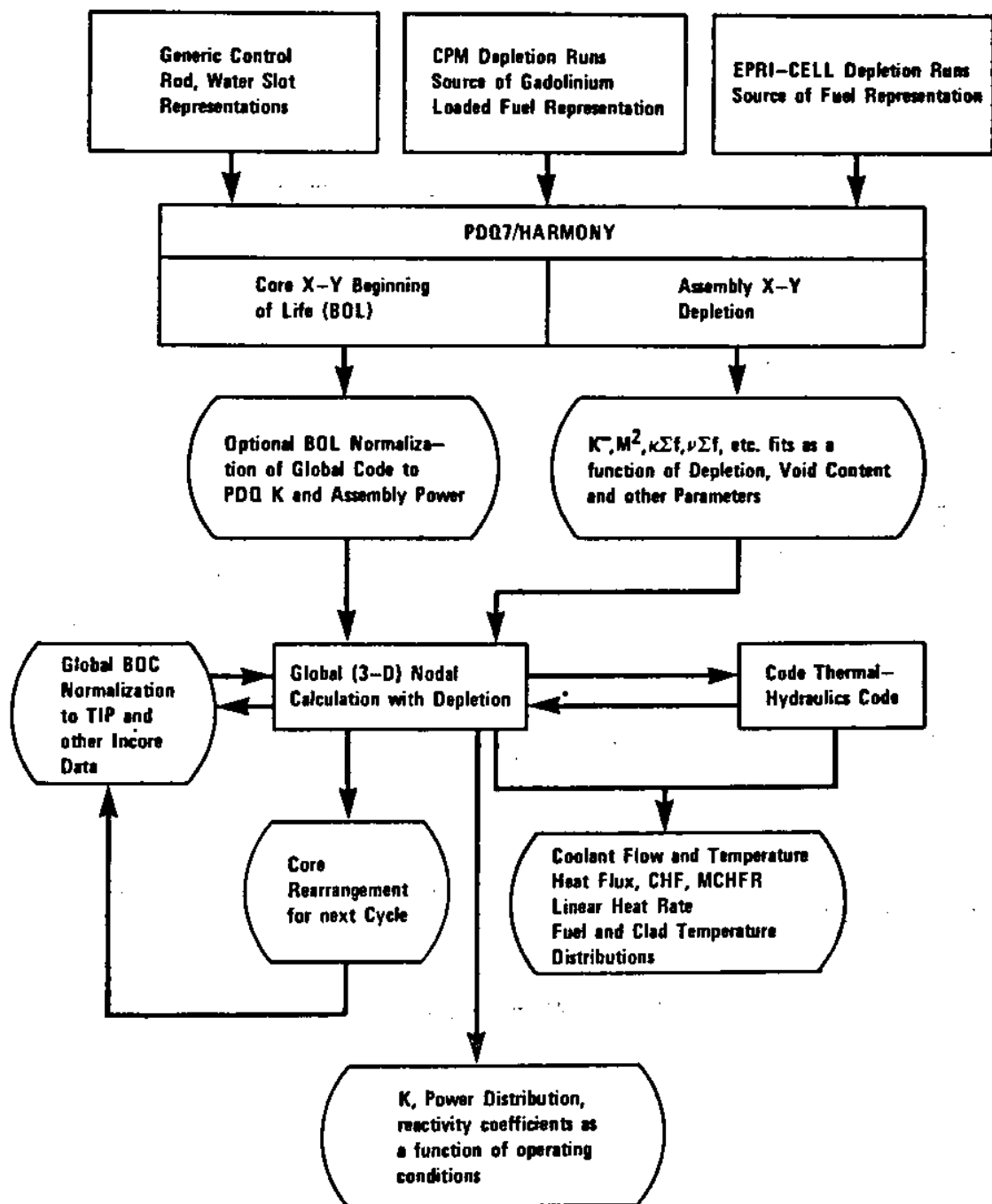


Fig. 5. Outline of BWR Data Flow

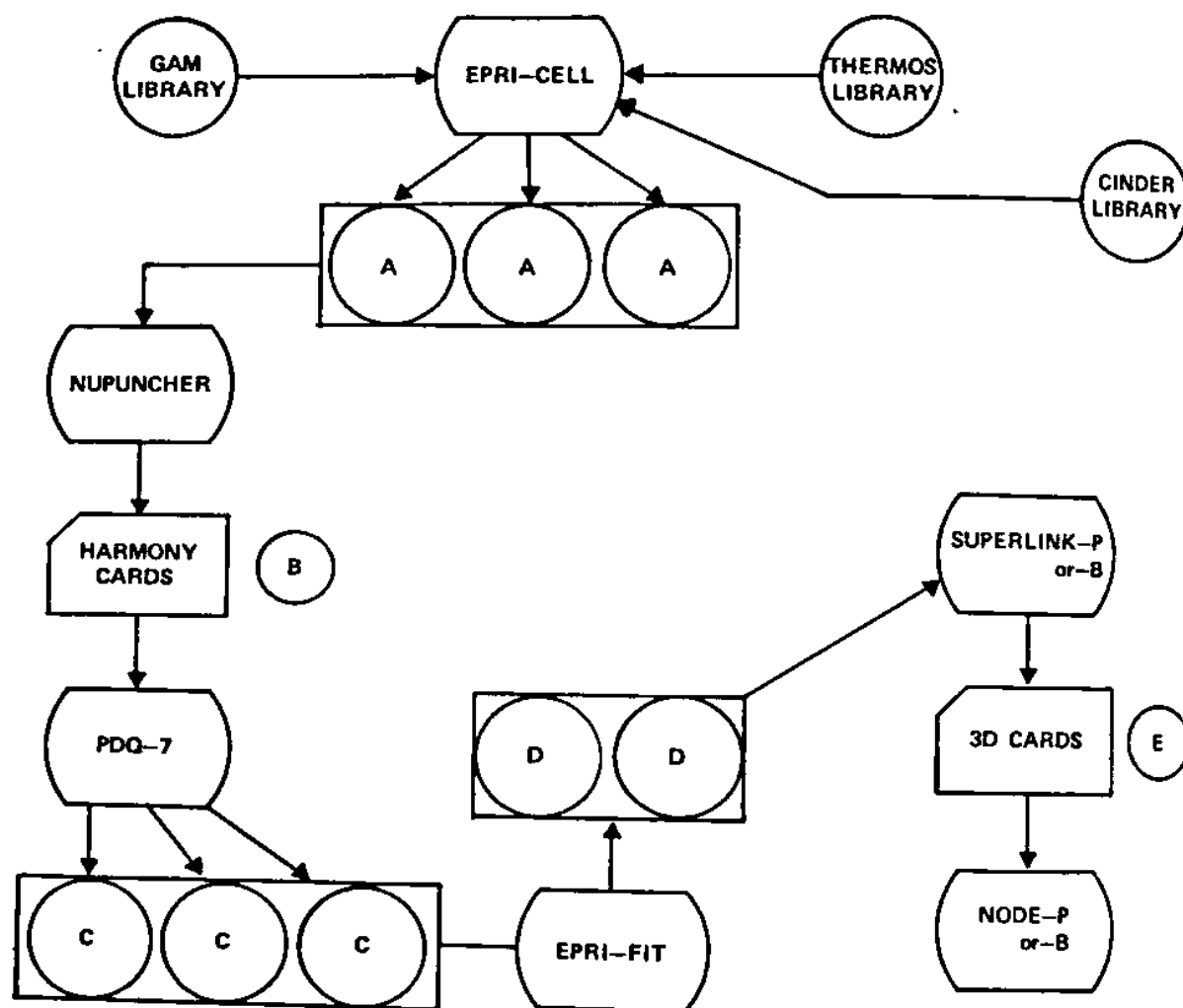


Fig. 6. Main Sequence Codes

### 2.2.2 Primary Auxiliary Codes

The six primary auxiliary codes are briefly described below:

1. EPRI-CPM: This is a multigroup transport code that constitutes a highly accurate

- calculational tool suitable for analyzing an LWR assembly with almost any kind of complexity. Because of its unique internal computational sequence, it essentially calculates a multigroup spectrum at each lattice location at each depletion step.
2. MICBURN: This is a sequence auxiliary to CPM which solves the problem of depletion of a gadolinium-loaded fuel pin with a time-dependent spatial solution.
  3. EPRI-SHUFFLE: This is a program auxiliary to the X-Y Diffusion code which allows the re-arrangement and/or replacement of individual fuel assemblies within a given array.
  - 4/5. NAI-THERM-P and -B: These are thermal-hydraulic codes capable not only of a macroscopic analysis of an entire core but also of a detailed subchannel analysis. Part of the output of each code is required as input to the corresponding nodal code.
  6. EPRI-LIBRARY: This refers to a set of environmental subroutines required by the CAS programs.

### 3. SPECIFIC ACTIVITIES LEADING TO TECHNOLOGY TRANSFER

#### 3.1 Prior to Startup

The installation of a Core Analysis System should begin prior to startup of the reactor, so that the System is operable about one year before the time of initial fuel loading.

##### 3.1.1 Installation of Core Analysis System

The installation process involves the training of utility nuclear engineers in the specific details of reactor core physics, thermal-hydraulics and fuel mechanical design analyses. It requires utility engineers to become familiar with all assumptions, approximations and philosophy employed in reactor design calculations. These fundamentals lead to detail procedures for application of the several modules. This phase of the transfer is accomplished by the engineers performing all the calculations required to build a core model.

During the installation of the Core Analysis System, all computer programs utilized in the model are transferred to the utility to be made operational on the utility designated computing system, either a data service or in-house equipment.

##### 3.1.2 Application to Decision Process

In the period prior to startup there are normally a number of areas related to the core where the trained Core Analysis System engineers can contribute. The installed Core Analysis System allows the utility's own CAS engineers to participate in calculations that

are often necessary to respond to safety review questions, and fuel utilization options, and thus be completely cognizant of the analysis and background upon which the answers to these questions are based.

### 3.1.3 Application to an Operation Reactor

The prime purpose of the Core Analysis System is the support of the operating plant. In order to perform this function the utility nuclear engineers must develop a confidence in the model as applied to all aspects of plant operation. Since the operation of reactors in developing nations is still some time away, their staffs are in a position to develop this confidence before having to apply the Core Analysis System to their own operating unit. NAI strongly recommends that utility nuclear engineers select an operating reactor of a similar type to their own where there exists a cooperative relationship between companies and set up a model to calculate the operating characteristics of the selected plant. This approach has been taken by NAI utility clients and has been very successful and the following benefits have resulted.

1. The nuclear analysts are forced to examine operating data in detail and understand how the measurements were made.
2. The nuclear analyst obtains a "feel" for the applicability of the model to various conditions such as differential rod worth, temperature coefficients, etc.
3. Errors in the application of the model or in input preparation are uncovered and corrected.
4. A specific calculational approach evolves where the assumptions have been tested.
5. Confidence is established prior to application of the model to their own reactor.

### 3.1.4 Review of Startup Procedures and Tests

The utility CAS engineers who will perform the core monitoring, performance evaluation, and prediction of long term fuel requirements and core performance characteristics should follow the startup testing. To benefit from the testing, it is mandatory that each of the assigned engineers completely understand these procedures. The CAS engineer will then be familiar with the considerations that go into each test (safety and practical) and what type of information is directly attainable by measurement and what is not.

### 3.1.5 Startup Calculations

Following the detailed review of the test procedures and prior to fuel loading it is recommended that a series of calculations be performed using the Core Analysis System to predict the results anticipated from the tests, Rod worth, etc. In order that this analysis be meaningful at the time of startup, it is absolutely necessary that the test procedures be understood. Only in this way is it possible to compare calculated and measured results



for the core conditions at the time of testing and thereby verify the model.

#### **3.1.6 Familiarization with the NSSS Data Logger and Computer**

One of the functions of the CAS engineer will be the utilization of the output of the Data Logger or Process Computer. In order to achieve optimum use of this data and in order to have confidence in that data, the CAS engineer must be familiar with the way raw results are treated by the process computer. He must know the method used in converting raw instrumentation signals to power, flow, etc., and have familiarity with equations used in the process computer such that any number given by the process computer can be duplicated manually if desired. The proper time to achieve this familiarization is prior to initial fuel loading so that at startup the process computer data will be meaningful. This familiarization is also first step in owner/operator generating and supplying constants for reload fuel supplied by a second vendor.

#### **3.1.7 Integration of Data Logger Data with CAS**

Core fuel loading and control system type data is required as input to the NSSS computer. These inputs are dependent on the fuel assembly characteristics and must be consistent with the fuel supplied by the manufacturer. For reload fuel purchased from the initial core supplier or other suppliers, the CAS engineer must assure that the computer software is compatible with the reload fuel and input parameters are updated to reflect the reload fuel characteristics. Communications equipment could be specified to link the data logger with the utility central computer on which the CAS codes are operational. This would permit automatic transmittal of operating data to keep current the core history files and remote access by the CAS engineers to the updated core model.

### **3.2 Startup Testing**

The first core startup testing period allows the utility CAS engineers the opportunity to go through the various steps involved in testing and interpretation of data concluded by the vendor without having the prime responsibility for startup. To take maximum advantage of this situation, the following steps are recommended.

#### **3.2.1 Initial Fuel Loading and Low Power Testing**

The CAS engineers who will later perform the reactor monitoring and fuel management functions should be present at the site for the initial fuel loading and low power testing. Their function should be to observe the testing and collect their own raw data insofar as it does not interfere with the test program. Having been previously familiarized with the test procedures, the engineers are in a position to judge to what degree the objectives of

each test are achieved. The CAS engineers should do their own on-the-spot data reduction and the interpretation during the testing, and later perform the detailed reduction and examination of test results and comparison with predicted results.

### 3.2.2 Power Testing

The CAS engineer should be present for escalation to new power levels, tests concerning recirculation flow variations, inlet temperature variations, boron changes, control rod interchanges, etc. As in the low-power test program, he should collect his own data, make on-the-spot interpretations and later perform the detailed inspection and evaluation of the data. He should also at this time observe the functions and use of the process computer. Prior to startup he had become familiar with the computer programs and their uses, he can now at first hand evaluate the actual application.

### 3.2.3 Calculations and Measurements

After the test program is complete (or during, if time permits) calculations and measurements can be compared and final normalizations of the Core Analysis System performed.

Prior to startup selected calculations are performed for conditions expected during testing. The likely experience is that most of these calculations will be sufficiently close to the conditions of the actual measurements to permit evaluation of measured and calculated results. However, some of the calculations may have to be redone for the exact conditions of the measurement.

The Core Analysis System can then be applied to the many various conditions recorded during the testing program and the reproducibility of the measurements examined. Minor adjustments necessary to normalize the model to the measurements are made at this time.

With the normalization complete, the Core Analysis is ready for use in data interpretation and in prediction of future conditions in the normal course of commercial operation.

## 3.3 Commercial Operation

After the initial startup and testing of the reactor, the plant enters commercial operation. At this time the utility nuclear staff can apply the Core Analysis System to Core Performance Monitoring and Fuel Utilization. Table 1 summarizes the types of application for which the Core Analysis System has been used; they fall into two categories summarized below.

### 3.3.1 Operations Support

#### 3.3.1.1 Core Monitoring

The monitoring of the core performance is a continuous process which must be done as

long as the plant is in operation. For purposes of discussion the monitoring functions can be separated into four main categories:

- Data Collection
- Data Interpretation and Utilization
- Operations Support
- Near Term Projections of Operations

Table 1. CAS Applications

- o power distribution and peaks
- o in-core instrumentation response and interpolation
- o fuel channel T/C response
- o ex-core instrumentation response
- o fuel temperature distribution
- o clad temperature distribution
- o linear heat rate distribution
- o DNBR distribution
- o CPR and MAPLHGR distributions
- o startup critical rod patterns
- o HZP critical PPM
- o boron letdown curve
- o control rod positions with burnup
- o burnup cycle length
- o fuel assembly isotopics
- o ejected rod worth and power peak
- o shutdown margin (one rod out)
- o moderator and fuel temperature coefficients
- o power coefficient
- o xenon worth
- o part-length rod effects
- o temperature distribution effects
- o xenon transient effects
- o load follow effects
- o fuel burnup effects and reload strategies
- o measurement interpretation
- o process computer verification

The area of data collection is of vital importance to the utility nuclear engineer. Insufficient data, incomplete data or incorrect data can lead to erroneous conclusions as to the plant performance; therefore, the CAS engineer must be aware and vitally interested in not only the data itself but how it is obtained. He must be completely familiar with the data logger (Section 3.1.6) and its functions; he should receive raw data (i.e., direct instrument readings) as well as the automatically reduced data from the on-line computer; he should periodically observe the data collection process and assure that the data he is receiving is what he understands it to be.

Once the data is obtained it must be interpreted and utilized by the CAS engineer. Since many of the parameters of interest cannot be measured directly (i.e., reactivity, rod worth, quality, fuel temperature, etc.), the Core Analysis System can be applied to the observed conditions and the nuclear parameters inferred.

The CAS engineer with the Core Analysis System available can rapidly analyze these conditions, examine a number of alternatives and recommend a course of action within hours.

#### **3.3.1.2 Fuel Utilization**

The term fuel utilization is used here to cover all the in-core fuel management functions that are required for the operation of the plant. Among these functions are:

- Projections of Burnup Cycle
- Analysis of Alternate Fuel Loading Patterns and Control Configurations
- Determination of Future Fuel Requirements (i.e., fissile material, enrichment, amount)

These functions all relate to the utility's task of long term projecting and planning the operation of the reactor.

Finally, the CAS engineer can be responsible for the determination of future fuel requirements. In this category fall all the functions that are required for reload core design.

#### **3.3.2 Core Analysis System Maintenance Improvement**

The Core Analysis System computer codes were described in Section 2.0. The system required two types of input to maintain its accuracy and efficiency :

- Current Status of Core
- Improved Methods

The first input is dependent upon fuel design and loading pattern of the fuel currently in the core as well as the total exposure and exposure distribution status of the operating core. The fuel design and loading pattern information can be input by the nuclear engineer during the reload fuel design, procurement, and loading phases. The burnup distribution can best be input automatically from actual operating data logged by the data logger transmitted to the utility central computer on which the CAS codes are operating.

The technology of core analysis is still evolving. It is expected, as operating data from current generation units becomes available, that analytical methods and basic nuclear data will continue to be upgraded. It will then be desirable to substitute or add these new methods and data to the Core Analysis System. A number of approaches can be taken to maintain the technology at the state of the art level. NAI recommends the cooperative approach concept whereby the development and implementation of these new methods are shared, thus enabling the cooperating parties to benefit by the experience of others. Further, the central computer will undoubtedly change over several years and reprogramming should be done to take advantage of the new computer's greater power--speed and size.

#### 4. COMPUTER RESOURCE REQUIREMENTS

The computer power needed for reasonable turnaround is of the size of a CDC6600. Table 2 gives a tabulation of the size and run times of the primary modules that make up the Core Analysis System.

Table 2. Estimates for Typical Use of NAI System on a CDC 6600

PROGRAM	SIZE	CPU Sec/Run
EPRI-CELL (Time 0)	120K	30
EPRI-CELL (Depletion)	120K	450
NUPUNCHER	60K	1
PDO07 (Time 0 unit assembly)	125K	50
PDO07 (Depletion, unit assembly)	125K	1550
PDO07 (Depletion, Quarter Core)	125K	Approx. 1000 sec/step
SHUFFLE	75K	400
EPRI FIT	40K	1
SUPERLINK	40K	1
NAI-NODE	125K	50
NAI-HYDRO	75K	15
ISOVEX	100K	5
NFCOST	40K	—
CPM (Time 0)	75K	—
CPM (Depletion)	75K	—
MICBURN	60K	—

## 5. SCHEDULE FOR IMPLEMENTATION FOR TRANSFER

The initial step in implementing the transfer of Core Analysis technology is the formal training of staff in the fundamental precepts of physics and thermal hydraulics. This is normally done at the university level and can commence any time after a developing country has made the decision for nuclear power.

The next phase should occur in the period from the ordering of the plant to approximately two to three years prior to initial criticality. It encompasses the training of the nuclear staff in the computer programs in the Core Analysis System and in the in-depth familiarization of the staff in the procedures for their application including the assumptions, approximations and rationals involved in each step. Also during this phase, the various program modules of the CAS should be installed, debugged and tested on the computer designated by the developing country.

As stated earlier, this is accomplished by developing the model for a specific reactor, preferably an operating plant. (See Section 3.1.3). This not only provides early-on contact with real data but also serves as the testing and verification process for the transfer of the system.

The third phase of this pre-operational period is the application of the system to the specific reactor that is to be operated by the staff. This model should be completed prior to operation (e.g., one year before) in order to allow the staff to perform the efforts described in sections 3.1.4, 3.1.5, and 3.1.6.

The startup and initial commercial operation are the next phases in the transfer of technology. During this period the staff is continuously applying the model to operating conditions and gaining the experience of day-to-day application.

The final phase is in multiple cycles when the staff has achieved experience and maturity and both staff and management have gained the confidence in the core model necessary to apply the model in the predictive mode independent of the NSSS supplier and consultant.

## 6. STAFFING REQUIREMENTS

The staffing requirements that are necessary to implement the transfer of core analyses technology depend upon the objectives of the reactor owner and the degree of independence desired. For example, in the U.S. there are nuclear utilities who have no capability in the core analyses area and depend upon the vendor, there are those with nuclear staffs but still rely mostly on the vendor, and there are those whose staff are very actively supporting operations. Assuming the objective is independence, the typical staff for performing the functions described in Section 3 might be as follows.

The initial staff would comprise two major sections; a methods section and an application section. For major commitment to nuclear power with internal requirements for ana-

typical Independence the method section would contain at least 6 people with backgrounds or interests in a number of areas such as: basic physics related to cross section and spectra analyses, in applied nuclear analyses related to nodal type modeling, thermal-hydraulic analyses, and measurement techniques and interpretation.

The applications section would contain at least 4 people per reactor whose background and interests are in applying the core analysis system for the operations support and fuel management functions described in Section 3.



## **TRAINING OF PERSONNEL TO ENGINEER NUCLEAR POWER PLANTS TO MEET SEISMIC CONDITIONS**

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### **1. INTRODUCTION**

Personnel involved in the design of nuclear power plants to meet seismic conditions have come into their assignments with backgrounds which vary a great deal from person to person. Some have strong backgrounds in structural dynamics and possibly earthquake engineering, but most do not, and many have little dynamics background. Since all Category I systems and components of a nuclear power plant require seismic qualification, there is a need for a large number of personnel skilled in such work. The demand for such people exceeds the supply so that it is necessary to conduct extensive training. This training takes place in the following five ways:

- (1) Attending both Bechtel and outside courses and conferences.
- (2) Reading and using of Topical Reports, Seismic Newsletters, Design Guides, and Specifications.
- (3) Consultation with staff, outside consultants, supervisors and other employees.
- (4) Membership on industry committees.
- (5) Doing.

### **2. ATTENDING BOTH BECHTEL AND OUTSIDE COURSES AND SEMINARS**

Bechtel sponsors structural dynamics courses aimed at the needs of its engineers. Different courses are taught in the several offices. In general, these courses cover material from simple systems up to and including specific applications of structural dynamics in seismic analysis and design of nuclear facilities. Engineers attend short presentations made by vendors on the seismic qualification of their equipment and made by testing laboratories on methods of seismic qualification. Engineers are sent to short courses at universities dealing with earthquake engineering and to conferences where the latest developments in seismic analysis and earthquake engineering are presented.

#### **2.1 Structural Dynamics Course**

This course is a graduate level course. This course meets twice a week for sixteen weeks. The course is broken into three parts. The first part deals with one and two degrees-of-freedom systems; the second part deals with multidegree-of-freedom systems; and the third

part deals with applications. An outline of the course is given in Appendix A.

Engineers are encouraged to attend any one or all parts of the course, and from time to time engineers will simply attend one lecture on a particular subject of interest. Also, they are encouraged to repeat parts of the course after having had some experience in a particular area so that they can clear up subjects which may have been difficult the first time through.

The first part of the course treats simple systems (one and two degrees-of-freedom systems) so that the basic concepts of structural dynamics can be introduced and a basic understanding of the material developed without dealing with the complications and mathematics required for multidegree-of-freedom systems. The concepts of mode shapes and frequencies are explained in terms of two degrees-of-freedom systems. The response to support motion is covered to introduce the idea of the manner in which a building responds to an earthquake. Since a large part of modern structural analysis is done by computer, numerical integration of single degree-of-freedom systems is covered. This gives the engineer the capability to deal with complicated forcing functions.

Part II of the course covers multidegree and continuous systems. Nuclear power plant structures and components are usually modeled as multidegree-of-freedom linear elastic systems. This part of the course deals directly with the methods of analysis used in practice. Beam vibrations are treated because of the obvious importance of beam analysis in any building. Various types of response analysis techniques used in earthquake engineering are discussed, i.e., both integration methods and the response spectrum method. Example problems are worked illustrating the application of these methods to nuclear power plants.

In Part III of the course, applications of the techniques discussed in the first two parts are covered as they apply to nuclear power plant components. The basic properties of earthquakes are discussed and the selection of design earthquakes. Structural modeling (mathematical) as it applies to computing structural response to earthquakes is covered. Since the fast Fourier transform method is now used extensively in soil-structure interaction analysis, the Fourier transform method is covered. The impedance function method as used in soil-structure interaction analysis is covered. There is increasing use of vibration testing, both for equipment qualification and for obtaining basic information. Thus, one lecture is given on vibration measuring devices and another given on the introduction to vibration testing.

## **2.2 Short Courses and Conferences**

Engineers are sent to short courses on earthquake engineering and structural dynamics offered by universities and private firms. For example:

- (1) Earthquake-Resistant Design of Engineering Structures, June 19-30, 1972, at the University of California, Berkeley.

This was a two week course which dealt with earthquake mechanisms, earthquake motions, the response of soils and the response and design of structures.

- (2) U.S. National Conference on Earthquake Engineering, Ann Arbor, Michigan, June 18-20, 1975. Sponsored by Earthquake Engineering Research Institute.
- (3) "ASCE Specialty Conference on Structural Design of Nuclear Power Plant Facilities", held biannually.

Also, there are private seminars offered by such organizations as Wyle Laboratories and J.D. Stevenson Consultants, Division of Arthur G. McKee & Company, dealing with seismic qualification of equipment.

### **2.3 Presentations by Vendors**

Vendors make presentations at Bechtel offices which show their methods of qualifying their equipment. While the main purpose of these presentations is to establish whether the vendor's equipment can be qualified to meet seismic criteria, the presentations and explanations can serve as teaching aids for engineers. The presentations usually start with statements as to what criteria are being used for qualification and then proceed through their methods of testing to meet these criteria.

Typical of the presentations are those made by cable tray manufacturers when presenting their testing procedures for qualification according to our specifications.

Other presentations have included ones by manufacturers of earthquake accelerometers and earthquake monitoring systems, and presentations covering the testing of electrical cabinets.

### **2.4 Special Courses for Foreign Companies**

When Bechtel is involved in design construction projects outside the United States, training programs for client personnel are frequently conducted to supplement their knowledge in the latest technology used in power plant design. An example of this type of program is the training course conducted by our Los Angeles Power Division for the Comision Federale de Electricidad of Mexico. A set of notes was produced covering the various aspects of power plant design in all engineering disciplines. These consisted of six bound volumes of lectures (one separate volume each for Plant Design, Mechanical, Civil/Structural, Electrical, Control Systems, and Environmental). Instructors were sent from Los Angeles to Mexico to conduct the course for Mexican engineers.

## **3. READING AND USING AVAILABLE LITERATURE**

An engineer has materials available to him for use, both in the open literature in the form of textbooks and journals, and in the company literature in the form of topical reports, design guides, Seismic Newsletters and specifications. Included in the available literature are the following:

### Books

1. Seigle, R.L., Earthquake Engineering, Prentice Hall, Inc., Englewood Cliffs, N.J., 1970.
2. Newmark, N.M., and E. Rosenblueth, Fundamentals of Earthquake Engineering, Prentice Hall, Inc., 1971.
3. Biggs, I.M., Introduction to Structural Dynamics, McGraw Hill, Inc., 1964.
4. Richart, F.E., J.R. Hall, Jr., and R.D. Woods, Vibrations of Soils and Foundations, Prentice Hall, Inc., Englewood Cliffs, N.J., 1970.
5. Clough, R.W., J. Penzien, Dynamics of Structures, McGraw-Hill, N.Y., 1975.
6. Blume, J.A., N.M. Newmark, and L.H. Corning, Design of Multistory Reinforced Concrete Buildings for Earthquake Motions, Portland Cement Assoc., Chicago, IL, 1961.

### Industry Standards

- "IEEE Recommended Practices for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations", IEEE Std. 344-1975. IEEE, 345-47th St., New York, NY, 10017.
- "Earthquake Instrumentation Criteria for Nuclear Power Plants", ANSI, N18.5-1974, American Nuclear Society, 244 E. Ogden Ave., Hinsdale, IL. 6051.
- Stevenson, J.D., "Structural Analysis and Design of Nuclear Plant Facilities", Draft for Trial use and comment, ASCE, 1976.
- "Guidelines for Retrieval, Review, Processing and Evaluation of Records Obtained from Seismic Instrumentation", draft of the ANS 2.10 Working Group.

### NRC Regulatory Guides and Regulations

- 1.12 "Instrumentation for Earthquakes" (Revision 1, 4/74, of Safety Guide 12).
  - 1.29 "Seismic Design Classification" (Revision 1, 8/73, of Safety Guide 29).
  - 1.60 "Design Response Spectra for Seismic Design of Nuclear Power Plants" (Revision 1, 12/73).
  - 1.61 "Damping Values for Seismic Design of Nuclear Power Plants" (10/73).
  - 1.92 "Combination of Modes of Spatial Components in Seismic Response Analysis", (12/74).
  - 1.100 "Seismic Qualification of Electric Equipment for Nuclear Power Plants", March 1976.
- Title 10 CFR-100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants", November 13, 1973.
- United States Nuclear Regulatory Commission, "Standard Review Plan".

### Bechtel Topicals, Design Guides and Specifications

- (1) Tsai, N.C., et al., "Seismic Analysis of Structures and Equipment for Nuclear Power Plants", Topical Report BC-TOP-4-A, Bechtel Power Corp., November 1974.
- (2) Cery, N., N.C. Tsai, "Structural Design of Seismic Category I Supports for Electrical Cable Trays", Design Guide C-2.7, Bechtel Power Corp., March 1974.
- (3) "Specifications for Seismic Qualification of Cable Trays", Appendix A to Specification E-034, February 1975.
- (4) Abe, T., N.C. Tsai, "Design Criteria for Seismic Category IE Electric Conduits and

Support Systems", July 1974.

- (5) "General Project Requirements for Seismic Qualification of Seismic Category I Equipment and Supports for the Hope Creek Generating Station Nos. 1 and 2 Units, Public Service Electric and Gas Co., Newark, NJ", Specification 10855-G-004(Q), 1976.

#### 4. CONSULTATION WITH STAFF AND OUTSIDE CONSULTANTS

The Chief Engineer in each office maintains a staff of engineers separate from the engineers on the projects who have expertise in various aspects of nuclear power plant design. Seismic analysis is one of these areas. The staff is available for consultation and assistance to project personnel as they are needed.

The degree of assistance offered by the staff varies depending on the requirements of the particular work. Most frequently, the assistance involves a short phone conversation which may clear up such a matter as the use of a specific feature of a computer program or clarification of an item on seismic equipment specification. At other times, the staff may perform a complete analysis of a building or component. This only occurs when there are no project personnel available to do the work.

Consultants from universities and private consulting firms are used in special problem areas. Engineers working on specific problems as well as their supervisors meet with these consultants from time to time. It has been found advantageous for the individual actually performing the work to meet with the consultant directly, rather than only his supervisor. This enables the consultant to obtain information he may need in detail and it offers the engineer the opportunity to learn directly from the consultant the method to be used for the problem solution. For example, Dr. N.M. Newmark meets with engineers in our offices on a regular basis. Problems such as the nonlinear analysis of a stack or the criteria for qualification of cable tray systems are discussed with him.

A company-wide seismic committee is maintained to assure coordination of procedures and techniques among the five offices and various projects. This committee produces a newsletter which informs engineers of the latest criteria and techniques being used within the company.

#### 5. MEMBERSHIP ON INDUSTRY COMMITTEES

Bechtel sponsors membership for a number of engineers on industry committees which are formed to develop standards. The primary purpose of committee membership is to develop good documents which can be used in design. It is in the company's interest to support membership on committees for this reason. From an educational point of view, this permits and encourages an engineer to learn more about the subject matter being addressed by the committee so that he can participate in the committee efforts and contribute to the development of the document.

In addition, information is exchanged at committee meetings, both on and off the record, which enables the member to learn what another company is doing in specific areas and upgrades both his and his company's capabilities. For example, an exchange of ideas on the development of mathematical models for structures of frequency calculation for cable tray systems. Examples of industry committees are as follows:

The committee which developed IEEE Std.-344, "IEEE Recommended Practices for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations".

IEEE Working Group SC4.9 committee to develop a standard for the "Application, Installation and Qualification of Class IE Raceway Systems for Nuclear Power Generating Stations".

American Society of Civil Engineers, Committee on Seismic Design.

American Nuclear Society 2.2 committee which developed the seismic instrumentation standard, ANS N18.5.

ANS 2.10 committee for retrieval and processing of seismic records from nuclear power plants.

## 6. DOING

The most common means of training is for an engineer to have an assignment which involves seismic requirements in some form. The particular assignment depends upon the individual's qualifications but may be one of a variety of assignments described below.

### 6.1 Building Analysis Including Soil-Structure Interaction

The process of obtaining the seismic forces and responses of Category I structures for a given project is a sizeable undertaking and usually requires three or four people for a project. The procedure starts by determining how a building will be modeled. Then the models are set up and the properties calculated. Computer analysis (either finite element or lumped parameter analysis) are then performed to obtain the building forces and acceleration time histories from which floor response spectra are calculated.

Someone with experience in seismic analysis either does, or decides on, the basic model. Engineers without a great deal of experience can perform the calculations using the available computer programs and, in so doing, learn and gain experience in seismic analysis and the capabilities of the computer program currently in use.

### 6.2 Writing Project Specifications for Seismic Qualification of Equipment

All types of equipment, mechanical, electrical, piping, and control and instrumentation equipment must meet seismic requirements. They all have their own characteristics which require special attention but must meet the same basic seismic requirements.

Each project produces specifications for the above types of equipment. Since progress



is continually being made in seismic qualification of equipment, the specifications are updated for each project making use of the information available at the time the specification is written. This information includes such documents as IEEE-344 (referenced above), other project specifications, and standard specifications prepared by the staff. The engineer preparing the specification has to develop an understanding of the material and include it in a project specification.

### 6.3 Reviewing Equipment Qualification Reports from Vendors

Bechtel seismic specifications provide general criteria which are to be met and permit the vendors to select a method of qualification for their equipment. The method of qualification to be used must be outlined in the bid proposal and clearly justified in the final report.

When the bid proposals are received, they are reviewed to ensure that the methods of qualification will meet our specification. The engineer responsible for the review of the bid proposal must have a knowledge of dynamics and the seismic specification. Some vendors, or the test laboratory or consultants they employ, have a good knowledge of testing methods and procedures so that working with the vendors offers an opportunity for the engineer to broaden his knowledge in this area.

### 6.4 Developing Project Standards for Conduit and Cable Tray or Conduit Systems

Bechtel has a basic document which provides criteria for the design of cable trays and conduit systems. However, the system design is done on each project. This design later takes into account the project seismic requirements and the particular hardware used on the project. The knowledge of dynamics required to perform such a design is not great, since the basic requirements exist in the design criteria and assistance can be provided to the engineer by a supervisor or staff member. This offers an opportunity to learn basic seismic design without being involved in or needing to learn sophisticated methods.

### 6.5 Other Seismic Assignments

Other jobs in seismic analysis also offer opportunities for continuing development. These include seismic analysis of piping systems, membership on the Seismic Committee, and a staff job in the seismic group. These jobs require a strong background in structural dynamics and earthquake engineering, and provide a position for an engineer in which he is exposed to the latest techniques being employed in earthquake engineering in the nuclear power plant field.

### 6.6 On the Job Training for Foreign Personnel

In addition to the special programs conducted for client personnel discussed in Section 2.4,



when a project is being designed for construction out of the United States, the local engineers participate in the design. This gives them an opportunity to learn from experienced Bechtel engineers. This is done when the design is performed in the United States and when it is performed in a foreign country.

When the design is done in the United States, foreign engineers will be brought to the United States and trained by working in the Bechtel offices on their projects.

When the design is done in a foreign country, a small staff of Bechtel specialists are sent to the country. First, the local engineers are shown how to do the work, then they work developing structural models and performing seismic analysis under the supervision of the Bechtel specialists. In this case, the Bechtel specialists are periodically brought back to the U.S. to be brought up to date on the latest criteria and techniques.

## **7. CONCLUSION**

Five means of training personnel in the area of seismic design of nuclear power plants have been discussed. It can be seen that both formal and informal means of training can be and are used to advantage. A job, an assignment, or any type of exposure to seismic requirements can be used effectively as a teaching and learning experience. At Bechtel these means are used not only to train the Bechtel personnel, but our clients and vendors as well.

## **APPENDIX A - STRUCTURAL DYNAMICS COURSE OUTLINE**

### **Part 1 - Elementary Systems**

#### **(A) Vibrations of One Degree-of-Freedom Systems**

1. Equation of motion of one degree-of-freedom systems
2. Free vibration of undamped 1 DOF systems
3. Free vibration of damped 1 DOF systems

#### **(B) Forced Vibration of One Degree-of-Freedom Systems**

1. Analytical approach
2. Harmonic vibration
3. Hysteresis curve of a 1 DOF system

#### **(C) Numerical Analysis of a Single Degree-of-Freedom System**

1. Linear acceleration method
2. Constant velocity or lumped impulse procedure
3. Newmark beta method

#### **(D) Undamped Free Vibration of a Two Degree-of-Freedom System**

1. Equations of motion
2. Natural frequencies

3. Mode of vibration and normal coordinates
- (E) Damped 2 DOF Linear System
  1. Equations of motion
  2. Uncoupled equations of motion
- (F) Forced Vibration of a 2 DOF Linear System
  1. Equations of motion
  2. Support motion
  3. Harmonic vibration

## Part II - Multidegree and Continuous System

- (A) Multiple Degree-of-Freedom Vibrating Systems
  1. Normal modes of undamped systems
  2. Damped systems with normal modes
  3. Approximate method for computing fundamental frequency
- (B) Vibrations of Beams
  1. Equations of motion for bending beam
  2. Solution of the homogeneous equation
  3. Boundary conditions
  4. Free vibration of a simply supported beam
  5. Forced vibration of a simply supported beam
  6. Vibration of a simply supported beam due to support motion
- (C) Longitudinal Waves in Prismatic Bars
  1. Equations of motion
  2. Wave solution
  3. Uniformly distributed compressive stress applied to the end of a bar
- (D) Response Analysis Technique
  1. Method of modal superposition
    - a. Theory
    - b. First mode by matrix iteration
    - c. Second mode by matrix sweeping iteration
  2. Step-by-step Integration method
  3. Direct Integration Runge-Kutta method
- (E) Transfer Functions and Responses of Multiple DOF Systems to Base Excitation
  1. Computation of transfer functions
  2. Examples
- (F) Response Spectrum Methods
  1. Response spectra for steady-state sinusoidal base motion
  2. Theory for arbitrary base motion
  3. Properties of response spectra
  4. Modal analysis response spectrum method

### **Part III – Applications**

#### **(A) Earthquake Properties and Design Earthquake**

1. Theory of earthquake occurrence
  - a. Terminology
  - b. Earthquake theory
2. Earthquake rating
  - a. Richter Magnitude Scale
  - b. Modified Mercalli Intensity Scale
  - c. Comparison of magnitude and scale
3. Properties of strong-motion earthquake accelerograms
  - a. Peak ground acceleration
  - b. Duration of strong-motion
  - c. Frequency content
  - d. Response spectrum
4. Selection of design earthquake
  - a. Conventional buildings
  - b. Safety-related structures

#### **(B) Structural Modeling**

1. Static and dynamic degrees-of-freedom
2. Modeling of rigid frame buildings
  - a. Mass lumping and dynamic degrees-of-freedom
  - b. Development of the reduced stiffness matrix
  - c. Vertical analysis
  - d. Element properties
    - 1) Effective width of composite beams
    - 2) Relative stiffness and mass properties
    - 3) Effective stiffness of concrete elements
3. Modeling of shear wall structures
  - a. Shear wall example
  - b. Modeling for earthquake analysis
  - c. Mass lumping and dynamic degrees-of-freedom for lateral analysis
  - d. Development of reduced stiffness matrix
  - e. Vertical analysis
4. Modeling of containment structure

#### **(C) Fourier Series Applications to Dynamic Problems**

1. Fourier series representation of a time function
  - a. Theory
  - b. Example
  - c. Remarks
2. Example of application

**(D) Method of Fourier Transformation**

1. Fourier integral and Fourier transformation
  - a. Theory
  - b. Example
  - c. Fourier transformation of velocity and acceleration
2. Method of Fourier transformation
  - a. 1 DOF systems
  - b. Multiple DOF systems
3. Discrete Fourier Transformation

**(E) Foundation Structure Interaction by the Foundation Impedance Method**

**(F) Introduction to Dynamic Testing**

1. Response of a lumped mass multidegree-of-freedom system to a sinusoidal force applied at one coordinate point
2. Response of a lumped mass multidegree-of-freedom system to sinusoidal forces applied at multiple coordinate points
  - a. Forced excitation of pure natural modes
  - b. An iterative process for exciting pure normal modes
3. Methods of damping determination
  - a. Decay rate or logarithmic decrement
  - b. Half-power phase method
4. Vibration exciters
  - a. Eccentric mass exciter
  - b. Electromagnetic exciter
  - c. Hydraulic vibration exciter

**(G) Earthquake-Resistant Design of Structures**

1. Philosophy of earthquake-resistant design
2. Ductility considerations
3. General design procedures
4. The UBC method
5. The dynamic analysis method
6. Other considerations
  - a. Structure types
  - b. Seismic drift control
  - c. Torsion

**(H) Seismic Qualification of Equipment for Light Water Nuclear Power Plants**

1. Seismic environment for equipment
2. Dynamic analysis
3. Testing
4. Combined analysis and testing

**(I) Vibration Measuring Devices**

1. Mass spring transducers

2. Distortion of wave form
3. Frequency limits
4. Characteristics of instruments
5. Types of accelerometers

**(J) Response of Structures to Missile Impact**

1. Structural response
2. Local effects

## TRAINING ENGINEERS FOR NSSS BID EVALUATION

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### ABSTRACT

When a country undertakes its first nuclear power project, it is desirable that its engineers play a meaningful part in the work. This paper describes how, in such a country, an engineering team without prior nuclear experience was trained to perform all the tasks in matching nuclear steam supply system and turbine generator proposals and evaluating the results. The paper further shows how, in the normal course of the work, the industrial capability of the country was assessed and the required foreign exchange was identified.

In the mid-1960's it had already been shown, worldwide, that for power station units in the range of 600 MWe to 1000 MWe nuclear energy had to be evaluated along with all other energy sources. Nuclear power facilities at that time were restricted to the more highly developed countries because of technical expertise and industrial capacity; fossil fueled or hydroelectric power units were in general use in all countries.

In our country it was decided to prepare specifications for a nuclear steam supply system (NSSS) and a matching turbine, take bids on this equipment, and then evaluate the bids. Concurrently, a fossil fuel plant could be evaluated to compare with the lowest cost nuclear plant. After discussion, it was agreed that NSSS specifications would be adequate for all commercially proven reactor types so that all countries with proven reactor experience could bid. Burns and Roe, therefore, prepared specifications for four reactor types: pressurized light water, boiling light water, pressure tube heavy water (CANDU), and gas cooled (AGR). The turbine generator specification was written to permit matching bids for each of the reactors.

A stated objective of this operation was to be the formation and training of a nucleus of engineers in nuclear power technology and bid evaluation by these engineers. The evaluation team was composed of engineers from the power commission, the Nuclear Energy Institute, and a private engineering company. These engineers were capable, mature men with experience in conventional power plants and heavy industry. All engineering disciplines were represented except those peculiar to the nuclear business such as shielding and accident analysis. There was no practical experience in nuclear power, there was some theoretical knowledge as a product of schooling in various countries.

A vertical evaluation of the anticipated bids, where one or two men review an entire

bid, could not be performed because the engineers on the evaluation team did not have the knowledge to support this approach, nor could adequate training be provided in the available time frame. A horizontal evaluation could be performed, that is, arrange the entire plant in systems and have one or two men evaluate the equivalent systems in each combination of NSSS and mating turbine generator bid. There are obvious advantages to this approach. The entire evaluation team would require indoctrination in the overall nuclear power plant concept, but each member of the team needs thorough training in a small manageable portion. Additional "on the job training" would take place as the team is led through its training and the team members would talk and question each other. It is also obvious that there should be no language barrier between the engineers leading the training and the engineers on the evaluation team.

The training program selected consisted of a general orientation in nuclear power stations followed by preparation of conceptual designs by the evaluation team for each of the reactor concepts in the specifications. Liberal assistance was given to each of the small groups in explaining to them the requirements of design, construction, and operation of the systems for which they were responsible. This was supplemented by after hours seminars in special subjects such as shielding, containment, radiation protection, seismic considerations, quality assurance, system separation, emergency operation, etc.

The training program could not function without training material; so two types of material were prepared. The first material is best called "bid information". We prepared sample technical information packages to approximate those expected to be received in valid proposals. The packages were the most accurate we could prepare and defined work scope, equipment supplied and interfacing requirements to be met. The degree of detail furnished in these packages was the same as would be in the actual proposals. The "bid information" was selected from public bids or from information available through normal commercial channels. Great care was taken not to infringe on the proprietary interests of any possible bidders.

The second package was a conceptual design information book prepared to guide the evaluation team through its work. This conceptual design book was a combination of explanatory material, design and performance criteria, outline specifications, design data, and guidance. The book matched interfaces expected in the bids. Sufficient data was included so that the evaluation team could design the "Owner" side of each interface. Each supporting system had its own writeup that describes performance, equipment components, material of construction, interface with the nuclear steam supply system or the turbine generator, design criteria, and governing codes and standards. The book is arranged in five sections:

1. General - contains background information.
2. Mechanical Engineering - contains data on balance of plant and power conversion systems.
3. Electrical - contains data on power generation, transmission and intraplant distribution. Plant protection, circuit physical separation, and protection



requirements are highlighted.

4. Nuclear - contains data on all supporting nuclear island systems. The radioactive waste systems are highlighted because they represent the most significant departure from conventional systems.
5. Civil/Structural - contains data on building design, load combinations, and design stresses. Highlights seismic criteria in as much detail as possible in the time available for preparation. Special mention is given to nuclear island system requirements whenever it is judged necessary.

As an attachment to the book, drawings and outline specifications are prepared. The specifications describe the major plant components in sufficient detail so they may be physically sized and the information used in arrangement studies. Additionally, information can be developed to be used in piping, ventilation, and power studies. The drawings include typical general arrangements, BOP and nuclear island flow diagrams, typical electrical plant single line diagrams, plus any special civil/structural drawings that may merit inclusion due to utility desires or peculiarity of a selected site. A typical Table of Contents for an Advanced Gas Reactor Instruction Book is included as Figure 1 at the end of the paper. Figure 2 is a detailed Table of Contents for the nuclear island. The book is arranged so that the "project" may be controlled by a Project Manager and work assigned to cover the entire plant. Care is used in writing each book to use the same terminology as will be used in the bids. Thus, a PWR book will talk about a chemical and volume control system while a BWR book will talk about a reactor water cleanup system. As the books are used, the evaluation team usually arrives at names in their own tongue for everything which becomes the actual terminology of the project.

Experience has shown that it is most useful to compile a glossary of terms which evolve as the work progresses. As in any other work, personnel are added to the project as the work increases and more people are needed. The glossary becomes the tool by which older team members communicate with the new ones as they are added. It also provides the basis for communicating with the rest of the utility and industry.

The assignment of systems to engineering groups has to be influenced by the ability and experience of the personnel available. In the electrical discipline three natural assignments exist: power generation, transmission, and intraplant distribution. The first two assignments are essentially the same as in the conventional plant. The power generation group must also handle the emergency power generation requirements of the station while the transmission group must provide for two incoming auxiliary power lines. The intraplant distribution group has to handle all normal internal plant power requirements, while at the same time it absorbs the requirements of emergency distribution, single failure criteria circuit separation, physical protection, etc.

In the mechanical-nuclear areas, the turbine auxiliary systems and the generator cooling systems are the same as in any other plant. The steam condensate-feedwater systems have variations that are peculiar to the individual reactor type and ought to be assign-

ed to a single group. Primary systems and steam generation should be handled together because that assignment will always handle radioactive material. One group should be responsible for all radioactive waste systems because the principles are the same in all plants even though detail implementation varies with the reactor. Another group should be responsible for reactor auxiliary systems handling coolant supply, makeup and purification. Yet another separate group should handle fuel manipulation and refueling activities.

The civil structural discipline is most naturally split by building. One of the groups, the containment group at first, must be assigned responsibility for investigation of seismic criteria and definition of seismic design rules to be used in this phase of the project. The criteria and design requirements ought to be as near to final as possible, they must be unchanging throughout the evaluation so that all bids are treated equally.

## PLANT DESIGN INSTRUCTION BOOK A ADVANCED GAS REACTOR

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Looking at Figure 2, it can be seen that each system to be handled by the nuclear engineering group has been identified and described. Hence, in assignment of engineering personnel to each system, the system description in the book defined whether an engineer with mechanical or chemical engineering background was indicated. Similarly, the descriptions in the book for civil/structural and electrical will indicate preferred backgrounds for these engineers.

In the initial evaluation of the work to be accomplished, it was decided that there would not be any individual instructions for instrumentation engineers, but that they would function as they normally do and support the other engineering disciplines as required. With the exception of nuclear instrumentation such as flux monitors, radiation monitors, neutron counting channels, etc., all the instrumentation is the same as normally

used in power or chemical plants. Time did not permit adequate theoretical and application training to be given to team engineers on nuclear instrumentation, so engineers from Burns and Roe did that part of the conceptual designs and gave as much on-the-job training as circumstances permitted.

The information described in Figure 1 represented the total "criteria" package for each plant type. The material was delivered to the evaluation team one plant at a time, spaced four or five weeks apart to permit the team to absorb the information and prepare a conceptual design. The team was comprised of design engineers, estimating engineers, designers and draftsmen. The modus operandi was simple. The material was given first to the design engineers and drafting room personnel. Burns and Roe engineers explained the information to the team members and answered questions. The team then started building a conceptual design from the information. Each conceptual design was pursued until equipment arrangements were satisfactory to both the using utility and the experienced engineers. Then the structural, mechanical, electrical, and instrumentation disciplines proceeded to develop greater detail in their respective areas. Containment penetration design and layouts were prepared so that the problems in arrangement and accounting became familiar. Shield wall penetrations for ducting and large piping were designed and the various techniques of offsetting and/or use of supplementary lead or steel were demonstrated.

Reactor containment was a completely new concept and was given special attention. The entire design team studied equipment arrangements inside containment to become familiar with the structures required for both shielding and structural support. The mechanical, electrical, and instrumentation engineers collaborated in evolving the arrangement and the configuration of walls, cells, cable trays, conduits, and large piping. This period was particularly fruitful because reasons had to be given for the massive structural barriers. The interplay of structural support, biological shield and missile shield was introduced and discussed. After these concepts were assimilated, the complication of dynamic analysis for earthquakes was added.

Using this information and the design basis accident defined in the information package, containment design criteria were calculated by the assigned team members with the assistance of an experienced engineer from the consultant. Some dynamic analysis of civil structures was done to determine if they would be controlling inside containment. Similarly, engineering groups from each of the disciplines - mechanical, electrical, civil/structural and instrumentation - were led into their work guided by consultants.

Each group received "on the job training" as the work progressed. At the start of the work, few questions were asked, literally because the men did not know any questions. As the work proceeded, the men became more knowledgeable and more confident. With increased knowledge came increased awareness of the information gaps and identification of questionable areas. The amount and validity of questions increased reflecting this growth of knowledge. The team members became able to associate the requirements of the nuclear plant with the practices and standard designs of their own utility.

The conceptual design evolved as building arrangements, mechanical flow diagrams, electrical one-lines, instrumentation block diagrams and structural skeleton drawings. The engineers then proceeded to flesh out their skeleton with preliminary calculations to establish power loads, pipe line sizes, slab thicknesses, beam and column configurations, etc. The designs were carried far enough so that a meaningful cost estimate could be made. This meant that the team produced single line routing of the main pipelines, cable trays, and ductwork. Under the guidance of the consultants, problem shielding areas were identified and designs evolved.

When sufficient design work had been accomplished, construction engineers and cost estimators took over. Now construction methods and sequences were studied and planned. These engineers, who knew the capabilities of their domestic contracting organizations, evaluated the new requirements and put quantitative values on them. A typical problem emerged - the port of entry had a load handling capability of only 100 tons - we had loads up to four and five hundred tons. These problems were solved and monetary values assigned. Whenever new or unusual construction requirements appeared, work methods were defined and costed.

A nuclear power station is not just a turbine-generator and a nuclear steam supply - It is also pipe, wire, cable, steel sheet and plate, cement, gravel, valves, pumps, switch gear, etc. Supply sources for these had to be established, either domestic or imported. Out of the need to maximize domestic participation, came an evaluation of the existing and planned expansion of the industrial capacity of the country. The questions that needed answering were the following types:

- (a) Can the correct material be furnished as steel plate - width, length, thickness?
- (b) Can the material be fabricated to the required tolerance?
- (c) Can sufficient material be furnished on schedule considering the overall needs of the country?
- (d) Are there planned industrial expansions that can be of assistance?
- (e) Are there skilled craftsmen available? If not, are they to be trained or brought in for a project?

As you see, gathering the answers to these questions evaluates the industrial capability of the country for both production facilities and craft personnel. The estimating process has the first effect on the country outside of the immediate project. The search for information and costs generates the first concrete contacts with industry and provides it with definitive requirements for material and services. The estimating engineers also look at international transportation facilities and freight handling ability. From this evaluation of "ship-to-site" transportation can come special costs associated with a particular type of reactor or a need to upgrade roads, bridges, railways or ports. The process of developing the detailed reference cost estimate defines the actual construction program that must be developed to build the plant. The "Energy Ministry" now knows the support it requires from other ministries and the national industry to complete its project. Completion of the reference cost estimates can be, if so desired, a natural stopping point at which to reeval-



uate the project's effect on the Infrastructure of the country. All the facts needed by national planners have now been developed - required expansion of heavy industry, needs for additional craft training, required improvements in the transportation system, and foreign exchange.

When the first cost estimate is completed, the estimating team proceeds on to each of the remaining designs, preparing an estimate for each design. As you may expect, each succeeding estimate increased the proficiency and perceptiveness of the estimators so that preceding estimates are revised and sharpened:

The estimate was prepared in the format of the Code of Accounts of the U.S. Federal Power Commission. This was convenient because it assured that all items would be covered, and it made cross-referencing between designs simpler. Each item was covered in as much detail as possible to permit future use of each estimate as a "reference base" during actual bid evaluation. Each item was defined in terms of unit costs for material and labor plus the number of units of each in any line item. Thus in actual bid evaluation, a line item could be sized for the bid in question and then by comparing the evaluation line item units of material and labor with those of the reference base a cost deviation from the reference base could be established.

This approach - "cost deviation" - is important because each turbine-generator manufacturer in the world can supply a turbine to match any reactor. Hence, with five to eight reactor bidders and seven to ten turbine bidders, it is possible that up to eighty bid combinations may have to be evaluated in four to six months. The "deviation approach" requires that during actual evaluation, system adequacy be confirmed and then differences with the reference design be identified. This can be done much more rapidly than costing out a complete conceptual bid package design. It will give much more accurate results on cost differentials than individual overall estimates. Actual total cost accuracy is good because the reference estimates are improved with increasing knowledge.

This training program requires about five months to implement properly for four different reactor types. It can, however, be scheduled so that it precedes actual bid evaluation by four months. This comes about because in the last month of the training program only the construction and estimating staff are busy; the design staff has finished its work. The receipt of bids can be scheduled after the design staff have completed their work and the initial work of actual bid evaluation by the design staff can overlap completion of the training program by the construction and estimating staff.

To summarize, competent engineers, unfamiliar with nuclear power stations, have been trained on a time schedule to evaluate many bid combinations of NSSS's and turbine generators; have successfully evaluated bids received; and have selected the optimum combination of bids to be negotiated.



## TRANSFERENCE OF KNOW-HOW FOR THE FABRICATION OF HEAVY COMPONENTS FOR NUCLEAR POWER PLANTS

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### 1. SUMMARY

After a brief description of reactor pressure vessels and steam generators for 1300-MWe nuclear power plants, methods of transferring know-how for the fabrication of these heavy components to a company yet to be established are discussed. The criteria for the qualifications of a know-how recipient are discussed. If a new firm is established the most important activities for the transference of know-how are planning of the factories, selection and training of personnel, delegation of specialist personnel, the transfer of documentation, and measures for transferring knowledge that cannot be documented. Contracts which lay down the mutual rights and obligations between know-how supplier and recipient are discussed.

### 2. HEAVY COMPONENTS FOR NUCLEAR POWER PLANTS

The heavy components under discussion here are pressure vessels for light-water reactors and steam generators for pressurized-water reactors of 1300-MWe standard type of Messrs Kraftwerk Union AG of Mulheim in the Federal Republic of Germany. For safety reasons both these components are subject to stringent quality controls which have now assumed unprecedented proportions. The developments in the size of reactor pressure vessels can be seen from Fig. 1.

A comparison of the dimensions and weights (total length  $l$  = approx. 8.8 m, wall thickness  $s$  = 58 mm and unit weight  $G$  = 57 t at the beginning of the 60's and total length  $l$  = 13.4 m, wall thickness  $s$  = approx. 240 mm, unit weight  $G$  = 540 t at the beginning of the 70's) shows how rapid the development of heavy components has been in little less than a decade. The larger dimensions, the more problematic the manufacture becomes. In the Federal Republic of Germany, Messrs Gutehoffnungshutte Sterkrade AG have played an active part in the development of manufacturing techniques for primary components right from the beginning and have made their mark on it.

The reactor pressure vessel (Fig. 2) encloses the nuclear heat source. It contains the core structure which holds the fuel elements in the prescribed position. The reactor pressure vessel of a 1300-MWe nuclear power station has a total weight of approx. 540 Mp. The lower part (see photograph in Fig. 3) comprising spherical head, cylindrical part

and nozzle flange with primary water inlet and outlet nozzle weighs approx. 400 t. The cover, onto which control-rod nozzles are welded, weighs approx. 140 t. Particular manufacturing problems are caused by the welding of large wall cross-sections (the cylindrical sections have wall thicknesses of 240 mm), by the austenitic overlay welding and by the manipulation of heavy parts.

In the steam generators (Fig. 4) the primary water heated up in the reactor core transfers its thermal energy to the secondary circuit through evaporation of the feedwater. A 1300-MWe power station has 4 such steam generators. They each weigh approx. 420 t. They are usually vertical U-tube type heat exchangers (Fig. 5). Particular manufacturing problems arise as a result of the combination of ferritic and austenitic materials (more than 4,000 tubes made of Incoloy 800 have to be welded into the tube sheet) and as a result of the stringent requirements as regards accuracy and cleanliness during manufacture of the tube bundle.

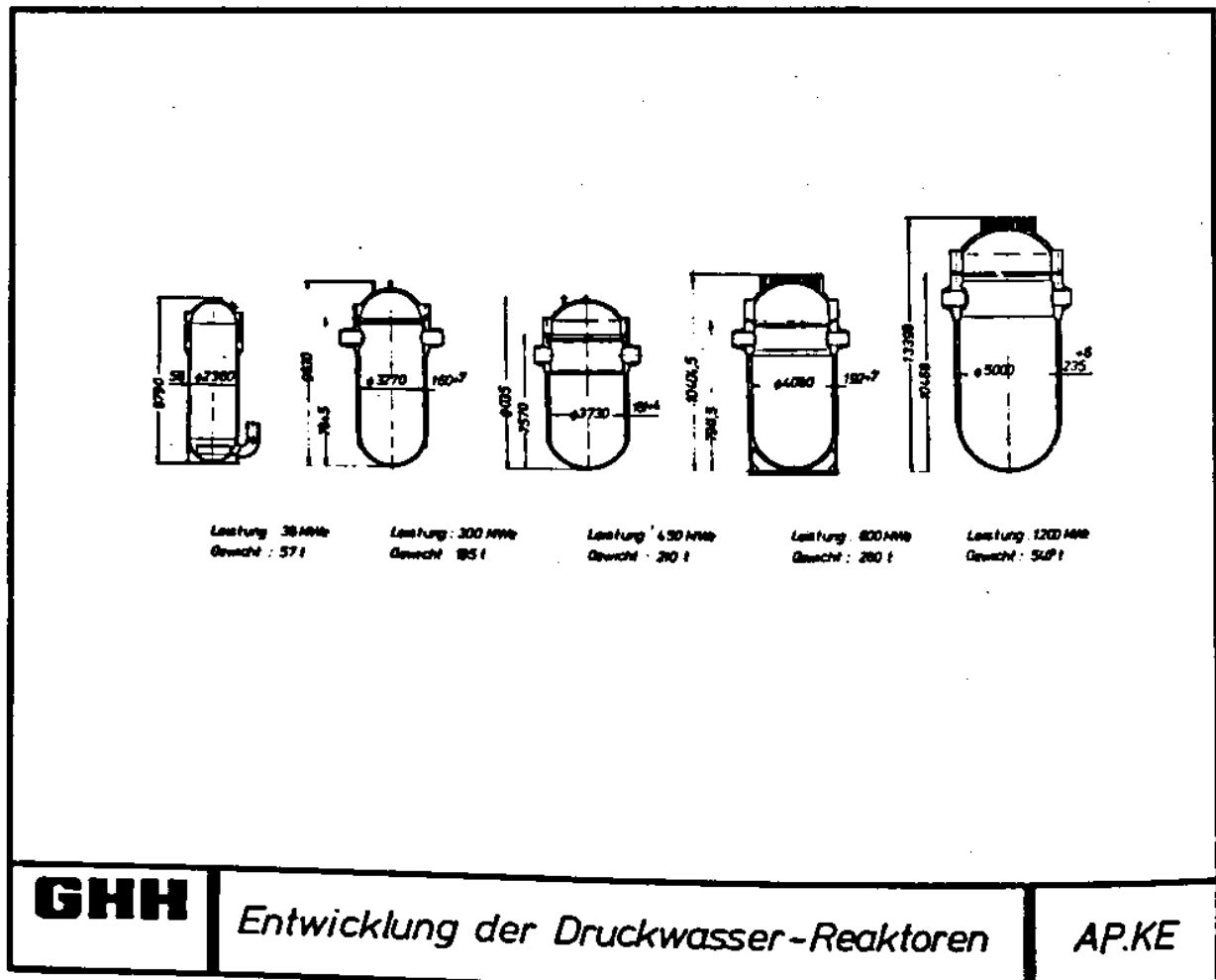


Fig. 1. Development of Pressurized - Water - Reactor Pressure Vessels



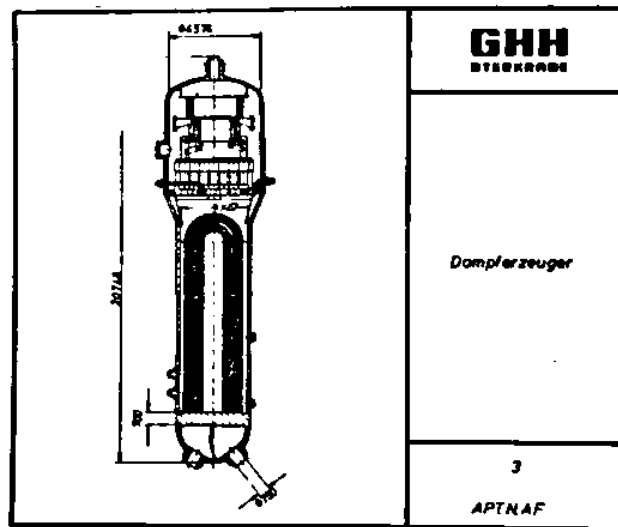


Fig. 5. Steam Generator, Cross Section

I do not intend here to go into the manufacture of primary components and its special problems, particularly with regard to quality control, which have led to a special type of component manufacture. They explain on the one hand the importance of the measures for transferring know-how for the fabrication of heavy components and on the other hand the difficulties which such a transfer of know-how can entail.

### 3. CHOICE OF KNOW-HOW RECIPIENT

The manufacture of heavy components is subject to strict requirements as regards personnel qualifications, equipment and quality controls. As a result, conventional component firms are not in a position to manufacture components without additional investment and re-organization, not to mention the location and the problems associated therewith. If there is no capable component firm in the know-how recipient's country whose location could solve the transport problem and whose facilities could be expanded for the purpose of reactor component manufacture, then research must be carried out with the aim of investigating the existing production capacity with a view to optimal utilization of the possibilities for expansion. The assessment criteria for such research are:

- Manufacturing facilities and possibilities for their expansion;
- Existing quality controls and ways of adapting them to the nuclear quality control system;
- Location of the production shops as regards the transport of heavy parts to and from the shops;
- Location of the production shops as regards the availability of qualified personnel and other infrastructure problems;

Possibilities for the training of personnel.

In addition to these purely technical questions there is the problem of whether the management is prepared to manufacture reactor components, something which is not without risks. In addition to the technical difficulties there are also economic difficulties since the market for such components is limited and is also influenced by energy policy decisions.

The research into the qualifications of know-how recipients can be carried out by a neutral engineering bureau who must, however, be conversant with the manufacture of heavy components. At all events it is advisable for the know-how supplier to carry out his own research in order to gain an impression of the capabilities of the various industries in know-how recipient countries. When choosing a know-how recipient he can at the same time find out which indigenous component firms can be approached for solutions to individual problems e.g. sub-suppliers or personnel training.

The research aims to show whether an existing component firm can at reasonable cost be put in a position to manufacture nuclear components, whether this firm is willing to expand their production program to include "nuclear components" or whether it is advisable to establish a new company for the purpose of constructing a heavy component factory. Here the best solution is probably the establishment of a new company specially for the purpose of running a nuclear component factory, with the State and various other component firms also participating. The capital participation of the know-how supplier in this company ensures his active interest in the policy of the company, which will manifest itself in the transfer of the know-how.

From now on, I shall assume that a new company will be established for the purpose of running a heavy component factory.

#### **4. MEASURES FOR TRANSFERRING KNOW-HOW TO A NEWLY ESTABLISHED COMPANY**

For the transfer of know-how to a newly established company the most important activities are:

- Planning and erection of the factory;
- Determination of the organizational set-up;
- Personnel selection and training;
- Delegation of know-how supplier's specialist personnel to the new factory;
- Transmission of documentation;
- Drawing up of measures for transferring know-how that cannot be documented.

##### **4.1 Planning and Erection of the Factory**

The factory planning and construction work can be carried out parallel to the work associated with the establishment of the company, such as contract negotiations, clarification of financing, obtaining of official and statutory permits, etc. The factory planning and erection program is subdivided into the following main phases:

Project study;  
Preliminary planning;  
Main planning;  
Erection and commissioning.

Before the company proper is founded the project study is meant to give the participants or prospective participants an overall idea of the size of the factory, the expected investment costs and the estimated time schedule. During the preliminary planning the assumptions made in the project phase and based on estimates are consolidated. The activities in the preliminary planning stage are as follows:

- Fixing of the products to be manufactured and the production program;
- Fixing of the final expansion stage of the factory (the size of the factory site is dependent on this decision);
- Choosing of the site taking into account such factors as transport, infrastructure and employment considerations;
- Determination of the size of the production bays and ancillary shops using local work-place studies based on the door-to-door time, determination of the office space required and of all other facilities associated with the running of a factory (e.g. amenities);
- Planning of the machinery and equipment;
- Cost estimates;
- Estimation of the deadlines for planning and erection.

The preliminary planning documentation helps the management to take decisions about the erection of the factory, to determine its size and the various expansion stages, and about its production range i.e. whether other components are to be manufactured in addition to heavy components; this may be necessary in order to increase the cost-effectiveness of the factory (by making the factory work at full capacity). A precondition for the manufacture of other equipment is that the stringent demands imposed on nuclear power plant components must also apply to this other equipment as well, otherwise different levels of quality will occur during production which will make it difficult to maintain personnel standards.

The main planning and the erection is left to engineering bureaus and construction companies in the know-how supplier's country, with the advisory services to be provided by the know-how supplier being contractually agreed upon and guaranteed.

#### 4.2 Organizational Set-Up

The legal form the company takes, the laws applicable in the know-how recipient's country, the products and the scope of the production program govern the organizational set-up of a heavy component factory (Fig. 6). The number of productive hours needed to manufacture the products, the necessary qualifications of the productive and non-productive workers and the legal form of the company are the basis of the organigramm for selecting

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For the start-up of the factory it will be absolutely necessary for some specialists of the know-how supplier to occupy staff positions with authority to give orders (indicated by "L" in Fig. 6). The importance of this increases with the amount of responsibility the know-how supplier assumes for proper manufacture of the components. To ensure the transfer of know-how the people holding these posts should each be assigned an assistant from the know-how recipients' personnel who can take over this post after the start-up phase.

There are no universally valid data on the number of trainees or on the number of specialists to be delegated. They depend on the state of development and on the availability of qualified personnel of the know-how recipient. For the running of a heavy component factory in a country with good component and machine-building plants the training of approx. 50 specialists (not taking into account fluctuations) and the delegation of 10 to 15 advisors should be sufficient for the start-up of the factory.

Training could also be given to skilled personnel, particularly productive workers in component firms in the know-how recipient's country and in machine suppliers' workshops. It must, however, be noted that here only the basic principles of component manufacture can be taught; the specialist knowledge required for nuclear component manufacture can only be acquired in the heavy component factory itself or in the know-how supplier's shops.

In view of this specialist knowledge that is required it is recommended that the first step in the new factory be the setting-up of a training school.

This results in the following ways of procuring skilled personnel which can be followed simultaneously:

- Training at the know-how supplier's works;
- Employment of the know-how supplier's personnel in staff positions;
- Provision by know-how supplier of advisors for know-how recipient's personnel;
- Training of personnel in existing factories in the know-how recipient's country;
- Training in the factory's own training centers;
- Training in the machine suppliers' works and by machine suppliers' personnel after installation of the machinery in the new heavy component factory.

#### **4.3 Transfer of Documentation**

The transference of know-how through intensive training and delegation of personnel is of the utmost importance. In the know-how supplier's works the trainees learn how to use all the documentation required for production. All the said documentation is of course placed at the disposal of the know-how recipient. It is recommended that all the documentation be for the components of a state-of-the-art nuclear power plant, the so-called reference plant. The most important documents to be transferred are:

- Workshop drawings of the components and their individual parts;
- Manufacturing and testing sequence plans;
- Welding plans;

Heat treatment plans;  
Parts lists;  
Regulations concerning special manufacturing stages;  
Shop orders;  
Drawings of special manufacturing equipment;  
Documentation concerning quality assurance and quality control.

#### **4.4 Know-How that Cannot Be Documented**

Skilled craftsmanship during manufacture and inspection cannot be recorded in tangible documentary form. For the transference of this kind of knowledge the training of specialist personnel and the delegation of advisors are of paramount importance. Here it is not always necessary for the advisors to work for long periods in the know-how recipient's works. The short-term delegation of specialists (trouble-shooters) is sufficient for solving special problems.

### **5. CONTRACTS FOR ASSURING THE TRANSFER OF KNOW-HOW**

The scope of the contractually agreed services depends not only on the scope of the know-how to be transferred but also on the relationship between the know-how supplier and know-how recipient. If the know-how supplier has a capital share in the heavy-component factory then the rights and obligations of both parties are laid down in a "Shareholder Agreement". This agreement forms the basis of the co-operation scheme. All other contracts are appended to the Shareholder Agreement.

The "Statutes" lay down the structure of the company on the basis of the laws of the know-how recipient's country and define the rights and obligations of the management.

An "Engineering Services Contract" governs all the engineering activities which have nothing to do with the transfer of know-how for the actual manufacture of components. This includes planning of the factory, importing of machinery, approval of main planning documents, planning of personnel and capacity, etc.

In the "Technical Information Contract" the nature of the know-how, its scope and the methods for transferring it and the rights and obligations of both parties are fixed. In addition to settling the commercial questions the contract also lays down the conditions governing the delegation of advisory personnel and personnel in staff positions.

The rights and obligations of the parties to the contract as regards the training of personnel and the scope of the training are laid down in the "Personnel Training Contract".

The know-how recipient's rights in using the know-how supplier's patents, the obligations arising from violation of third parties' patents and the possible feedback of future patents are laid down in the "License Contract".

In order to avoid disputes the scope of the services, the procedures for providing the services, the settlement of the costs, the guarantees and the liabilities must be defined as

precisely as possible in the contracts. Formulation of the contracts is always difficult because provision cannot be made for all eventualities.

Finally it should be pointed out once more that the measures discussed here for transferring know-how are based on the assumption that a new company will be formed for the purpose of running a heavy component factory. The methods of know-how transference will be the same if an existing component firm receives the know-how. The formulation of the contracts, which are likewise unavoidable here, may be different, e.g. the Shareholder Agreement can be dispensed with. The scope of the know-how transferred will depend on the state of development of the know-how recipient. Research by the know-how supplier into the capabilities of the know-how recipient will provide information as to the method and the scope of the know-how to be transferred.

## **TRAINING AND QUALIFICATION FOR ENGINEERING INSPECTION PERSONNEL**

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### **ABSTRACT**

The paper describes a scheme for recruitment, training and qualification of engineering inspection personnel, especially applicable when the personnel is active in the nuclear field. The recruitment scheme covers the definition of the profile, and the evaluation of the candidate, both from the point of view of his technical knowledge, his capabilities and his character profile. The qualification scheme is based on a classification of the technical fields or speciality to be covered and a description of the duties to be carried out in each of them. These duties are next classified in levels according to their difficulty. Qualification and Training Plans will be developed accordingly. Training objectives are assigned to the individuals, and rounded-off by examination. After formal recognition of the qualification, attention is paid to keep up the qualification.

### **1. INTRODUCTION**

The training and the qualification of engineering inspection personnel is not yet in discussion on the international scene; nevertheless, an engineering inspection organization or department needs a training program and a qualification scheme for assuring the quality of the services provided, especially when working in the nuclear field where Quality Assurance undoubtedly applies to such organizations or departments. This paper describes such a scheme.

Training can be provided either within one's own company, or within a sister company or specialized institutions, and instructors and teachers can grow up in the company or can come from well established organizations. It is however important that training is provided by people who actually have the practice of the techniques considered.

### **2. SELECTION OF THE CANDIDATES AT RECRUITMENT**

An indispensable preliminary to qualification is the right selection of the candidate for the job. This selection must therefore be conducted very carefully, on the basis of a personal contact between the candidate and the manager, and the final decision should involve the

evaluation of more than one evaluator. The successive steps in the selection procedure can be as follows: definition of the profile of the individual needed, preliminary selection, personal evaluation of the candidates, evaluation by the candidate, final selection and proof period.

### 2.1 Definition of the Profile Requested

A correct definition of the profile of the individual needed can save a lot of time for the manager, and increases the chances of attracting the right man. The description of the profile may require all or part of the following information: academic education, description of the function, field of activity, special or specific knowledge, description of the circumstances for the performance of the job, practical requirements, age limits, advantages offered by the company, information and documents to submit.

### 2.2 Preliminary Selection

A preliminary selection can be done on the basis of the answers to advertisements or on the basis of questionnaires sent to the candidates. Such questionnaires gather information on the identity of the candidate, his academic background, his professional and practical background, his knowledge of languages, his ability to drive, to climb, to dive, his attitude to travel and stays abroad.

### 2.3 Evaluation of the Candidate and Evaluation by the Candidate

The candidates who successfully pass the preliminary selection are submitted individually to an interview with the manager. This interview must allow an evaluation on both sides: to know if the candidate is suitable for the job, and to know if the job is suitable to the candidate.

A first topic for such an interview is a short description of the company and its activities, with a more detailed description of the open function and all related duties and requirements for the performance of the job, together with the possibilities for promotion and the advantages the company offers.

A second topic is the evaluation of the technical and linguistic knowledge of the candidate. The technical knowledge, both theoretical and practical, is evaluated through a technical questionnaire. The languages are evaluated both from the passive, the spoken and the written point of view by exercises on the spot.

A third topic for the interview is the evaluation of the general capabilities of the candidate (no longer his knowledge), and of his character profile. This evaluation is made during the interview without any specific test or tool. The result of the evaluation is qualitatively shown and recorded on the evaluation form by the use of check lists. For staff people this evaluation should be confirmed by psychotechnical tests conducted by a

specialist.

A fourth topic for the interview is the evaluation against the different kind of tasks involved with the function (technical, public relations, ...). The evaluation again is made only on the basis of the talks with the candidate and recorded on the evaluation form.

The final topic of the interview is the evaluation made by the candidate of his interest in joining the organization. To make up his mind, he disposes of two tools: the information about the company and the job, and the technical questionnaire, the questions of which are designed to reflect the problems inspection personnel are daily faced with.

## **2.4 Final Selection and Proof Period**

The final choice is made of the individual whose profile is as close as possible to the required profile, taking into account the financial conditions of the contract. A proof period of several months is then initiated, during which the candidate is submitted to activities requiring extra physical and moral will. A reevaluation is made at the end of the proof period and the selection confirmed.

## **3. QUALIFICATION SCHEME - TRAINING BY OBJECTIVES**

### **3.1 Lay-Out of the Qualification Scheme**

In order to assure the quality of the inspection services, it is necessary that each intervention is carried out by an individual qualified for the type of intervention considered. However, for evident reasons of organization and money-saving, it is necessary to regroup as much as possible, tasks belonging to the same field of interest. In order to send on duty for an intervention only a limited number of people, even just one, and to train the people accordingly. One must therefore successively

- (a) identify the needs in terms of qualification types, as apparent from the assignments the organization is entrusted with.
- (b) differentiate those assignments taking into account the abilities needed, by introducing several levels of capability.
- (c) for each qualification type and level, describe the related duties; this defines at once the interventions the qualified individual will be allowed to carry out.
- (e) select teachers and give them the necessary pedagogical schooling.
- (f) set up a training program to give the people the missing theoretical and practical knowledge.
- (g) check if the abilities and the knowledge are sufficient, by introducing qualification tests and examinations.
- (h) maintain the acquired qualifications.

The manager then defines in agreement with the individual, the objectives to finalize in terms of qualification types and levels. However, it is not sufficient to provide the

candidate with all didactic tools necessary to realize the goal. It is of the utmost importance that the candidate should be properly motivated, and this can involve the self-interest of the individual in terms of technical, professional, financial or social interest.

One must also stress that the qualification of the individual is a necessary condition, but is not a sufficient condition to assure the quality of the services. The qualification must be part of an organization which disposes of specialists in all related fields (material, equipment, inspection techniques, codes, discipline,...) and must rely upon an efficient technical substructure (maintenance of equipment,...).

### **3.2 Identification of the Needs in Terms of Qualification Types**

It belongs to each engineering inspection organization to define its needs, based on the activities of the company. Distinction should be made between hardware inspection work in the shops and on site, and software inspection work in the office. It may be necessary to split some qualification types into categories, in order to limit the schooling of the individual only to the extent necessary.

Typical qualification types are: materials, welding, boilers and vessels, piping, valves, rotating machines, plastics, quality assurance,... Typical categories are e.g. for materials: plates, tubes, forgings, castings, bolting, clad plates, welded tubes, finned tubes,...

### **3.3 Differentiation of the Qualification Levels**

The degree of difficulty or complexity related to some assignments for which special abilities are requested, are backed-up by introducing several levels of qualification. Four qualification levels are described: trainee, level I, II and III.

#### **1. A trainee**

- Is an individual whose training is in process, before he gets the first available qualification level
- may work in a team, under the direct supervision of a qualified individual, to carry out specific tasks according to specific instructions
- does not carry out tests or examinations, nor interpret results, nor write reports, nor sign certificates

#### **2. A level I individual, for the qualification type and category concerned,**

- is able to carry out correctly a test or a simple and/or repetitive well defined verification, according to a written procedure (includes the use of possible tools or equipment)
- is able to evaluate the results of the test on the basis of objective acceptance criteria, defined quantitatively and/or qualitatively
- is able to write reports of results and to check reports and certificates established by the manufacturer



- carries out duties which are supervised by a L-II or L-III individual
3. A level II individual, for the qualification type and category concerned, is able to
- work in the frame of a usual specification, code or standard
  - work on usual steels and on usual procedures (fabrication, tests, ...)
  - carry out assignments without any special feature, and for which the possibility of calling for the support of specialists or a L-III individual exists
  - survey the interventions (materials, fabrication, tests, inspection, quality assurance) of the suppliers and manufacturers, on the basis of approved documents
  - correctly carry out tests, verifications and inspections related to the qualification (including the correct use of possible equipment, except the computer)
  - interpret the indications and the findings, formulate and communicate the conclusion
  - write reports (procedure and results), sign reports and certificates
  - give training on-the-job and supervise work of L-I individuals and trainees

An individual qualified for hardware work is, in addition, able to assume the management of the inspection program in the shops and on site. An individual qualified for software work, in addition,

- is able to approve design documents (drawings, calculations, equipment specifications, ...)
- is able to elaborate inspection programs
- is able to assume the overall management of the inspection program
- is able to assume the technical and administrative management of the inspection contract
- is able to participate in the elaboration of equipment specifications
- does not carry out shop or site inspections or tests for which a non-interrupted practice is required.

The designation of the usual codes, standards and steels, as well as the description of the usual supplies, equipment and procedures are given in the Qualification and Training Plans (QFB), established for each qualification type.

4. A level III individual, for the qualification type and category,
- is able to work in the frame of less usual codes or standards
  - is able to work on supplies and equipment of less usual construction
  - is able to work on special materials and on special procedures
  - is able to carry out assignments requiring special vigilance and/or special experience
  - is able to carry out assignments for which it is not possible to call for the support of specialists
  - is able to evaluate the adequacy of activities to accomplish objectives, and

to act as a consultant

- Is able to elaborate or to participate in the elaboration of inspection procedures criteria when none are available
- Is able to evaluate the adequacy of the type, the time, and the test procedure
- Is able to give on-the-job training and to supervise L II work

An individual qualified for hardware work is, in addition, able to

- participate in the elaboration of inspection programs when none exist
- approve documents related to construction and inspection (materials specifications, fabrication and inspection procedures, ...)

An individual qualified for software work, in addition,

- is able to interpret and explain texts, codes and standards
- does not carry out shop or site inspections or tests for which a non-interrupted practice is required

### **3.4 Requirements for the Access to the Qualification Levels**

1. A trainee must realize all conditions which will allow him to get the aimed qualification level.
2. A level I individual must satisfy the following
  - be at least a high-school graduate of a three-year course, in mathematics, sciences or technical subjects
  - have experience in engineering inspection or equivalent, for the period mentioned in the QFP, have followed the L I training program defined in the same QFP, and have passed the tests with satisfaction
3. A level II individual must satisfy the following
  - be at least high-school graduate of a four-year course, in mathematics, sciences or technical subjects
  - have experience in engineering inspection or equivalent, for the period mentioned in the QFP, have followed the L II training program defined in the QFP, and have passed the tests with satisfaction
  - have a passive, spoken and written competence with all national languages
4. A level III individual must satisfy the following
  - be at least a high-school graduate of a four-year course, in mathematics, sciences or technical subjects
  - have experience in engineering inspection or equivalent, for at least 7 years; 4 years of this experience should be as L II of the aimed qualification type and category
  - or
  - be a graduate of a five-year engineering or science college or university, in mathematics, sciences or technical subjects
  - have experience in engineering inspection or equivalent, for at least 5 years;

2 years of this experience should be as L II of the aimed qualification and category

and

- have followed the L II training program described in the QFP, and have passed the tests satisfactorily

The first L III Individuals for each qualification type are designated by a small committee of experienced graduate engineers and/or inspectors, chaired by the management. The designation is pronounced considering the normal requirements of the scheme. Those first L IIIs are also appointed as first teachers and examiners. When the management decides for a new type of qualification to be added to the scheme, the same committee certifies the first L III following the same pattern. This L III then has also the duty to develop the QFP.

### 3.5 Description of the Duties Related to the Qualification

This description is necessary in order to determine the knowledge required for a proper performance of those duties, and in order to list the tasks for which the individual will be qualified. The descriptions are given in the QFP.

### 3.6 Determination of the Required Knowledge

The knowledge to be acquired is split into theoretical knowledge (general and specific) and into practical knowledge. General knowledge is school or college knowledge, whereas specific knowledge relates to all specific topics of the inspection activities. This makes it possible for a well educated candidate to start ahead of a lesser educated one. The required knowledge is split into four levels of information in order to give the candidates the most appropriate information as regard to the level aimed. The required knowledge, the level of information and the training time are defined in the QFP.

### 3.7 Selection and Schooling of the Teachers

It is recommended that the teachers i.e. the individuals responsible for the theoretical training, as well as the training manager, are pedagogically prepared by a specialist. This can be important for the efficiency of the training program. Furthermore, in order to improve this efficiency unceasingly, the training lectures given and the exercises conducted by the teachers are watched by the training manager not only from the technical point of view but also from the pedagogical point of view. Finally the answers to technical questionnaires also indicate to what extent the teaching methods and the teachers are efficient.

### **3.8 Training in the Training Room and on-the-Job**

1. The training in the training room covers essentially theoretical and associated matters, and is supported by all necessary didactic material such as instruction books, bibliographic material, audio-visual material (photos, dias, optic and/or visual tapes), samples of materials and documents, etc. All of this is structured and presented so that the training can be performed to a large extent, either in the group under the guidance of a teacher or by individual study even at home. Practical demonstrations however are held in the training room.

Where useful, evaluation questionnaires can be used in order to direct correctly the training effort. For starting candidates, one shall determine the training level to start with; for candidates already under training, one shall evaluate the acquired knowledge and the progress made. In some cases, the evaluation questionnaires are replaced by evaluation exercises.

2. On-the-job training is of course practice and experience orientated. The candidate is linked to an instructor for a certain period of time, during which he will be taught about all practical aspects of the job and about the general behavior of an Inspector, he will participate actively in inspection and verification work, he will be made familiar with equipment and materials, he will gather experience on the general human level. A check-list enumerating the activities to be performed helps the instructor in his task. When the company decides to introduce new techniques, on-the-job training with sister companies having the know-how may be necessary.

### **3.9 Qualification Tests - Certification**

Qualification testing aims to evaluate the abilities, the knowledge and the experience of the individual and comprises a physical examination, tests in the examination room, and tests on-the-job.

1. Each individual must be found physically capable of performing the assigned task, and shall have sufficient visual acuity and color vision.
2. Tests in the examination room are carried out under the supervision of a L III. There are open book tests, closed book tests, practical and language tests. The open book tests aim to determine the ability of the candidate to use a code or a standard (usual code for L II, less usual for L III), and other reference documents. The closed book tests aim to evaluate the theoretical general and specific knowledge of the candidate. The practical tests aim to evaluate the practical experience of the candidate on topics which are frequently encountered on the daily job.

The open and closed book tests are written tests using multiple-choice questions and/or questions requiring calculations, explanations, sketches;

the duration is defined in the QFP but never exceeds 4 hours. The practical tests may comprise the examination of samples or documents, the demonstration of techniques or of the use of equipment, the performance of calculations, the writing of documents, the verification of documents, etc.; kind and duration are defined in the QFP.

3. Testing on-the-job aims to evaluate the candidate on the spot, regarding both his human abilities and his technical experience. The evaluation is carried out during normal assignments by L III examiner, and is facilitated by the use of check-lists.
4. The overall result of the tests is determined by the formula

$$R_t = R_o W_o + R_f W_f + R_p W_p + R_l W_l + R_x W_x$$

where  $R_t$  = total result

$R_o$  = result of open book test

$R_f$  = result of closed book test

$R_p$  = result of practical test

$R_l$  = result of languages test

$R_x$  = result of on-the-job test

and where  $W_o$ ,  $W_f$ ,  $W_p$ ,  $W_l$  and  $W_x$  are percentile weights, whose value is defined in the QFP. Results are satisfactory if the total result exceeds 80%, and if each partial result exceeds 70%. When the results are not satisfactory, the answers are reexamined by another L III. If the failure is confirmed, the candidate is not allowed to pass another examination before the period indicated in the following table in months:

- open or closed book tests	L I : 1 L II : 2 L III : 3
- practical tests & on-the-job	L I : 1 L II : 3 L III : 6
- total result	L I : 1 L II : 3 L III : 6

5. After successful test, a certificate valid for a three-year period is issued.

### 3.10 Maintenance of Qualification

The maintenance of the qualification is assured by periodic revalidation of the certificate, and by periodic training meetings set up by the training manager.

1. Each individual has to be reevaluated and recertified every three years, except when he has carried out without interruption work of the aimed qualification type and level. Reevaluations within the three-year period are carried out when a doubt arises about the quality of work of an individual. When the results of an evaluation are not satisfactory the individual is suspended from the level concerned for the time shown in paragraph 3.9.
2. The prime purpose of the training meetings is exchange of information between people who actually practise the activity, together with a short theoretical refresher-course. Those meetings generally cover the following: recall of the

guidelines of techniques, illustration by audio-visual means, demonstrations on samples, round-table discussions on real and actual cases, interpretation of code texts.

#### **4. CONCLUSION**

The recruitment, training and qualification schemes presented in this paper are exemplary. Their description can be of some assistance to managers of engineering inspection organizations or departments, especially in production companies where inspection activities are marginal. They should in any case dispose of an adequate scheme and procedures for the control of the inspection services which are an important quality-related activity, especially in the nuclear field, where quality means safety and reliability.

# **PUBLIC EDUCATION AND ACCEPTANCE OF NUCLEAR POWER**

## **PARALLEL SESSION**

**Co-Chairmen:** E. Evans (*Hanford Engineering & Development Lab/USA*)  
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## **PUBLIC EDUCATION AND ACCEPTANCE OF NUCLEAR POWER**

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### **SUMMARY**

The nuclear profession has the responsibility not only to educate but also to re-educate the public about nuclear power. There is a continuing need to respond to the emotional rhetoric of the critics and their improbable scenarios which overstate nuclear accidents. In two decades, nuclear power has reached maturity with a remarkable safety record and has been in successful competition with fossil fuels. Nevertheless, there is a compelling need for a vigorous campaign to assert the unique benefits and advantages of nuclear power. Over thirty years ago, Albert Einstein gave the following prophetic advice: "to the village square, we must carry the facts of atomic energy."

The success of nuclear power proponents in seven states in the U.S. in defeating nuclear shutdown initiatives is very encouraging. Those who took part in this campaign were impressed by the positive response made by the majority of the public when they were informed of the facts by competent speakers from industry, universities, and national laboratories. The most useful source of information for teaching the public about nuclear power has been a pamphlet which provides the answers to often asked questions about nuclear power (Ref.1). The major issues to be addressed when discussing nuclear power in a public forum are summarized below.

### **1. STATUS OF NUCLEAR POWER**

The general public has little knowledge of the status of nuclear power. Most people do not realize that there are now 170 nuclear power reactors in operation in 19 countries and approximately 550 more are planned or under construction in 42 countries. The highest per capita use of nuclear energy is in Switzerland, which produces 18% of its electricity using nuclear power. The oil-rich country of Iran has moved to first place among developing countries and is fourth among nations in total nuclear commitments (27,000 megawatts by 1994).

Even some engineers are ignorant of the status of nuclear power. A professor of mechanical engineering from a developing country was highly indignant at a proposed plan to build nuclear power reactors in his country because, as he stated at an international conference on energy, his country would be used as a "guinea pig" for testing power react-

or operation. He exhibited monumental ignorance of the fact that there are already over 1000 reactor years of operational experience in the developed countries.

## 2. ECONOMICS

There is also a need to publicize the true relative costs of electricity generated by nuclear and fossil-fueled plants for every country with a nuclear power program. For example, in 1975, electricity costs in the U.S. were 12.27 mills/kWh nuclear, 33.45 mills/kWh oil, and 17.54 mills/kWh coal. Boyer (Ref.2) has pointed out that if two 1000-MW(e) plants were to be equally utilized over the course of one year, the nuclear units would cost about \$150 million less than the coal-fired units and about \$175 million less than the oil-fired units because the higher capital costs of the nuclear units are more than offset by the much lower nuclear fuel costs. In addition, the cost of uranium ore would have to rise to about \$540/kg before the total costs of nuclear units would equal the total costs of coal-fired units with scrubbers.

## 3. PERFORMANCE

Wide publicity has been given to nuclear reactor incidents and forced shutdowns, and the public has thus been led to believe that nuclear plants have a poor performance record. The fact is that the reliability of the majority of nuclear plants is about the same as the reliability of fossil plants, and this fact must be more widely publicized. Nuclear power experience in the U.S. during 1975 was as follows:

	Type of Plant (%)			Average Oil/Coal (%)
	Nuclear	Oil	Coal	
Forced outage rate	13.7	26.9	11.1	15.2
Availability factor	73.8	70.3	79.5	76.4
Capacity factor	64.4	42.5	54.8	49.7

## 4. AVAILABILITY OF FUEL

The concern over the limited supply of uranium for light water reactors can be countered by stressing the tremendous potential of breeders and the symbiosis of breeders and high converters to extend the duration of nuclear fuel resources to many thousands of years. This strongly suggests that advanced reactor systems should be developed as vigorously as possible. As Roddis (Ref.3) pointed out in 1969, "We would have a breeder reactor today had the concept been given the same type of persistent and demanding attention that Admiral Rickover gave water reactors." An astonishing and reassuring fact is that once

fast breeder reactors are on line, no uranium will need to be mined in the U.S. for 200 years because the depleted uranium in storage will suffice for fast breeder reactors for approximately 200 years.

## 5. SAFETY, SAFEGUARDS, AND WASTE DISPOSAL

The public does not appreciate the immensity of the effort which has been expended on reactor safety, safeguards, and waste disposal. There has been no comparable effort regarding the greater hazards of fossil fuels. For example, very few people know that the U.S. Nuclear Regulatory Commission has a staff of over 2500 and the budget of over \$250 million per year or that there are stringent legal requirements and safety standards for federal regulation of nuclear power plants in all countries. One of the most effective and cogent statements quoted in the California nuclear initiative campaign was a comment made by Stathakis (Ref.4) at a congressional hearing on reactor safety, namely "... anyone familiar with reactor safety analyses knows that safety begins with the assumption of imperfection, as Professor Rasmussen has explained. We assume that equipment failures, operator mistakes, design errors, and instrument failures will occur. To design for safety means to design so that ordinary and even extraordinary imperfections do not lead to hazards and can be detected and repaired in good time. That is what redundancy is all about, that is what design margins are all about, and that is what preventive maintenance is about."

There have been excessive objections to leaving the long-lived radioactive waste materials to our descendants. However, if our descendants have the intelligence to survive on this planet, they will certainly be smart enough to guard the very small volume of isolated solidified waste they will inherit. After all, humanity has inherited thousands of poisonous chemicals and plants and natural hazards over the past millions of years and has managed to survive even in the most primitive stages of evolution.

The critics of nuclear power are particularly adamant in grossly exaggerating the danger of plutonium, predicting millions of cases of cancer from minute releases of plutonium to the environment. Boffey (Ref.5) has made the cynical comment that "... it may take the churches to tell us whether plutonium is a gift from God or a temptation from the Devil." They ignore the fact that there have been no known deaths attributable to plutonium, even though several hundred people have been accidentally exposed to fairly large doses of plutonium (up to ten times the permissible level) since 1945 in military projects. In addition, atomic bomb tests have distributed worldwide an estimated 5900 kg. of plutonium, which is far greater than any conceivable amount of contamination from nuclear wastes.

The problem of nuclear weapon proliferation is surely the most complex and difficult public relations challenge faced by the nuclear community. The public needs to be convinced that effective controls against proliferation can be established. Dr. Henry Kissinger's comments on proliferation also deserve wider recognition (Ref.6) "... (nuclear power) is not a problem to be addressed solely through the technical and legal framework of safeguards

and export controls, vital as these avenues may be. There is a direct link between our efforts in nonproliferation and our broader efforts to construct a more secure international climate. If countries remain convinced that regional and global tensions can be reduced through cooperation, that disputes can be resolved in a peaceful manner, and that their legitimate security requirements can be met, there will be no need for them to develop nuclear weapons."

## 6. CONCLUSIONS

The primary goal of public education about nuclear power is to inform citizens of all countries about the technical, economic, social, and environmental factors associated with energy resources and the benefits and improved quality of life which would accrue from nuclear power. The public's valid concerns can be resolved by stressing the positive achievements of nuclear power and pointing to the greater risks and tensions for the world which will result from banning nuclear energy just when fossil fuels resources are being rapidly depleted. The public will accept nuclear power only when they are convinced that it can satisfy the continuous need for increased energy production and provide the world with the energy capacity to help solve many pressing human problems in the shortest time, at the lowest cost, and with a minimum impact upon the environment.

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## **PUBLIC ACCEPTANCE OF NUCLEAR TECHNOLOGY IN THE DEVELOPING COUNTRIES**

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### **ABSTRACT**

The technological development of developing countries is severely affected by the shortage of electric energy. The combined indigenous coal, oil and gas resources in most of the developing countries are quite inadequate in the light of energy demand. For energy they must rely on high priced imported oil. Moreover, fossil fuel reserves are not unlimited. These fuels are to be conserved for producing petrochemicals. Therefore it appears obvious that nuclear power will have a vital importance in covering an increasing proportion of electric energy demand in the developing countries.

People of the developing countries are prepared to accept risk, if there is any, from the operation of nuclear facilities if they realize that the benefits are great. It is our duty as scientists and engineers in the nuclear fields to inform the public about the benefits and risks of nuclear power programs with special emphasis on public health and safety.

Therefore, the need for nuclear power in the developing countries together with its benefits is discussed. Special emphasis has been placed on how to achieve benefits keeping risks as minimal as possible. The role of an atomic energy commission in the developing countries and the International Atomic Energy Agency in controlling the risks and in the public information campaign is also discussed.

Public acceptance of nuclear power depends upon a combination of educational and remedial actions. These parallel and concurrent activities are discussed.

The establishment of regional nuclear centers and national nuclear laboratories to help developing countries to be equipped with nuclear power plants is suggested.

In developing countries there is a shortage of skilled manpower to tackle the complex problems of nuclear facilities. Therefore, some suggestions on the development of skilled personnel have also been given.

### **1. INTRODUCTION**

The nature of a society is determined by the characteristics of its technology, and social development is determined by the technological changes a society invents or develops. The need for technological advance, especially the advance of nuclear technology, becomes all the more important and critical in developing countries in order to improve the

standard of living and to stop drainage of natural resources. In advanced countries there has been a rapid development of nuclear installations such as power reactors, processing and reprocessing plants, fuel fabrication and waste treatment plants etc., together with a proportionately balanced development of the applications of radiation sources in a wide variety of fields such as medicine, industry, agriculture and research. In developing countries, however, the only progress in the field of atomic energy has been in the application of radiation sources in medicine - although agriculture, industrial and research applications are slowly increasing. In addition, some developing countries have nuclear reactors for research and isotopes production and for power generation. Others are recognizing the need for nuclear reactors for power generation and desalination plants for water resources to improve their food producing capabilities.

The people of the developing countries are very much aware of the shortages they have such as food, money, medicine, water, housing, energy, trained manpower and many other things and are aspiring to and striving for the development of suitable technology to overcome their difficulties. They know that energy plays an important role in their economy as a whole.

The people of the developing countries take many risks in their day to day affairs and are prepared to accept risk, if there is any, from the installation and operation of nuclear facilities in order to achieve a rapid increase in resources, to raise the standard of living, standard of hygiene, education and to solve problems of housing, unemployment and malnutrition.

Though, at present, there is no opposition to nuclear power programs in developing countries, it is most probable that in the next decade a convocation of antinuclear forces will grow in these countries if the public is not properly and correctly informed about the uses and abuses of nuclear technology.

Therefore, in this paper the need for nuclear power in the developing countries and its benefits and risks are discussed. Special emphasis has been given to the problems of public acceptance of nuclear energy in the developing countries and the formulation of an appropriate factual structure for communicating to the public. The role of an atomic energy commission in the public information campaign is also discussed.

## 2. THE NEED FOR NUCLEAR POWER IN THE DEVELOPING COUNTRIES

The whole history of mankind since the start of civilization has been influenced by the continual search for greater power. The use of fire, to prepare our food, to keep us warm, to run our industries, the introduction of the steam and petrol engines for powering the railways and pumping water; the introduction of the motor car and the aeroplane - all these steps gave more power to man's elbow. This power helps man to raise his standard of living and to support several times the population that could be supported before the industrial revolution.

For the last half a century man has withdrawn the raw materials of energy from the



earth at a rate and in total quantity greater than the combined withdrawal for the entire previous period of his recorded history. Now, within the past decades or so, he has awakened to the facts that his resources are not unlimited and that secondary effects of energy utilization could, if unchecked, offset the benefits he is gaining. The use of oil and gas is rising so rapidly that it is clear that discoveries cannot go on forever matching the increasing rate of usage and surely some day the limited supply of oil, gas and coal in the earth's crust will be exhausted.

Many estimates of the depletion of the energy resources have been made by many investigators.<sup>(1,2,3)</sup> They have estimated that all our oil, gas and coal supplies will fall short early in the next century.

The hydroelectric potential in both advanced and developing countries is limited.

So far as solar energy is concerned, it is so diffuse a form that it is unlikely to become a source of central station power before late in this century or early in the next. The same limiting delays can be expected in the cases of other sources of energy such as geothermal, wind power, tidal and wave power and the like. Massive contributions from these sources of power cannot be achieved overnight.

Therefore the only alternative for meeting world energy needs late in this century and early in the next century is nuclear power. If we look at the developing countries we find that the combined indigenous coal, oil and gas resources in most of the developing countries are quite inadequate in the light of energy demand. In view of this inadequacy of coal oil and natural gas resources, the very high price of imported oil and also considering the value of gas and oil for the production of chemicals and fertilizers etc., the most economic sources of future electricity production in the developing countries would be nuclear and hydropower.

As the hydroelectric potential in most of the developing countries is limited, it has become obvious that nuclear power will have vital importance for covering an increasing proportion of electric energy demand of these countries.

### 3. BENEFITS OF NUCLEAR POWER

The benefits of nuclear power are great with respect to low-cost, preservation of environment and conservation of resources. It will provide a virtually inexhaustible resource of energy for many applications in succeeding generations. The people of many developing countries, where there is a great shortage of water, will be able to desalt large quantities of sea water at a reasonable cost for domestic, industrial and agricultural use.

In developing a balanced approach to meeting power needs, the following benefits of nuclear power must be taken into account.

- (a) The amount of energy in nuclear fuel resources is many hundreds of times that of the most optimistic estimates of fossil fuel reserves. By using advanced reactors - the breeder - we can use essentially all of the uranium and thorium in nature and thus supply as much energy as we can use for centuries to come.

- (b) Nuclear power provides competition to other energy sources by keeping power costs and rates down.
- (c) The unit cost of nuclear power plants decreases more rapidly with increased size compared with the unit cost of other plants.
- (d) Nuclear power costs do not vary appreciably with location - a fact of considerable consequence for regions which are distant from fuel sources.
- (e) Nuclear energy has considerable potential for improving operating economies.
- (f) The use of nuclear power will decrease the burden on nations' transportation systems.
- (g) Nuclear power plants produce neither the soots, smoke and noxious chemicals nor suffer from fuel transportation and storage problem that fossil fuel plants do.
- (h) Nuclear power has substantially less effect on the overall environment than fossil fuel plants, especially in regard to smoke pollution.
- (i) With the development of nuclear power the public can have both additional low cost power and a healthy and desirable environment. They will benefit from such an achievement.
- (j) The radioactive effluents from nuclear power plants are so minimal as to constitute an almost unmeasurable fraction of the level of activity permitted by established radiation standards.
- (k) Nuclear plants have an aesthetically attractive appearance and in many instances provide opportunities for recreational activities in areas surrounding them.
- (l) The use of nuclear power will help to conserve fossil fuels for purposes for which they are uniquely suited - such as raw materials for producing chemicals, rubber, plastics etc.
- (m) The energy of the atom can also be devoted to other purposes such as desalting sea water. The conjunction of two new technologies - nuclear power and desalting - adds a vast new dimension to man's search for energy and water especially in countries where water resources are limited. Large dual-purpose nuclear plants will enable the developing countries to take advantage of both the above as a resource for energy and the ocean as a resource for obtaining fresh water.
- (n) If industrial and agro-industrial complexes are built surrounding the nuclear power plants then these complexes can utilize cheap energy from the nuclear power plant. Such a grouping might include interrelated industrial processes for the production of fertilizers and other chemicals and large-scale desalting of sea water for highly intensified irrigated agriculture. The great need for the developing countries is to utilize their natural resources by developing suitable industries and to increase their food production by expanding agro-industry. In these respects the cheap energy from nuclear power plants can help the developing countries to a great extent. The availability of cheap energy would also make possible the exploitation of low-grade ores found in many developing countries.
- (o) Nuclear reactors can also help the developing countries to produce radioactive

materials for medical, industrial, agricultural and research applications and stop importation of such materials.

- (p) Experience in nuclear fission power will enable us to enter into fusion power development which may be the Utopian answer to unlimited power.

### 3.1 How to Achieve These Benefits

To achieve these benefits, of course, will involve accepting certain risks. Scientists and engineers, who are responsible for developing nuclear industries, are very much aware of these risks and have made deliberate attempts to understand and control them. This approach has taken a great deal of planning, research and development, training and careful operations. This point was emphasized in a pioneering report by the National Research Council, National Academy of Science<sup>(4)</sup> (1956) which stated, "The use of atomic energy is perhaps one of the few major technological developments of the past 50 years in which careful consideration of the relationship of a new technology to the needs and welfare of human beings has kept pace with the development". Almost from the beginning of the development of nuclear technology attention has been given to the biological and health aspects of the subject.

As a result of this approach nuclear industry has been considered as one of the safest of industries from the standpoint of radiation hazards as well as of ordinary industrial risks.

The chances of damage to any individual in a society from any of the effluents of a nuclear plant are so low that there would be fewer people hurt by them than there would be if the same amount of electricity was being produced by a coal plant releasing pollutants into the air.

Society has forced upon us many, many risks. Even crossing the street is a risk. Our experience to date in nuclear technology provides us with a measure of satisfaction and confidence that the risks are being minimized. If the nuclear industry is developed in a manner consistent with public health and safety, much emphasis being given to safety, then why should the public not accept it?

Nowadays the subject of public acceptance of nuclear technology is one of very great interest. The environmental question is now in the eye of the public. In addition to the basic scientific questions there is also the question of public acceptance. The dropping of atom bombs on Nagasaki and Hiroshima frightened people all over the world. They always think about the ill effects of nuclear energy and oppose the development of nuclear industries. It is our duty as scientists and engineers in nuclear fields to inform the public about the benefits and risks of nuclear power plants with special emphasis on the public health and safety.

Therefore, in the remaining pages we shall discuss in brief what the main concerns are and how to enlighten the public so that they will have confidence in nuclear power resulting in acceptance and promotion.

#### **4. MAIN CONCERNS OF THE PUBLIC**

The main concerns of the public in the expanded use of nuclear energy are summarized below:

- (a) The greatest concern in the expanded use of nuclear energy is that it may contribute to the spread of nuclear weapons.
- (b) The threat of nuclear attack.
- (c) The development of nuclear weapons by any additional country could provoke another country to do the same and lead to further proliferation of nuclear weapons.
- (d) Attempts of terrorists to steal nuclear materials to make crude nuclear weapons or to contaminate the environment as an act of blackmail.
- (e) Careless use of nuclear materials leading to contamination of the environment or unjustified hazards to employees or to the population.
- (f) Contamination of atmosphere by radioactive effluents.
- (g) Effects of heated water from nuclear plants.
- (h) Problems of safe operation of nuclear plants and safe storage of radioactive wastes.

#### **5. CONTROLLING THE RISKS**

##### **5.1 Spread of Nuclear Weapons**

By far the greatest risk in the expanded use of nuclear energy is that it may contribute to the spread of nuclear weapons. The problem of expansion of nuclear weapons is political in nature. If a country is determined to demonstrate its ability to build its own nuclear weapons, probably no international framework can prevent it from doing so. Many countries have the scientific, engineering and technological skills to develop nuclear weapons or peaceful nuclear power programs. The solution to this problem is political and international. It will not go away by banning the construction of nuclear power stations. To deter decisions to make nuclear weapons remains a matter of "high politics". First, concerned parties must dampen regional rivalries and secondly, super powers and other nations which have nuclear weapons must promote nuclear armament reduction and discourage proliferation to other nations.

We are happy to say that great progress has been made through the International Atomic Energy Agency (IAEA) Non-Proliferation Treaty which has been signed and ratified by an encouraging number of countries.

To check nuclear weapons proliferation it is vital to have a strong multinational framework for the control of nuclear facilities and materials. Only through such a framework can both safety and safeguards be steadily improved and the world hope to achieve a bearable balance between expansion and risk. All the nations in the world should do everything they can to support such a multinational framework.

We are glad to mention that such a framework already exists in the IAEA and it is any nation's duty to help IAEA to expand and solidify its functions and operations.

## **5.2 Safety and Safeguards Against Diversion of Nuclear Material by Nations or by Individuals or Groups**

To discuss the problems of safety and safeguards of nuclear material against diversion, it is required to give a short technical preface about the stages of the nuclear fuel cycle.

### **5.2.1 Enrichment Plant**

Most nuclear reactors today use uranium enriched to a maximum of roughly 3.5 percent. This is well below the percentage required for weapons-grade material. Of course the enrichment process used is the same for both. The only difference is that for weapons-grade material the raw material is to be cycled additional times through enrichment processes to raise its enrichment level. Thus the enrichment facilities could be a major point of diversion.

### **5.2.2 Fuel Fabrication**

After the enrichment process for reactor fuel there is a stage of fuel fabrication where uranium is formed into pellets and enclosed in tubing to form fuel assemblies. The material at this stage is not enriched enough to build an atom bomb.

### **5.2.3 Reactor**

During the reactor operations, the fission process produces highly radioactive by-products in the fuel that would be extremely hazardous to would-be terrorists or hijackers. The reactor spent fuel contains a mixture of remaining U-235, a considerable amount of U-238, a variety of plutonium isotopes and of other by-products - some of which are intensely radioactive. This spent fuel is shipped in heavily shielded casks to storage pools or reprocessing plants. The sheer bulk and weight of these casks and their own self-protecting radioactivity inside the massive shield makes them immune to hijacking.

### **5.2.4 Reprocessing Plant**

The fuel reprocessing plant is the most critical stage for diversion of bomb material. The spent fuel contains original U-235 at reduced amounts and significant amounts of plutonium, and it is not difficult to separate plutonium from spent fuel. But the entire process must be carried out by remote control within expensive and highly shielded hot cells. We know that in the West very little reprocessing of commercial fuel has been carried out to date. But in

the future, reprocessing of spent fuel may be needed to meet the world future-energy needs.

#### 5.2.5 Problems of Transportation and Physical Security of the Containers

The spent fuel material, being moved from the reactor to the reprocessing facilities or to the storage pools, may be dangerous, but it is not weapons-grade in the form in which it is transported. In the event that reprocessed fuel, including plutonium, is used in reactors in the future, however, its transportation would include weapons-grade material.

From the above discussion of the nuclear fuel cycle it is found that safeguards can concentrate on strategic points. They do not have to cover every move, since the diversion of nuclear materials is only practically possible at a few key stages. Hence under the present distribution of enrichment facilities, fuel fabrication plants and commercial reactors, even a small IAEA inspection team can in practice do an effective job. It can do this by auditing records, by studying the plans of the nuclear facilities and by periodically examining the sites themselves. When large quantities of plutonium or highly enriched uranium are being processed, the inspector may actually remain in residence round the clock at the facility. Therefore, it is a nation's duty to strengthen systematically the stature, capabilities and responsibilities of the IAEA. It is also necessary to enhance the prestige of IAEA so that people from both sides of the world (advanced and developing countries) have good faith in this organization.

#### 5.3 Establishment of Regional Nuclear Centers Around the World

The establishment of a series of regional nuclear centers around the world, as suggested by Doub and DuKert in 1975,<sup>(5)</sup> is essential in order to help the developing nations to be equipped with nuclear power plants and to expand national enterprises. Such centers might contain reprocessing facilities, enrichment facilities, fuel fabrication plants and waste handling facilities in addition to some nuclear power units to generate electricity. These centers must be multinationally financed and would provide services to a number of countries who are financing them. These regional nuclear centers should be safeguarded by the IAEA who inspects their design, site selection and is involved in their direct operation.

The reprocessing and enrichment will be more economical if the facilities are tied to a large number of power stations.

The existence and availability of service facilities in various regions would help to remove any lingering temptation to expand national enterprises. At the same time, existence of these regional centers would help to stop diversion of nuclear material and greatly contribute to enhance public support for peaceful use of atomic energy.

#### 5.4 Thermal Effects

Nuclear stations currently produce more heat than fossil fuelled stations of the same capacity. This, of course, must not give an erroneous impression because both types of



plant (nuclear and fossil) must reject sizable portions of the heat to the environment. The thermal effects are not necessarily bad in all situations. The effects may be detrimental, beneficial or insignificant depending on many factors such as the way the heated water is returned to the source water, the amount of source water available and the ecology of the source water. The heat rejected by the power plant may be disposed of to the environment by constructing cooling towers and artificial lakes where large lakes and rivers are not available for cooling. The combinations of cooling methods, such as construction of cooling towers and the use of large lakes and rivers, can also be used effectively in many situations. In countries with cold climates, waste heat may be put to useful purposes. Research programs, aiming to study the biological effects and the utilization of waste heat, are to be planned.

### 5.5 Environmental Effects

Another risk of nuclear power plants is that relating to environmental effects. To meet our growing energy needs there is no way that the environmental effects can be totally eliminated. The real challenge is to ensure that they are well enough understood and kept as small as possible consistent with meeting our energy and other needs. Our experience has shown that the radiation doses from the environmental contamination caused by nuclear power plants can be kept well within the limits imposed by current radiation protection standards. Continued efforts are being made to reduce still further the dose to the population.

Nowadays even the critics of nuclear power in the advanced countries admit that the conditions today are not too unsatisfactory. But their main concern is about the situation that might apply towards the end of the century when nuclear programs will increase 10 to 20 fold. They predict that at the end of this century there will be larger movements of plutonium and an increase in the amount of radioactivity being processed and the situation may get out of control.

We quite agree that the situation in 25 years' time will not be the same as the situation today, but we are happy to say that nuclear industry is an industry of laboratories, clean chemical plants and the highest quality of engineering. It is a skilled industry where experts of high proficiency work together; and the regulatory control is there. Therefore, we are optimistic that in this period of time much improvement can be made in line with the requirements placed upon them and that the situation will not be worse at the end of this century.

### 5.6 Reactor Safety

To assure that nuclear power plants are built and operated safely the following points must be considered:

- (a) Achievement of superior quality in design, construction and operation of basic



reactor systems so as to ensure a very low probability of malfunctions.

- (b) Integration into the plant of accident prevention safety features such as emergency reactor shutdown systems. They are needed to prevent any unlikely malfunctions of the reactor systems from escalating into more serious problems.
- (c) Construction of containment shells to confine or minimize the escape of fission products if they are released from the fuel and the reactor systems.

It is encouraging that almost all the manufacturers of nuclear power plants have given stress to the above points to make it the safest industry in the world.

It would be the responsibility of the Atomic Energy Commissions (AEC) of the developing countries to conduct extensive safety research and development programs and foster and encourage industry efforts along these lines. They should emphasize the need for management know-how, foster the development of industry standards and encourage the development of trained personnel. They should have an on-going inspection program which requires that the plants be operated strictly according to approved written procedures and technical specifications. These types of action need thorough planning and advanced preparation and contribute significantly to the safe introduction of nuclear power programs.

#### **5.7 Waste Management and Disposal**

Public concern over nuclear safety focuses also on the storage of radioactive wastes or effluents which are generated. These wastes fall into two main categories – high and low-level. High level wastes are produced during the reprocessing of the spent fuel elements of nuclear reactors and are not processed or disposed of at the reactor site. The spent fuel is removed from the reactor, securely packaged and shipped to a reprocessing plant or a storage pool. Nowadays, wastes are stored primarily in solidified or liquid form at ground level in heavily shielded containers. This technique is adequate to contain the wastes for hundreds of years.

Such storage is not adequate when we consider the tremendously long-term character of the problem, since some of the materials will remain radioactive or toxic or both, for periods running into thousands of years. The solution to this problem is to solidify and transform these wastes into physically and chemically inert form and dispose of them in tunnels, deep in the earth, possibly in salt formations deep underground.

The second category refers to the low-levels of radioactivity which occur in air, water and solids outside the fuel elements during routine operation of nuclear reactor. They can be controlled by regulations and procedures.

#### **6. PUBLIC INFORMATION CAMPAIGN**

The prime objectives of the public information campaign are:<sup>(6)</sup>

- (a) To provide information on the energy demand, the relationship of economic growth

and energy consumption, of research and development for the efficient and economical utilization of energy as well as for the new energy sources.

- (b) To increase the confidence of the public in the functioning of democratic processes in the nuclear energy controversy and to restore confidence where necessary.
- (c) To increase knowledge of the organization and the physical and technical aspects of nuclear power plants, of the nuclear fuel cycle and the reactor safety with special consideration for environmental influences.

Realizing the future guarantee of energy supply from nuclear energy, we should attempt to bring about a broad consensus on the need for this new source of energy, its safety and any resulting risks which can be reasonably expected to be accepted. Therefore, a massive publicity campaign should be launched to ensure that the public gains the fullest understanding of the underlying facts in this matter of vital national concern. The campaign should be divided into two areas:

- (a) Supply of information to the public
- (b) Dialogue with the public.

The main techniques in the national campaign should be serial advertisements in the newspaper and magazines and radio and television advertisements. Pamphlets of the question and answer type, dealing with some of the most frequently raised issues associated with the peaceful uses of nuclear energy should also be prepared and circulated among the public. With good writing and colorful diagrams and illustrations all the complex issues must be presented in a way that should certainly stimulate well-informed public interest. The established atomic energy facts should also be made available to the public in a simple way through newspapers, journals and magazines and through films and exhibits.

The dialogue with the public is to be sought during meetings and press conferences, during seminars on selected subjects, where experts and the general public can take part.

The meetings, symposia and press conferences should be planned in such a way as to bring together competent scientists and engineers working in the nuclear field, scientists working in the field of radiation effects and recognized authorities in many fields of endeavor. The participants for the meetings, symposia and press conferences should be selected on the basis of their recognized expertise and their diverse points of view on the various aspects of the nuclear energy controversy. They should elucidate objectively the diverse points of view on the nuclear energy and face one another in a neutral forum to present sound and verifiable information and debate the issue. An academic atmosphere is to be created to promote discussions where the proponents<sup>(7)</sup> of diverse views could face each other in a calm, reasoned manner appropriate to men who respect one another. The atmosphere of the meeting should be such that the contributors will get the opportunity to question one another and the audience will also be able to participate in the discussion. In time answers to many questions will be forthcoming.

The mass media disseminate information gathered by whatever means modern technology makes available. They are not, however, in a position to evaluate scientific

information unless they have the fullest cooperation from scientists. The mass media must be permitted to come into the picture in the early stages of evaluation of such problems as the environmental one.

Sometimes vital and completely acceptable statements made by scientists have occasionally been wrongly quoted by the disseminators of public information and correct, soundly-based scientific statements cannot reach the general audience quite often. Therefore, to get the support of the general public a cooperation of scientific and mass communication experts is needed.

The public also has a responsibility to study the facts and then make their own judgements. As we know that the concepts of nuclear energy are complex, the scientific community - in the universities, in the AEC, in the laboratories and industries - can and should play a large and more responsible role in assisting the public to understand the facts and to make their own judgement.

## **7. ROLE OF ATOMIC ENERGY COMMISSION ON PUBLIC INFORMATION CAMPAIGN**

Considering the shortage of qualified manpower and financial problems in the developing countries we are of the opinion that the responsibilities of the development and supply of nuclear energy must lie with the Atomic Energy Commission (AEC). At the same time the attitude of the AEC should not be such that they are the sole authority in nuclear energy and selling this energy to the public. They should not have any pretensions to be able to convert ardent opponents of nuclear energy. Rather they will be interested in stimulating a well-informed democratic debate on the problems among the mass of the population who are only just becoming aware of the fact that there is a controversy.

Therefore, the roles of the AEC in a public information campaign should be:

- (a) To undertake an extensive program of public information from the very onset of a particular project.
- (b) To open public information centers at the nuclear plant sites. These centers should be set up at an early stage of construction of the plant and be superbly equipped with audiovisual display.
- (c) To develop adequate monitoring procedures and assure the public by giving facts and figures that their nuclear installation meets all the present safety requirements.
- (d) To discuss with the public at any time about facts and records of what the AEC people are doing, what discharges the plants are making to the environment and to make comparative studies on the effects of nuclear power with that of any other solution to the world's needs of energy.
- (e) To try to deal with specific issues as they arise and disseminate them to the public through a monthly publication and a number of special meetings and press conferences.
- (f) To find qualified speakers for public meetings and press conferences.
- (g) To make available to the public established atomic energy facts in a simple way

through newspapers, journals and magazines.

- (h) To produce instructional materials, training models, slide series, charts and other audiovisual systems and make them available for use in schools and universities.
- (i) To write well illustrated books on nuclear energy for the audience of young people or interested adults.
- (j) To publish radiation protection standards and the established radiation protection guides.

## **8. DEVELOPMENT OF SKILLED MANPOWER IN THE DEVELOPING COUNTRIES**

As far as the construction and safe operation of major nuclear installations are concerned, the problems of nuclear and radiation safety have proved to be broadly the same for both advanced and developing countries. In each advanced country there is a hard core of well-trained specialists who have been able to tackle quite successfully the complex problems on hand. But in the developing countries there is a shortage of such skilled personnel. Therefore, an evident minimum need in the developing countries includes a good technological base and strong interaction of the scientists and engineering staff with industry, government agencies and university sectors. These countries should develop personnel familiar with overall nuclear phenomena based on experiences and established practices with a small research reactor if they have aspirations for developing a nuclear power plant.

A national nuclear laboratory is also essential to a developing country. Without establishing a national nuclear structure a country will find it difficult to appreciate and solve problems that will arise in all fields of engineering and quality control, materials, chemistry, radiation damage, environmental control and technical management. This laboratory should be a nucleus around which the academic, public and private sectors can develop. It is well-known that such national nuclear laboratories are a stimulus to science in general in developing countries.

## **9. CONCLUSION**

The technological development in the developing countries is severely affected as a consequence of the shortage of electric energy. The fossil fuel reserves in most of the developing countries are quite inadequate in the light of energy demand. They rely on high priced imported oil. Moreover, the fossil fuel reserves are not unlimited. They should be conserved for producing petrochemicals. Therefore, it has become obvious that nuclear power will have vital importance in covering an increasing proportion of electric energy demands in the developing countries.

The benefits of nuclear power are great. It has two great potentials: (a) providing a clean, cheap and virtually inexhaustible resource for energy for many centuries to come and (b) providing large quantities of pure water from the sea at a reasonable cost for

domestic, industrial and agricultural purposes. To achieve these benefits will involve some risks. These risks are properly understood and are being minimized. Technical ingenuity and controlled care in operation will continue to enhance the safety of all aspects of the nuclear program.

People of the developing countries take many risks in their day to day affairs and are prepared to accept risk, if there is any, from the operation of nuclear facilities if they realize that the benefits are great. Though at present there is not much opposition to nuclear power programs, it is most probable that in the future a convocation of antinuclear forces will grow in these countries as well if the public is not properly and correctly informed about the benefits and risks of nuclear facilities. It should be as much our mission to make nuclear power a truly acceptable public option as it is to satisfy ourselves that nuclear power will be built and operate safely and economically and with minimal adverse impact on the environment. If the nuclear industry is developed in a manner consistent with public health and safety, then why should the public not accept it?

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## **PUBLIC ACCEPTANCE DIMENSIONS OF NUCLEAR TECHNOLOGY TRANSFER IN THE PHILIPPINES**

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### **ABSTRACT**

This paper discusses the matter of public acceptance within the context of Philippine culture. It is described against the setting of a developing country just starting to embark on a nuclear power program. The paper starts with the nature of nuclear energy and its credibility in a societal mix of two different worlds - the urban and the rural, one with the trappings of the sophisticated West and the other, simple and relatively unspoiled - polarities characteristic of Philippine society.

The dynamics of public acceptance for nuclear technology transfer under Philippine conditions is presented, making liberal use of the strategies of public relations and the feedback process. Public reaction to nuclear-oriented projects has not always been salutary. The promotional efforts have had to be orchestrated to attune hostility, indifference and acceptance into a harmonious whole. While complete acceptance is not likely, the countervailing forces must be reduced so as not to militate against the creditable support of the advocates. However, caution has had to be exercised in the promotional drive. A low-key profile has been found more in keeping with the demands and character of nuclear energy than a media overkill. The ventilation of issues and the medium used are explained in this paper from the perspective of the country's socio-economic milieu.

Public opinion has been recognized as a key to acceptance and effort is exerted to mold a responsive and favorable attitude. Bridging the gap between the technological institutions and the end user, as well as the people in general, has called for public education. This has established the preparatory stage to acceptance. Toward this end, the opinion makers and thought leaders have been tapped to support the program. Without their active participation, it has been found very difficult to gain adherents to the cause of atomic energy.

The Philippine public acceptance strategy has thus addressed itself to policy makers, planners, educators as well as the mass media and end users - the potential project beneficiaries - in an attempt to overcome the constraints common in reactions to nuclear energy.

### **1. INTRODUCTION**

The Philippines, at the eastern end of Asia, is a country with a total land area of 300,000 square kilometers and a population of 42.5 million people. It consists of 7,100 islands



although there are only eleven major islands, the biggest of which is Luzon with an area of about 110,000 square kilometers and a population of around 20 million. 14.6 million persons or about 35 per cent of the population live in the urban areas. Metro Manila, the seat of the nation's capital, has a total population of 7.8 million occupying 68.4 square miles.

The literacy rate of the population is 76.4 per cent with 86.6 for urban and 70.7 for the rural. Literacy in Metro Manila is 96.4 per cent. The Philippines has at least 80 dialects but only four major dialects are spoken by 76% of the people. English is a second language. The Philippine educational system still retains strong traces of the American system.

Philippine society is characterized by a wide economic gap between the rich and the poor. The bulk of Filipino families belong to the low income group with an annual average income of less than ₱3,000. The national income per capita as of 1975 was ₱1,827.50.

There exist two recognizable but disparate societies - the urban and the rural - interdependent yet alienated in ways of life. The urban retains many aspects of the foreign cultures brought into the country by major colonial powers, notably Spain and the United States as well as those influences that came from trade and commerce with countries like China. Such foreign accents may be noted in the life styles and values of the urbanites who sport cosmopolitan tastes and attitudes in glaring contrast to the rural folk among whom the old Filipino traditions of simplicity, frugality and kinship ties predominate. Against the Philippine environment and the stark reality of the social fragmentation of two polarized sectors yet making one nation, we place in perspective a novel technology - the nuclear.

## 2. BEGINNINGS OF ATOMIC ENERGY IN THE PHILIPPINES

Nuclear technology was formally introduced in the Philippines with the signing of the Agreement for Cooperation on the Peaceful Uses of Atomic Energy between the Philippines and the United States government in 1955. This paved the way for the creation of the Philippine Atomic Energy Commission (PAEC) in 1958.

Shortly afterwards, public concern for nuclear activities in the country started to be felt with news of the coming acquisition of a nuclear research reactor. Questions were propounded in the daily newspapers on the wisdom of bringing into the country a facility associated with the horrors of Hiroshima. It was too close to the harrowing war experiences of a badly battered nation to be taken casually.

The PAEC had anticipated such public reaction so that from its inception, it has established a Classification and Information unit intended not only for technical information dissemination through library and documentation service but also to handle its public information program. Most of its public information work at the beginning centered on press releases and feature articles on the peaceful uses of atomic energy and the technical activities of the PAEC.

As early as 1960, the PAEC had recognized the vital role of the press in swaying public opinion. That year it conducted the first Atomic Energy Course for Journalists, a five-day



Intensive lecture-forum type of seminar which was very well attended by media representatives of the major daily newspapers and broadcast stations. This also served as an eye opener and may, in fact, be considered as pioneering in the recognition of a growing need to put up a science beat in the reportorial assignments among news agencies.

The Philippines has always taken pride in the enjoyment of press freedom so that any newsworthy issue gets ventilated in the newspapers, national and local. However, access to newspapers has been limited, mainly because of economics, physical accessibility and degree of literacy. So, until the Philippine government, through its community development efforts, brought the transistor radio to the farms in its information outreach program, such government projects as atomic energy were virtually unheard of outside Manila and its environs. Even then, very little, if any, nuclear matter was mentioned in radio broadcasts except perhaps the news on the initial attainment of criticality of the research reactor in 1963. By this time, with the media seminar conducted earlier by PAEC, such terminology as the reactor becoming critical was already a familiar term to newsmen covering the science beat.

Occasionally, some foreign news would be picked up by the local press on nuclear developments such as actions of health authorities on distribution of irradiated foods and the proliferation of nuclear weapons. Such news items would, however, be taken for granted by the general public as exercises by the developed nations and which, considering the slender resources of the Philippine government, could not be associated with the PAEC which had not become as yet a nationally well-known institution. Its presence had been established mainly among the scientific community and higher institutions of learning offering sciences and engineering.

This general indifference and tolerance of the public towards atomic energy lasted until the middle sixties. All this time, PAEC adopted a low-key profile not only because of the emotionalism with which anything nuclear is associated, but also because its research results were still quite insignificant as most of the projects undertaken were more on initial investigations and nuclear techniques familiarization and development.

### **3. COMPONENTS OF THE NUCLEAR TECHNOLOGY TRANSFER PACKAGE**

#### **3.1 Nuclear Training and Education**

While the PAEC was building up its research and development capabilities, a nuclear manpower training program was started. Its initial offering in 1960 was a basic Radioisotopes Techniques Training Course (RTTC) using borrowed equipment and with International Atomic Energy Agency (IAEA) assistance. The technology transfer agents were mainly PAEC scientists and technologists who had had specialized training in nuclear establishments abroad, predominantly Argonne and Oak Ridge National Laboratories. By 1960, some 58 Filipinos had been trained in various fields of atomic energy such as physics, engineering, radioisotope applications, reactor technology, nuclear, radiochemistry and health physics.

As the PAEC R & D Program was firmed up, the PAEC Nuclear Training Institute correspondingly programmed and conducted, in addition to the basic RTTC, other courses on the Industrial Uses of Radioisotopes, Radiological Health and Safety, Medical Uses of Radioisotopes, Agricultural Uses of Radioisotopes, Neutron Activation Analysis and Radiochemistry. These courses were offered to researchers of science-oriented agencies and educational institutions.

With the lack or inadequacy of formal nuclear courses in schools, the PAEC influenced and cooperated with, the University of the Philippines in offering a master's degree in engineering, major in atomic energy. At the same time, in an effort to upgrade science teaching, the PAEC also offered a Nuclear Technology Course separately for college instructors and secondary school teachers, now scheduled as a regular PAEC summer offering.

So far, as of December 1976, the PAEC Nuclear Training Institute has graduated some 1980 trainees, statistically the picture of direct local nuclear technology transfer efforts. Foreign nuclear technology transfer from the more advanced laboratories to the Philippines has been effected through an overseas fellowship program dependent to a great extent on technical assistance from the IAEA. As of December 1976, 352 fellowships have been availed of by Filipinos. While the bulk went to the training of PAEC personnel, a sizable number have been given to other agencies, government and private, numbering 40 and consisting, over the years, of 127 fellowship slots or 40% of the total overseas training grants.

### 3.2 Demonstration Effects: Radioisotopes Applications

The spread of the gospel of atomic energy cannot be a one sided affair. As the PAEC experience has shown, the most credible drumbeaters for general acceptance have been the PAEC trainees - the practitioners of nuclear medicine, the industrial users, and the agricultural scientists who have successfully utilized nuclear techniques in plant breeding and pest control.

The use of radioisotopes in medicine has been among the most readily accepted areas of nuclear applications. Radioisotope production in the PAEC has been expanding primarily to meet the needs of the local hospitals and, with their initiation by the better-known medical specialists coming from the state university-operated Philippine General Hospital, their gradual acceptance by patients was effected without much difficulty. In fact, the bigger problem at present is how to make radioisotopes available as needed and more cheaply to everyone, rather than public acceptance. Psychology has played a significant role here - the credibility of nuclear medicine brought about by the confidence given to the medical practitioners by the elite groups established radioisotope applications in medicine as a sort of status symbol. Nuclear medical practitioners are now found in the exclusive and expensive private medical centers as well as in the better-equipped government hospitals in the Metro Manila Area.

The demonstration effect has been also found in other areas to be most effective in public understanding and eventual acceptance. The savings in industrial operations using radiography instead of time consuming conventional procedures, when explained to a cost-conscious consumer group who eventually shoulder the expenses, get the sympathetic ear of this consumer public. And the farmer has but to be shown the difference in crop yield or disease resistance of a radiation-induced variety to become a forceful ally in the dissemination of the beneficial uses of atomic energy. From these experiences in winning over a favorable public attitude, we have taken a cue for the public acceptance program for nuclear power.

#### 4. "SELLING" THE NUCLEAR POWER PROJECT

The Philippine Nuclear Power Plant project may be seen in the light of three major parameters: first, as a development project in the total national effort at enlarging the economic base of Philippine society aimed ultimately at improving the quality of life of every Filipino; second, as an immediate as well as a futuristic approach to the local energy insufficiency problems under the impact of global developments; and third, public reaction to atomic energy.

##### 4.1 A Development Strategy

Energy has always been recognized as a vital component in national development. For the Philippines to push through its national development plans and programs, energy has become a critical item. While basically agriculture-based, the Philippine economy is being boosted by an industrial strategy that is gaining momentum. The growth of industries, the infrastructure for tourism, the expanding facilities for transport and commerce, household consumption of a population aspiring to the luxuries of the more developed countries - are among the major contributors to the increasing energy requirements. In the face of the oil crisis, the Philippines has had to search for alternative sources of fuel. Considering the limited known local resources and the country's oil dependence, the nuclear option was inevitable to the Philippines. However, being a developing country where the basic essentials are scarce and still to be met adequately for a greater majority of the population, the need for public understanding of a project with the magnitude and financial implications of the nuclear power project becomes vital. In the face of our socio-economic problems like low income, poor housing, inadequate sanitation, illiteracy, undernourishment, the benefits from this project must be justified. For in this country where the majority of the population are poor, the expense of \$1.1 billion or about ₱7.5 billion for a single project like the nuclear power plant is staggering and does not lend itself to ready public acceptance.

## **4.2 Public Reactions**

In the Philippine experience, the transfer of a heavy technology like nuclear power, developed for industrially advanced countries, has been received with mixed reactions. There have been divergent public attitudes regarding its place among investment priorities and development strategies towards self-reliance. Lately, concerned citizens have been quite vocal about its contribution to environmental degradation and the issue of possible diversion of nuclear fuel material for the fabrication of nuclear weapons. The economics of nuclear power together with the accumulation of radioactive waste products from a nuclear power plant have also provided ready arguments against this technology. Working at public understanding for the nuclear power project has therefore required continuing justification of outputs far outweighing investments.

Articles have recently appeared in local publications on the safety of nuclear power plants. The main issues discussed revolve around the risk-benefit controversy. To quote one editorial: "Are the benefits resulting from nuclear power worth the risks? What kind of dangers should be tolerated in exchange for what kind of benefits? With how much uncertainty of specific kinds does the public care to live?" These apprehensions have been articulated in the local press from time to time, mostly in the form of articles either culled from foreign releases or as reprints, and, more often than not, on negative issues.

Reports in the local papers of the resignation of the General Electric Company engineers involved in the nuclear power projects in the United States and their major participation in the antinuclear campaign have also sparked some noises against the local nuclear plant project.

Newspaper accounts of nuclear tests also serve to refresh fears about an atomic bomb's disastrous effects on the population. Apprehension over dangers from fallout continue to give rise to scare stories.

The current pollution controversy in a Philippine industrial area close to the first nuclear power plant project is also likely to set back some gains in the public acceptance campaign for nuclear power, despite assurances of nuclear energy being the cleanest source of energy available relative to impact on the environment.

## **4.3 Public Issues**

As monitored from PAEC information campaigns, public fears of nuclear power ultimately redound to the following issues:

1. That the nuclear plant might explode like an atomic bomb;
2. That there is danger of radiation accidents which would result in deaths or serious illness among the population;
3. That nuclear power plant would cause higher incidences of cancer and undue environmental risks from continued release of radioactivity;
4. That the operation of a nuclear power plant would bring about a legacy of

highly toxic, long-lasting radioactive wastes with no acceptable measure for their permanent disposal; and

5. That the operation of the nuclear power plant would have adverse results on marine life and would deprive fishermen of their livelihood.

The PAEC after an analysis of the situation has identified the public acceptance dimensions of the nuclear power program, namely:

1. As a social responsibility;
2. As an ecological issue;
3. Technical credibility; and
4. Public expectations.

The public attitude to the project has subjected a socially responsible decision to the test of whether it does not in fact produce unfortunate social consequences. Hence, the total approach has been to project a strategy that combines engineering, legal and community standpoints in terms of a social, economic and political environment. The factor of credibility has also had to be attuned to the vast number of signals from society, both from the general and special publics.

#### 4.4 The General Public

The general public for the nuclear issue consists of a societal mix of rich and poor, enlightened and unenlightened, urban and rural, capitalist entrepreneur and the masses. As varied in outlook as are their interests they react in various ways.

The average educated Filipino digs into his knowledge of economics and comes up with arguments against it, primarily, that his descendants for a number of generations to come will be assuming the burden of this public debt. However, he also loves to enjoy the luxury of a well-lighted home and household appliances which are labor-saving although energy-consuming devices.

The intellectual few tend to be very sensitive, hence more concerned, about vital national issues. They are the more articulate crusaders for a clean environment and keeping nuclear power programs under control. They are therefore potentially influential for or against the nuclear power issue.

The strategy for acceptance, to have any significant impact on the bulk of the Filipino masses, has been thus planned to center on the resource commitments, risk perceptions, values and preferences of the average Filipino. For instance, the new technology is presented to show the tradeoffs between benefits and the magnitude of risks involved. In the Philippines, the prospects of electrification for the unlighted areas and of progress with the possible introduction of new industries is a welcome promise of relief to those living in conditions that are almost primitive. This is particularly true for the local folk who have visited the big city, Manila, and experienced some of the conveniences of electricity and modern living. The nuclear technology package must relate to better

living conditions and the creation of job opportunities as against the prospects of fouling of the environment and creating additional health risks.

#### 4.5 A Special Public

With the addition of nuclear power in the electric system, every energy-consuming citizen has a vested interest in the nuclear power program. But there is one special group that deserves attention - the residents in the vicinity of the nuclear power plant. These people have a stake in the project which could be either positive or negative. By way of benefits - area development, rise of cottage or small-scale industries, improved facilities such as roads and markets, better schools and health services, job opportunities; on the minus side - family displacements, loss of livelihood, environment degradation and other hazards. The effects being so polarized, each side can be persuasive as the other. Seen, however, against the peculiar nature of atomic energy and the past horrors associated with it, the odds against are quite strong. Besides, the mere mention of risks and hazards seems to increase suspicion instead of confidence. All these point to the imperative of a program to gain acceptance. A high degree of rapport with the public obtained through confidence and mutual trust is mandatory. This underscores the need to promote public understanding.

#### 4.6 Reactions to the PNPP-1

The experience on the first Philippine Nuclear Power Plant Project (PNPP-1) illustrates these quite well. Although the plant site including its exclusion area is primarily a government forest reservation, some privately owned farm lands were affected and thus had to be expropriated. This resulted in the displacement of some land-owning families living in the selected site. The issue of human settlements, particularly relocation, surfaced because this had not been given due consideration during the initial planning stages of the project. To the dislocated families, the search for a new habitat which should also provide a new means of livelihood was depressing, if not traumatic. Their plight has been picked up by a sympathetic community as an issue of social justice versus progress. Between the present reality of home loss and a future promise of better living conditions, the existing situation and the difficulties it had imposed had become more compelling and a whole community was roused to take sides against the project. At the same time, site data needed for the engineering design and baseline environmental and ecological conditions were gathered with hardly any explanation of the objectives of the program or activities. This led to doubts and later, suspicion and distrust of the project by an entire community. These conditions brought out the need for the National Power Corporation (NPC), which is charged with the construction and operation of the nuclear power plant, to undertake an information drive. However, the very first try by the NPC at a public information campaign ended on a sour note because the military was requested to come to the meeting area in order to provide security. This, the townspeople resented. NPC has since then changed



strategies but it will take some time for the problem to be overcome. Furthermore, unless satisfactorily resolved, the hostility aroused in the first project could be precedent-setting and may lead to more vigorous opposition to any additional plants that may be constructed in other areas in the future. This factor has also taken priority in the NPC campaign for acceptance.

## 5. THE PAEC INFORMATION DELIVERY SYSTEM

### 5.1 Strategies and Techniques

The PAEC, on the other hand, has adopted certain strategies in its drive for public acceptance, namely:

1. Identification of effective communication tools;
2. Gaining support of opinion makers, thought leaders as well as power and authority centers;
3. Establishment of continuing and dynamic linkages with the mass media and government information offices;
4. Saturation of the various publics with desirable positive information; and
5. Cooperating with environmentalists in pollution projects.

These strategies are implemented using a public relations approach which recognizes the need for correct timing, relevant content, appropriate medium and adequate resources. Being a government agency, however, the PAEC can count only on very scarce resources for information work. So it has to maximize time, content and medium through an integrated approach.

Time. Information materials are prepared to be ready for use before, during and after a staged event like seminars. Announcements and follow-up releases and publications are planned and executed on schedule as faithfully as the conduct of the information campaign proper.

Content. News, feature articles or scripts are edited carefully for specificity, completeness and relevance to the particular public for which they are intended and, preferably, with human interest angles.

Medium. Choice is dependent on subject matter, the type of audience or readership, and availability of facilities to the various publics.

The PAEC information drive takes the form of scientific seminars and conferences, tours of the PAEC laboratories and facilities with special lectures, dialogues and interviews with local officials and townspeople, participation in science fairs and exhibits. A loosely organized pool of PAEC scientists and technologists is a ready source for speakers and resource persons requested by schools or scientific societies from time to time. They are also fielded for foundation days or meetings of civic organizations like Lions or Rotary Clubs.

The PAEC nuclear information network covers technical and general public sectors on



a national scale although present concentration is in the Metro Manila area since most government research and educational institutions are located here. However, recognizing the need for national understanding, its benefits being meant for all Filipinos, the PAEC has also launched regional, provincial and municipal drives. So far, two major regions in Northern Luzon have been stomped during one to two month-long campaigns. Audiences were composed of varied sectors - young and old, educated and unlettered, professionals, farmers, community and civic leaders, entrepreneurs, housewives, teachers, and students. The feedback, obtained through survey questionnaires and interviews, has been encouraging and plans are to continue similar drives until the whole Philippines is covered.

Institutional arrangements have been made with the Department of Public Information, Department of Education and Culture and Department of Local Government and Community Development. Joint information work with the Public Relations staff of the NPC is also being done.

These local sorties are not only informative but also cause the foregoing of cooperative agreements particularly in the form of research and training grants-in-aid to schools of science and technology, thus bringing about another technology transfer medium. The PAEC has also launched a scholarship program to encourage brilliant students to pursue careers in nuclear science and technology.

As a major event, a Presidential decree has proclaimed the second week each year as Atomic Energy Week. This becomes an occasion for national celebration marked by open house at the PAEC, science exhibits, scientific sessions (which turned into a Nuclear Congress last December), field trips, mobile demonstrations and continuing press and TV coverage.

## **5.2 Mass Media Linkages**

All these approaches have so far been highly effective in nuclear information dissemination but the most far reaching is the relationship which the PAEC has with the mass media. The PAEC has brought the mass media into its clientele public through seminars on atomic energy for journalists. About twenty newsmen from the leading national newspapers and magazines attended the first seminar and the results have been a continuing coverage of PAEC activities. In 1974 and again in 1976, live-in seminars were conducted with considerable attendance from both print and broadcast media. The participants have formed an organization of Nuclear Energy Communicators, which assures PAEC of prime newspaper space and spot announcements and interviews on TV and radio. Monthly press conferences are given by the PAEC Commissioner so that the media-PAEC liaison continues under mutually satisfying conditions.

## **5.3 The PAEC Information Staff**

Providing backup to the mass media is the corps of nuclear information writers and editors in the PAEC Management Service. This group is charged with the responsibility of publish-

ing the *Philippines Nuclear Journal*, *Philippine Atomic Bulletin* and the *Philippine Atomic Bulletin* and the *ATOMEDIA Philippines*, the first a purely technical publication, the second a semi-technical issue for lay readers, and the third also semi-technical but intended for policy makers, administrators and planners besides. To channel the interest of school children and out-of-school groups into reading nuclear literature suited to their level of understanding, the PAEC has published a *PAEC Komiks* magazine in the national language, incidentally the major vernacular spoken in the Philippines. Subjected to a survey on its effectiveness as a teaching aid and as a means to disseminate nuclear information, the response was overwhelming so that it is now published in serialized quarterly issues. Arrangements for the airing of a 20-episode radio series, each of fifteen to thirty minutes duration dramatizing case studies on nuclear applications are being finalized with the broadcast media. Two documentary films on local utilization of atomic energy have been produced by the PAEC and which are shown in local movie houses in Metro Manila as well as in provincial theaters.

With a lead time of five years before the operation of the first nuclear power plant, the systematic information drives being conducted by the PAEC, and the initiation of other public relations projects as the plant construction progresses, the Philippines is hopeful of obtaining public understanding and support for this government project in time.

## **PUBLIC ACCEPTANCE OF NUCLEAR DEVELOPMENT IN SPAIN**

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### **ABSTRACT**

Organized opposition to nuclear energy started in Spain some four years ago. Before, there only had been a few isolated and differently motivated attempts. In this paper we analyze the causes of such an opposition and its expansion all over the country. We also present in a schematic way the different types of opponents to nuclear energy, the various reasons for such an opposition and the interactions between them.

A summary is presented for the present opposition existing in connection with every nuclear facility proposed by the Government. As well, three practical cases are studied in detail, which correspond to quite different facilities, enabling us to analyze the real origin of opposition and of the opponents. The three facilities we selected are: a fuel element factory, a nuclear research establishment and a radioactive burial ground. The beginning of the opposition is described for each of them, as well as types of opponent classified in accordance with the above mentioned scheme and the solutions suggested.

The paper also describes the actions taken by the Government within its acceptance policy, including a critical analysis of them and some conclusions and recommendations based upon the Spanish experience.

### **1. INTRODUCTION**

A careful study of Spain's energy possibilities led the Government to elect the nuclear option as the sole manner of achieving stability and the future economic development of the country. The main lines of the present energy program, in general, and of the nucleo-electrical plan, in particular, were drawn up almost 15 years ago, as demonstrated by the nuclear power plants in use and those under construction. Later, the world energy crisis, begun in 1973, forced the Government to reconsider the national energy policy in order to adjust it to the new situation.

#### **1.1 Spain's Nucleo-Electrical Program**

In January 1975, the Spanish Government approved the National Energy Plan, revisable every two years, which has been of great importance in the nuclear field. This Plan predicts a nuclear electrical power capacity in 1985 of 22,000 MW, capable of producing some-

what more than 50% of the electrical energy needs. Besides, from that year on, any increase in electrical energy capacity in the peninsula will be covered by nuclear power plants.

This objective is linked to two others also of great significance in the nuclear field; these are:

To guarantee the supply of nuclear fuel in all of its phases and to increase the domestic production of uranium, including even participation in exploitations abroad, making it possible to cover a part of the domestic needs.

The first of these two missions is entrusted to the Empresa Nacional del Uranio, S.A. (ENUSA), 60% state owned with a 40% private participation on the part of the utilities. For the second mission, the Spanish Government approved the National Uranium Exploration Plan during the Council of Ministers Meeting of 30th August 1974, for a duration of 10 years, and endowed it with 12,420 million pesetas. The management of this Plan is entrusted to the Junta de Energia Nuclear, and the basic objective is the exploration of 100,000 km<sup>2</sup> of sedimentary land, which, in principle, is considered as having possibilities.

Spain has a sufficiently strong nuclear tradition to guarantee fulfillment of the objectives of the National Energy Plan. The Junta de Energia Nuclear, with over 25 years of experience, is the advisory body of the Government in nuclear matters, and is in charge of carrying out the necessary research and the training of staff in accordance with the country's needs.

At the present time, Spain has 3 nuclear power plants in operation ("Jose Cabrera", 160 MWe; "Santa Maria de Garona", 460 MWe; "Vandellos-1", 500 MWe); 4 power plants under construction ("Almaraz", 2 x 930 MWe; "Lemoniz", 2 x 930 MWe; "Asco", 2 x 930 MWe; "Cofrentes", 975 MWe); 4 power plants contracted for ("Trillo", 2 x 1000 MWe; "Sayago", 1000 MWe; "Valdecaballeros", 2 x 1000 MWe; "Vandellos-2", 1000 MWe); and 2 power plants with preliminary license ("Vandellos-3", 1000 MWe; "Regodola", 900 MWe).

There are also 12 requests for new power plants presently under study in the Junta de Energia Nuclear in order to send the Ministry of Industry the report necessary for granting the preliminary license. The total power of these 12 plants is approximately 19,000 MWe.

## 1.2 Socio-legal Context of the Nuclear Development

In light of the role which nuclear energy was destined to play in the supply of energy in Spain, adequate legislative measures were adopted to provide the legal framework for its development. In 1964, Law 25/1964 of 29th April was passed with regard to Nuclear Energy. This wide ranging law applied to all the activities related to peaceful applications of nuclear energy, whether in nuclear installations or in radioactive installations, transportation, ships, etc., and to all questions referring to these, such as their control by the Administration, the system of civil responsibility for any damages that might be caused, protection against radiation, penal or administrative measures, etc. Also, the Law provided for the development of its precepts through Regulations setting down the concrete measures of

application. Two such Regulations have been published up to the present: the Regulations of Coverage from the Risk of Nuclear Damage and the Regulations concerning Nuclear and Radioactive Installations, both approved by Decree.

Without going into an analysis of this legislation - which is not to the subject being treated here - it is nevertheless appropriate to emphasize some important aspects for the later study of the problem of opposition; some are because certain opponents, ignorant of the reality of the situation, feel that the security of the installations is not sufficiently guaranteed; others, because they express an evaluation of the interests for and against the installation before it is authorized and the possibility of the population participating in the relevant decisions. In the first place, it must be pointed out that there is strict control on the part of the Administration with respect to Nuclear Energy, which is evident in the requirement of administrative authorization for any activity whatsoever related to it and in its vigilance with regard to the fulfillment of safety and radiological protection requirements.

The body particularly given charge of this control by the Administration is the Ministry of Industry, whose Directorate General of Energy is entrusted with the processing of the authorizations. Also, the Junta de Energia Nuclear, an autonomous organization depending directly on the Ministry of Industry, has important functions to fulfill in this aspect, as it must issue its required report on the nuclear safety and radiological protection of the installation whose authorization is being applied for, as well as grant licenses to the staff of these installations, besides watching that throughout the life of the installation - once it has been authorized - its operation observes due conditions of safety and protection. Also, it must be added that the control of these Bodies does not exclude that which should be exercised within their specific areas by other Departments, Organizations or Authorities, such as, for example, the Ministries of Public Works and of the Interior, the City Governments, etc. That is, the intervention of the Administration regarding nuclear energy is carried out on different planes and on all facets which could affect these aspects.

Another important aspect to be emphasized is that in the authorization process of the nuclear installations (which required three successive authorizations - preliminary, for construction and for start-up), attention is given to whether the installation is justified on account of a real necessity and whether there are legitimate interests which could be harmed by the existence of the plant. In effect, in the processing of the first of the authorizations (the preliminary license required for all nuclear installations except those for storage and research reactors) as an indispensable condition for applying for construction authorization, the applicant must demonstrate the needs to be satisfied by the installation, its justification, as well as the suitability of the site.

Besides, the application is submitted to other Departments, Organizations and Authorities for reports, in the event that these, from their respective points of view, could have some objection. Likewise, in this phase the public is given the possibility of participating in the administrative decision, since a period of public information is opened during which the persons or Entities who may consider themselves as affected by the project are able to submit whatever allegations that may be felt pertinent within a limit of thirty days. This

option to the public is offered for all of the nuclear installations, since even those which are exempt from the obligation of obtaining preliminary license are submitted to public information in the processing of the construction authorization.

## 2. PUBLIC OPINION REGARDING NUCLEAR DEVELOPMENT

### 2.1 Nuclear Opposition in Spain. First Manifestations and Present Situation.

Opposition in Spain to nuclear energy has followed the vicissitudes of the opposition in Western Europe, with the same attitudes, groups of opponents and causes as in other European countries with nuclear programs. The Spanish political structure has prevented, up to now, violent opposition movements; however, it would not be surprising in the near future if the nuclear energy question is raised in the struggle among political parties, in view of the new political structure which is approaching.

A retrospective examination makes it possible to distinguish two stages in public opinion with respect to nuclear development. The first, from the beginning of nuclear energy in Spain up to mid 1973; the second, from the middle of 1973 up to the present time.

(a) During the first stage the opposition was only evidenced sporadically without it being possible to speak of an organized movement. The "Nuclear Energy Center" of Madrid, present headquarters of the Junta de Energia Nuclear, the "Uranium Concentrates Factory" of Andujar (Jaen) which began operation in 1959, the "Irradiation Unit for the Radiosterilisation of Medical-Surgical Equipment" of Barcelona (1972), the "Radioactive burial ground for residues with low and medium activity" of Cordoba (1961) and the "Jose Cabrera" (1968), "Santa Maria de Garona" (1971) and "Vandellos-1" (1972) power plants were fully accepted by the public with no apparent opposition. Some isolated facts were the subject of manifestations against specific installations on the part of the press, without any massive opposition by the public. This was the case with the leakage of some 40 liters of liquid containing radioactive products in solution during an operation of transporting liquid residues on 7th November 1970 in the "Juan Vigon" National Nuclear Energy Center in Madrid. In spite of the position of reserve adopted by the Junta de Energia Nuclear, during the first moments in order to avoid unjustified alarm until the extent of the accident was known, the news was found out by the press and published a few days later. The investigation carried out showed that at no time were abnormal values of radioactivity found in the watering canals of the Jarama River in which the liquids were spilled, and a complete report was sent to the press for information.

(b) Starting in 1973, the opposition movements which were arising in the greater part of Western Europe against projected nuclear power plants as well as those under construction, reached Spain. This opposition has been increasing and



today denounces any installation whatsoever which bears the designation "nuclear" or has some relation to it. It can be said that both the plants that were under construction during that year (and which continue today) as well as those authorized at a later date have received enormous criticism in the press, by nearby residents of the installation's location and by political groups. The main promotor of these attacks has been the Spanish Association for the Regulation of the Environment (AEORMA), an entity of a private nature operating on a nationwide level in defense of the environment. Recently other associations of a regional nature have been founded, which under the title of defenders of regional interests, including the environment, have clearly shown their opposition to nuclear installations; this is the case with the Society for the Defense of the Interests of Lower Aragon (DEIBA).

In 1976, this opposition extended to nuclear installations different from the power plants, and thus harsh attacks were made against the new Nuclear Energy Research Center which the Junta de Energia Nuclear plans to construct in the province of Soria, the factory of fuel elements of Juzbado (Salamanca) and the radioactive burial ground of Sierra Albarrana (Cordoba) in spite of the fact that this last installation has been operating perfectly and safely for almost 15 years.

The sensationalist press which evidences permanent opposition to the Government contributes to this position.

## 2.2 Analysis of the Different Attitudes and the Groups Opposing Nuclear Energy.

As we have just said, the present situation of the opposition in Spain is very similar to that which can be deduced from the observation of reality on a world-wide scale.

For the purpose of framing the anti-nuclear movement in Spain within the world-wide nuclear opposition, an analysis has been made of the opposition movements in various countries in an attempt to arrive at a classification of the different attitude and opposition groups. In this way it is hoped that it will be possible to easily compare the characteristics of each opposition in particular and to adopt, if applicable, corrective measures to neutralize it.

In effect, an analysis of the opposition movements reveals that there are three attitudes contrary to this type of energy: a "systematic opposition", that is, a continual opposition to the use of nuclear energy, in general; an "individualized" opposition, that is, directed against a particular nuclear installation in a specific location; an "occasional" opposition, which occurs at a given time or due to specific circumstances. Of course, this distinction, which offers certain advantages, should be conceived only as a basic hypothesis for the study of the problem and does not intend to imply that the three attitudes mentioned are to be considered as airtight compartments; there will be interaction among them. In turn,



within each type of opposition, various groups of opponents can be distinguished.\*

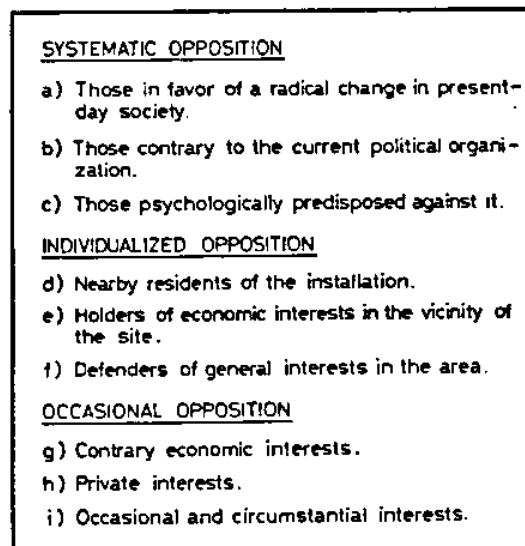


Fig. 1. Attitudes and Groups of Opponents to Nuclear Energy

2.2.1 Systematic opposition. In this type of opposition we find the following groups of opponents:

- (a) Those in favor of a radical change in present-day society. These are individuals or organizations convinced that present-day society should be radically changed. Their procedure is to preach a return to nature as the ideal state of man and thus reject all that is contrary to this. This classification includes the Associations or Movements of a national or international nature, whose purpose is to defend the environment to the utmost degree, denouncing nuclear energy as a factor of aggression against it. An organization of this type in Spain is the Spanish Association for the Regulation of the Environment (AEORMA), mentioned earlier.
- (b) Those opposed to the current political organization. Individuals or groups who are not satisfied with the current political organization and oppose nuclear energy as a part of the structure they wish to combat. Sometimes they base their opposition on the fact that such energy has been adopted by the political structure they are attacking, and on other occasions, because their objection to nuclear energy serves as a basis for their opposition, and they feel that this could help them to

\* The analysis described herein, in summary form, appeared some months ago in the article "Approach to a Sociological Study of the Opposition to the Nuclear Energy" by M. Lopez Rodríguez and L. Corretjer Palomo, published in Energía Nuclear, No. 104, November-December 1976.

win over additional followers. It is interesting to point out how the "objectors" of all countries, no matter what political structure they may have, join ranks in the protest against nuclear energy and wield political arguments even when ecological concerns are involved.

- (c) Those psychologically predisposed against it. This group includes those attitudes which, whether due to fear of the risk of nuclear energy or because of vague feelings of dissatisfaction or aggressiveness, object to nuclear energy. This group is perhaps the most important one because of its extent and because of the influence and pressure it can exert. Generally speaking, this attitude is maintained by individuals with insufficient education to enable them to evaluate on their own the risk and the risk-benefit balance which should precede any rejection or acceptance of a technical fact and by those who have been influenced by the propaganda of other groups. However, scientists or persons with knowledge on the subject can also adopt these attitudes at a given moment for particular psychological reasons, exaggerating the risks and becoming objectors to nuclear energy.

2.2.2 Individualized opposition. The following groups can be included here:

- (d) Nearby residents of the installation. These are persons who live and have their means of living near the site foreseen for a nuclear installation and are afraid of being harmed in their person or their possessions.
- (e) Holders of economic interests in the vicinity of the site. This group corresponds to those individuals or entities who have economic interests in the vicinity of the site foreseen for an installation and fear their depreciation on its account. Examples are construction firms planning a development who fear the expropriation of their lands or the depreciation of the remaining land, industrial companies which fear a rise in salaries, etc.
- (f) Defenders of the general interests in the area. These oppose the site of a nuclear installation in a certain area because they feel that it would be better for the area, or the country in general, to devote it to other activities, such as tourism, cattle raising or forestry. This specific attitude, whether mistaken or correct, can be maintained by individuals or entities even without any direct interest. It should be noted that in contrast to the positions adopted by the other groups, this individualized opposition is sometimes backed up by Legislation, as in all countries, either the Law or special norms regarding the authorization of nuclear installations provide for and regulate the opposition to a determined activity which could harm legally-protected interests. In this regard, Legislation provides for periods of public information, administrative or legal appeals and other legal means.

Nevertheless, on occasions, the opposition to a determined installation can become violent, as although at the start there are only demonstrations of local groups opposed to the installation, later they become pretexts for the contentions of political groups.

2.2.3 Occasional opposition. The attitudes making up this type of opposition can be summed up in the following groups:

- (g) Contrary economic interests. These are attitudes against nuclear energy, often concealed, adopted by individuals or groups with financial interests in fields in which the use of nuclear energy competes with their interests, with the possibility of serious detriment. This group of attitudes is related to a specific economic situation which can vary; its influence can be extensive, as they can support the opposition campaigns of other groups, by mobilizing material means of propaganda or by financing such campaigns. As a general rule, their intervention will be suspected, but it will be difficult to obtain evidence to prove it.
- (h) Private interests. Here can be included a great variety of attitudes of individuals or groups who at some time will declare themselves to be opponents to nuclear energy if this position will benefit their own particular interests, which could be a craving for notoriety, snobbery or the power to rise as a leader of a certain group. Those who act in this manner are considered as occasional opponents, because their attitudes fade away if the general current does not support them, and can even go on to adopt an attitude of support at a given moment.
- (i) Occasional and circumstantial interests. These are attitudes which, without opposing nuclear energy itself, can at some time oppose a nuclear program on account of various specific motives such as the technology used, the manner of carrying it out or the degense of some positions contrary to it, due to pressures or for purely altruistic reasons.

The different attitudes and opposition mentioned are summed up in the table which follows.

## 2.3 Causes of the Opposition to Nuclear Energy.

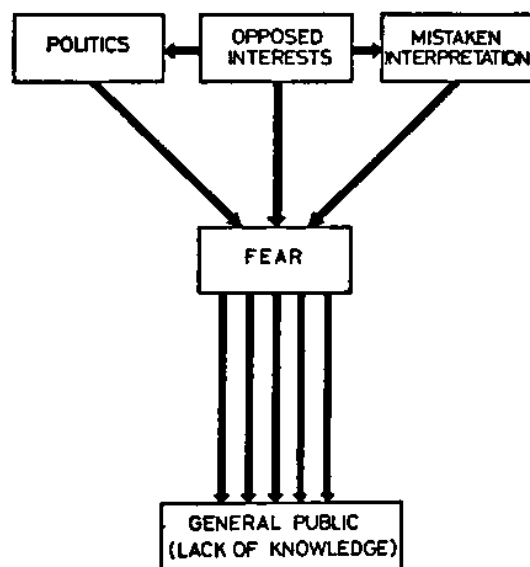
Now it is appropriate to ask oneself what are the deep-rooted reasons behind such attitudes, which appear so different from each other. A careful analysis shows that in reality the number of causes is very small and is limited to the following four:

- A. Fear. This is the cause prompting a large number of people to actively oppose or to sympathise with those who object to nuclear energy. It is appropriate to note that occasionally this fear is not clearly determined, but is rather a vague feeling within a psychological context of fear with regard to technological change in general; the fear of man's destruction by man, which has inspired so many pessimistic visions of the future. This explains why some persons with education sufficient to evaluate the risk inherent in nuclear energy allow themselves to be carried away by this fear, which means that they have not progressed with the speed required by present-day circumstances in order to adjust to the change. At times, this fear is seen in individuals predisposed by various personal factors, such as hypochondria, aggressiveness, social unadaptableness, etc.

- B. Counterposed interests. Although this motive moves a smaller number of individuals, it can, however, exercise great strength as a motor of opposition in individuals or organizations. Sometimes these interests are contrary to the establishment of nuclear energy as a source of supply in the energy programs because they feel it is contrary and damaging to their interests which are founded on another source. Other times, individual and groups will feel that nuclear energy is a direct threat to their interests in an area or in a country in general, because their economic interest is concerned with agricultural, cattle, forestry, touristic and even industrial interests, for which the nuclear programs or a determined nuclear installation could be a threat. We can mention some examples based on this cause: the expropriation of land in order to carry out the installation, the depreciation of land or consumer goods, or the scarcity of cheap labor as a consequence of the new industry.
- C. Opposition to the form of government or the political structure. Although in principle apart from the nuclear energy question, this cause motivates opposition on the part of individuals or groups. Sometimes the opposition to nuclear energy will be inserted in the attitude radically opposed to the political structure of the country where a nuclear program is being carried out, which will be denounced not because of what it signifies itself, but rather because it is considered a work of that political structure and consequently inadmissible. Other times, the opposition to nuclear energy will only be a pretext for carrying out a determined political campaign. A certain Administration will be attacked on the basis of the nuclear program adopted by it, alleging motives such as excessive extension, inadequate technology for the interests of the country, etc.
- D. Mistaken interpretation of the scientific, technical or economic data. This cause impels individuals or organizations to oppose nuclear energy who, in good faith, mistakenly interpret the basic suppositions of the use of nuclear energy, in such a way that they reach the conclusion that this is not necessary or is not advisable. Normally, these tend to be persons with higher education or at least sufficient preparation for the handling of these data, who however, either due to preconceived ideas impelling them to see the problem in a partial manner or because they do not use the data adequately, reach conclusions motivating their opposition. Often, even when the opponents are scientists, these will not be experts in nuclear energy and here is where mistaken interpretation can occur. The reasoning based on this cause can follow along different avenues. For some, even though they admit as the initial premise the increased energy demand, their opposition to nuclear energy will be based on the conclusion that in order to meet this demand, faced with the fact that this cannot be done through conventional forms, new sources should be used, such as solar, geothermal or wind-generated energy, because they feel that these involve greater advantages due to their lower risk, thus falling into the error of attributing to them a commercial function before

they have passed through the experimental stage. Others will base their arguments on the possibility of a hypothetical saving in the consumption; without contrasting this to the real situation, they will draw up their theory against nuclear energy.

An analysis of these four causes of the opposition to nuclear energy points up two important facts: 1. among these causes there are interactions; 2. all of these end up putting pressure on another cause not analyzed as yet, but which in fact leads many to support any one of the other causes. This new cause is *lack of knowledge*.



**Fig. 2. Interaction of the Causes of Opposition to Nuclear Energy**

In effect, as outlined in the attached figure, the counterposed interests sometimes exert pressure heavily on political causes and on mistaken interpretation, mainly through contrary information campaigns. In turn, the three have influence on the fear which is strengthened by the arguments of the preceding causes, but which on its part acts as the drive or support of the others. Finally, all of these act on lack of knowledge which thus becomes a cause of opposition. In fact, lack of knowledge of the economic and technical reality behind the adoption of nuclear energy as an important source of supply in the energy programs, lack of knowledge of the real risk involved and above all of the safety and protection measures to prevent them bring about the fact that this situation becomes a cause of opposition. The "man in the street", who, when he first learned about power plants, was satisfied and even amazed at the progress of the era in which he was living, began to consider this energy with distrust when influenced by the oppositions as he had not received objective judgements which would have allowed him to form an unemotional opinion on the question.

Having described the problem in these terms, we can arrive at only one solution: provide the necessary data for an adequate knowledge of the question to the recipient of pro-

gress - man -, to those persons who if they object to nuclear energy, it is because they are unaware of its need or exaggerate its risks, influenced by pressure from other causes. Thus, the average man, who must in the end decide on his living conditions, will be able to do so with those groups whose motives are interested, either politically or economically, or erroneous, both on account of the inadequate handling of scientific data as well as exaggerated or unfounded fear.

#### 2.4 Influence of the Communications Media on Public Opinion In Spain

In the beginning of the production of electrical energy of a nuclear origin, the Spanish communication media devoted space to information, praising the technological advances of Spain in nuclear matters; this situation lasted almost up to 1973 when, slowly at the start and later continually, the change to opposition began to take place. Of the media, the press has been the main vehicle of information, although the radio and television have devoted some space to the subject, only a small volume within the information in general has been included.

In order to ascertain the role played by the press in forming public opinion, the Ministry of Industry and the Junta de Energia Nuclear entrusted a specialized firm with the realization of a study on the space dedicated to nuclear energy during a specific length of time (in 1975), the subjects of main interest and their influence on the public.

The results obtained are as follows:

1. The volume of information during the time selected was significant with respect to other news of national interest. The information in favor of nuclear energy represented 17.4%, the information against it 38.4% and neutral 44.2%.
2. Of the persons interviewed, 11.2% felt that the information received was sufficient, 36.7% considered it to be insufficient and 36.5% considered it very sparse.
3. Within the subjects covered by the information, those most treated as arguments for the opposition were the contamination and degradation of the environment, the problems associated with the elimination of residues and the risk of accident, which represented 21.3, 11.6 and 9.1% respectively.
4. Insofar as the influence of the information on individual attitudes in favor of or against nuclear energy, 37.3% of the persons interviewed who were opposed attributed their position to the information received through the media, while only 11.3% of the persons in favor recognized the information as the origin of their position.

From these results it can be deduced that up to the date when the study and survey was made, the effect of the information media on the acceptance of nuclear energy had been negative, as in many cases it has been found that the information contained erroneous concepts of the scientific and technical fundamentals, which has led to the sowing of confusion in the public, giving rise to the opposing attitudes. The absence in Spain, up to that time,



of a policy of acceptance of nuclear energy and of neutralizing information campaigns has been the reason why the opposition movement has progressed enormously.

### 3. EXAMINATION OF SOME SPECIFIC MANIFESTATION OF THE OPPOSITION.

As we said before (2.1), since 1973, the antinuclear groups have practically manifested their opposition to all of the nuclear power plants both under construction as well as in the project stage. This opposition has spread to other nuclear installations different from power plants, which we will examine below, to accomplish two purposes: a) to show to what extent the opposition is becoming a true national antinuclear movement, and b) to prove that the causes and groups of opponents correspond to the classification described.

The opposition to these installations, as it lacks meaning on its own account, can only have an explanation when included in a general context of opposition to nuclear energy, as is the case of "systematic opposition", either by those in favor of a radical change in present-day society, or by groups contrary to the current political organization, or by persons psychologically predisposed against them (\*). The expression of objection appears to be an "individualized opposition" as it is directed against certain installations, in specific sites; however, on carefully analyzing each situation in particular, we see that the two components are there, with a clear distinction between the different opposing attitudes and the various groups of opponents.

The cases we have selected correspond to opposition movements occurring in 1976, which are as follows:

- (a) Opposition to the construction of a fuel elements factory.
- (b) Opposition to the installation of a new Nuclear Research Center.
- (c) Protests over the existence of a radioactive burial ground.

#### 3.1 Fuel Elements Factory in Juzbado (Salamanca)

##### Background

Towards the summer of 1975, the Empresa Nacional del Uranio, S.A., (ENUSA) decided to construct a fuel elements factory in the town of Juzbado (Salamanca). Besides the technical reasons which led to the selection of this site, there is the fact that it is a town relatively close to Madrid where it was advisable to build up industrial activities. Its proximity to Salamanca, a city with a great university tradition, also contributed a positive aspect with respect to the education of the children of the factory staff.

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(\*) These three groups are those we have distinguished within the "systematic opposition" of paragraph 2.2.1.



### Characteristics of the factory

The factory is designed for a capacity of 800 tons (in weight of uranium) of fuel elements in 1985, beginning with a smaller capacity of approximately 300 tons in 1978. The elements to be manufactured will be of the two types of commercial reactors in Spain, the PWR and BWR. The staff will number about 400 persons in 1980 and 1000 in 1985, with an estimated investment up to 1980 of 3,000 million pesetas. For the manufacture of these fuel elements, ENUSA has signed license and technical assistance agreements with the Westinghouse Electric Corporation and the General Electric Company.

### Prior informative actions

Before applying for the preliminary license, ENUSA sent the local newspapers complete information on the factory, its characteristics and manufacturing process, the safety conditions and the socioeconomic effects on a national and local level. On 23rd December 1975, ENUSA submitted the official documentation for applying for the authorization of the factory in the Delegation of Industry in Salamanca. This event was also published in the local newspapers. Several days later ENUSA sent clarifying information to the Authorities and to bodies which might also be interested, and offered to provide more information on request. The Official Bulletin of the province of Salamanca of 19th January published a notice of the Provincial Delegation of Industry submitting the application for preliminary license to public information, and again the local newspapers published the fact "for the better information of the residents of Salamanca".

At a later date, the Rector of the University requested a report on the factory and informed the public in general through the press; the report was favorable.

On February 1976, the Authorities of Salamanca requested the Ministry of Industry to hold a round table discussion at the University of Salamanca, in which three highly qualified persons from the Junta de Energia Nuclear participated and explained publicly the operating conditions of the factory, safety measures, the risks of radioactive contamination and the impact on the environment, and all of the questions of most concern to the public. The Company exploiting the installation (ENUSA) did not participate, in order to give the meeting an independent nature.

### The state of public opinion

In July 1976, the firm "VSA-CONSULTORES, S.A." carried out a survey to find out the state of public opinion in the town of Juzbado and Ledesma. This survey revealed a generalized uncertainty due to the lack of objective information on the subject. This fact is a result of three factors.

1. Opinions connected with persons exerting pressure against it.
2. Omission of positive factors or their simple consideration.
3. The idiosyncracies of the population, their cultural level and the social attention they receive.

Among the conclusions reached by the survey, the following deserve mention:

- (a) The population is subjected to a flow of information of a negative nature which creates a state of doubt and unease, and does not allow the inhabitants of the area

to adopt a personal, objective criterion regarding the problem. Part of the population confuses the functions of the factory with those of a nuclear power plant.

- (b) There is a general consensus among the population affected by the problems desirous of objective and complete information which would make it possible to become thoroughly familiar with the subject, its advantages and drawbacks, the possible effects on the social and economic aspects of the area as well as the safety measures. In this way, they could alter their position, which is rather cautionary than negative, faced with an unknown fact and influenced by external agents.
- (c) This defensive position has been broken down in persons who on their own account have obtained the information necessary to dissipate their state of confusion. The persons who have sought information - among all those interviewed - are in favor of the installation of the factory.
- (d) The main agents of information against the installation are as follows : a University professor, a group of important landowners, members of the political party General Workers Union (UGT), groups of students and the Salamanca press. On occasions, these same agents have taken action by boycotting informative meetings, provoking demonstrations (subsidized by the landowners) or by inciting the owners of tractors to use them to destroy the works of the installation as they are progressively carried out.

#### Positive actions of the Company exploiting the installation (ENUSA).

To dissipate the fears of the residents of the vicinity, as deduced from the questions raised in the round table discussion, the articles published in the press, both local as well as national, the interviews held with management personnel of the Company and the survey carried out by VSA-CONSULTORES, S.A., ENUSA organized a visit to similar installations in Europe and invited persons representative of the area involved. The visit was made in mid November to the FBFC and RBU installations in Belgium and Hanau (Germany), respectively. Twelve persons from the area made the visit (5 mayors, 2 physicians, 1 pharmacist, 2 local newspapermen and 2 farmers), and had the opportunity to speak freely with cattlemen, farmers, technicians and factory workers as well as the general public of the towns they visited. Some of the people invited refused to make the trip, as they did not consider themselves "involved".

#### Conclusions

1. The opposition movement against the construction of the fuel elements factory in Juzbado (Salamanca) fits in the general classification previously established, both in light of the attitudes expressed as well as on account of the groups of opponents and causes of opposition. This is an opposition which follows along the lines of the nuclear energy opposition movements, without having given rise to events with serious consequences up to now. The opposition has substantially delayed the start of the construction of the factory.
2. The information prior to the construction authorization was unplanned and

Inadequate. The lack of a well-organized informative campaign is evident as this would have unmasked the traditional opponents and eliminated the confusion among the public. The informative action of ENUSA, although late, has been positive, as seen by the consequences of the visit to Belgium and Germany.

3. A careful study of the motivation behind the opposition groups, taking as a basis the statements of the press, the interviews carried out and the results of the survey, makes it possible to assure the co-existence of the following typified causes:
  - (a) Fear in the public in general, mainly promoted by the pressure groups and propagated constantly by the sensationalist press.
  - (b) Private and counterposed interests, basically centered on the landowners who will have to pay higher salaries as the standard of living will rise in the area. As an anecdote, the survey revealed that these individuals who have been propagating their concern for the welfare of the area and its contamination often throw dead cattle into the river.
  - (c) Opposition to the form of government or the political structure, mainly on the part of the General Workers Union (UGT) and seconded by student groups and the press, who act as reflex agents of the opposition centers of the capital of the province.

Finally, with regard to the University professor, the real causes of his objection are still unknown, and it has not been ruled out that he may even act out of concern for the safety of the inhabitants of the area (according to those interviewed in the survey), in which case the motivation would be lack of knowledge or false interpretation of the scientific and technical bases on which the operation of the installation is supported.

### 3.2 Nuclear Energy Center of Soria

#### Background

The impossibility of expanding the present facilities of the Junta de Energia Nuclear in its "Juan Vigon National Nuclear Center" in Madrid, and the need for new installations in order to continue the technological development in the nuclear field, led some time ago to the consideration of the expansion of its means of work through the establishment of a second Nuclear Research Center. Consequently, the search for possible sites was begun throughout the country, in accordance with established guidelines and plans.

The area selected is located in the town limits of Cubo de la Solana (Soria), situated very close to a main road, 205 km. from Madrid and 10 km. from Soria.

The authorization for the installation of the Center was agreed upon in the Meeting of the Council of Ministers on 9th January 1976.

#### Characteristics of the Center

This is a Research Center which will include the following installations:

- (a) An experimental reactor, swimming pool type, of 20 MW.

- (b) Laboratories for the production of isotopes.
- (c) An experimental fast reactor with zero power.
- (d) A sodium circuit for the testing of components.
- (e) Installations for working in fusion by inertial containment.
- (f) An installation for the manufacture of fuel elements for research reactors.
- (g) A pilot installation for treatment of irradiated fuels.
- (h) Installations for the treatment of radioactive wastes.
- (i) Laboratories for the study of mixed oxides.
- (j) Hot metallurgical cells.
- (k) A multiple-use gamma irradiation unit.

The surface foreseen for the Center is approximately 1500 hectares, of which 647 have been purchased already. It has been estimated that the Center will begin to operate around 1980, with a staff of 700 persons which will progressively increase to a total of about 1200 in 1987.

#### Prior informative action

In April 1976, the general guidelines foreseen for the Center were published in the local press (there are two daily newspapers in Soria), and later lectures were given in Soria and Almazan (a town near Soria, bordering on the site). The lectures were given by qualified staff of the Junta de Energia Nuclear and had as their purpose a public explanation of the objectives of the Research Center, the facilities and laboratories to be constructed, the safety measures of these and the benefits on a local and national scale. The Junta de Energia Nuclear invited the Authorities of Soria as well as groups of farmers and professional people to visit its installations in Madrid.

Simultaneously with this information, the Spanish Association for the Regulation of the Environment (AEORMA) organized round table discussions, lectures and colloquia for the purpose of convincing the public that they should oppose the construction of the Center.

#### The state of public opinion

As a consequence of the tendentious and distorted information of the opposition leaders, the general public became tremendously confused, in spite of the favorable information in the local press. When the two newspapers in Soria refused to insert articles or notices contrary to the construction of the Center, AEORMA distributed tendentious pamphlets among the citizens of Soria. Through the literature distributed, the round table discussions and the lectures given by the opposition leaders, the public eventually confused the Research Center with an atomic weapons factory, a national radioactive burial ground or a power plant.

In some towns in Soria, painted walls or signs can often be seen with the slogan "NO TO A NUCLEAR SORIA" and young students wear lapel buttons with the same message.

The main agents of information against the Center are: two University professors, some landowners, members of the Communist Party and groups of students from the University College of Soria. It is significant that neither of the professors live in Soria, but

come from their home towns in order to give lectures or participate in round table discussions. Often these agents have taken action by boycotting special informative meetings convoked by the Civil Governor in which scientists and technicians of the Junta de Energia Nuclear took part, by provoking demonstrations organized by members of the Communist Party and young University students, and threatening and insulting the Mayor of Soria, who defends the Nuclear Energy Center.

#### Positive actions of the Junta de Energia Nuclear

In September 1976, in view of the increasing opposition and confusion of the public on account of distorted and erroneous information provided by the objectors, the Junta de Energia Nuclear began an Information campaign directed to the people of Soria, through the local newspapers and distributed to the most representative citizens of Soria (500 persons), through the Civil Government of the province. The information was supplied during a three-month period (September-November) and included the following subjects, all related to the Research Center itself.

- (a) Criteria for site selection.
- (b) Description of the Center.
- (c) Nuclear research centers throughout the World.
- (d) Nuclear safety.
- (e) Radiological protection and watchfulness over the environment.
- (f) The benefits derived from the installation of the Center in the province of Soria.

The information distributed now fills a printed volume of 100 pages.

Simultaneously, the Junta de Energia Nuclear invited the students of the Institutes and Colleges of Soria to visit its installations in Madrid, and provided the transport Soria-Madrid-Soria.

Both actions have given extraordinarily positive results, and a slowing-down has been noted in the opposition movement since the month of September until recently when it has surged forth again on the occasion of the presentation of the documentation in February in order to apply for the preliminary license to begin the period of public information.

The Junta de Energia Nuclear has offered to clarify any doubts which could arise in the public of Soria, in view of the information distributed.

#### Conclusions

1. The opposition movement against the Nuclear Energy Center in Soria has not as yet delayed the start of construction since the Junta de Energia Nuclear continues to fulfill the program established.
2. The positive local information on nuclear energy, prior to the decision of the Government to build the Center in Soria was null and very sparse immediately after the decision, which led to great confusion among the public on account of the flow of negative information. The activity of the antinuclear movement diminished significantly when the Junta de Energia Nuclear began the information campaign, while the leaders of the opposition were easily unmasked.



3. The two local newspapers are in favor of the construction of the Center and have greatly facilitated the spreading of information. The cattle-raisers and farmers (Soria is a farming and cattle-raising region) have not made any objections as yet, as their position is of "expectation".
4. The four motivations we have typified as causes of opposition have been detected; fear in certain parts of the population, the private interests of the landowners on account of possible scarcity of labor, political groups (in this case, members of the Communist Party) and the University professors who, as can be concluded from their lectures, have handled the scientific and technical data with a great lack of knowledge or in a tendentious manner.

### 3.3 Radioactive Burial Ground In Hornachuelos (Cordoba)

#### Background

The storage facility for radioactive wastes belongs to the Junta de Energia Nuclear, and from 1961 on, the radioactive wastes produced in the National Energy Center in Madrid or in hospitals and clinics throughout the country have been stored in it. Up to the present time, none of the wastes stored comes from nuclear power plants.

When the Regulations for Nuclear and Radioactive Installations was published in Spain in October 1972 (Official Statement Bulletin, 24th October), the Junta de Energia Nuclear initiated the authorization processing in accordance with the requirements of the current Legislation. The authorization was granted by the Ministry of Industry on 20th October 1975, in accordance with the reports of the Ministry of the Interior, the Military Staff, the Provincial Delegation of the Ministry of Industry in Cordoba and the communications sent to the City Government of Hornachuelos, where the storage installation is located.

#### Characteristics of the installation

The installation is designed for storing solid wastes of low activity and not for the storage of irradiated fuels after their use in nuclear power plants nor for wastes with high activity. The installation was formerly an uranium mine exploited by the Junta de Energia Nuclear until exhausted in 1960. Shortly thereafter the mine was converted to a radioactive burial ground. It is located in Sierra Albarrana which pertains to the City Hall of Hornachuelos in the province of Cordoba.

The site is ideal for the purpose of the installation, as indicated in the topographic, geological, hydrological, hydrographic, meteorological, seismic, demographic and ecological studies carried out. The installation is equipped with adequate safety and protection systems, and during its 15 years of operation no contamination of the environment has occurred, as shown in the periodic tests made.

The radioactive wastes are solidified through mixing with cement and are set in reinforced concrete. This in turn is contained in steel drums hermetically sealed and homologated according to the international standards of the IAEA, adopted in Spain. These drums are always transported in vehicles owned by the Junta de Energia Nuclear, especially

equipped for this purpose.

In accordance with the studies carried out, there is no possibility that the drums could come into contact with surface or underground waters, that is, there is no possibility of radioactive contamination of the surface or phreatic waters.

#### Prior Informative action

The Junta de Energía Nuclear has been storing radioactive wastes in the Sierra Albarrana burial ground for 15 years. Although in 1961 no public information was given on this activity, the town of Hornachuelos was aware of the existence of the storage. On 14th June 1974, in order to fulfill the provisions of the new Regulations for Nuclear and Radioactive Installations published at the end of 1972, the Descriptive Report of the Installation was sent to the City Hall of Hornachuelos requesting the pertinent report. In view of the silence of the City Hall, the report was repeated on 21st January 1975 and as there was no response after 16 months, the Ministry of Industry, after completion of the processing, authorized the installation.

#### The state of public opinion

There was practically no mention in the local or the nation-wide press of the radioactive burial ground in Hornachuelos until October 1976, when a Madrid journalist, unfamiliar with the subject, brought it to public light along the informative lines of the anti-nuclear press. In view of the magnitude of the inexact data propagated in the first article and those published in other newspapers along the same lines during the following days, the Civil Government of the province of Cordoba intervened to clarify the facts and properly inform public opinion on the installation. For this purpose it held meetings with scientists and technicians of the Junta de Energía Nuclear and Civil Protection, and later with the information media. As a result of these meetings, the Civil Government of Cordoba sent the press an official note denying the distorted information given before, clarifying the situation and calming down the public. However, the sensationalist press has continued to repeat the earlier information, overlooking the official declarations.

#### Positive action of the Junta de Energía Nuclear

From the start of the opposition, the Junta de Energía Nuclear established contact with the City Hall of Hornachuelos and the Civil Governor of Cordoba in order to hand over all of the existing documentation. In order to clear up any doubts which could exist in persons or entities with regard to the objectivity of the official statements, the Junta de Energía Nuclear invited the Authorities, journalists and residents of Hornachuelos to visit the facility. These visits have been completely positive, especially for the newspapermen who have objectively informed public opinion.

#### Conclusions

1. The protests motivated by the existence of the radioactive burial ground of Hornachuelos fit in the campaign of "systematic" opposition to nuclear energy in Spain, in spite of the fact that this is a particular installation with 15 years of operation. The reaction of the residents in the vicinity of the installation has been sparse.



2. Public information prior to the authorization of construction was inadequate, although since this is an installation operating for 15 years, it was not absolutely necessary. The administrative silence on the part of the City Hall of Hornachuelos in its lack of response to the requests of the Ministry of Industry contributed to this lack of information.
3. The opposition movement was initiated by agents outside the locality of the site, attempting to upset the program of the nuclear power plant. In the newspaper articles it was said that the Hornachuelos burial ground stored the radioactive wastes of the Vandellos nuclear power plant. In this way it was intended to establish a conflict between two Spanish regions: Andalucía and Cataluña, as can be deduced by the newspaper articles themselves. The people of Andalucía did not want to become a "colony" of Cataluña, and much less bury in their region the atomic wastes of its nuclear power plants.
4. The main agent of the movement was the press of the opposition, seconded by political groups and AEORMA, through opinions published in this press. This Association expressed doubt that the storage actually served only for the type of wastes mentioned and suggested between the lines that wastes from the power plants were being buried. Its main argument exhibited lack of information.

## THE NUCLEAR POWER CONTROVERSY IN SWEDEN

*PELLE ISBERG*

*Public Information*

*ASEA-ATOM*

*Vasteras, Sweden*

### ABSTRACT

The issues of the controversy over nuclear power have been the same in Sweden as in other countries. The debate has possibly been more complete in this country than elsewhere, however. It started late but passed rapidly through a number of stages, gained a tremendous attention, and culminated in September 1976 in a general national election, where nuclear power was one of the major issues. Experiences from this debate are discussed in the paper.

### 1. THE APPARENT ISSUES

I will begin my lecture with a few words about the apparent issues of the nuclear controversy. I prefer to call them the apparent issues, as we have found them not to be the real basic issues at all.

These apparent issues are manyfold and you have all heard about them before. There are the emissions of radioactive products, both routine and after accidents, and the acute and delayed damage that these emissions may cause. There are the radiation exposures of plant personnel and the emission of heat to the environment. There are the waste handling and the waste storage and the proliferation and the power transmission systems, and the power cost, and the dependence on foreign countries for the supply of energy, and the possible global shortage of uranium.

You have also all heard I am sure the allegations and the accusations from the nuclear opponents in these various areas and the rebuttals from the protagonists for nuclear power. The emphasis of the debate has varied with time and from country to country, but in its essentials the nuclear debate has been pretty well the same all over the world. It is not my job therefore to discuss in any detail any of these subjects at this conference.

My task, as I have understood it, is instead to tell you something about the experience gained from the controversy in a country which has been through a very gruelling nuclear debate.

## 2. THE RELEVANCE OF THE ISSUES

There are essentially two ways of defending nuclear power against attacks on all the lines I have mentioned. One is to point out that the damage done, though undeniably there, is small compared with what we are used to and accept from other manifestations of our so-called civilization. The other and more specific way is to limit the comparison to the various ways of producing electric power and to show that the nuclear version is no worse than any other. The issues in the nuclear controversy are as relevant to other power sources as they are to nuclear power. At least to all power sources that are available to us here and now in the 20th century.

In fact nuclear engineers can, and I believe they should, claim that nuclear power is better than all the available alternatives on most of the points that are said to be specific difficulties for nuclear power. The protagonists will be attacked when pressing this claim, but it is still part of their job to press it.

### 2.1 All the Little Things

There are a great many "little things" in the nuclear controversy that seemingly should be easy to handle by these arguments. It has been one of our most painful experiences that they are not.

There are of course a number of people who will accept arguments such as that there is waste heat coming from fossil plants as well as from nuclear plants and that hydro-electric systems influence the temperature of rivers very considerably. There are people who are willing to believe that a coal economy will waste much more land and kill and hurt many more people than the corresponding nuclear economy. And there are people who will believe that a wind power system will need at least as many power lines as a nuclear power system of the same size.

These listeners are often important people who make decisions and influence others, and this line of argument must therefore be pursued. It is an important and vital part of our defense of nuclear power against its vilifiers.

But in Sweden most politicians on the national scene and a majority of the influential journalists based in Stockholm have not accepted this non-relevance line of argument. Thorbjörn Fälldin, who is now our prime minister, has not accepted it.

I am not saying that these people are not susceptible to our reasoning in any of the specific examples I gave a moment ago, but they are of the general opinion that most of the allegations against nuclear power are specific to this new power source.

And as the public believes in these politicians and journalists, they also believe that nuclear power carries all these evils with it and that other power sources are more or less free from them.

I should add that when I am criticizing now and later on our new prime minister, it is not for other political reasons than his position vis-a-vis nuclear power. I myself voted

for the coalition that brought Mr. Falldin to power last fall.

## 2.2 The Cancer Scare

However, all the "little things" are not decisive to the man in the street, when he makes up his mind about nuclear power. What people are really concerned about are the delayed effects of ionizing radiation. These are cancer and genetic mutations, but I am going to call them "cancer" for short here.

People readily discuss with us and at great length a number of detailed aspects on things like waste disposal, plutonium and routine emissions. But when the discussion is prolonged to where their real concerns are laid bare, it is always cancer that emerges. If it were not for the "cancer scare", people would not be concerned about the plutonium or the long life of the waste products. This is our most important finding during the four years of nuclear controversy in Sweden.

Now, as you know, this more basic issue can also be handled by the non-relevance arguments. The delayed effects are not specific to ionizing radiation. There will be as much cancer and mutation per kWh if the power comes from fossil plants as when the power is generated in nuclear plants. It is possible that there will be much more per fossil kWh. But this argument is ineffective when put forward by the nuclear engineers and other protagonists of nuclear power. And of course there is no reason why people should believe us on a point like this, where we are not experts.

Unfortunately the real experts in this area have not come out in the nuclear controversy in the way I believe they should have. They have tried, and they are, as far as I know, all of the opinion that nuclear power is better than fossil power. But these people like many others do not really like to become involved in the controversy. Also when they do involve themselves, they speak more of pesticides and similar chemicals than of the carcinogenic products of high temperature combustion.

I leave this piece of advice with you. The most important task for those who fight for nuclear power is to make the biologists, the geneticists and the physicians join the debate and tell the people what they believe and to refute men like Gofman, Tamplin, Geesaman and Sternglass.

The importance of this task is underlined in our country by one of the favorite statements of our new prime minister. Mr. Falldin invariably says in all his speeches on nuclear power that other power sources may be dangerous too but that "the risks connected with nuclear power have a special dimension".

This dimension to him is partly cancer, partly the long time of the waste products. And as some waste products of fossil fuel have an infinite life, it is not really the long life of the radioactive products he is concerned about. His waste argument also boils down to cancer.

### 2.3 The Catastrophes

The cancer scare is not altogether alone, however, as the basic concern that people have with respect to nuclear power. The acute effects from the use of weapons and from large reactor accidents are a real concern to people also, and of course rightly so. But neither of these issues is specific to nuclear power, or at least they are not to nuclear power plants. My personal view is that the weapons issue is the least specific of the two. Nuclear power plants are not needed for making nuclear weapons but power is a very necessary prerequisite. It can and should be made clear that it would not be more difficult to make nuclear weapons if all nuclear power plants were torn down. It is extremely important to point out this fact in the nuclear debate.

Catastrophes could also be caused by accidents in nuclear plants, even though, as the Rasmussen report shows, this is extremely unlikely. This low but not infinitely low probability of a large accident is of course the reason why nuclear plants are not located in the middle of large cities.

This argument is not specific to nuclear power either, however. Catastrophes can be caused by fossil power plants as well as nuclear. 4000 dead is the greatest single accident toll of fossil combustion so far, while nobody has yet been killed by nuclear power outside the plants. That is also important to point out in the debate.

In Sweden it has been interesting to note that on this issue popular beliefs go much further than the nuclear foes have asked for. Very many Swedes believe that a large accident in a nuclear power plant could make the whole of the country unfit to live in. And a public poll shows that two Swedes out of three believe that a nuclear reactor may be able to explode like an atom bomb.

The anti-nuclear activists have not claimed either of these things, at least not during the seventies. The belief is without doubt the result of clever editing of picture sequences in the media, made by journalists who want to guide the opinion as they believe that it should be guided.

## 3. OUR FAILURE IN SWEDEN

### 3.1 The Public

We have fought this debate in Sweden for four years now, and we, the protagonists, have lost the debate. We lost it in the sense that we have not been able to convince the people in our country that nuclear power is no more dangerous than other power sources that are at our disposal today. There is little doubt that a referendum would today go against nuclear power in our country. At least it would do so, if people were simply asked whether they want nuclear power or not.

That the Swedes are left with grave doubts about nuclear power is also quite obvious to us from our encounters with the public. And we have really met with the public and not

only with the activist anti's. The former government arranged a nationwide grass roots study of energy problems in 1974-75. It was performed in many thousands of small groups all over the country, and I gave lectures to a number of these groups. Groups of youngsters, groups of farmers, groups of housewives etc. The participants were almost all very much concerned about the ill effects of nuclear power.

### 3.2 The News Media

The journalists and the news media have shown a variety of reactions and attitudes during our debate in Sweden. The provincial press has been less apt to believe in the accusations from the opponents than have other media. The television people and some big city newspapers have eagerly grabbed all the opportunities that the debate has given them to create ever new sensations. And the largest and most influential national newspaper is also the one which is most completely unreasonable in its anti-nuclear attitude.

Some newspapers have followed signals from political parties and several papers quite clearly obeyed political orders to switch sides in the controversy.

### 3.3 The Politicians

That the politicians have been extremely cautious on the nuclear issue is understandable. That most of them have learned very little about the issues and are therefore easily impressed by even the most superficial and non-relevant of allegations is less pardonable. With a few notable exceptions speeches and particularly newspaper articles presented by politicians on the nuclear issue have been poor attempts to summarize the issues, showing elementary misconceptions of facts and relations.

Led by Thorbjorn Falldin the agrarian Center party came out against nuclear power very early. And Falldin made nuclear power the biggest single issue in the general national election we had last fall. The outcome of the election put Falldin in the Prime Minister's chair, even though his party lost four per cent of its voters. The polls show that he gained strongly among some groups, however, and the consensus of opinion is that the nuclear power issue saved the party from a bigger setback.

The coalition led by the new Prime Minister is very divided on the nuclear issue, however, and when this paper was written the new government had not stopped the construction of any of the seven nuclear plants being built in Sweden. Much less had they stopped the operation of any of the five plants which were already operating.

The Prime Minister still remains convinced that nuclear power will be phased out no later than 1985, however. And this in spite of the fact that Sweden uses oil for about 70% of its primary energy, and is altogether dependent on foreign countries for the supply of this oil.

## 4 THE REAL BASIC ISSUES

### 4.1 How Did This Happen?

The question is of course now: How did Sweden get into this situation?

Well, explanations may be found in the actions and the inaction of the various groups involved. The protagonists came out too late and in many cases not at all. The antagonists were very active. People also seem to want the experts to be wrong and the popular media personalities to be right. And I have told you about the attitude of the politicians and the media. These things all contributed, and I will explore a couple of them a little.

One important explanation of why the Swedish public has turned against nuclear power lies in the powerful effect of repetition. This effect has been exploited very cleverly by the nuclear opponents and by some news media people. Where the protagonists are less than fully convincing, the opponents just keep hammering their allegations. Where an issue has been effectively killed, they drop it for six months or a year and then bring it up again. In the mind of the public the memory of a controversy lingers on but nothing of the facts or the outcome.

Norman Mailer has coined somewhere the word "factoid" for a statement which becomes an accepted fact by being repeated many times and often enough. We have indeed seen in Sweden how very powerful this effect is. People just seem to be unable to accept that there is not something to a statement which they have heard repeated many times.

But we have noted that the factoid affects not only the public. Even mighty tycoons of industry have proved to be susceptible to its lures.

But there must be deeper reasons also, and one that has been put forward says that people feel uncertain in a highly developed and highly mechanized society. I believe that there is a great deal of truth to that, but our experience in Sweden makes me rephrase and extend this explanation somewhat.

There is thus no question but that people feel uncomfortable in the comfortable society. And one important reason for this is their awareness of the fact that we are rapidly depleting some of the most important resources of this planet. They know that later generations will be very critical of the wasteful way of life of the generation which lives in this last part of the 20th century. They or rather we do not like the thought that we are behaving badly but we are on the other hand not willing at all to change our way of life. The only change that we are willing to accept is in fact that steady improvement of our living conditions which we have become accustomed to and have learned to expect.

I want to explore these theses a little more.

### 4.2 The Need for Power

There is one issue in the nuclear controversy which I have not touched upon before. While all the other issues are environmental, this one is not. It says:



"We don't need more power!"

This line of argument is pursued by nuclear opponents and also by other people. In Sweden they point out that the Swedes consumed very much less power in 1950 and 1960 than they did in 1976 and that we were no more happy in 1976 for all our gluttonous use of the precious commodity than we were fifteen and twenty-five years ago. They also point at public polls, which say that a majority of the Swedes would accept a lowering of their living standard as long as this means that we are not going to have nuclear power in our country.

The rebuttals are again of course easy. The Swedes have not shown any tendency to lower their demands for energy at all during the last few years. Consumption is not only a function of our own consumption of power. It also depends on the power consumption of competing nations. If these countries continue to increase their power consumption, we will have to do so too, or we will not be able to export our manufactured products. And finally, of course, we would need to increase the use of some power source, even if we were to stop the increase of the total consumption. Oil will get more scarce and more expensive, and 65 to 75% of the power Swedes consume comes from oil, depending on how we count.

But people do not want to listen to these rebuttals either. In spite of the oil crises of 1973-74 they believe or want to believe that oil will be forth-coming for the duration and at no catastrophic increase in price.

#### 4.3 The Distrust of the Experts

This is where we find the reason why people do not want to listen to experts any more. Why as a matter of fact, they want the experts to be wrong.

The resource experts enter into people's dilemma in two ways. They are partly the people who remind the rest of us of what we are doing, when we would rather forget about it or be told that we may spend with good conscience. And these experts are also the people who put the tools into the hands of society by means of which production and consumption may be increased.

So it is an easy and natural reaction to blame the experts for the wasting of the earth's resources and for the pollution of the environment that goes with it. And people do blame the experts. An amazing number of them do. And power experts are natural targets, as power is the base for all other kinds of expansion. Chemists and chemical engineers are another group that is a natural and common target.

One case from our country may be worth mentioning here. A favorite statement in the election speeches of the new prime minister, Mr. Falldin, gave as motive for dropping the new power source that "the experts do not agree about the safety of nuclear power". But Falldin never agreed to divulge the names of his own experts when the nuclear engineers wanted to discuss the issues with them. And the press and the people and even the political opposition never pressed this demand. They were all in obvious agreement that Falldin was simply saying that he did not believe the experts. And they obviously

found this position of his quite acceptable, whatever opinion they happened to have about nuclear power.

The experts on the "alternative power sources" are no more believed by the public than are the nuclear experts. Here the public, abetted by the politicians, want to hear that solar power and wind power and other alternatives will soon be cheap and will then replace nuclear power. And the reason why they press this demand is quite clearly that they want a sedative to aid their flight from reality.

The politicians also do. In various countries they have used their research funding powers to buy tranquilizers from the scientists. They suddenly become very positive to the experts and tell them how very little money they have got for their research and what miracles they could perform if they were to get as much money as the nuclear engineers get.

This strategy has not been limited to the energy field. It has been a hallowed practice in many fields and many countries for a long time. And usually the politicians find easy takers among the scientists who are chronically short of research money. Much harm has been done in this way. Harm to various fields of science and engineering and to the credibility of the experts. It has certainly been the case in Sweden during the energy controversy.

Lately, however, the politicians in our country have found it more difficult to get the number of scientists into energy research that they would like to see there. I don't yet know, but it may be that our scientists have found out that they will not be able to live up to the expectations of the politicians and that it may be dangerous for them to become involved with things that are too obviously only sleeping pills.

#### 4.4 The Popular Media Personalities

The nuclear controversy has shown again that the influence of popular personalities over the public is tremendous. In Sweden Hannes Alfvén, the pride of the country because of his Nobel prize for magnetohydrodynamics, started the nuclear debate and he has dominated the antinuclear scene throughout the four years. His credibility seems not to have suffered from the fact that he has been shown to be wrong on a number of strictly scientific points which he himself brought into the debate.

But a great number of more regular media personalities have also joined the debate on the antagonist side. They don't claim expert qualifications, but they speak out with the aplomb of experts and they are regarded as experts by an admiring public. There is no question but that very many people identify themselves with these popular personalities and want them to be right.

We have found these media people not to be susceptible to any kind of information. They habitually regard everything people in industry say to be completely unworthy of any trust. They may, for all I know, be directed by their conscience sometimes, but they have not been so in Sweden in the case of the nuclear controversy. At least very few of them

have. They have followed the sparkles of the Noble prize and the scents of sensations and opportunism.

##### 5. WHAT WILL BE THE END OF THE CONTROVERSY?

If I may finally make a prediction of the outcome of the nuclear controversy in Sweden and indeed in the world, I must come back to the ambivalence of the public with respect to growth and living standards.

While striving naturally to improve their lot, people still resist all kinds of change except this improvement. I believe that strife will overcome this resistance and that the timing of this change will be determined by power shortages and by the price of oil. When the cost of this precious commodity, of which you have so much here in Iran and we in Sweden nothing at all, has begun to make real inroads in our standard of living, then the people of Sweden will demand nuclear power. A real shortage of power will have the same result and may be earlier in arriving.

This does not mean that I believe that we should continue to expand. I just believe that people are not willing to stop expanding for the sake of saving resources for future generations. And the job of the power engineer is neither to tell the public what they should do about this choice nor to force savings by cutting power supply short. His job is to find and harness the power source that does the job in the best way.

It is also his duty as an expert to tell the people about the real advantages and disadvantages of the various power sources. This remains his duty, whether people listen or not. Just do the job, that is my advice to the nuclear engineer and informer, even if young girls shout obscenities at you as they have done to me when we have been discussing the waste problems. And even if flushed old ladies attack you as they have attacked me for having a different opinion on radioactive emissions then their favorite TV reporter.

My beliefs do not mean either that I necessarily recommend an increase in the oil price. I would feel such an increase sorely in my pocketbook. I just sincerely believe that when a certain point is reached, the issues in the nuclear debate will all be forgotten and the newspapers will roar to the experts: "Why didn't you tell us that nuclear power causes less cancer than do the fossil fuels". And the Prime Minister will say to the Swedes: "I have consulted my experts again and having studied the problems carefully they now believe that nuclear power is the safest and cheapest power source".

In some way the media and the politicians will then also be able to claim that the nuclear controversy has been good for the country and for nuclear power. This they have not been. Great damage has been done, particularly by making a whole generation of young people suspicious and afraid of a power source that they will have to live with throughout their life. And scaring good people away from a very important profession.

## **PUBLIC ACCEPTANCE OF NUCLEAR POWER DEVELOPMENT IN JAPAN**

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### **ABSTRACT**

With the rapid increase in nuclear power development, public concern over nuclear power safety, environmental impact and radioactive waste management has been gradually deepened, and public acceptance affairs have become one of the most immediate issues to be resolved for future development programs. This paper describes the characteristics of anti-nuclear movements in Japan, and future policy and programs to be performed by both government and private sectors in the efforts to win public acceptance.

### **1. INTRODUCTION**

With scarce indigenous energy resources, Japan is placed in an extremely fragile position compared to other industrial countries, since she has to depend on foreign countries for nearly 90% of her primary energy resources. As increased production of petroleum is expected to reach its peak within the next 10 years, there is much need for this country to reduce as much as possible the dependence on foreign oil and to diversify the sources of primary energy. From this point of view, the shift to nuclear energy, as the most reliable major source of primary energy, is essential for Japan in maintaining her economy.

According to long term demand for primary energy, drafted in September 1975 by the Overall Energy Policy Committee of the Ministry of International Trade and Industry, primary energy requirement for 1985 was estimated to be 760 million kl in oil equivalent of which nuclear power accounted for 49,000 MWe or 9.6% of the total. While the increase of demand for the total primary energy was calculated to be an average of 5.3% per annum, that of the nuclear power was estimated as high as 32.3%. However, as things developed, it soon became apparent that nuclear power construction programs would be delayed and the target of 49,000 MWe is unlikely to be achieved. New target figures are now 25,000-27,000 MWe or even lower for 1985. For the most part, siting has proved to be difficult due to lack of understanding and support on the part of the local citizens. This was triggered because of their concerns over the safety of nuclear power and their interest in protecting their established fishing industry from the adverse effects of thermal waste water. This paper explains the present situation concerning public acceptance of nuclear power and measures taken by both public and private organizations to deal with it.

## 2. STATUS OF PUBLIC ACCEPTANCE

Japan first began developing nuclear energy for peaceful uses in 1956. Today, nuclear power plants in operation, as of March 1977, are 13 units with a total capacity of 7,430 MWe.

During 20 years of Japan's nuclear history, the first half was devoted to research and development, which was pursued enthusiastically with the support of all political parties. However, as the development of nuclear power progressed and the social involvement increased, people began to raise doubts as to how it should be developed. The situation reached its worst in the last 2 to 3 years as a series of operating troubles of nuclear power plants and radiation leakage from the reactor of the nuclear ship "Mutsu" were reported.

The anti-nuclear movements were initially local, focusing on the safety of nuclear power and on the fact that nuclear power plants to meet the demand of the electricity consuming big cities were constructed in the areas where electricity consumption was rather small. However, as the progressive forces (political opposition parties and labor unions) and the affiliated scientists and intellectuals became involved, it evolved into a political issue, having undergone a qualitative change in its nature. Moreover, it has become a national movement linking up with the consumer movements in large cities and practicing closer cooperation with anti-nuclear organizations around the world.

There are 3 cases of law suits demanding the government to withdraw construction permits for Shikoku Electric's Ikata Power Plant, Japan Atomic Power Co.'s Tokai No.2. Power Plant and Tokyo Electric's Fukushima Daini Plant. In October 1976, the Japan Federation of Bar Associations, to which all lawyers in Japan are affiliated, published a statement demanding a review of the nuclear power development program, including the suspension of construction and operation of nuclear power plants.

The reasons behind this active anti-nuclear movement in Japan can be accounted for as follows: (1) Unique national sentiment arising from experiences with atomic bombs and the radiation exposure to fishermen by the nuclear explosion at Bikini Islands, as Dr. Husimi stated in his opening remarks. (2) The latent anxiety of the people about nuclear power, amplified by various news media willfully distorting the picture and fighting the issue on ideological grounds. (3) Increased awareness of the public about polluted air, water and the destruction of the environment and other impacts on nature which accompanied conventional industrial developments.

If one were to summarize the issues raised by the opponents of nuclear power they are: (1) distrust of the nuclear administrative setup; which stemmed from the radiation leakage of the nuclear ship "Mutsu", and the increased criticism of the responsibility of authorities for nuclear safety, (2) doubts about the adequacy of Emergency Core Cooling Systems, performance of the cladding materials and the related engineering safety to nuclear facilities as well as the impact of thermal waste on marine life, (3) doubts against the economy of the nuclear power plant and LWR technology because of the repeated operating troubles of the early power plants, and the resultant low load factor, (4) lack of policy and



measures for the back end of the nuclear fuel cycle, such as the management of radioactive wastes.

### 3. FUTURE POLICY AND PROGRAMS

In response to this situation the following measures are being taken in Japan to win public acceptance for nuclear power development.

#### 3.1 Establishment of Nuclear Administrative Setup

With regard to the nuclear administrative setup, the private advisory body to the Prime Minister, the Council on Nuclear Administration, Dr. Hiromi Arisawa, Chairman, the Japan Atomic Industrial Forum submitted a set of recommendations on July 30, 1976, after a year and a half of deliberations. The first point taken up concerned the status of the Atomic Energy Commission. It suggested that the AEC, which has hitherto held dual responsibilities for both the development and regulation, should be separated to form two independent organizations, namely, the new Atomic Energy Commission and the Nuclear Safety Commission.

The second point concerned the consistency of nuclear safety administration. It recommended that the Science and Technology Agency be responsible for the facilities during the developmental stage, and the Ministry of International Trade and Industry for industrial facilities such as the power plants, and the Ministry of Transport for the nuclear ships, so that consistent safety regulations can be implemented. It also recommended that the Nuclear Safety Commission make safety standards and review the safety analysis reports prepared by administrative organizations.

Subsequently, the Government decided on the establishment of a nuclear Safety Commission to streamline the nuclear safety administration. The related bills are now before the Diet for deliberation and the new commission is expected to come into being sometime in October. Public hearings on the nuclear power construction program were held, according to the regulations laid down by the Atomic Energy Commission, only on occasions deemed necessary by the AEC. And for this reason, and others, including complaints that the speakers are appointed, speaking times are allocated and that questions and answers are not permitted, public hearings had not been held since September 1973, when one was held concerning the construction of Tokyo Electric's Fukushima no.2 site unit 1.

Considering these factors, the Council for Nuclear Administration suggested the revised procedures to conduct "open hearings" to be effective possibly after October this year. According to the recommendation, "open hearings" are to be held two times for all nuclear power plants. The first one is to be held by the Ministry of International Trade and Industry before the electric utilities' nuclear power plant projects are to be reviewed by the Electric Power Resources Development Coordination Council. In this case, general discussions will be conducted on the environmental, economic and social aspects of the

projects with the attendance of local people in the vicinity of siting areas.

The second one will be held under the auspices of the Nuclear Safety Commission, inviting MITI and the residents, the former to explain to the latter the substance of its own report on reactor safety and to answer questions asked by the residents. Taking into consideration the questions and opinions expressed by the residents at the hearing, the Nuclear Safety Commission would then examine the report on reactor safety prepared by MITI.

Thus, the two step "open hearing" system is expected to be more effective in getting public acceptance of nuclear power compared with the present system, and with this, licensing procedures could be reliably facilitated.

In addition, the Council made suggestions for a 'public symposium'. The objective of this symposium is that on highly specialized issues such as nuclear safety and energy policies, the scientists and specialists should be invited to discuss them thoroughly on independent, fair and scientific grounds, for the benefit of the people making decisions.

### 3.2 Strengthening Researches on Safety and Environmental Impacts

The basic requirement for public acceptance of nuclear power is of course the assurance of safety. There are currently a number of safety studies conducted by the Japan Atomic Energy Research Institute including ROSA (Risk of Safety Assessment) and NSRR (Nuclear Safety Research Reactor). There are also joint works conducted at the international level, through bilateral agreements with the US or West Germany and also through the International Atomic Energy Agency. A Nuclear Engineering Test Center was established in 1976 with the cooperation of both the public and private sector to demonstrate and test the anti-seismic strength of nuclear reactors. Furthermore, the Nuclear Safety Research Association is conducting a probabilistic assessment for nuclear safety, which can be termed a Japanese version of the Rasmussen study. Because of the limited nature of geography in Japan, the nuclear power plants would have to be concentrated in certain areas which consequently will raise important concerns for environmental impact on fishes. The Marine Ecology Research Institute was established in 1975 to conduct systematic research on the impact of thermal waste on marine resources. The National Institute of Radiological Sciences is involved in the study of the effect of radiation on life.

### 3.3 Improvement of Capacity Factors and Establishment of LWR Technology

The average capacity factor for nuclear power plants in 1975 was recorded at an extremely low figure of 35.7%. Consequently, the economy of nuclear plant was questioned. The low performance was caused by leakage in PWR's steam generator pipes, and stress corrosion of BWR pipes, and the need to shut down the plants for a prolonged length of time. Capacity factors of light water reactors have improved since to 63% in the first half of fiscal 1976 as troubles were remedied with the cooperation of reactor manufacturers and electric



utilities.

Meanwhile, since it is important for Japan to develop the LWR technology more conducive to our environment, MITI is currently engaged in efforts to improve and standardize this type of reactor. Standard types of 800 MWe PWR and 1,100 MWe BWR will be applied to Kyushu Electric Co.'s Sendai unit 1 and to Tokyo Electric Co.'s Fukushima no. 2 site unit 2 respectively.

### 3.4 Measures Concerning Management of Radioactive Wastes

The need to set up measures to cope with the back end of the nuclear fuel cycle, and the management of radioactive wastes in particular, is increasingly becoming an important issue in gaining public acceptance and continuing with development programs.

Japan's present measures relating to radioactive wastes are embodied in the basic policy published in October 1976 by the Atomic Energy Commission. Accordingly, the roles of the state and the private sector are defined for the solidification and temporary storage of high level radioactive wastes and the deep sea disposal of the low level solid wastes.

Reflecting the definition of the respective roles, the utility companies and the fuel manufacturers jointly established in October 1976 the Radioactive Waste Treatment and Disposal Center, which will undertake feasibility studies for various disposal methods for the low level wastes and demonstrate the safety of such treatment and disposal works.

In the meantime, the pilot reprocessing plant (210t/year) of Power Reactor and Nuclear Fuel Development Corporation at Tokaimura is expected to start a hot run test operation using spent fuels, and high level wastes from the plant are to be stored in a tank over 5 years. There is of course an urgent need to develop technology for solidification and to decide on the practical means of disposal for the period beyond, considering the second reprocessing plant.

The Study Group on High Level Radioactive Waste Management under Japan Atomic Industrial Forum, after studying this problem has recommended that a permanent central organization be established to proceed with research and development in this area.

### 3.5 Japan's National Policy vis-a-vis the Regions with Nuclear Power Plants

Needless to say, successful acquisition of sites for nuclear power plants demands first of all the understanding and cooperation of the local citizens. Towards meeting that goal, the assurance of safety as well as the reflow of advantages accruing from such facilities, in terms of economic development and improvement of social welfare, must also be guaranteed.

It was for this reason, that in 1974, three laws concerning power sources development were enacted. They are the Law for Adjustment of Areas Surrounding Generating Plants, the Law on the Special Account for Power Sources Development, and the Power Sources Development Taxation Law. This enabled the local communities to receive grants, 300

million yen (1 million dollars) for 1,000 MWe over 5 years, which will be used to improve public facilities such as sports, recreational, educational, cultural, and other facilities, including roads, harbors, water supply services.

#### **4. CONCLUSIONS**

Gaining public acceptance will inevitably vary from country to country. There is no royal road for getting public acceptance. In other words, no one method is right for all. But one basic concept may be shared by all, that safety criteria, safety research, licensing procedures and all aspects related to environment are managed for the benefit of the public. As long as this basic concept is shared, international cooperation in the field of public acceptance beyond national boundaries is possible. And as long as nuclear technology is international, closer international collaboration in the field of public acceptance of nuclear power must be pursued.

## **IS THE NUCLEAR CONTROVERSY TRANSFERRED BY TRANSFERRING NUCLEAR TECHNOLOGY?**

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### **ABSTRACT**

After a period of impetuous development in nuclear energy over the past thirty years, it has become, to an ever increasing extent, the subject of public discussions concerning its pros and cons, and that at a moment when nuclear energy has proved its competitiveness with conventional energy sources and when it has attained an extraordinarily high level of safety. In the industrialized countries, this controversy has come to public resolutions, political initiatives and the occupation of sites intended for the erection of nuclear power stations.

The reasons for this situation may be found in the vanishing belief in technical progress in industrialized countries and in the state of saturation reached as far as the standard of living is concerned. In addition, there is an increased sensitivity to environmental impacts of a most diversified nature which is consequently combined with a relativization of growth and quality of life.

Is now the transfer of nuclear technology to developing countries inevitably combined with the transfer of the nuclear controversy? The existence of completely different pre-conditions speaks against this presumption.

As the result of an analysis it is shown that the initial positions of industrialized nations and developing countries are basically different as far as the introduction of nuclear energy is concerned and the objectives and conditions are completely divergent.

On this basis the prerequisites for an arising nuclear controversy in the developing countries are investigated. In the light of experience with the introduction of nuclear energy in several countries a proposal is made for an information program helping to avoid difficulties and offering the instruments required to diminish the resistance which will possibly occur and to counteract misgivings caused in this connection.

At the end of a period of rapid growth in the field of peaceful uses of nuclear energy during the past 30 years, public discussion concerning the pros and cons has continually gained in vehemence in industrialized countries. At the outset of the development in the field of nuclear energy, the predominant majority of the population applauded the technical and economic progress apparently connected with nuclear energy while there was only subliminal disapproval as far as military uses are concerned. However, in recent years, ideological, political and ecological arguments have been raised to an ever increasing

extent against any kind of nuclear energy utilization.

The controversy today is reflected by public resolutions, political initiatives, demonstrations and occupations of sites envisaged for nuclear plants. It is especially violent at a moment when nuclear energy has proved its competitiveness and even economic superiority to conventional sources of energy and, more than that, could reach an extremely high level of safety so that, after thorough investigations<sup>(1)</sup>, the risk of nuclear energy for the population is by many orders of magnitude smaller than that of other civilizational and technical installations.

To inform the public about the complex and intricate correlations of nuclear energy, extensive activities were displayed by various governmental, private and industrial agencies. Information was given about the future development of energy requirements and the possibilities of covering them, the mode of operation of nuclear power stations and their safety, the special problems concerning the fuel cycle and the different environmental impacts, particularly, the effects of radiation. The most diversified target groups were addressed both verbally and in writing with versatile representations on the benefit and risk perspective of nuclear energy.

Although in the opinion of many persons involved such information was far too late, it is certainly true that as a result of this the absolute majority of the population looks favorably upon the introduction of nuclear energy to the energy supply system of the individual industrialized countries, while another part is accepting it with reservation. It must be admitted, however, that it has not been able to prevent an extremely active minority from organizing fierce resistance to nuclear energy.

Unlike the silent majority, this minority is in a position to express itself with great effectiveness. It may be ascribed to the engagement of this minority that due to an exponentially increasing number of objections to licensing procedures, notable and very expensive delays have occurred in the completion of planned nuclear power stations. Fig. 1 illustrates this situation for the hearing of the population involved in the Federal Republic of Germany according to the licensing procedure provided by the Atomic Law. Moreover, legal proceedings before ordinary courts against the construction of nuclear power stations have given rise to temporary paralyzation of nuclear power stations under construction at three building sites in the Federal Republic.

Reasons for this situation might be sought in the vanishing belief in progress presently observed in industrialized countries as well as in a certain degree of saturation of the standard of living. Furthermore, the consciousness in favor of energy requirements has been lost since it is taken for granted that sheer unlimited quantities of fuels for heat production and of electricity are available for almost all spheres of daily life.

This habituation to a certain stock of energy sources available has given rise to the fact that the multiple dependencies on these sources of energy are not clear to the individual. Representative functions of such dependencies are economic growth, employment position, standard of living, industrial development, technological progress and the gross national product; the latter is represented in Fig. 2.

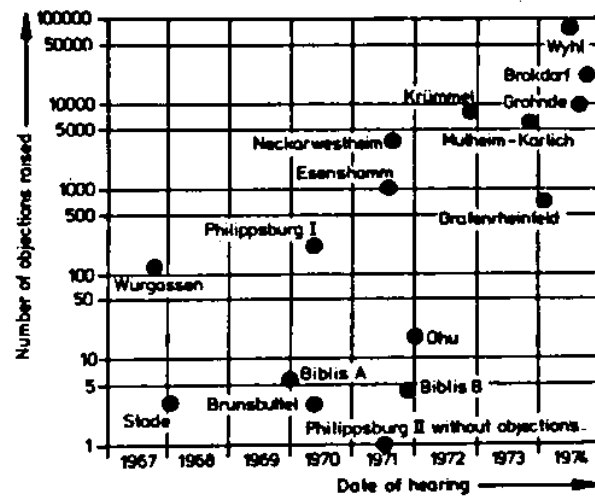


Fig. 1. Number of Objections Raised against LWR Power Stations in the FRG (Hearing According to Para. 7 of the Atomic Law)

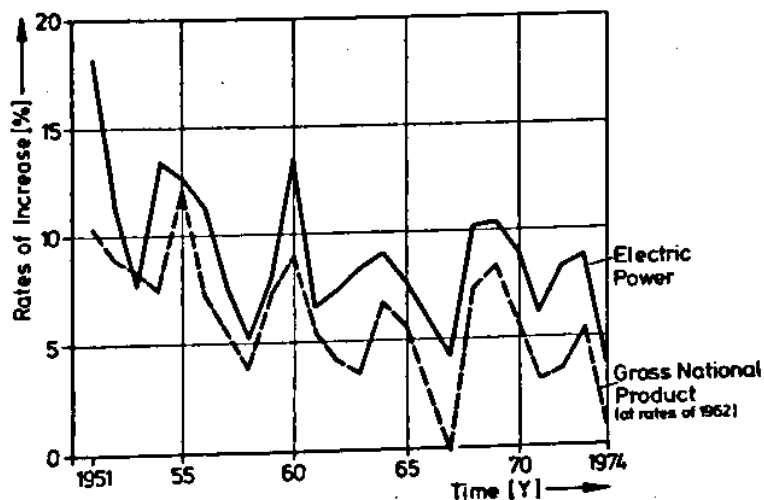


Fig. 2. Rates of Increase in Power Consumption and Gross National Product

In addition, there is an increasing sensitiveness to environmental impacts of the most different kinds. These impacts have already reached certain limits of reasonability as a result of industrial plants erected in part with outdated technology. Consequently there is a reduced readiness to accept new risks even if they are of a different nature.

These arguments are strengthening the trend already existing among the population towards a pronounced relativization of growth and quality of living aspired to, which was

Initiated by the analysis of the Club of Rome<sup>(2)</sup>.

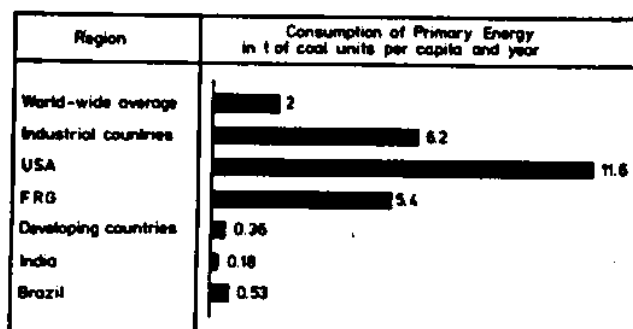
This basic attitude is accompanied by subliminal apprehensions of a psychological nature in respect of an invisible, dissimulated danger. The deplorable results of the military application of nuclear energy in the form of the atomic bombs of Hiroshima and Nagasaki give an optical impression of the picture too easily forming in the imagination of intimidated citizens. It is evident in this situation that more emotional arguments concerning the problems of safety, risk and effect of radioactive radiation will meet with response more easily.

To sum up, it can be said that, as a result of the overall outlook, considerable resistance is being put up by a qualified minority to the introduction of nuclear energy, although it is the opinion of almost all experts that without nuclear energy it will be impossible to expand or even to maintain the standard of living in those countries.

The question arises now as to whether, in line with the desirable transfer of nuclear technology from industrialized countries to developing countries, the nuclear controversy will inevitably be transferred, too. The salient differences in the prerequisites for introducing nuclear energy to industrialized and developing countries induce us to answer the question in the negative.

The utilization of nuclear energy offers an excellent chance to increase the level of development of a country and to raise the standard of living of the individual, a fact which is also confirmed by relevant studies. This is particularly true after the exorbitant increases in crude oil prices by which the developing countries are affected incomparably more seriously than the industrialized nations so that the trend to catch up with the standards of industrial development is aggravated in addition. It is just the availability of sufficient energy resources which offers the possibility of obtaining economic growth and, consequently, an enhancement of the standard of living. Whereas in highly industrialized countries the correlation between economic growth and increased requirements of energy can be equated to 1 or may be slightly below this factor on the grounds of technological progress, this correlation will reach double the value in the developing countries, i.e. the increase of energy requirement is about double the growth attained by it. When considering the actually prevailing rates of energy consumption per capita of the population in the various regions throughout the world, as illustrated by Fig. 3, it becomes clear that it is an absolute necessity to make energy available to a sufficient extent for a specific development aspired to.

However, if a further deterioration should occur in the oil market there would be a gap in coverage of energy requirements which can be closed solely by nuclear energy. The supply of nuclear energy allows the development of industrial capacity rooted in the region. It enables own reserves of raw materials to be exploited and refined, and, particularly, it will promote the utilization of uranium resources. Chances of employment during construction and operation of nuclear energy plants promote the industrial structure and will create a domestic system of know-how. Altogether this will accelerate the commencement of the diverse phases of development aspired to.



*Fig. 3. Consumption of Primary Energy per Capita in Different Regions in the Year 1972*

The Industrialization of developing countries finds itself in an early phase with high annual growth rates. Per capita income and level of training exhibit a pronounced graduation, i.e. a well educated and well earning stratum is confronted with the broad mass of population which can only gain in education and property. In addition, there exists full confidence in industrial progress from which the population of a developing country rightfully expects advantages and evolution.

There is naturally not any consciousness of environment in the developing countries such as is formed in industrialized countries which are in part considerably handicapped by ecologically harmful substances. The construction of each industrial plant and also that of a nuclear power station means the creation of additional jobs and a possible improvement in the social position. Industrialization is generally welcomed as progress and far less considered to be a potential confinement of the living space or destruction of natural environment. To undergo personal financial sacrifices for the preservation of the environment is completely unintelligible to the broad mass of the people.

Such a positive basic attitude towards the introduction of nuclear energy is supported and maintained by imparting know-how and transferring technology where the training in the relevant scientific disciplines should take place in line with information about benefit and risk of nuclear energy.

Which points of crystallization are now imaginable or perceivable for a commencing nuclear controversy in a developing country or in a country at the threshold of industrialization?

A certain upper class of the population generally has good contacts with government and industry and will be prepared to support and share their decisions. A partly elite-conscious middle class is in general well informed by international media and contacts with foreign countries and is in a position to perceive the significance of a nuclear energy program for a developing country. This may give rise to a trend towards an "imported" fundamental disapproval of nuclear energy. Criticism originating from this category of people may be constructive to a high extent, their opposition, however, might become a



serious obstacle to the implementation of development projects on the basis of nuclear energy. Therefore this social stratum will have the function of a jointly responsible supporter of such programs as well as that of a regulative control. Engineers, scientists, project managers, teachers and university professors are recruited from this class.

As an example Brazil has shown by the reaction of its Physics Society (Soziedade Brasileira da Fysika), following the conclusion of the German Brazilian Nuclear Energy Agreement, that the problems arising were subjected to an early discussion and studied by a special commission. The result of the investigations was a list of measures to be taken which, exactly as in the case of industrialized countries, were within the scope of safety problems and environmental impacts of nuclear power stations, but which also provided for the development of an adequate training program and long-term research planning for the evolution of independent reactor systems<sup>(4)</sup>, a fact which is rather typical of developing countries. These efforts were quite beneficial and likely to speed up the relevant training programs, arousing the interest of universities and research institutes in taking part in nuclear programs. Consequently, the specified arguments should be taken into consideration for the conception of nuclear energy programs.

Despite the fact that the scientists are willing to cooperate, accentuated criticism is being observed at congresses which are made public by the press and find wide response.

Owing to the skillful policy of information by the government and to their unbiased reporting, it has so far been possible to avoid any stronger polarization of the discussion. Thus, nuclear energy has been able to continue to meet with the approval by the broad mass of the people.

Critical reactions in the press and sometimes even in the public were provoked by the choice of power station sites, particularly in those cases where they are located in beautiful landscapes of value to tourism. Such reactions should be observed attentively since in this case the inclination of the broad majority of the population to consent to nuclear energy programs in developing countries might be affected adversely. Accurate information about nuclear energy should avoid the possible arousal of fear of the unknown by an elitist group. This is especially important for the press of the developing countries in their detailed reporting on the nuclear energy debate carried on in industrialized countries.

A further aspect for a nuclear controversy in developing countries is manifested by the behavior of political oppositionists or by the reaction of neighboring countries to nuclear energy programs. It is often insinuated that in the first line the country in question apparently intends to develop nuclear industry with a view to producing nuclear weapons or at least to creating the prerequisites for this purpose on a long-term basis. This is not the moment to discuss the realizability of such intentions, but rather the aspect of the grave misgivings exhibited by nations and groups of population which fear to be immediately affected by this. However, the non-proliferation treaty seems to be of special importance in the context.

A further motivation is the fear of economic preponderance caused by the fact that low-

priced nuclear energy enables growth out of proportion and jeopardization of the local economic equilibrium. These apprehensions frequently give rise to the demand for autonomous nuclear energy programs in the neighboring countries.

While the fear of nuclear threats can be attenuated by treaties and international arrangements, economic competition between adjacent countries may contribute to a more rapid development of domestic industry. Recent developments in Brazil and in Argentina even give rise to the hope that a bi- or multi-national economic policy might arise.

The initial position of industrialized nations and developing countries is basically different as far as the introduction of nuclear energy is concerned; the objectives and marginal conditions are completely divergent. Nevertheless, there is a certain risk of nuclear opposition being organized and, consequently, of a nuclear controversy, particularly with a view to a social structure subjected to a rapid change in line with advancing industrialization.

In this connection, it is recommended to embark upon comprehensive educational and informatory efforts, which in the light of the negative experiences undergone in industrialized nations, are apt to eliminate difficulties, to avoid or to reduce resistances and to stem apprehensions.

Based on the belief in progress existing among people, information about nuclear energy should be imparted along with knowledge required for industrialization. This information should point out the possibilities involved in the development of nuclear energy with respect to its eminent significance for both improvement of the standard of living and growth perspectives of the country concerned. This knowledge must be presented to the respective group of persons interested in a receptive manner and in a form sufficiently illustrative, particularly, if any visible symptoms of nuclear energy development, such as research reactors or similar installations do not exist.

The reactions among population groups which, as a result of their level of education and their information possibilities, are in a position to follow the international discussions concerning the pros and cons of nuclear energy, are similar to those observed in the industrialized nations. Just these groups should therefore be interested in imparting knowledge and they should be actively involved in a campaign of information. Universities, scientific institutes, teachers and professional organizations should also be interested in such a measure. The same applies to persons entrusted with the enhancement of the development stage, with the task of raising the standard of living and with the procurement of energy as well as to organizations, administrations and government agencies.

Informing the media, particularly the press, as early as possible, offers the chance for a broad discussion and creates the prerequisites for qualified and unbiased reporting.

Special emphasis should be placed on information at schools and universities, because, as a rule, the age pyramid in developing countries exhibits an extremely broad basis. As an example, attention should be focussed on the PR-campaign of the Nuclear Energy Information Committee of the German Atom Forum aimed especially at a target group consisting of school students and their teachers. This campaign includes a colored book about nuc-

lear energy and three color films about special nuclear topics. Besides that teaching materials such as colorgraphs for overhead projection, audio-cassettes, slides, posters, and teachers' manuals have been produced.

It is necessary, even among the young generation, to create a solid basis of knowledge, which helps diminish the fear of unknown technologies and prevents military exploitation and peaceful uses of nuclear energy from being measured with the same yardstick.

This intensive education will in addition create the basis for a personnel capacity required to skip, within a relatively short period, over a gap in development, which was filled out by several decades of intensive work in industrialized countries. Negative examples of industrialized nations will have to be neutralized, while positive hints from other developing countries might be of great assistance.

Special intensive and early information should be given to politicians, since in the last analysis, it is up to them to make binding decisions on nuclear energy programs. They should be furnished with all and any information available on the possibilities offered by nuclear energy for the development of their country and on the alternatives possibly available to them beyond nuclear energy.

Misconstrued parallels to the developing countries are likely to impede progress in a country if such parallels are drawn in the sphere of the controversy about nuclear energy. The conditions outlined above form a positive basis for a successful organization of the information policies suggested. In this manner, it should be possible to transfer nuclear technology to developing countries without exporting the controversy about nuclear energy from industrialized countries.

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## THE NUCLEAR CONTROVERSY IN EUROPE: IS THE BALANCE POSITIVE OR NEGATIVE

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### ABSTRACT

The nuclear controversy definitely delays the implementation of some European nuclear programs. An attempt is made to analyse the negative and the positive aspects of the opposition to the utilization of this new form of energy.

### 1. INTRODUCTION

Electricity has an important role to play to cover part of the world future energy need. Electricity is easy to transport. It can be used in an efficient and versatile manner. Furthermore, it does not create any pollution at the consumer level. These aspects of electricity put it first on the list of possible substitutes to the world dwindling oil and gas resources. It is, therefore, reasonable to assume that electricity demand will grow in the years to come.

Even with the lowest possible hypothetical growth rate coupled with intensive energy economy, Europe's growing electricity requirements will have to be met with the construction of new power stations. Some of these new stations will definitely have to be nuclear stations.

Without the construction of these nuclear stations, the entire increase in electricity demand must be met either by oil and gas or by coal. The use of oil and gas for electricity generation is in contradiction with the principle of substitution and will inevitably lead to price rises as a result of resources depletion. The use of coal, though it is quite plentiful, will be restricted by the severe social, technical and environmental problems, arising when it is burned in the huge quantities required.

In fact, it is not unrealistic to assume that without nuclear power, Europe could be set on the road to industrial, economic and then cultural decline by the end of the century.

Can nuclear energy help Europe to avoid this decline? On purely technical and economic bases, the answer is definitely yes. Nuclear energy is almost certainly the safest and the cheapest way to produce electricity known today. Politically and from the point of view of public acceptance the answer is more difficult. The nuclear controversy is in full swing and its outcome is today quite unpredictable. This paper will study the origin and the organization of the nuclear opposition in Europe, its methods of action and the results achieved thus far.

## **2. THE OPPOSITION - WHENCE DOES IT COME?**

In order for any opposition to develop, there must be either a public appeal or a public fear to build on.

The fear is definitely at hand because with the Hiroshima and Nagasaki bombs, nuclear energy entered on the scene with the image of a force capable of destroying mankind. Philosophers and learned people of all reaches have claimed that one day, scientists and engineers, like the sorcerer's apprentice, will not be able to master their invention any more. This invention seems the more threatening in that it deals with phenomena where the infinitely small, the infinitely fast and the infinitely strong mix together. In this line of thinking nuclear energy appears to be a tremendous supernatural force resting in the hands of a small group of privileged people securing in this way an extraordinary power that could enable them to control humanity.

The appeal is here too, though less easy to define. It has certainly to do with the realization that the materialistic attitude that has prevailed during the last decades in the industrialized countries leads to absurdities if pushed too far. It also involves, at least in the same countries, the awakening of an interest in the protection of the environment against the pollutions produced by poor technologies.

The fears and appeals are being used in many countries as a political weapon against governments as well as against the existing structures of society. In this manner, nuclear power is assimilated to the police state, multinational trusts and the consumer society. Instead of nuclear power, a zero growth economy and soft decentralized energy technologies are proposed without any supporting technical evidence and analyses of possible consequences if implemented.

With these motivations, it is interesting and not surprising to observe that most people active in the nuclear opposition are recruited from among the better part of the population. These people are often active in or close to environment and consumers' organizations. In most European countries, as in the United States, they have a large influence on the media: press, radio and television.

Last but not least, careful attention should be given to the actions of a small but very active and sometimes very violent group of extremists using opposition to nuclear energy as a means to disrupt the economy and the organization of democratic countries.

## **3. ANTI-NUCLEAR ACTIONS**

The arguments used as a base for anti-nuclear actions are changing with time, place and political circumstances. Discussions of the effects of radioactive effluents during normal plant operation and of biological damage resulting from low doses are followed by questions on reactor safety generally centered about very hypothetical catastrophic accidents or results of human failure. Plant cooling problems lead to questions about the financial and economic aspects of nuclear energy to end up with considerations on power

growth, conservation and uranium resources. Today, the physical protection of nuclear materials against terrorists, the non-proliferation issue as well as the safe disposal of radioactive wastes are in the limelight. The recent judgment of the court of Freiburg in Germany might raise again the question of catastrophic rupture of pressure vessels.

All these arguments lead to anti-nuclear actions which are diverse. Some are spectacular, others less obvious but often more insidious. Their effectiveness can range from negligible to being capable of delaying or stopping a nuclear power program.

Among the commonest actions are:

- Violent demonstrations: destruction of boundary fences and walls, of geological and meteorological testing machines, of vehicles and mobile equipment generally ... attempts to destroy installations under construction and even those in operation ... attacks on offices. These actions are normally the work of small groups of devoted extremists.
- Peaceful demonstrations, which however sometimes get out of control and degenerate into violence. Such demonstrations normally begin as protest meetings at sites proposed for nuclear plant, or sites where construction is already under way. They may involve hundreds or even thousands of protesters, though it is rare for them to reach 10,000. Many of those involved will have come from far away (even from other countries) in private cars, coaches, or on foot from nearby assembly points. Local participation is normally minimal, and appears to be due to curiosity rather than a desire to protest. Sometimes the demonstrations are combined with folkloric events, "pop" festivals, rustic fetes etc.
- Occupations of nuclear installation sites, frequently coupled with youth rallies and meetings (teenagers, university undergraduates and some young graduates) at which all aspects and problems of today's world and way of life are discussed and debated.
- Public meetings, to which the organizers invite representatives of the electric utilities and construction companies concerned, with the intention of discrediting them in the public eye. There is growing recourse at these meetings to well-known "specialist" nuclear opponents, highly experienced in confusing and confounding inadequately prepared engineers over ecological and related questions.
- Publication of tracts, brochures, pamphlets, satirical papers and magazines, which are widely distributed at protest demonstrations and public meetings (even meetings which may be organized by "neutral" local authorities or by organizations supporting nuclear power), and distributed also through the letter-boxes of those living near a proposed nuclear site.
- Publication of articles in respected newspapers and periodicals, which believe in providing space for all matters of current public interest.
- Posters, car stickers, flags, steamers, slogans in chalk or paint on walls etc.
- Hostile participation in radio and television debates, which are more and more



commonly organized for the discussion of energy questions in general, and nuclear energy in particular.

Local and national authorities may themselves provoke (unintentionally or otherwise) impediments to nuclear development as a result of:

- site authorization and plant licensing enquiries and hearings;
- requests for additional studies (environmental, economic, demographic etc) by electric utilities and construction companies wishing to build nuclear plant;
- linking the nuclear proposals with other developments (oil storage depots, motorways, airports, social and sports centers, archaeological centers etc);
- application in the most restrictive sense possible (often tantamount to modification) of norms for environmental radioactivity, cooling water discharges etc;
- raising social problems linked with the integration of construction workers (frequently immigrants) into the local populations;
- taking advantage of local political circumstances (coming elections, possible regrouping of communes etc) to avoid decisions whose political repercussions are unpredictable;
- accepting the creation of commissions of enquiry;
- proposing further public debates, notably in parliament;
- proposing (or organizing) referenda;
- accepting (or organizing) avoidable legal procedures and associated enquiries.

These actions are reinforced by the excellent communications and exchange of information existing among opponents from various countries i.e., the so called anti-nuclear grapevine. A large amount of anti-nuclear information and slogans have been exported from the United States to European countries and some international ecologist organizations are working as clearing houses for information exchanges between countries.

To day, some efforts are made to extend this collaboration to a tighter coordination between the various groups active in the nuclear opposition.

#### 4. EFFECT OF ANTI-NUCLEAR ACTIONS

The results of the nuclear controversy are difficult to evaluate in a global manner.

Nevertheless, a few facts are certain. First, nuclear energy exists, and it is impossible to "disinvent" it. Because of its many advantages over other forms of energy conversion it is also very unlikely that a general abandonment of its use could take place. Furthermore, the future needs for energy and particularly for electricity are such that it is foolhardy to reject any available practicable source especially on the ground that it should not be used before the last small detail about safety and reliability has been worked out. Technology just does not work this way. Progress and improvements come step by step, and the only way to achieve results is by building facilities as soon as it has been asserted that the associated risks are not larger than risks usually taken in existing industrial undertakings of the same field.



With this in mind, the effect of anti-nuclear actions can only be a delaying one, and the negative and positive results of these actions can be stated as follows:

#### Negative

- Ever increasing delays in obtaining site approvals ... frequently involving several site changes (and sometimes resulting in the sites finally approved being less technically suitable - and more expensive to develop - than those rejected). The heavy expense of site exploration and investigation is of course related approximately linearly to the number of sites investigated before one is approved.
- Increasing construction delays due to protest manifestations, strikes (on site and in factories supplying materials and components), and various separate authorizations needed at particular stages of building.
- Additional delays when, the plant being completed, operating licences have to be sought.
- Additional costs for unnecessary construction work (over-complex inlet and outlet tunnels for cooling water, large and unsightly cooling towers, defensive measures against possible sabotage, costs of ecological studies which are invariably shown to have been unnecessary.

To all these delays and additional costs must be added the very substantial losses due to the obligation to meet a rising electricity demand, requiring the continuation in service of old and inefficient power stations, and even the construction of new "conventional" plants having much higher production costs than would result from the nuclear stations.

#### Positive

- The public is now much better informed.
- Safety aspects of all nuclear installations are studied in exceptional detail and with exceptional thoroughness, from the viewpoints of both the general public and the workers in the installations.
- Improved understanding of the phenomena of radioactivity, especially those related to public health and food chain.
- Carefully studied "integration" of nuclear power stations into the local topography and human environment. Touristic considerations.
- Careful consideration of (and technical aid for) local agriculture, pisciculture, town heating.

Analysis of the effects of the controversy on plant costs shows an average cost increase of about 15% due either to delays or to the necessity, justified or not, of installing additional equipment. Whether the money so invested could have been invested more profitably in other activities remains unanswered for the time being.

## 5. CONCLUSIONS

It is probably as yet too early to conclude whether the balance from the nuclear controversy is positive or negative, but it is already indisputable that it has resulted in

vast additional expenditure that will necessarily be paid by electricity consumers. Furthermore, this large expenditure is withdrawn from the economy and cannot be spent elsewhere.

The data to determine if other uses of this money could have yielded more profitable results are not available today. One positive result the nuclear controversy could produce would be the undertaking of comparative cost-benefit analyses of additional safety among the various energy conversion systems available today. It is probable that such analyses would show that compared to oil, gas and coal, nuclear power is outstanding as an example of safety and prudence.

## **SAFETY CONSIDERATION OF NUCLEAR POWER SYSTEMS IN NON-NUCLEAR AND DEVELOPING COUNTRIES**

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### **ABSTRACT**

Rising international demand for nuclear power plants raises many questions regarding quality assurance procedures and safety regulations aspects of the transfer of nuclear technology to non-nuclear countries. The public attitudes toward the spread of nuclear energy utilization are assessed to provide a frame of work for examination of safety aspects of nuclear power plants in developing countries. Public attitude in nuclear countries is found to be distinctively different from that in non-nuclear countries. The safety-related problems of building nuclear power plants in developing countries are investigated. Procedures to provide adequate quality assurance and to set appropriate safety regulations are suggested. Methods of implementing safety programs are also considered.

## 1. INTRODUCTION

Recently, several developing countries have finalized agreements to import nuclear power plants. Practically all other countries are considering nuclear energy as a major element in future development whether as part of short term or long term plans. The desire to acquire nuclear technology is in many cases independent of national energy demands. The realization of this goal for a given country depends on its human and monetary capital. The large investments and the specific qualification of manpower required for construction and operation of nuclear power plants have made some of the developing countries hesitant to seriously consider the nuclear energy option even where it is needed the most. In many situations, scattered electrical power demand centers and low consumption of electric energy in addition to the costs involved in inefficient plant utilization have discouraged planners from pursuing their ambitious projections. In fact, development of economical small and medium size reactors would accelerate the participation of many countries in the utilization of nuclear energy. Political factors also have a great impact on the international market.

Projected global expansion of nuclear energy utilization has surfaced several questions related to the safety aspects of commercial power reactors currently used in nuclear countries. Answers to those questions may involve departure from present practice by introducing changes in safety provisions and modifications in the design features. The questions are centered around identification of global and local safety-related problems which are likely to arise in building the nuclear power capabilities of non-nuclear and developing countries, in establishing safety criteria and in setting up the ground rules for a universal safety philosophy that is flexible enough to accommodate for local constraints. In this paper, public attitudes, safety, and quality assurance are put into the perspective of the transfer of nuclear technology picture drawing on experience in both nuclear and non-nuclear countries.

## 2. PUBLIC ATTITUDE

To provide a framework for safety analysis of nuclear power plants employed in developing economies, world wide public opinion has to be examined.

Generally, the attitude of the people towards specific issues assumes variable dynamic states that change in space and time. Often the changes occur fast enough to make the prediction of a consistent pattern meaningless. However, attitudes towards general issues can be examined for a given country or a group of countries with common background at nearly the same level of development.

### 2.1 Nuclear Countries

Thus far, the major concern in nuclear countries is about potential diversion of nuclear materials from electric generating plants. The fear is worldwide and the problem does

require serious attention; however, it has been blown up out of proportion, specially by nuclear opposition factions. Many of the suggested approaches tend to undermine the engineering ingenuity and the global implications of the issue. Other significant safety problems have not received proportionate due consideration. However, the general attitude in nuclear countries towards spread of use of nuclear energy is that of reservation, suspicion and doubt. Public statements regarding the safe operation of nuclear power plants in developing countries often have a territorial overtone and usually reflect a "father knows best" attitude.

The public feels indifferent towards training and education of persons from developing countries in nuclear energy fields. This includes establishment of special programs for that purpose in nuclear countries. Many people in nuclear countries feel that now is the right time to harvest the fruits of long years of hard work and of huge monetary and human capital investments. Hence, they are entitled to protect their products from misuse which may eventually have an undesirable impact on their safety. Naturally, a person with high stakes in a given venture would be reluctant to surrender parts of his rights to others having lower assets. The vulnerability of many regions in the world to wars and local disturbances has created a risk aversion towards sharing responsibility in an area of great uncertainties.

Small segments of the public in nuclear countries have different views. Some feel that unless skills to handle nuclear systems are developed in non-nuclear countries and adequate manpower becomes available nuclear energy use should not spread. Concern about the unwillingness of some of those countries to abide by international treaties has also been expressed. Others feel that transfer of nuclear technology to developing countries should be accelerated under the control of their own country, otherwise, the competitive nuclear energy market may somehow encourage uncontrolled spread of construction of nuclear power plants. A nuclear country exporting nuclear reactors now could do so under strict safety regulations. High standards and adequate engineering safeguards systems could be imposed and hence, the exporting country would have a guarantee of the safety of operating such reactors. The situation may change in the future and the competitive nuclear energy market may be opened for inferior systems to gain high, fast profits. In that case, control on safety practices will be hard to implement and the welfare of the general public may be endangered. The worldwide deterioration of the economy could create such a situation. Extreme positions have also been taken by anti-industrial expansion and anti-nuclear advocates. They feel that they have suffered enough from the evils of mechanization and industrial ventures. Consequently, they preach that efforts should be dedicated to save the rest of the world from the nuclear-energy hazard and from other industrial evils before it is too late. Those who are upset by environmental deterioration caused by industrial activities feel deprived of the beauty of nature. Hence, they advocate keeping parts of the world as a last-resort refuge for those who are only willing to take the risks of the natural environment. However, aesthetic values are a luxury for those who can hardly make ends meet.

## **2.2 International Attitude**

The public attitude in nuclear countries has greatly affected the implementation of the many international treaties which have emphasized encouragement of transfer of peaceful applications of nuclear technology. Thus, international agreements emphasize initiation of training programs and arrangement of exchange of scientists. International agencies have given special considerations to some facets of nuclear safety. Rules of handling radioactive and toxic materials were set. Guidelines and recommendations regarding specific safety issues have been made and frequently revised.

## **2.3 Non-nuclear Countries**

People enjoying a relatively high standard of living are more concerned with improving the quality of life as well as the quantity compared to those who are still in the developing stage and who are more concerned about the quantity. Thus, the public attitude in non-nuclear countries is geared towards acquiring modern goods and sharing the benefits of local industrial expansion. This attitude is affected to a great extent by political, economic and social factors which vary from one place to the other. The public attitude anywhere is rather sensitive to the state of world affairs and hence is often unpredictable.

The public in most developing countries is anxious to develop strong industries, to maximize the use of local human and material resources in improving the standard of living and in acquiring means of comfort, and to have self-determination in planning future development. This attitude has often resulted in hasty decisions and underestimation of the time element. In many countries, people have a lot to gain and nothing to lose taking into consideration all credible and incredible risks of nuclear power. Thus, their attitude is that of aggressiveness and willingness to gamble and share the risk. Other facets of the public attitude in those countries include opposition to industries completely controlled by outsiders, concern about economic loss caused by international politics, and fear of establishing a new elite by expanding heavily in one technological sector requiring special training and a high level of sophistication.

## **3. IMPACT OF PUBLIC ATTITUDE ON SAFE TRANSFER OF NUCLEAR TECHNOLOGY**

Public attitude towards the safety of nuclear power plants is likely to shape future policies indirectly. However, development plans cannot closely follow the evolution of public feelings under any system of government. In the case of nuclear technology the safety questions often raised by the public are based on the implications of the past history of nuclear energy. Hence, the current fears, doubts and challenges in the minds of the people can be abated by providing information and understanding and giving assurances about the safety of nuclear systems.

Public pressure in the United States of America has made the nuclear industry the most

regulated industry in the whole world. Quality assurance and reliability are greatly emphasized in each phase of a nuclear power plant project. Design flaws have been eliminated in early stages. Inspection and highly developed testing procedures have provided high confidence in fabrication and construction practices. Consequently, the nuclear industry has the best safety record. Nevertheless, some drawbacks have resulted from extreme reactions to nuclear safety, for example, unnecessary costly delays in construction and licensing of nuclear power plants. However, these problems are likely to be solved with the eventual understanding of the role of nuclear energy and the safety aspects of its use as an energy source.

The public attitude in nuclear countries towards the transfer of nuclear technology to developing countries is likely to slow down the transfer process. However, this will indirectly stimulate the transfer of safety and quality assurance technologies which will benefit developing countries even in the development of non-nuclear industries. However, unreasonable delay in transfer of nuclear technology would lead to risky complications. Pressure by one or two nuclear countries to slow the process down will not prevent other nuclear countries from controlling the market. In addition, the number of nuclear energy experts in non-nuclear countries is rapidly increasing. Local development of nuclear technology can eventually be made in several developing countries especially with the fast economic growth in those countries. In this situation, safety measures employed may become inferior compared to the current safety practices in nuclear countries.

The attitude of international organizations is unlikely to change, although global energy policies are of current interest. This is because of the diplomatic role of many of the international agencies. Transfer of nuclear technology may, however, benefit from the information, training and exchange programs organized by those agencies.

The attitude of the public in non-nuclear countries towards local use of nuclear technology is formed by challenges of development and by the notion that the strength of a small country can be greatly increased by participation in nuclear energy programs. Aggressiveness and underestimation of the time element involved in the acquisition of nuclear power could result in setbacks in technology transfer process. This may also have a negative effect on the safety of operation and construction of nuclear systems. Training programs need to emphasize patience, technical decision-making, execution of cognitive tasks and understanding the time factors involved in each phase of the project. Participation of experts from nuclear countries in the decision-making process may be of value provided that the role of experts is limited to advising rather than to imposing certain policies.

In many of the developing countries slogans of equality, social justice and democracy have been taken out of context. Hence, confusion between class structure and management structure has resulted in resentment towards regulation and technical authorities. This phenomenon is well handled by proper understanding of its nature. Basically, it is a contemporary social change which associates evolution from a rural and/or nomadic environment to industrial social structure. Several investigators deal with this problem as part of the cultural background and hence, unworkable solutions have often been suggest-



ed. A viable approach towards resolving public attitude differences is to provide a system of public information and to carry on the development projects gradually. It is important that local planners become familiar with the social implications of transfer of nuclear technology and recognize the associated need for changes in the present management structure.

#### 4. QUALITY ASSURANCE

In several countries the absence of competitive markets or industries and the fact that the desire to expand is not supplemented by well thought out plans have placed emphasis on quantity rather than quality of products. This has led to deterioration of workmanship and negligence of quality assurance, which does not go beyond red tape procedures. Also, the absence of heavy and precision industries and the lack of experience in industrial and engineering management of large projects have caused a deficiency in perceiving the value of maintenance and high operation standards. Consequently, a safety program has to concentrate on: standardization; quality assurance; developing clear and cognizable procedures of operation, inspection and maintenance; availability of spare parts; replacement instruction; automatic control and operation; adequate design of control panels and rooms; tight and strict supervision; comprehensible alarm system and reliable stimuli, fail-safe protection system; passive safeguard systems; communication; and mitigation of isolated or negligence actions. The consequences of improper consideration of some of these aspects could exceed the outcome of a nuclear material diversion incident.

However, some of these requirements may not be satisfied unless special reactor designs are made for non-nuclear countries. This option is not economically feasible at this time due to the present size of the nuclear energy market which is insignificantly small. To insure high quality assurance measures in the operation of nuclear power plants in developing countries, emphasis must be placed on quality and safety training of the personnel involved. Training on quality control should not be limited to the nuclear energy sector but must be enforced in other activities especially those associated with power plant construction and operation. Technicians need to be initially trained in industries which require precision and high quality workmanship. Control authorities may stimulate the interest of workers in quality through rewards and national slogans. This type of motivation should also include field training especially in the area of quality assurance and control. Although most of the engineers in those countries have acquired high quality engineering and technological education they often linger behind their peers in developed economies. This is attributed to the fact that engineers in developed countries start their careers working under supervision of experienced professionals in purely engineering design and procurement tasks. In contrast, engineers in developing countries are entirely involved in administrative work. Their first assignments usually include powerless supervision of projects under very rigid rules. Adequate maintenance and quality assurance in developing countries require the development of supporting industries. Importing spare parts, inspection equipment and tools, and foreign experts is not an effective

tive method in establishing quality assurance programs due to delays in importing procedures and complications in relying on foreign experience.

The involvement of foreign personnel in operation, inspection and maintenance is likely to cause communication gaps and increase the potential of negligence, sabotage and isolated accidents. Safety procedures are best implemented by delegation of responsibility to local people, by participation of local technical personnel with experienced outsiders in designing and developing instructions and procedures, and by motivation of local groups to think safety and quality and to provide solutions and devise measures for prevention of accidents, including diversion of nuclear materials incidents.

Centralization of authorities in one group is a general practice in all industrial activities in many developing countries. Although this system has functioned efficiently in the presence of small industrial activities such a system is not adequate in large nuclear projects. Formation of an independent quality assurance group is deemed necessary. Specific authorities must be delegated to the group which reports to the superintendent of the plant. This would eliminate a state of diffused responsibilities and would help in pointing flaws in execution of quality assurance procedures. Such management system has been tested in developed countries and was found to be more reliable than combining quality control with other activities in the plant which is the present practice in many developing countries.

## 5. SAFETY REGULATIONS

In dealing with regulations and standards of safety, decisions must involve the customer and exporter. Field experience has shown that imposition of rules leads to chaos even under strict external control. Local economic and humanistic balance has to be made in setting up safety criteria for the design through cost-benefit analysis especially for those countries where the economic element is rather critical. Some of the safety measures employed in nuclear countries are deemed insufficient in some situations and unnecessary in others; for example, stringent containment designs may or may not be needed depending on the site; on the rated power of the plant; and on the economic, social and political stability of the country.

To assure compatibility of safety regulations with the local situation in a given country, a group of experts from that country may set the rules and procedures. The group should act independently of the authorities involved in the purchase and operation of the nuclear power plants to assure objectivity. The proposed regulations can be reviewed and revised by a team formed from: international experts, the local regulatory agency and representatives of the vendors from the nuclear country involved in the design and construction of the plant. Enforcing the regulations and standards must be handled by the local regulatory agency. Foreign authorities may be consulted in resolving generic problems. This approach will guarantee satisfaction on the part of the recipient country and assure that safety measures are enforced and not overlooked by the local authority in charge of the project.



# **ROLE OF ORGANIZATIONS IN TRANSFER OF NUCLEAR TECHNOLOGY**

## **PARALLEL SESSION**

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## INTERNATIONAL INSTRUMENTS FOR THE TRANSFER OF NUCLEAR TECHNOLOGY

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### ABSTRACT

The benefits of nuclear power can best be achieved throughout the world by a sharing concept that is just and serves the interests of people of all nations. The technological fact is that only a few nations have mounted the scientific effort to harness the atom. Since the original Atoms for Peace proposals by President Eisenhower, a fundamental characteristic of worldwide nuclear development has been a commitment of sharing among nations. This commitment has been carried forward in the Non-Proliferation Treaty as well as the policies of nations with nuclear technology. To translate this fundamental concept into a workable program, the seven nations selling nuclear technology have developed legal instruments. These instruments establish government-to-government relationships as to the transfer of nuclear technology and outline the conditions and circumstances of that transfer.

The principal supplier states including Canada, France, Japan, United Kingdom, United States, USSR and West Germany have developed through the years a system of international instruments which define the understanding among states on the peaceful use of transferred nuclear technology. When the growing dynamic tension between commercial interests and nonproliferation concerns is reviewed in light of these agreements, international legal principles can provide guidance on the rights of states which have relied upon these agreements.

As nations alter their policies concerning technology transfer, these will be reflected in the international instruments that implement those policies. A careful review of these instruments, therefore, provides historical perspectives and a guide to the trends of the future.

### 1. INTRODUCTION

From the beginning of the effort of nuclear states to share the benefits of the peaceful atom with the rest of the world, great emphasis has been placed on cooperation through legal instruments that govern the transfer of nuclear technology. In a sense, the emphasis upon legal commitment as defined in written instruments was based on a recognition of the immutable fact that the ultimate secret -- the atomic bomb -- was beyond controls based solely

on technological restraints.

These legal instruments include bilateral state-to-state arrangements, trilateral arrangements involving states and the International Atomic Energy Agency ("IAEA"), bilateral state to IAEA arrangements, and multilateral agreements -- treaties in the classic sense, including the Statute of the International Atomic Energy Agency and the Treaty on the Nonproliferation of Nuclear Weapons (the "NPT"), as well as regional agreements, including EURATOM and the Treaty of Tlatelolco.

This analysis will deal with the existing agreements that have facilitated the flow of nuclear technology, equipment and material in the past and the present and those arrangements proposed for the future as a response to the heightened concern primarily of supplier states with nonproliferation. Further, I will describe how international legal principles could affect the rights of states under existing agreements in the face of efforts by supplier states to modify or unilaterally amend existing agreements by domestic legislation or other domestic measures.

## 2. INTERNATIONAL TREATIES

One of the most basic international treaties affecting nuclear power is the Statute of the International Atomic Energy Agency. As originally conceived and expressed in the Statute, the principal purpose of the IAEA is a positive one-- to assist in the "development and practical application of atomic energy for peaceful uses throughout the world."

To further this purpose, the Agency was given broad latitude to develop its activities. The IAEA is allowed to "perform any operation or service useful in research on, or development or practical application of atomic energy for peaceful purposes," including acting as an intermediary for the transfer of nuclear material, equipment, facilities and services between members of the Agency.

The Agency's safeguards responsibility is a vital portion of its function. However, an imbalance in the role of the IAEA has developed since its creation because of the emphasis of supplier states on the development of Agency safeguards activities without corresponding emphasis on the potential spectrum of other activities the IAEA could perform to aid consumer nations in the enjoyment of the peaceful atom. It is not surprising, therefore, that the Agency today is under increasing pressure by consumer nations to place more emphasis on its other objectives as expressed in its Statute, namely, the supply of materials, training, and personnel to be used in peaceful nuclear programs.

The potential role of the Agency, therefore, in assisting in the spread of nuclear technology for peaceful purposes remains largely unexplored at this time. It does, however, remain a future source of aid for consumer nations desirous of sharing in the benefits of the peaceful atom. The language found in the Statute of the Agency is totally supportive of a greatly expanded role for it. For instance, the Agency is required to "take positive steps to encourage the exchange among its members of information relating to the nature and peaceful uses of atomic energy" and it should serve as an intermediary among its mem-



bers for this purpose. Toward this end, all IAEA members are required to make available for the Agency all scientific information developed as a result of Agency assistance, as well as such other information members feel would be helpful to the Agency in the performance of its functions. The Agency is in turn required to assemble this information and to make it available to its members.

On the issue of transfer of nuclear technology, Article XI of the Agency Statute directs the IAEA to assist members in their efforts to set up projects for research on, or development and practical application of, atomic energy for peaceful purposes. This assistance can involve the Agency in efforts to secure special fissionable and other materials, services, equipment, and facilities necessary for these purposes. The assistance may also include efforts by the Agency to arrange outside financing for the consumer states. The Agency, itself, can supply the necessary materials, services, equipment and facilities either through materials made available to the Agency by its members or by arranging for the supply of these items directly to consumer states from other Agency members.

The Treaty on the Nonproliferation of Nuclear Weapons, which entered into force in 1970, signaled a new understanding among certain states on the terms to be applied to the transfer of nuclear technology. The IAEA was not a party to the NPT, although the NPT directly concerned its activities. The Treaty's emphasis is not upon the duty of the IAEA to facilitate the sharing of peaceful benefits of nuclear energy, but on the obligations of supplier states to assist in this flow of technology if the consumer nations adhere to certain safeguards requirements and forego development of nuclear weapons and explosives. The NPT also directed supplier states to negotiate concerning control of nuclear weapons already possessed by nuclear-weapon states. The full meaning of the various obligations assumed by both consumer and supplier states, parties to the NPT, is now a matter of considerable debate among states directly affected by these provisions.

Thus, the IAEA administers two safeguards systems, NPT and non-NPT. There are two principal differences between NPT and non-NPT type IAEA safeguards systems. In terms of scope, the non-NPT type agreement covers only specified nuclear materials and equipment whereas the NPT safeguards are applied to all of a state's peaceful nuclear activities. Under the non-NPT type safeguards arrangements, safeguards are applied only to exported materials and equipment included on "inventories" compiled by the IAEA. Thus, the IAEA would be notified about an export by the supplier and recipient states involved and the export would be added to the inventory of safeguarded items. In this type of agreement, the IAEA would only apply safeguards to exports from the specified supplier state to the recipient state. In contrast, the NPT requires non-nuclear weapon states, parties to the Treaty, to arrange for the application of IAEA safeguards to all of their peaceful nuclear activities through a bilateral agreement between the IAEA and the individual states or their regional organizations.

The purpose of each type of safeguards arrangement is expressed in different terms. In non-NPT arrangements, the recipient state agrees not to use exported nuclear material and equipment for military purposes. "Civilian" nuclear activities are condoned. There

is debate today, however, concerning the character of nuclear explosives as civilian or military. Many supplier states, including the United States and Canada consider the development of any nuclear explosives precluded by the restriction to only peaceful usage in their safeguards agreements. Other states do not view peaceful nuclear explosives as equivalent to weapons or other military usage and interpret the non-NPT agreements to allow development and use of peaceful nuclear explosives. The NPT was explicit in its prohibition of the development of peaceful nuclear explosives in non-nuclear weapon states which are promised access to the benefits of PNE's as developed by nuclear weapon states. In an NPT safeguards arrangement, the state agrees to limit itself to only peaceful uses expressly excluding the development and construction of PNE's.

Besides the effect of the different language on the issue of PNE's there are other differences between the civilian/military and peaceful/non-peaceful standards relied upon in these two types of safeguards agreements. For example, under the non-NPT type agreement, any military nuclear activity is prohibited but it is disputed whether this also precludes use of nuclear explosives for civilian purposes. In contrast, the NPT arrangements' endorsement of peaceful uses could be construed to allow military activities but would expressly forbid explosives. Thus, the categories of activities approved and prohibited in each set of agreements are not identical, though there is an overlap.

There are also regional agreements among states for cooperation in the development and use of atomic energy for peaceful purposes. The oldest such agreement is the EURATOM Treaty which provides for cooperation among the members of the European Community in this area -- France, Belgium, Luxembourg, Germany, Netherlands, Italy, Ireland, Denmark and the United Kingdom. Under this agreement the European Community regional organization is assigned responsibility for application of safeguards on materials supplied and used within the Community. Suppliers do not have separate safeguards arrangements with each member of the community but rather one umbrella agreement with EURATOM, pursuant to which EURATOM safeguards are applied to facilities and materials in each EURATOM member. These agreements should soon be amended, in recognition of the EURATOM-IAEA safeguards arrangement which will implement NPT-type IAEA safeguards through changes in the EURATOM safeguards system. Although each of the EURATOM members still operates independently in nuclear research and power programs, there are many common projects among them. One of the benefits of a regional organization in this field is the uniformity of standards imposed and the freedom of movement allowed among member states. For example, there is a so-called "free transfer" provision of the EURATOM arrangement whereby once nuclear exports enter into one EURATOM country they can be transferred to another EURATOM country freely. This provision provides special benefits to the member countries and special dangers in the eyes of certain supplier countries. EURATOM has presented an example of the potential benefits of cooperation among states within a region in the development and use of nuclear energy and formulation of an energy policy.

The Latin American states have concluded an agreement to create a military denuclear-

lized zone in Latin America, the Treaty for the Proliferation of Nuclear Weapons in Latin America, the Treaty of Tlatelolco. The signatory states pledge themselves not to purchase or develop atomic weapons. These states expressly retain the right to enjoy the peaceful uses of the atom including peaceful nuclear explosives. The IAEA has concluded a safeguards agreement with these states to implement their treaty obligation. In response to the Latin American States' commitment to a nuclear weapons free zone, the United States, United Kingdom, France and the People's Republic of China, have agreed in a second Protocol to the Treaty of Tlatelolco not to use or threaten to use nuclear weapons against the parties to the Treaty and not to otherwise contribute to the violation of the Treaty.

### 3. STATE-TO-STATE AGREEMENTS

The existing agreements governing the transfer of nuclear technology involve an understanding between the major supplier countries and the recipient states. The major supplier states include: Great Britain, Canada, France, Japan, the Soviet Union, the United States and West Germany. More recent members, as represented at the London Suppliers Conference, include: Belgium, Czechoslovakia, East Germany, Italy, the Netherlands, Poland, Sweden and Switzerland. Most of the major supplier states have concluded a series of arrangements with individual recipient states and regional organizations to define the terms of their cooperation in the peaceful use of nuclear energy and the application of safeguards. The United States has 32 agreements for cooperation, and 15 trilateral safeguards agreements. Canada has 15 agreements, including the Indian and Pakistani agreements. The USSR has 6, France has 8; Germany has 5; and the United Kingdom has 13.

Although there are differences among the agreements negotiated by each supplier state, and even among those agreements utilized by a supplier state, these agreements are similar in content and tone. They provide for cooperation in the transfer of nuclear technology to be used for peaceful purposes. The agreements vary in the explicitness of their definition of "peaceful." There is dispute as to the extent of the prohibition against nuclear weapons -- that is whether or not it also prohibits the use of peaceful nuclear explosives. Most of the agreements are not so explicit as the NPT in their ban on the development of nuclear explosives in non-nuclear weapon states.

With regard to their safeguards requirements the agreements are of both non-NPT and NPT type. The non-NPT refer only to safeguards to be arranged on "inventories" of those materials and items exported from the supplier state and recipient state involved in the agreement. The agreement can provide for safeguards to be applied directly by the supplier state or for suspension of such bilateral safeguards in favor of the application of IAEA safeguards. Generally, the agreements provide for the settlement of disputes through international arbitration. The states are requested to seek modification of the agreement through negotiation. Each state is usually given the right to terminate the agreement upon notice. The duration of the agreement, if neither state terminates, is stated as a term of years if

it is stated at all.

The agreements do not usually discuss sanctions which shall be applied by the supplier state or the recipient state in the event of a material breach of the agreement by the other state. Generally, the supplier state reserves for itself in the agreement some authority over the subsequent use of the exported material, including the removal of exported fuel from the reactor, and its alteration, reprocessing or retransfer. Some countries, such as the United States, have inserted language into the agreements which subject all exports to compliance with the export licensing regulations in force in the exporting country. Whether or not this provision would justify drastic modification of the agreement through legislation in the exporting nation subsequent to the agreement is not clear and remains a source of considerable dispute.

The existing agreements among states controlling the transfer of nuclear technology are under new pressures today because of efforts by supplier states to restructure these controls. Examinations of the recently announced policy changes by Canada and the proposed changes in the United States illustrate the difficulties.

Just as other supplier states had done, Canada concluded a series of bilateral arrangements with consumer states in the 1950's to define the terms on which it would transfer nuclear material, equipment and technology. Since 1974, Canada has revised its nuclear export criteria twice in a significant manner. After the Indian explosion in 1974 of a peaceful nuclear explosive device constructed from plutonium which had come out of a Canadian supplied research reactor, Canada undertook to renegotiate all of its existing agreements for cooperation to make clear its prohibition of peaceful nuclear explosives built or constructed with or through use of Canadian nuclear exports. The inability of Canada to conclude such strengthened agreements with India and Pakistan has resulted in the cessation of all nuclear trade with those countries.

More recently, on December 22, 1976, Canada announced it was going to impose an additional set of export criteria on recipient states. This would include: (1) limiting shipments of reactors and uranium to non-nuclear weapon states which have ratified the NPT or otherwise accepted international safeguards on their entire nuclear program; and (2) terminating all nuclear shipments to any non-nuclear weapon state which explodes a nuclear device. This prohibition extends to PNE's constructed through the use of materials supplied from non-Canadian sources as well as from Canadian exports.

In response to questioning, the Canadian Minister for External Affairs said that because of Pakistan's refusal to accept both the earlier proposed modifications as well as the most recent set of revised nonproliferation controls, nuclear cooperation between Canada and Pakistan was effectively at an end. However, the Canadian Minister said that with the exception of the Pakistani contracts, Canada was not going to abrogate contracts which predated the new policy but would seek to upgrade these contracts through negotiation without breaching the obligations it has already assumed pursuant to them. The terms of its existing agreements for cooperation, however, would not apply to future contracts unless the agreements are modified to include the new criteria.

Since the 1974 Indian explosion, the United States has been examining its nonproliferation policies with an aim to reformulating them. There has been controversy as to a choice between an "incremental" or a unilateral approach to redefinition of this policy. The incremental approach is the usual method for developing an understanding between states in nuclear matters. It relies on negotiation between sovereign states to achieve agreement. In contrast, unilateral modifications, as exemplified by Canadian policy, do not await the outcome of the negotiation process but proceed to redefine the relationship between supplier and recipient states in nuclear commerce through domestic legislation or policy statements of the supplier state.

The United States Congress is now considering legislation which in effect rejects the "incremental approach," in favor of reliance upon modification through unilateral measures. The United States has favored the incremental approach in the past preferring to define nonproliferation policy and export controls through negotiation with other states and review of the individual circumstances posed by each recipient state and nuclear export.

Bills now under review, however, would impose a uniform set of criteria on all nuclear exports without regard to the terms of existing agreements. The more significant bills being considered now include two sets of criteria: one which would become effective immediately, and one whose effectiveness would be delayed 18 months, during which the United States would attempt to renegotiate its existing agreements to include these criteria. The criteria which would be applied initially would require:

1. IAEA safeguards on all U.S. nuclear exports of material, equipment and derived material, (this is a significant extension of the United States safeguards requirement to include "derived material," that is, material produced from or through the use of United States nuclear exports);
2. Restrictions on the development of peaceful nuclear explosives applicable to all non-nuclear weapon states regardless of whether or not they are parties to the NPT;
3. Physical security systems designed to deal with the threat of terrorist diversion from nuclear facilities;
4. Prior United States approval for retransfers of exported material, equipment or technology or derived material;
5. Prior United States approval for enrichment, reprocessing or alteration of exported material or derived material; and
6. Extension of export licensing criteria to all replicated material and equipment and special nuclear material used in or produced through the use of replicated material or equipment. (Replicated material and equipment is defined to include material or equipment which is produced or constructed by recipient states through the use of United States nuclear exports.)

Many of the bills in the U.S. Congress also include a much more stringent set of criteria to be applied to all nuclear exports from the United States at a period 18 months after the enactment of the legislation. Presumably, during the 18 month period the United



States will attempt to negotiate with recipient states to modify existing agreements to be consistent with the new licensing criteria. In any event, however, licensing criteria will be applied to all exports regardless of the terms of the existing agreements as of the date of the effectiveness. These conditions will include:

1. NPT type safeguard arrangements,
2. Prohibition of any PNE construction development or construction,
3. Physical security measures on all nuclear activities in a recipient state,
4. No transfers of nuclear equipment technology or material by recipient state to another state without application of criteria identical or equivalent to that imposed on United States exports, and
5. No reprocessing or enrichment in national facilities in non-nuclear weapon states of any material of whatever origin.

Reprocessing and enrichment are endorsed only if done in facilities in nuclear weapon states, in facilities on international territory and in facilities managed under international auspices. In addition to these activities, fuel fabrication and heavy water production are also put under stringent controls and prohibited in certain circumstances. Furthermore, storage arrangements for fuel elements contained in special nuclear material or spent nuclear material are to be in facilities approved by the United States. The President of the United States is given some authority in this legislation to suspend the application of one or all of these criteria to a particular nuclear export because of the individual circumstances presented. However, even this degree of discretion is sharply limited because the approval of Congress is required to support the President's action. Other elements of a future United States strategy as reflected in proposed legislation include endorsement of a nuclear free zone, of the NPT, of the IAEA safeguards systems, and of supplier states joint arrangements.

While Congress is continuing to consider this legislation President Carter has been preparing to announce a new United States nonproliferation policy. The President is expected to make a series of statements affecting the nonproliferation issue by discussing separately the domestic and international aspects, and the energy and nonproliferation aspects of the problem. On April 7, 1977, the President made his first statement on future United States nuclear energy and nonproliferation policies. The President recognized the unique role that nuclear power must play in the energy strategies of both the United States as well as other states which do not have the other natural resource options which the United States has available to it. The details of the new Administration's nuclear export program have not been released; however, the President's statement did announce a continued embargo on the exports of enrichment and chemical reprocessing technology and equipment by the United States and a suspension in the development of reprocessing for domestic purposes and redirection of the breeder development program. To encourage a delay in reprocessing and development of the breeder abroad consistent with the United States' program, President Carter promised expansion of United States enrichment capa-

city and guaranteed full supply contracts. He did not discuss any possible conflicts between existing agreements and the new policy. In a reference to the NPT, he acknowledged that this policy will go beyond the NPT.

As illustrated by the recent controversy in the United States over its approval of retransfers abroad of spent fuel for reprocessing, the United States faces considerable difficulty in attempting to reconcile the continuation of reprocessing activities in other states while attempting to enforce a delay on reprocessing and its development in the United States. In December 1976, the United States government approved the requests submitted by Spain and Switzerland for the retransfer for reprocessing of United States origin spent fuel. Under the terms of its agreements with these countries, the United States must approve such retransfers. Each of these states are faced by very limited storage capacity for spent fuel rods in the event of an undue delay in the granting of their requests for retransfers. Yet, in effect the United States has approved reprocessing of United States origin fuel in European states despite President Ford's statement last fall that the United States would enter into a three year delay on reprocessing. How this inconsistency can be resolved within the context of the United States interest in fuel that it has sent abroad for its reactors in other states remains a troublesome question which was not addressed by President Carter in his April 7th statement.

#### 4. INTERNATIONAL LEGAL PRINCIPLES

Legal arrangements between states to facilitate the transfer of nuclear technology have assumed added significance in the context of today's concern with nonproliferation and nuclear power. Both supplier and recipient states have relied upon the content and form of these arrangements, usually identified as treaties. The international law of treaties contains principles applicable to govern the interpretation of these agreements and their force in the face of changes in supplier states' nonproliferation policies. Supplier states have not shown great concern with the potential application of these principles to these arrangements, but recipient states should examine the potential avenues for redress available to them under international law for changes in supplier states policy or conduct which they consider a violation of existing agreements.

The Vienna Convention on the law of treaties, though not technically a treaty in force itself, has been recognized as an authoritative source of both established international law principles as well as principles of developing law. The definition utilized for treaties in the Vienna Convention describes a treaty as an "international agreement concluded between states in written form and governed by international law whether embodied in a single instrument or in two or more related instruments and whatever its particular designation." The agreements for cooperation between nations, the trilateral IAEA, supplier and recipient state agreements, the NPT and the IAEA Statute are all treaties under this definition.

As a treaty that is a pact between two sovereign states, the existing agreements cannot



be modified by domestic legislation of one of the party states unless both states agree. It is unreasonable for supplier states to interpret language in the existing agreements to condone modification through unilateral means. Although the domestic effect of changes in legislation of the state is a question to be decided by that state's internal law, the effect of these changes on the nature of the obligations assumed by the states in treaties is governed by international legal principles which place the treaty above such domestic law. Most of the agreements relied upon by the supplier states to define the conditions to be imposed upon nuclear trade contain provisions defining procedures to be followed when a party wishes to discuss modification of the agreement or to settle a dispute which has arisen concerning the agreement. These provisions prevail over change of the agreement through domestic legislation. If a state acts otherwise and does not utilize those procedures outlined in the agreement, its action could be construed as a breach of the agreement. In the face of such a breach, the recipient state would have several options including seeking enforcement of the agreement through bilateral negotiation or in the International Court of Justice or terminating the agreement and seeking damages.

Although some supplier states today have voiced their dissatisfaction with the terms of existing agreements for cooperation and proposed or enforced modifications of these agreements, none has suggested that the agreements should be terminated or replaced with an entirely new regime.

To answer the question of the options open for a recipient state in these circumstances the specific agreements involved must be examined. There are, however, principles of international law that provide guidelines for the courses of action available to states involved in controversy surrounding reformulation of nonproliferation policy. For example, agreements for cooperation, just as other treaties, can be analyzed in terms of separable provisions. However, the critical question of which provisions could be terminated without terminating the entire agreement is not clear on the face of many agreements although in some instances it appears clear that termination of certain key provisions with regard to guarantees of technology transfer and reprocessing and retransfer control could go to the essence of the agreement and void it in its entirety. Termination has been recognized as an option for a state when the other state has committed a material breach of an agreement between them. This principle is embodied in the Vienna Convention. The types of changes which supplier states are now attempting to incorporate or superimpose on existing agreements without negotiation could arguably be construed as affecting the most important aims of the agreement. Such action by the supplier states, therefore, could be interpreted as a material breach depending upon the facts of each individual case. Agreements for cooperation have a dual purpose: nonproliferation of nuclear weapons and development of nuclear power for peaceful purposes. As demonstrated by the increasing debate over future nonproliferation strategies, an action by a supplier state could be viewed as consistent with the nonproliferation purpose of an agreement but destructive of the nuclear power perspective of the same agreement.

Other principles of international law could affect a determination of the legality of the

action of supplier and recipient states in relation to their obligations under existing agreements. Because of the heightened concern over the development of peaceful nuclear explosives and possession of reprocessing and enrichment capacity by non-nuclear weapon states, supplier states could attempt to assert that there has been a fundamental change in circumstances since the agreements were concluded. This principle, commonly referred to as rebus sic stantibus, is often relied on in inappropriate circumstances by states attempting to justify a breach of international obligations. Therefore, states should use it cautiously. It applies only in the most drastic circumstances when an unforeseen event occurs that the parties did not contemplate at the time of their agreement and which changes those circumstances that formed the essential basis of the consent of the parties to be bound by the treaty and transforms the extent of the obligations that the parties initially agreed to perform under the treaty. The key element is foreseeability. In relation to the issue of the transfer of reprocessing and enrichment technology and facilities and the development of peaceful nuclear explosives, it is clear that these technological developments were foreseen at the time that most existing agreements were concluded.

A further principle of international law, commonly called jus cogens, was included in the Vienna Convention as a statement not of established but of emerging international law. This principle recognizes that the international community is ruled by certain moral norms that cannot be changed even by agreement between states. Even at the time of its inclusion in the Vienna Convention during the drafting, however, there was considerable discussion and debate among the representatives of various states as to exactly what norms presently existed that could demonstrate what was meant by jus cogens. The extent of the debate is reflected in the fact that the Convention contains no example of jus cogens in existence today.

In relation to the transfer of nuclear technology today, some states are arguing that indeed there is a preemptory norm of international law which under the principle of jus cogens would prohibit non-nuclear weapon states from developing weapons of explosives potential for whatever purpose. In effect, proponents of this argument point to the provisions of the NPT and argue that its restrictions on the development of peaceful explosives are applicable to all states - all non-nuclear weapon states - whether or not they are parties to the NPT. This is a radical application of the principle of jus cogens and overlooks the established principle that states shall not be bound by agreements to which they have not assented. As much as some states may desire it, it is obvious from the conduct of states today that the provisions of the NPT have not entered into the realm of jus cogens. There is, thus, still a need for bilateral arrangements between states which establish effective nonproliferation controls while enabling the continued spread of the benefits of atomic energy.

In this regard, I would refer you to the American Bar Association's soon to be published book on existing agreements. It is entitled "International Instruments for the Transfer of Nuclear Technology." It has been organized to serve as a guide to these arrangements viewed in terms of the individual supplier states and international practice. Many of the more significant agreements are reprinted in one place for the first time. It tells where we

are now in terms of legal written agreements.

## 5. CONCLUSION

Aside from this view of the force of existing agreement in terms of international legal principles, it is necessary to look at pragmatics as well as the newer principles of law asserted by developing countries as essential to their survival.

While the nonproliferation concerns of supplier and especially nuclear-weapon supplier states are evident, the need for nuclear power as an energy option in developing countries, which lack the resources available in other countries are not as commonly recognized. Dependence upon energy imports raises critical issues for survival in any state - developed or developing.

Industrialized states must also formulate long term energy strategies now which include increased dependence on nuclear energy if they intend to avoid the energy crunch which has been predicted. Despite his nonproliferation concern, President Carter recognized in his most recent statement on this topic that "the benefits of nuclear power are very real and practical" for both the United States and other states.

In a developing country the questions relate very directly to the overall future rate of growth and development. The financial aspect of increasing dependence upon costly energy imports provides a powerful incentive for the developing countries to continue to seek access to nuclear technology. In this regard, recycling spent reactor fuel and the eventual use of the breeder reactor can be most important.

The Charter of the economic rights and obligations of states issued from the United Nations establishes, as a right of developing countries, access to technology developed in industrialized states. This right is considered central to efforts to achieve a better life for the peoples of developing nations. Nuclear technology is a prime example of the type of technology which developing countries need to acquire.

Supplier and recipient states appear to be approaching an impasse in continued cooperation for the transfer of nuclear technology because of conflicting priorities and analyses of the nonproliferation and energy issues involved in nuclear power. President Carter's April 7, 1977, Statement on United States nonproliferation policy at least brought the conflict more clearly into focus.

Agreements have been a part of the past policy of nuclear transfers and have worked reasonably well. A future strategy which relies upon them will not represent a radical break with the past. If there is dissatisfaction with the extent of present controls as defined in existing agreements, the appropriate course is negotiation among states to strengthen the controls placed on transfers of equipment, materials and technology. President Carter's emphasis on the importance of international cooperation through systematic and thorough international consultations in his Statement is a positive sign for international relations in this area.

Only an understanding built upon consent and not force can provide the assurance of

nonproliferation which supplier states are now seeking and the benefits of nuclear power needed by developing countries.

## APPENDIX A

EMBARGOED FOR RELEASE UNTIL CONCLUSION  
OF 11:15 am BRIEFING

APRIL 7, 1977

Office of the White House Press Secretary

### THE WHITE HOUSE

#### STATEMENT BY THE PRESIDENT ON NUCLEAR POWER POLICY

There is no dilemma today more difficult to resolve than that connected with the use of nuclear power. Many countries see nuclear power as the only real opportunity, at least in this century, to reduce the dependence of their economic well-being on all foreign oil-- an energy source of uncertain availability, growing price, and ultimate exhaustion. The U.S., by contrast, has a major domestic energy source -- coal -- but its use is not without penalties and our plans also call for the use of nuclear power as a share in our energy production.

The benefits of nuclear power are thus very real and practical. But a serious risk accompanies world-wide use of nuclear power -- the risk that components of the nuclear power process will be turned to providing atomic weapons.

We took an important step in reducing the risk of expanding possession of atomic weapons through the Non-Proliferation Treaty, whereby more than 100 nations have agreed not to develop such explosives. But we must go further. The U.S. is deeply concerned about the consequences for all nations of a further spread of nuclear weapons or explosive capabilities. We believe that these risks would be vastly increased by the further spread of sensitive technologies which entail direct access to plutonium, highly enriched uranium or other weapons useable material. The question I have had under review from my first day in office is how can that be accomplished without foregoing the tangible benefits of nuclear power.

We are now completing an extremely thorough review of all the issues that bear on the use of nuclear power. We have concluded that the serious consequences of proliferation and direct implications for peace and security -- as well as strong scientific and economic evidence -- require

- a major change in U.S. domestic nuclear energy policies and programs; and
- a concerted effort among all nations to find better answers to the problems and

risks accompanying the increased use of nuclear power.

I am announcing today some of my decisions resulting from that review.

First, we will defer indefinitely the commercial reprocessing and recycling of the plutonium produced in the U.S. nuclear power programs. From our own experience we have concluded that a viable and economic nuclear power program can be sustained without such reprocessing and recycling. The plant at Barnwell, South Carolina, will receive neither federal encouragement nor funding for its completion as a reprocessing facility.

Second, we will restructure the U.S. breeder reactor program to give greater priority to alternative designs of the breeder, and to defer the date when breeder reactors would be put into commercial use.

Third, we will redirect funding of U.S. nuclear research and development programs to accelerate our research into alternative nuclear fuel cycles which do not involve direct access to materials useable in nuclear weapons.

Fourth, we will increase U.S. production capacity for enriched uranium to provide adequate and timely supply of nuclear fuels for domestic and foreign needs.

Fifth, we will propose the necessary legislative steps to permit the U.S. to offer nuclear fuel supply contracts and guarantee delivery of such nuclear fuel to other countries.

Sixth, we will continue to embargo the export of equipment or technology that would permit uranium enrichment and chemical reprocessing.

Seventh, we will continue discussions with supplying and recipient countries alike, of a wide range of international approaches and frameworks that will permit all nations to achieve their energy objectives while reducing the spread of nuclear explosive capability. Among other things, we will explore the establishment of an international nuclear fuel cycle evaluation program aimed at developing alternative fuel cycles and a variety of international and U.S. measures to assure access to nuclear fuel supplies and spent fuel storage for nations sharing common non-proliferation objectives.

We will continue to consult very closely with a number of governments regarding the most desirable multilateral and bilateral arrangements for assuring that nuclear energy is creatively harnessed for peaceful economic purposes. Our intent is to develop wider international cooperation in regard to this vital issue through systematic and thorough international consultations.

## THE AMERICAN NUCLEAR SOCIETY AND INTERNATIONAL TECHNOLOGY TRANSFER

JOSEPH R. DIETRICH

*President-Elect*

*American Nuclear Society*

*U.S.A.*

Science, and the enterprise of applying science in peaceful technologies, have been among the important forces for international understanding and cooperation in the past, and I believe will continue to be so. In the search to find the universal laws of nature, and in the application of those laws to improve our tools and techniques for the business of living, men have found a common endeavor which more often than not transcends the parochial interests of individual nations.

The professional technical societies have contributed greatly to this internationalizing process, by providing the rapid and effective means of technology transfer and the sense of community which are essential to the success of such an ecumenical endeavor. Although the quest for knowledge and the drive to apply the knowledge have been the basic unifying forces, the opportunities for communication and personal contact provided by the societies have been the essential means through which scientists and engineers have found a ground for mutual interest and respect which knows few geographical boundaries. Over its twenty-two-year lifetime the American Nuclear Society has held to the international tradition and I am confident it will continue to do so in the future.

The American Nuclear Society is a technical society whose scope covers some areas of fundamental science and a rather broad range of technologies. The exchange of technology is generally a more complex undertaking than the exchange of information in the pure sciences, for applied technology becomes strongly involved with those institutions which keep the business of the world operating. These not only place some restrictions on the exchange processes, but also expand the need for exchange into new areas. I believe that the techniques employed by the American Nuclear Society for coping with these complexities are quite effective, and that a brief exposition of them will be useful to you, whether you desire to make use of them by some kind of affiliation or interaction with the Society, or to use them as a base of experience in designing the mechanisms for exchange in new societies.

The journals and the general meetings are of course the backbone of the communication effort of any technical society. The four major publications of the American Nuclear Society cover a range of needs for information transfer. Nuclear Science and Engineering is the medium for publication of papers dealing with the more fundamental aspects of nuclear technology, while the journal Nuclear Technology covers the more applied aspects. The published Transactions of the regular meetings in effect provide a semiannual updating of



new developments in the technology, and thereby provide the timeliness of coverage which is important in a rapidly developing technology. Nuclear News serves the essential functions of keeping Society members in touch with the ever changing environment within which the nuclear industry operates, of covering the areas where technical considerations interact strongly with social and institutional considerations, and of informing members of Society activities. It also has the flexibility to give timely reports on purely technical matters when the occasion warrants.

But there are limitations to the effectiveness of formal publication as a means of information transfer in a technology which has reached the stage of important commercial applications. Commercial and proprietary restrictions then begin to limit the publication of information in some of the areas that are of most interest - areas in which new developments are being made. Yet there are certain avenues of communication which minimize the effects of commercial restrictions, and these play important roles in the activities of the Society.

Perhaps the most important of these is the program of Nuclear Standards development. This activity brings together qualified experts to develop, for the total industry, the best possible general specifications for the design of safe and reliable nuclear equipment and processes. The members of these small groups can be so thoroughly familiar with the technology within the limited area covered by a particular standard that they are able to produce generalized information. For the use of the whole industry, which embodies the essence of the most advanced thinking without encroaching upon the legitimate restrictions imposed by commercial considerations. Thus the nuclear community gets, in a digested form, the information which it would not be able to get in the raw form.

Within the Society there are fourteen professional divisions, some of which also play especially important roles in the commercialized areas of the technology. These divisions, through the sponsorship of special sessions during the general meetings of the Society, and the sponsorship of topical meetings which concentrate on specific areas of the technology, also bring together relatively homogeneous groups within the Society whose detailed knowledge of the field covered is such that the effects of commercial restrictions are minimized. In the nuclear power field the Nuclear Reactor Safety Division, the Nuclear Fuel Cycle Division, the Power Division and the Reactor Operations Division all play important roles in organizing and promoting the exchange of technology with strong commercial significance.

In the case of nuclear power the widespread practical application has not only complicated the process of information exchange, but has also added a new dimension to the need for exchange. As nuclear power has grown in importance in the world it has become evident that the exchange of information and technology are needed not only within the nuclear community, but also between the nuclear community and other groups: citizens' groups, governments, governmental agencies, and even religious groups. The American Nuclear Society has expanded these activities rapidly in the last few years. It has unique capabilities because of the large number of potential speakers and writers within its



membership, because of the wide geographical coverage of its local sections, because its membership covers the entire range of nuclear expertise, and because it has the resources for organizing and coordinating the gathering and dissemination of information.

These capabilities were exercised vigorously in the recent series of nuclear initiatives which were brought to the ballot in seven states of the United States last year. These initiatives proposed various restrictive measures relating to nuclear power, whose effect would have been to restrict severely, if not terminate, the use of nuclear power in those states. The American Nuclear Society, largely through its local sections, was very active in disseminating information as to the facts about nuclear power and the true significance of the proposed measures. All of the initiatives were defeated at the polls, where a total of some 14 million votes were cast on those issues. The over-all ratio of votes against restricting nuclear power to those favoring restrictions was 2 to 1, and the largest percentage vote for restrictions in any one state was 42%. I have no doubt that the public information activities of the Society played a significant part in this sensible outcome. Along with our satisfaction at this demonstration of a strong majority in the United States who favor the use of nuclear power must come a sense of responsibility to continue to provide public information whose truth and objectivity are beyond question.

I might say in passing that I believe the question and answer volume Nuclear Power and the Environment, <sup>(1)</sup> a special publication of the Society which contributes heavily to our public information capabilities, is a good example of a factual and objective treatment of many of the questions relating to nuclear power.

It is indeed unfortunate that the very aggressive opposition to nuclear power by a vocal minority has almost forced those of us who take a rational view to assume the posture of partisans. I believe that as scientists and engineers our dedication must be a dedication to truth, and, although we are convinced that we must bend every effort to the task of bringing the benefits of nuclear power to the world, we must be on our guard lest the violence of the nuclear debate cause us to lose our own objectivity. Particularly, we must recognize that there are many of the general public who have fears about nuclear power which to them appear quite justified. Although these may result largely from a lack of information and understanding, we must also recognize that often there is a foundation of fact, upon which misunderstanding has built a towering edifice of doomsday speculation. We must listen with sympathy and understanding to the expression of those fears, and in responding to them be careful that in our efforts to dispell the fancy we do not downgrade the importance of the facts.

In providing information for our government officials we must not only strive for objectivity but also recognize that we may have something to learn ourselves. All questions relating to the use of nuclear power cannot be answered in terms of technology alone. A number of them involve questions of domestic and international relationships in which most of us cannot claim expertise. Here we should strive to learn, so that we can respond to the total problem, for without such a total response satisfactory solutions are unlikely to be found. In these remarks I am speaking from the vantage point of experience

In the United States; but opposition to nuclear power is not confined to the United States, nor is the ability for the nuclear opposition to recruit support because of inadequate public knowledge. It would be prudent for any country moving into the nuclear age to take measures for adequate public information at an early stage, and thereby hope to prevent strong opposition rather than wait to cope with it after it occurs. For this reason I believe that the U.S. experience is pertinent in the international sense, for whatever can be learned from it.

It would however be misleading to imply that the main significance of the American Nuclear Society for international technology transfer is as a source of vicarious experience in dealing with the problems of nuclear power and of technology and information exchange in general. The Society is, in its own right, an important part of the machinery of international technology transfer. Its membership recognizes no national boundaries: there are over 1000 professional members outside the United States, as well as nearly 100 student members. The professional membership abroad represents 11.3% of the total professional membership, and includes members in 50 different countries. There are six local sections outside the United States, in Belgium, Central Europe, France, Italy, Japan, and Latin America. There are student branches in Canada and Mexico and others are under discussion. The meetings of the Society are always completely open, both to members and non-members: its journals welcome papers of merit from all over the world, with no requirement that authors be Society members.

It is the policy of the Society to encourage the formation of national nuclear societies in other countries, and to encourage the affiliation of such societies with ANS. Regardless of formal affiliation, the Society cooperates with related societies in other countries, and with national and international agencies, for the transfer and exchange of nuclear technology: this conference itself is an instance of such cooperation. The Society co-sponsors a general International Meeting every year, the most recent in Washington, D.C., in November, 1976, with the European Nuclear Society as co-sponsor. Other recent jointly sponsored meetings have been the first European Nuclear Conference, in April 1975, in Paris, which was also co-sponsored with the European Nuclear Society, and the joint meeting with the Canadian Nuclear Association in Toronto, in June 1976. The Society also sponsors or participates in numerous international topical meetings. These are particularly effective for technology transfer, for the restricted scope of a topical meeting makes possible a coverage in depth which can address more effectively the practical problems of the technology. A recent example is the First Pacific Basin Conference on Nuclear Development and Fuel Cycle, which was held in Honolulu in October 1976, co-sponsored by the Pacific Coast and Japan local sections of the Society. A Second Pacific Basin Conference is already in planning for 1978. Through special reports in Nuclear News the Society also gives timely coverage to the technological substance of important international meetings sponsored by other organizations. The Geneva Conferences have been covered and a special issue is planned to cover the IAEA Conference on Nuclear Power and Its Fuel Cycle, which will be held in Salzburg in May of this year.

One of the most effective means of international technology transfer is through students who cross international boundaries to pursue their education. The American Nuclear Society has fifty-four student branches which cover most of the universities in the United States with substantial nuclear engineering programs. These student branches can serve the important function of transferring information from the laboratories to the universities, where it has maximum effectiveness in the education process, and whence it diffuses throughout the world. The Society also has a Professional Division on Education which gives special attention to the techniques for effective information transfer within the educational systems. The impact of this activity results not only from the improvements in technology transfer which result in the home institutions of the members of the Education Division, but also from the development of techniques which can themselves be used in other countries to increase the effectiveness of the education and transfer processes.

In conclusion I would like to return to my original thesis that the professional societies in the nuclear field have the opportunity not only to help bring the benefits of nuclear power to the whole world, but to further, at the same time, international good will and friendship. The professional technical society is devoted to the interests of its members as individuals. Thus technology exchange within such a society has a characteristic which is not shared by other more formalized and more self-conscious means of exchange: it is a person-to-person exchange. This is the type of exchange which fosters friendship, respect, and understanding at the personal level, and some base of understanding at that level is certainly necessary for the soundest understanding and friendship between nations. That consideration is quite pertinent to this conference, for the full benefits of nuclear power, and certainly the benefits of technology transfer, are unlikely to be realized in any world but a friendly one.

## THE ROLE OF GOVERNMENT IN THE PROMOTION AND TRANSFER OF TECHNOLOGIES

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### ABSTRACT

1. After the Second World War governmental engagement in research and development (R & D) grew rapidly in many countries. This is particularly true for new and large technological projects and development lines involving high commercial risks like nuclear engineering.

In the Federal Republic of Germany government and industry took up research into and utilization of nuclear energy for peaceful purposes in 1955. The situation at that time, the initial activities and the distribution of responsibilities between the government and the private sector as well as the special role of the present Federal Ministry for Research and Technology (BMFT) are described.

2. Government support for the development and introduction of nuclear energy in the Federal Republic of Germany has followed the lines of four Nuclear Programs. The most important objectives and results of these programs are presented; some projects which failed are analysed.

3. Government support for nuclear R & D is effected by different means and measures. The building up and equipment of training facilities at the universities and research institutes, as well as the financing of prototype and demonstration plants are mentioned. The different ways of providing support and the corresponding engagement on the part of government and industry are described.

4. By its support, the Federal Government acquires title to technological knowhow. When utilizing this knowhow commercially within the Federal Republic of Germany, or when transferring it to partners abroad, certain rules have to be followed. These rules are briefly described.

5. The utilization and transfer of technological knowhow encounter many difficulties and barriers on the knowhow-producing side (very often the governmental side) and on the industrial side. Experience in the Federal Republic of Germany and approaches to reduce or overcome the transfer barriers are presented.

6. Important objectives of the Federal Government's Research and Technology Policy are

- to contribute to the modernization of the economy, not only through supporting big industrial companies, but by an effective utilization of R & D results, especially from university and government institutes, and by the promotion of the

technology transfer within the country; and

- to introduce national scientific and technological knowledge into international cooperation, thus making such knowhow accessible above all to the developing countries.

The large government-supported nuclear research establishments are of particular importance in the transfer of technological knowhow to developing countries. Their possibilities and role are discussed.

7. In the field of nuclear energy the Federal Government is not only a promoter of R & D and the owner of a comprehensive knowhow - It is equally responsible for preventing the abuse of nuclear materials.

Some of the basic principles of the Federal Government's nuclear export policy are presented.

1. This paper is presented at a time when, in the Federal Republic of Germany, the use of nuclear fission for the generation of electric energy has encountered a major and serious crisis: Citizens, political parties and Parliament are split over the question whether or not, and to what extent, nuclear energy is essential for the electricity supply of the country. They are uncertain and disturbed with regard to the real dimensions of the potential dangers and risks of the large-scale use of nuclear power. Decisions and activities of both the government and the electric utilities in introducing nuclear energy meet with growing distrust and increasing criticism.

Doubts and opposition expressed with regard to nuclear energy, distrust, and criticism of the responsible institutions and individuals in government and industry go hand in hand with a general scepticism of modern science and technology. They coincide with the fear of a state, administered far from its citizens by an anonymous technocratic bureaucracy. But they also meet with isolated, but nevertheless intensive, movements which criticize our political system and desire to change it radically. All these elements focus in a broad spectrum of "citizen initiatives" which fight actively and efficiently both in public discussions and in demonstrations, but also with formal legal means, against the utilization of nuclear power.

The controversy in the Federal Republic of Germany is now governed by the discussion of the problems of reprocessing and radioactive waste disposal. As a consequence, government licenses for the construction of new nuclear power stations are refused unless a sufficient solution for the disposal of highly radioactive waste, particularly from a planned large reprocessing plant, is presented. The start-up of at least some of the 14 nuclear power stations at present under construction with an output of 12,000 MWe is threatened by possible legal interventions on the part of nuclear opponents and by the jurisdiction of the responsible courts. Necessary technical changes or repairs in one or another plant of the 13 nuclear power stations already operating with an output of 6,500 MWe could result in a longer or even in an unlimited shutdown of such a plant.

The issues do not involve nuclear energy alone: The construction of new coal and oil-fired power stations is also prevented due to the delaying or already inhibiting effect of Court decisions passed as a result of the applications of environmentalists. Energy policy in total and future energy needs of the nation are under discussion together with the fundamental problem of further growth, its quantitative and qualitative aspects in a highly industrialized country.

The urgency of adequate governmental decisions and measures with regard to the future paths of energy policy and to nuclear power coincides with alarming developments and serious problems in the employment field. Since 1975 the annual average percentage of unemployed persons in the country has been more than 4% of all employable persons. It is higher by far than the percentage recorded in the years before that date. Large numbers of young people will finish school and university in the coming years and will look for secure working places. The reduction in industrial man-hours due to a decreasing demand for electric power stations must lead to a reduction in employment. Figures quoted in the discussion show that the construction of one nuclear power plant of 1,300 MWe requires the average activity of 5,000 workers over a period of 8 years.

Last but not least, substantial political problems arise from the question of non-proliferation. They influence export possibilities, thus affecting the Government of the Federal Republic of Germany as well as the German nuclear industry which needs nuclear exports in order to maintain a competitive production capacity.

We are certain that all these serious difficulties have to and will be overcome. But our understanding of the role of government in the promotion and transfer of nuclear technology cannot be defined without taking into account the actual circumstances. We clearly have learned that the problems of "Going Nuclear" within a country cannot be handled in an isolated way. We have to take into account national policy in this total energy field, and the involvement and participation of citizens in it. We have to consider industrial policy and foreign relations as well. We have to think in terms of sufficiently large social, political, and technical systems, not only in single, separated elements of them.

Experiences such as those now being learned in my country are useful for the assessment of whether or not standpoints, arguments, and decisions of the past were right and whether they included sufficient forecasting. We should learn from these experiences. We should improve our ability for prognosis, which we need urgently in order to find our way in a world which is becoming more complex from day to day.

2. After the Second World War, governmental engagement in research and development (R & D) grew rapidly in many countries. This is particularly true of new and large technological projects and development lines which resulted from military use, such as computers or nuclear energy. The enthusiasm and commitment of scientists, industrialists and politicians pushed these technologies forward to peaceful applications thus creating big industries on the results and prospects of big science. More and more funds were invested in steadily growing R & D activities.



In the Federal Republic of Germany, science, industry and government took up research on and utilization of nuclear energy for peaceful purposes in 1955. The role of the Federal Government during the initial phase was to build up R & D capacities in universities, in government laboratories outside universities and in industry, so that the expected benefits and possibilities of nuclear energy would be made accessible to the country.

In the industrial sector at the same time, private companies took on their share in rebuilding an appropriate manufacturing and electricity generating structure.

Destruction and the need for the recovery of science and industry in the Federal Republic of Germany 20 years ago were still so large, and the will to rebuild, to enlarge industrial production and productivity was so overwhelming that it was possible for a rather global government support of a broad technology push in the nuclear field to result in remarkable progress in education, in the organization of R & D and production teams and in the construction of experimental R & D installations and industrial facilities. Valuable advantages during this phase were gained from international cooperation, particularly from scientific and industrial contacts with the USA.

In 1955, government responsibilities for the support of nuclear R & D and all other aspects involved were assigned by the Cabinet to a new Federal Ministry for Atomic Affairs. The responsibilities for the licensing and supervision of nuclear activities were transferred to the governments of the 11 states (Länder), because in our federal system similar conventional tasks in the safety field already rested with these Länder. The Federal Government remained responsible for legislation and the general supervision of Länder actions.

There is no doubt today that massive and overproportional Government support of nuclear research and technology was, and is, necessary. This field still involves high commercial risks, heavy financial burdens, and unforeseeable political uncertainties. But there are certain doubts today as to why energy R & D in all industrialized countries and government promotion were, in practice, entirely concentrated upon the nuclear sector up to 1973. During that year, the oil-producing countries changed their price policy for this most important fuel. Today we agree that a country must include all energy resources in its energy policy, and in its energy R & D all those resources which have been already developed and which are in wide use as well as new ones. All possibilities - in highly-industrialized countries particularly the vast potential for a cautious and rational use of energy, for a critical review of the energy needs updated forward to the suppliers - must be taken into account in order to serve the main objectives of energy policy today to assure cheap energy on a basis most favorable to the environment, serving the needs which are really necessary, and relying as far as possible upon such primary resources which are at maximum accessible and independent of crises.

The attainment of these objectives in large country like the Federal Republic of Germany means to dispose of adequate technical capabilities and the necessary nuclear industry. It also means that domestic energy reserves - in the Federal Republic of Germany, mainly coal - are of particular importance.



A possible second question concerns the delegation of certain licensing and supervising tasks to a decentralized body of authorities, in our case of 11 Lander. The contrary way would be centralization within the Federal Government. There are remarkable pros and cons for and against the way chosen. But the fundamental intention of our constitutional system, namely to keep an appropriate balance of power between the federal and state governments, thus relying on a form of checks and balances, might be the dominant reason for our approach. Nevertheless, such a division of legislative and executive powers in the nuclear safety and radiation protection field requires a lot of additional time-consuming coordinating action.

In diagram 1 I have tried to show in a simplified manner the division of responsibilities for nuclear energy in the Federal Republic of Germany between the private and government sectors.

3. Government support for the development and introduction of nuclear energy in the Federal Republic of Germany has followed up to 1976 the lines of four Nuclear Programs. The term "program" in this context stands for two things: Firstly, it describes the totality of planned actions or activities - governmental, scientific, industrial - for the attainment of specified objectives. Secondly, it means a document in which these objectives, the underlying situation and status, the activities, past results and those planned for, or expected from the future, are formulated together with the financial - mainly government- and personnel resources for these activities and the ways chosen for carrying them out. Our normal planning period covers 4 years. It covers the same period as the general medium-term financial planning of the Federal Government. It is evident that the objectives envisaged in most cases lie in the future beyond these 4 years.

The programs - here understood as documents - serve two tasks: They oblige the responsible government institution to submit its analysis, ideas and planning to scrutiny by Parliament and to open discussion by the interested public and by other partners, for example at the international level. The programs inform R & D teams, R & D institutions, and industrial companies about the intentions and possibilities of government support. This is necessary because a large part of the program is performed outside direct government influence on the basis of applications and competition for the announced public funds.

The last and fourth Nuclear Program (1973 - 1976) was presented as a draft to a large public and finally discussed in an extensive panel meeting. Experience and a fair understanding of democratic processes show us that in such sensitive and important fields as energy policy or energy R & D, planning cannot be carried out without a wide participation of all groups which are involved, either really or potentially, in the measures and their consequences. Plans cannot be set up without a comprehensive and permanent dialogue in which experts and responsible representatives of industry and government try to submit in an objective way all the necessary information. Autocratic decisions or curtains of secrecy do not pay.

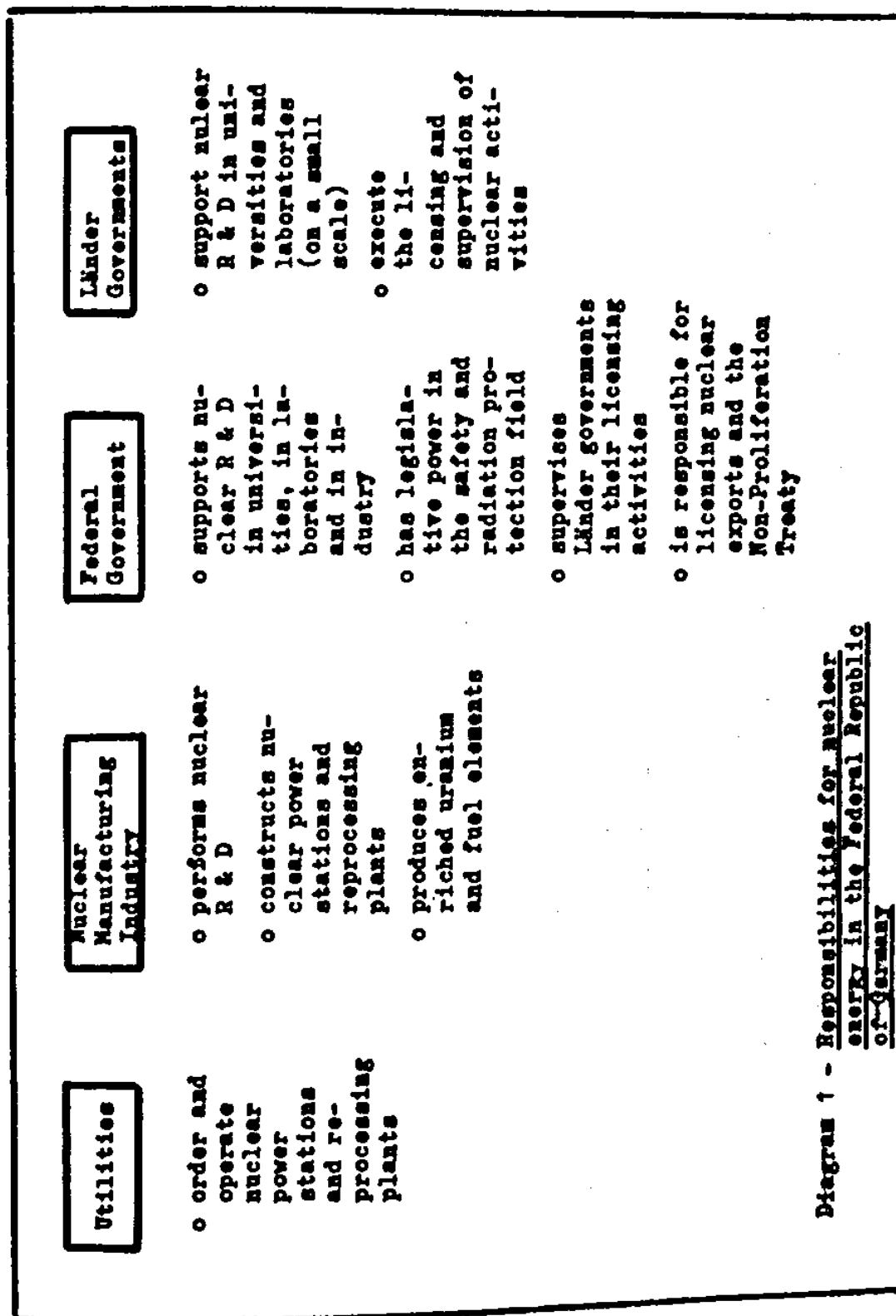


Diagram 1. Responsibilities for Nuclear Energy in the Federal Republic of Germany

Diagram 2 gives a rough survey of the past 4 Nuclear Programs of the Federal Republic of Germany, their breakdown into the main program fields and the corresponding government funds. The large program field of Basic Nuclear Research makes practically no contribution to the task of introducing nuclear power into the energy system of the country. It must be omitted in all cost-benefit discussions of nuclear R & D.

Let us take a look at the objectives of the four programs and see how these objectives reflect the evolution of the role of nuclear energy and of government support. All our programs were R & D programs. They were not concepts for the total energy supply of the country.

	1st Nuclear Programme 1956-1962	2nd Nuclear Programme 1963-1967	3rd Nuclear Programme 1968-1972	4th Nuclear Programme 1973-1976	1956 - 1976
Basic Nuclear Science (including Fusion Research)	706	1.540	2.530	2.840	7.616
Nuclear Energy R & D	380	1.220	2.380	3.365	7.345
R & D in Safety and Radiation Protection	30	60	260	485	835
R & D in Isotope Techniques	60	250	390	170	870
Total	1.176	3.070	5.560	6.860	16.666

Diagram 2 - Expenditure of Nuclear Programmes of the Federal Republic of Germany  
(in mill. DM - nominal values -)

Diagram 2. Expenditure of Nuclear Programs of the Federal Republic of Germany  
(in mill. DM - Nominal Values)

In the first German Nuclear Program - a memorandum by high-level experts from science and industry presented to the Government in 1957 - the development of power reactor lines stood at the center of activities. 4 or 5 experimental power reactors, each with a 100 MWe capacity and developed in the country, were planned for construction. None of these lines was of the light water reactor (LWR) type - a type which would prove so successful for German nuclear industry later on. But the memorandum mentioned the construction of such LWR stations on the basis of licenses from abroad as an additive action. In the memorandum, first ideas on the fuel cycle were presented, mainly concerning the head of the cycle - prospecting for domestic natural uranium resources, fabrication of fuel elements. Advanced reactor types like breeders and high-temperature reactors with a direct cycle were already mentioned for studies and material research. Finally, the buildup of safety, licensing and radiation protection experience was deemed essential. The financing of the nuclear plants was intended to be borne by the utilities themselves, by savings from tax exemptions and by special government credits. I should add that the First Program in 1957 was backed up by the necessary legislation dealing with the licensing of all nuclear work and setting up standards for radiation protection. This legislation was passed in the first few years of nuclear activities - an essential task for government and a necessary supposition for the use of nuclear energy in the country.

The Second German Nuclear Program (1963-1967) widened the objectives of its forerunner to the full extent of basic nuclear research and education, applied nuclear R & D and the technical realization of nuclear engineering. The introduction of nuclear energy into the energy system of the country was forecasted to take place at the beginning of the seventies. Consequently the program in its central part provided for this introduction of a substantial reactor program. There were plans for several power reactors of an already proven type - LWRs and gas graphite reactors constructed by German firms with licences from abroad to be ordered by utilities with limited government support, as well as the development of advanced types - breeders and HTRs. Here substantial public funding was considered necessary. A small reprocessing plant for LWR fuel (30 t/a) was planned for construction, also research on waste disposal in order to propose a final storage place. Activities on nuclear safety and radiation protection were included in all parts of the program.

The Third Program (1968-1972) continued the broad government support for nuclear R & D. It was launched at a time when the first large LWR power plants in the country started operation and German reactor constructing companies had demonstrated the knowledge they had gained in cooperation with industrial partners from the USA. The task of the further introduction of nuclear power stations was now left totally to private industry. Government funds concentrated on advanced reactor lines and fusion, nuclear safety research and the elements of the

fuel cycle from the support of uranium prospecting work and enrichment techniques up to reprocessing, waste solidification and safeguards research.

The Fourth Nuclear Program (1973-1976) was formulated in 1972, prior to the events in the fall of 1973. It integrated nuclear energy R & D into a broad national energy and industrial policy and into a system of manifold international collaboration. For the first time it contained a chapter on cooperation with developing countries and offered technical assistance on a bilateral and multilateral basis.

The main technical activities of the Fourth Program concerned the development and construction of prototype installations for fast breeders, HTRs, and uranium enrichment, reprocessing and waste R & D and the operation of the national research centers which had at this time reached a capacity of more than 11,000 employees, a number which was felt to be sufficiently high.

To sum up, I would like to mention the following main results of our four Nuclear Programs since 1956:

- by rebuilding, staffing, and equipping university institutes in the fields of nuclear research and engineering, by establishing and operating large nuclear research centers outside universities for all necessary big science studies and experiments on the pre-industrial phase (the nuclear centers in Jülich and Karlsruhe should be mentioned here), by promoting the international exchange and cooperation of scientists and engineers, the Government established the personnel and scientific basis for introducing nuclear energy into the economy;
- by funding the construction and operation of research and prototype power reactors, together with the fabrication of the necessary fuel elements, the Government helped reactor building companies to acquire practical experience and know-how for their present production capacity and competitiveness;
- by taking over most financial risks in the operation of nuclear prototype and demonstration power plants, the Government helped utilities to go nuclear;
- by funding R & D and the construction and operation of prototype plants for enrichment, plutonium handling, reprocessing, waste treatment and storage, the Government established - together with the financial support of natural uranium prospecting work - the basis for the nuclear fuel cycle, the responsibility of which is now taken over more and more by industry;
- by appropriate legislation and by promoting nuclear safety and radiation protection R & D, government action and support assured that the utilization of nuclear energy is performed with a minimum of harm and risks to the environment and to the population.

R & D with great technical risks cannot be without mistakes and failures. This is also true of nuclear R & D. Let me answer the question, where have there been unsuccessful projects in the Federal Republic of Germany in the course of government promotion and what has been the main reason for their failure:

projects developed unfavorably in all such cases where too large gaps existed between an offered technological system and the demand and possibilities of its users, the market or, said in another way: Where the transfer of technology already either in its original potential or in the course of the project due to unforeseen constraints was too small.

As the national and international market in the power reactor field can only accept a very limited number of different reactor types, parallel developments of new reactor lines could only be successful in a very small number. So also in the Federal Republic of Germany several reactor systems had to be cancelled from further development, corresponding experimental facilities and prototype plants had to be shut down. This holds particularly true for a heavy water moderated  $\text{CO}_2$  cooled and a light water moderated steam-cooled reactor, each in the range of 25 - 100 MWe. It also holds true for the futuristic concept of an incore thermionic reactor for space applications. Here the development phase was terminated without constructing an expensive prototype. In the advanced reactor field, development of a steam-cooled fast breeder was stopped.

What we learn from this is that the government unit responsible for R & D should be cautious in pushing ahead a new technological system without the partners who need it, who will use it and who are willing to pay for its application - at least partially according to their possibilities. In consequence of this lesson we try hard to include the costs of nuclear R & D as much and as early as possible in the prices for the energy produced by the application of the R & D results, i.e. the costs should finally be borne by the energy consumer. Ideally it means that the utilities side should finance nuclear R & D when it is approaching the phase of market realization and market introduction.

Projects which are not successfully concluded do not mean that all investments are in vain. The practical experience and skill gained remains with the developing teams and with the constructors and can be applied in further work.

4. By federal support, R & D institutes and industrial companies acquire title to substantial technological knowledge. A part of this knowledge is protected by patents.

What is the attitude of government towards this knowhow financed with the taxpayer's money, particularly under the aspects of transfer within the country and in the framework of international cooperation?

Firstly, I should state that all R & D results obtained with government support have to be published or open to access to everyone who might be interested in them. For government R & D institutions this rule is laid down in their statutes. For industrial projects, such general obligation is part of the conditions for granting government funds.

In most cases the publication of results does inform only in a rather general way about the R & D activities. It is sufficient to prevent unnecessary parallelism or duplication of work, but it is not yet, or is only partially, suitable for direct practical utilization, particularly for industrial use and applications. So direct contacts of interested users with the institute or industrial company having performed R & D work might start a more substantial cooperation. Industrial companies generally are not limited by any government restric-



tions on such cooperation to the extent that the knowledge gained with government support is not protected by patents. Government institutes need government agreement for all substantial cooperation with non-government partners both within the country and abroad.

Special attention must be paid to patents protecting knowhow gained with government help. These patents will not be owned by Government.

The use of protected knowledge by institutions or industrial companies from abroad has to follow normal commercial rules, respecting the interests of the patent owners. So the Federal Government cannot force a supported industrial company to give a license which would injure its market positions abroad. But protected industrial knowhow has to be made available for non-commercial international cooperation at government level. When a government laboratory is the patent owner, the exchange is possible as long as an exclusive license has not been given to a domestic partner.

5. The utilization and transfer of technological results and knowledge encounters many difficulties and barriers. This is particularly true when these results and knowledge are part of more generally applied research, where there is still some distance from industrial use and users, and where non-industrial institutes are involved in the R & D.

The difficulties and barriers are not specific for the Federal Republic of Germany alone: Many scientists are more interested by far in new and fascinating scientific results than in the practical application of such results, so that very often valuable knowledge is not transferred into new applicable technologies and innovations. The same effect might exist because scientific and technological results are often presented by their authors in a way where these results are hardly to be understood; there is a barrier of communication. On the opposite, industrial side engineers and industrialists have difficulties in transferring knowledge from external sources to their research and development work, in their planning and construction of technical apparatus - the well known "not-invented-here-effect". The role of government is to reduce such barriers in the technological and innovative process, particularly where there is massive government responsibility in the research system - in universities and non-university institutes. Attention has to be paid to the side of procedures of knowledge, the scientists and scientific organizations. Encouragement has to be given to the staff, incentives have to be created for an improvement of transfer activities, a proper organization to be set up for pushing ahead this transfer. An example for such measures is the present organization or intensification of bureaus of utilization in our big nuclear research centers.

On the other side the communication process, contacts of various kinds between scientist, engineers and industrialists - on both the staff and the organizational basis - have to be improved in various ways. One of these ways is the intensified participation of research institutes in industrial fairs. For this reason we included last year for the first time an "Innovation market" in the program of our most important industrial fair in Hanover. The promising experiment will be repeated this year.

The described sort of communication is particularly essential for the cooperation of government institutes with a large number of small and medium sized industrial companies



which would otherwise not come into contact with government-supported R & D. Contacts are much easier where, in the course of large projects like reactor or fuel cycle developments, an intensive and permanent contact exists between nuclear research centers and the corresponding industrial national "champions".

The exchange of specialists, particularly a delegation of industrial experts to government R & D institutes, is also a proven element of transfer strategy. It is the classical instrument for all phases of international transfer, particularly between industrialized and developing countries.

6. My explanations up to now have already illustrated that the role of government in the general promotion and transfer of technologies focusses on two sets of objectives, a national and an international one:

- firstly, to contribute to the modernization of the national economy by the support of innovation within industrial companies of large and smaller size, by an effective utilization of the vast potential of existing and permanently produced R & D results, especially from university and research institutes, and by the promotion of technology transfer within the country.
- secondly, to introduce national scientific and technological knowledge into international cooperation, thus making such knowhow accessible above all to developing countries.

There is no doubt that these objectives are in a very substantial way correlated to the task of securing an appropriate energy supply, and here nuclear energy has an important role. This is also confirmed by article IV of the Non-Proliferation Treaty (NPT). Technology transfer in the nuclear energy field from industrialized to developing countries is one important element to support developing countries in their evolution and to reduce the social and economic gap between the northern and southern hemispheres of our world. For the Federal Republic of Germany, nuclear technology transfer is of increasing importance for industry and for the overall economy. The Federal Republic of Germany accounts for about 12% of the total world exports. About a quarter of our gross national product is based on exports. About 18% of all employed people are dependent on exports. About 40% of the turnover of our industry is based on export orders, the figure for the capital-goods industry is even 47%. Export will not lose its role for our economy. We know that in the forthcoming years our export products must be based to an even greater extent on new and special technologies, large and complex technical systems and installations particularly those in the chemical, electrotechnical and mechanical engineering sectors. Nuclear technology presents a key example of such technical products.

In our opinion economic relations between a highly industrialized country without large reserves of raw materials like the Federal Republic of Germany and developing countries should include in the future more than just an exchange of products with high built-in technology on the one side and of more simple consumer goods and raw materials on the other side.

Economic relations must develop into industrial cooperation and partnership which will provide the basis for common investments in the developing country and for joint ventures of the industries concerned. The Federal Republic of Germany took this path, for example, in its cooperation with Brazil and Iran. Here common activities in the nuclear energy field are a new and important part of manifold economic and political relations.

Both examples show how such new common activities develop from an existing basis in the political, economic, scientific and cultural fields and how government can prepare and promote those activities. As early as in 1969, an agreement on scientific and technical cooperation was signed by the governments of Brazil and the Federal Republic of Germany. Such agreements pave the way for manifold contacts of scientists and engineers of the countries. Experience in cooperative work and the simple but important effect of personnel acquaintance and the mutual confidence in the capability and responsibility of the respective partner are important aspects for the establishment of close contacts between the scientific and industrial communities. This is a very important basis for a successful technology transfer.

Scientific, technical and industrial cooperation in the nuclear energy field implies contacts and relations between many partners of different interests and includes specific political elements. Therefore, it follows that government or government institutions must assume the role of coordinator and moderator in such a cooperation. Naturally coordinating and moderating activities on the part of government will – as far as possible – respect the commercial interests of industrial partners, particularly when the latter are privately-owned companies.

But the connection between political, scientific, technical and commercial activities is more or less so close that there cannot be a complete separation between them.

For nuclear technology transfer to developing countries, a special official agreement has been shown to be a useful basis. It covers all those questions for the handling of which government or government institutions are responsible. Here the different subjects of cooperation are described, together with the rules for defining and performing common programs and projects. Also all questions concerning the exchange of personnel between government institutions and the handling of safeguards and patents are treated. Finally, the agreement establishes procedures and instruments such as a common commission for the overall control of cooperation.

Nuclear technology transfer in the framework of such broader scientific, technical and industrial cooperation and partnership includes several specific fields of activity. Cooperation in nuclear science and engineering constitutes the elementary basis. Here useful activities are the exchange of scientists and engineers, the organization of lectures and common seminars and joint projects both in the industrialized and in the developing country. Government research laboratories and university institutes are the main partners in this form of cooperation. It presumes that in the developing country some trained and experienced R & D groups already exist, so that the exchange of scientific and technical knowledge is – at least to some extent – a mutual one.

Elements of nuclear education and training have to be offered additionally to the partner. This holds true particularly for the phase of launching a larger program of nuclear power plants in a developing country. Here scientists, engineers, reactor operators, nuclear technicians, safety and radiation protection specialists as well as administrators have to be trained and prepared for autonomous work. For such training certain possibilities have been built up in the Federal Republic of Germany by Government laboratories, reactor building companies and utilities. Of special importance is the School of Nuclear Engineering in our Karlsruhe Research Center. Here also several training courses of the International Atomic Energy Agency (IAEA) have already been organized. Training courses held in the developing country itself are also of growing importance. A major advantage of such courses is that the experts and lecturers from the developed country are confronted on the spot with the specific conditions, circumstances and needs of the developing country. As an example I would like to mention training activities which are organized under the Brazilian-German cooperation in Brazilian universities, covering fields such as reactor physics and engineering, reactor safety, quality control and material testing.

The transfer of experience in the licensing and supervision of nuclear activities is a matter of great importance in the cooperation between industrialized and developing countries. The future of peaceful nuclear energy utilization depends on the careful handling of regulations. Nuclear accidents in one part of the world would influence the acceptance of nuclear energy in all other parts. The Federal Republic of Germany thus is willing in the range of its possibilities to submit experience in the nuclear safety and licensing field and also within the framework of bilateral cooperation. The new joint German Gesellschaft für Reaktorsicherheit (GRS) (known up to 1976 under the names of TÜV-Institut für Reaktorsicherheit (IRS) in Cologne and Laboratorium für Reaktorregelung und Anlagensicherung in Munich (LRS)) as well as other institutes and organizations have already given practical support to developing countries in the licensing and supervision for nuclear power plants.

Finally let me mention briefly the industrial side of nuclear energy technology transfer within the broad framework of private and government cooperation. Here an essential aspect is the integration of the industrial sector of the developing country into the transfer. Not only the classical tasks in constructing and operating nuclear power plants should be performed by domestic companies: the preparation and establishing of the infrastructure of the site, the construction of buildings, the delivery of smaller conventional mechanical or electric engineering products. Also larger components like pumps or control equipment should come from domestic industry. Production facilities should be built up when there is a major and long-term nuclear energy program. Joint ventures between industrial companies of both countries could provide the necessary capital and knowhow. Also the transfer of experience from nuclear power plant operators, the utilities, should be incorporated into the cooperation. As there is no direct interest of the utilities of the supplier country in such a transfer, it could be organized and performed on an advisory level.

Cooperation and technology transfer between more and less developed countries do not

take place on a bilateral basis alone. The frameworks of multilateral organizations are of equal importance, and also here the Federal Republic of Germany is contributing due to its technical, scientific and economic capability. Thus particularly the Technical Assistance Program of the IAEA is supported by the government not only by the normal contribution to the Regular Budget and to the General Fund but also by various additional voluntary activities. Multilateral cooperation and assistance is particularly important for developing countries in the preparation of nuclear programs.

7. In the field of nuclear energy the Government of the Federal Republic of Germany is not only the main promoter of R & D, an owner of comprehensive knowhow and the moderator and coordinator in scientific and technological cooperation. It is equally responsible for preventing the abuse of nuclear materials, so contributing to the reduction of potential dangers from modern technologies to the world and to human beings.

Having this in mind, the Federal Government has established several basic principles for its nuclear export policy and has adhered to them systematically. The German Government holds that the transfer of a modern technology like nuclear technology to developing countries during their progress towards industrialization cannot be denied when such countries utilize this technology subject to sufficient public and international controls. Not preventing sensitive nuclear technology transfer radically, but embedding both supplier and receiver countries politically and legally in an efficient international control system, is the only way to guarantee on a long-term basis worldwide acceptance of the principles of non-proliferation and the rules of the NPT. A policy of denial of sensitive nuclear technology transfer, for example reprocessing, may, on the contrary, lead soon to uncontrolled sensitive nuclear activities, the scientific basis and general technological knowhow of which are more or less described in open literature and therefore accessible to consequent efforts. Being convinced of the important role of nuclear energy to cover the energy needs of the world, particularly in developing countries with a high population, stressing the importance of the domestic industries of these countries to ensure working places and to raise the living standard of their population on the one hand, but withholding the necessary knowhow or even guaranteed access to services and materials required at any time do not make a coherent policy designed to enhance peace and international well-being and to lessen tensions in the world. The Federal Government regards the IAEA control system as the basis for safeguards. It has supported its set-up since the beginning and it is contributing within the framework of the Agency and by additional efforts in national research centers to develop and improve the safeguards techniques. Having agreed on the export of sensitive knowhow to Brazil, which has not yet signed the NPT, is no contradiction, because the transfer forms part of a whole nuclear energy program and will for the first time be subjected to the IAEA control system. An agreement was concluded between the IAEA, Brazil and the Federal Republic of Germany for the application of safeguards to all nuclear activities coming under or evolving out of the Brazilian-German bilateral agreement of June 27, 1975. A new feature of this Safeguards Agreement, which goes beyond requirements of the NPT and earlier IAEA safeguards agreements, is that it also covers

technology transfer. This means that not only "hardware" such as nuclear installations and fissionable material will be controlled. But also the transfer of "software", i.e. information and knowhow will trigger IAEA-Safeguards on the hardware produced on that basis. This Safeguards Agreement, which is the tightest ever concluded by IAEA, was approved by the IAEA-Board of Governors in February 1976.

Nuclear exports from the Federal Republic of Germany are only possible when, with respect to articles II and III of the NPT, the importing country guarantees international safeguards i.e. control measures by which it is verified that all imported materials and installations are not used for military purpose or other explosive devices. All exports of specific nuclear materials, installations and knowhow by industry need licenses on the basis of the official German export regulations.

What we need is again more confidence in international treaties, agreements and partnership. International solutions to the non-proliferation problem, for example wide cooperation in multinational fuel cycle centers, will only be found when this confidence has been established. The Federal Republic of Germany is willing to contribute to the enlargement of this confidence. It offers its experience, capabilities and the potential of both government and industry to the great task of technology transfer for the peaceful utilization of nuclear energy.

## TRANSFER OF NUCLEAR TECHNOLOGY FROM THE VIEWPOINT OF A GOVERNMENTAL ELECTRIC UTILITY

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### ABSTRACT

The Turkish Electricity Authority, being responsible for the erection and operation of the power plants and the interconnected system in Turkey, started the preparatory work for its first 600 MWe nuclear power plant five years ago. During 1976, preliminary projects were finalized and the site license was issued by the Turkish Atomic Energy Commission for a site on the Mediterranean Sea Coast. Recently, bids were invited for the nuclear and the turbine islands.

Erection of the first nuclear power plant in a developing country like Turkey brings a series of technology transfer problems with it. Generally, transfer of a new and sophisticated technology might be considered in three consecutive levels, namely:

- Training of man-power
- Local participation in engineering and management
- Local participation in manufacturing and erection of components.

This report will deal with such problems and suggested solutions related to the transfer of nuclear technology from the viewpoint of a governmental electric utility.

### 1. INTRODUCTION

Known energy resources of Turkey are comparatively limited. Local production of petroleum can only match approximately 20% of the total consumption. The rest must be imported. Coal resources are also rather limited so that they are preferably reserved for industrial use. For these reasons, electricity generation is mainly based on local hydroelectric and lignite resources.

It is expected that a major part of the hydroelectric and lignite resources will be exhausted within 10-15 years. Current electrical energy generation is  $20 \cdot 10^9$  kWh. Considering the relatively high average increase rates of electricity consumption (around 12%) and short doubling times (6-7 years), one can easily conclude that the total generation will reach  $100 \cdot 10^9$  kWh in the early 1990s. On the other hand, the total hydroelectric capacity of Turkey is estimated to be  $70 \cdot 10^9$  kWh. An additional energy generation of  $50 \cdot 10^9$  kWh can be based on known lignite resources. Consequently, alternative energy resources are needed to cope with the rapidly growing energy demand after the 1990s. Nuclear



Energy will then be the only alternative.

The hydroelectric potential of Turkey has appreciable seasonal and yearly variations so that hydroelectric power plants are operated as peak load power plants. In order to keep the balance between hydroelectric and thermal power generation at an optimal level, nuclear power plants must be integrated into the system even at earlier years.

In the light of the above considerations the Turkish Electricity Authority planned to have its first 600 MWe nuclear power plant operative in the year 1984, followed by other units with 2-3 year time lags. After 1990s almost all the newly installed power plants will be nuclear.

## 2. HISTORICAL BACKGROUND

Initial steps for the introduction of nuclear technology in Turkey were taken more than two decades ago by the establishment of the Turkish Atomic Energy Commission in the year 1956<sup>(1)</sup>. The first 1 MW "swimming pool" type research and training reactor started operation in 1961 at Cekmece Nuclear Research Center near Istanbul.

The first investigation related to the erection of nuclear power plants in Turkey was carried out in the year 1965 by an IAEA - Mission<sup>(2)</sup>. During 1968-69 a foreign consultant-engineering consortium prepared a feasibility study<sup>(3)</sup> in the name of the Ministry of Energy and Natural Resources for a 300 MWe nuclear power plant which was planned to be operative in 1977. This project could not be realized due to political and economical difficulties in early 1970s.

In the year 1970, the Turkish Electricity Authority was established by merging the previous governmental institutions in one single organization responsible for the planning of the Turkish electric system, erection of thermal and nuclear power plants and network, and operation of all the generation (including hydroelectric power plants), transmission and distribution systems. The Nuclear Energy Division of this governmental utility started its activities in November 1971.

After a careful evaluation of the changed electrical energy demand and supply conditions, revised feasibility studies<sup>(4)</sup> were finalized at the end of 1973 for a 600 MWe nuclear power plant, planned to be operative in 1984. Comprehensive site investigations have led to the selection of Akkuyu at the Mediterranean shore as the first nuclear power plant site<sup>(5)</sup>. The site license was granted by the Turkish Atomic Energy Commission in June 1976. Preliminary projects<sup>(6)</sup> and bid specifications were then finalized up to the end of last year and bids were invited for the nuclear and turbine islands during January 1977.

## 3. TRANSFER OF NUCLEAR TECHNOLOGY

In developing countries that have reached a certain technological stage, a sufficient number of scientists are usually available in universities and research institutes, knowledgeable in basic scientific and engineering aspects. However, very often there is a lack



of man-power experienced in practical application of a new technology. Especially in the case of nuclear power plants, completely new and sophisticated technologies and skills have to be acquired. This necessitates a very close contact and cooperation among knowledgeable persons, firms and institutions of developed countries and unexperienced partners in a developing country, if a quick introduction of this new technology is aimed at.

In general, transfer of a new technology might be considered on three consecutive levels, namely:

- Training of man-power
- Local participation in engineering and management
- Local participation in manufacturing of components, construction and erection.

Problems and practical solutions related to these aspects are briefly discussed in the following.

### 3.1 Training of Man-Power

Any technology transfer implies automatically a giving and a receiving partner. Without having a sufficient amount of well qualified man-power on the side of receiving partner, a fruitful technology transfer is not possible. In such cases, erection of a plant based on a new technology alone helps very little for a real introduction into this new field. A high portion of foreign aid and participation is still required for a second application. Difficulties might arise during operation. Therefore, availability and training of man-power plays an essential role in the success and efficiency of the technology transfer.

Governmental organizations in developing countries have often to cope with restricting rules and insufficient payment conditions so that the establishment of a well-trained team needs a long and cumbersome preparatory phase. The Turkish Electricity Authority tried to apply different parallel strategies in order to establish a team capable of cooperating with foreign partners. These are:

- Recruitment of senior staff among engineers and scientists already experienced in developed countries.
- On the job training of man-power and attendance of courses in developed countries.
- Preparation of Master's theses in related subjects.
- Cooperative research projects with Universities and other governmental institutions.
- Cooperation with foreign consultants and experts.

Preparatory training for senior staff would take an impracticably long time as compared with the usual lead times of a nuclear power project. Therefore, senior staff for leading positions were selected among engineers and scientists already experienced in the nuclear or related fields in developed countries. As can be seen from Table 1, most of the senior staff have a professional experience above 15 years, including a long stay in foreign countries. Four of them obtained their Doctor's Degrees in foreign universities.

Table 1. Qualifications of Senior Staff in the Nuclear Energy Division of Turkish Electricity Authority (TEK)

POSITION	AGE	UNIVERSITY DEGREE	NAME OF UNIVERSITY	PROFESSIONAL EXPERIENCE		YEARS
DIRECTOR	41	Dipl.Mec.Ing.	T.H.Hannover	Escher Wyss A.G.Zürich	Research Division	1,5
		Dr.Sc. Tech.	ETH,Zurich	EIR Switzerland TEK	Engineering " Nuclear Energy Division	8,5 6
DEPUTY DIRECTOR	41	Elect.Eng. MSC	Technical University of Istanbul	State Hydraulic works Electrical Power Resources Survey and Planning Administ- ration TEK	Operation and Maintenance Division Project Division Planning "	1 4 9
					Nuclear Energy Division	1,5
HEAD INVESTIGATIC DEPARTMENT	38	Geophysicist, Geolog	University of Istanbul	State Hydraulic Works Ersan Petrol Earthquake Research Institute IISEE-Japan	Underground Water Division Deputy Director seismological studies Research on seismology	3 1 7 1
HEAD PROJECT DEPARTMENT	41	Civ.Eng. MSC. Ph.D	Technical Univer- sity of Istanbul University of Southampton	State Hydraulic Works INEC-Portugal EMCH-BERGER Bern AG. TEK	Research Division Structural model techniques Nuclear Plants Division Nuclear Energy Division	11 1 3 1

Table 1. (Cont'd)

POSITION	AGE	UNIVERSITY DEGREE	NAME OF UNIVERSITY	PROFESSIONAL EXPERIENCE	YEARS
HEAD OPERATION DEPARTMENT	35	Licentiate of Physics Dr. of science	University of Istanbul University of Ege	Research Division Electricity and Electronics Lab. Nuclear Energy Division	9,5 8 3
HEAD SAFETY DEPARTMENT	38	Phys. Eng. BSc. MSc.	Cekmece Nuclear Research Center University of Saskatchewan Can. TEK	Health Physics Division Radiation Safety Office Nuclear Energy Division	3,5 8,5 1,5
HEAD, FUEL DEPARTMENT	36	Dip. Chem. Ing. Dr. Sc. Tech.	EIDG Tech. Hoch- Schule, Switzerland " " " " " " " "	Research Assistant Hot-Laboratory Nuclear Fuel Division	4 3 2
HEAD, NUCLEAR INSTALLATIONS AND COORDINATION DEPARTMENT	36	Civil Eng. MSc.	The George Washington University Morrison-Knudsen Mk-River Con. Str. Bechtel Co. TEK	Civil Design and Construction Construction and process pipe erection Pipeline Construction Nuclear Pow. Plant Design and Constr. Supv. Nuclear Energy Division	3 1 1 7 1,5

On-the-job training of inexperienced man-power in developed countries is probably the most efficient way to acquire the necessary knowledge and skill in a new field. As can be seen from Table 2, altogether 19 persons were sent to developed countries for on-the-job training for a period of 1-2 years. Such training took place in utilities or construction firms and purposely not in academic institutions. Additionally, 8 persons with comparatively higher experience attended IAEA International Training Courses on Nuclear Power Project and Implementation and on Nuclear Power Plant Construction and Operation.

Table 2. On-the-job Training and Attendance to Courses in Developed Countries

	NUMBER OF PERSONNEL	DURATION	PLACE
<b>1) ON-THE-JOB TRAINING:</b>			
PRACTICAL WORK ON THE DESIGN, CONSTRUCTION AND OPERATION OF NUCLEAR POWER PLANTS BY CONSTRUCTION COMPANIES OR UTILITIES	7	1-2 YEARS	W.GERMANY
	2	2 MONTHS	PAKISTAN
	4	1-2 YEARS	FRANCE
	1	10 MONTHS	ENGLAND
	3	2 MONTHS	SWITZERLAND
	2	2 YEARS	SWITZERLAND
<b>2) ATTENDANCE IN COURSES:</b>			
IAEA INTERREGIONAL TRAINING COURSE ON NUCLEAR POWER PROJECT PLANNING AND IMPLEMENTATION AND NUCLEAR POWER PLANT CONSTRUCTION AND OPERATION	6	3.5 MONTHS	ARGONNE (USA)
	2	3.5 MONTHS	KARLSRUHE (W.GERMANY)

Up to now 5 engineers have been trained in existing conventional power plants in Turkey. They were integrated into the erection or operating staff at that plant for a period of 1-2 years. Usually, operational staff of the nuclear power plants are preferably selected among personnel previously experienced in conventional power plants. Increased use will be made from training possibilities in conventional power plants for the training of erection personnel and operators. It is also planned that nuclear reactor operators will initially be trained on training reactors and facilities in research centers attached to the Turkish Atomic Energy Commission.

In order to attract young graduates of Universities and introduce them to nuclear problems, they are enabled to prepare master's or doctor's theses on subjects closely related to their work. By doing so, scientists of the Universities are also encouraged to widen their field of interest in practical applications. Subjects of the master's theses prepared or under preparation by the young members of the Nuclear Energy Division are given in Table 3.

Table 3. Master Thesis Prepared or under Preparation

UNIVERSITY	SUBJECT
Middle East Technical Uni- versity (METU)	<u>Prepared:</u>
METU	1) Economic and technical aspects of the nuclear fuel cycle.
METU	2) HTGR-Technology Fuel Cycle cost calculations.
METU	3) Economic and technological aspects of thorium fuel cycle.
METU	4) Technolglcal and economic aspects of fast breeder reactors and fuel cycle cost calculations.
METU	5) Reserve-Allocation in Power Systems and frequency regulation.
METU	6) Transient Stability and the frequency deviation studies on the integration of a large generating unit into power systems.
METU	7) Alternative methods and their comparison for the rejection of condenser heat in nuclear power plants of 600 MWe to be built in Turkey.
METU	8) Analysis of thermo-hydrodynamic phenomena in a PWR primary cooling system in case of pipe rupture.
Technical University of Istanbul (ITU)	9) Investigation of LOCA analysis in PWR.
ITU	10) Radioactive waste management
METU	11) Use of radioactive tracer technique in the determination of wear of cutting tools.
ITU	12) Engineering calculation of 5 MW TR-1 reactor by using two-group theory.
ITU	13) The Control and Kinetics of nuclear reactors.
ITU	14) Heat transfer Calculations in the fuel elements.
ITU	15) Burn-up calculations
	<u>Under Preparation:</u>
METU	1) The Implications of relative fuel price changes for Turkish Electricity Investment Planning.
METU	2) The possibility of switching a steam turbine in the heating system of the METU.
METU	3) Design and functioning of emergency cooling system in case of loss of coolant accidents.
METU	4) Response of a single-degree of freedom, second order system to burst-type random excitations.
METU	5) Thermal Pollution of Nuclear Power Plant

Cooperative research projects with Universities and other governmental organizations were extremely useful for the training of our staff, as well as for the integration of an appreciable number of knowledgeable scientists in the solution of practical problems related to the nuclear power project. Investigations related to the selection of the first nuclear power plant site were carried out by a team of experts from different Universities and Governmental Research Institutes almost without foreign participation. At the time being, cooperative research programs are formulated with different Universities to develop or adopt computer programs for safety evaluations.

Finally, close cooperation with foreign consultants and experts, as will be described in section 3.2 in more detail, has greatly contributed to enhance the knowledge and experience of the personnel.

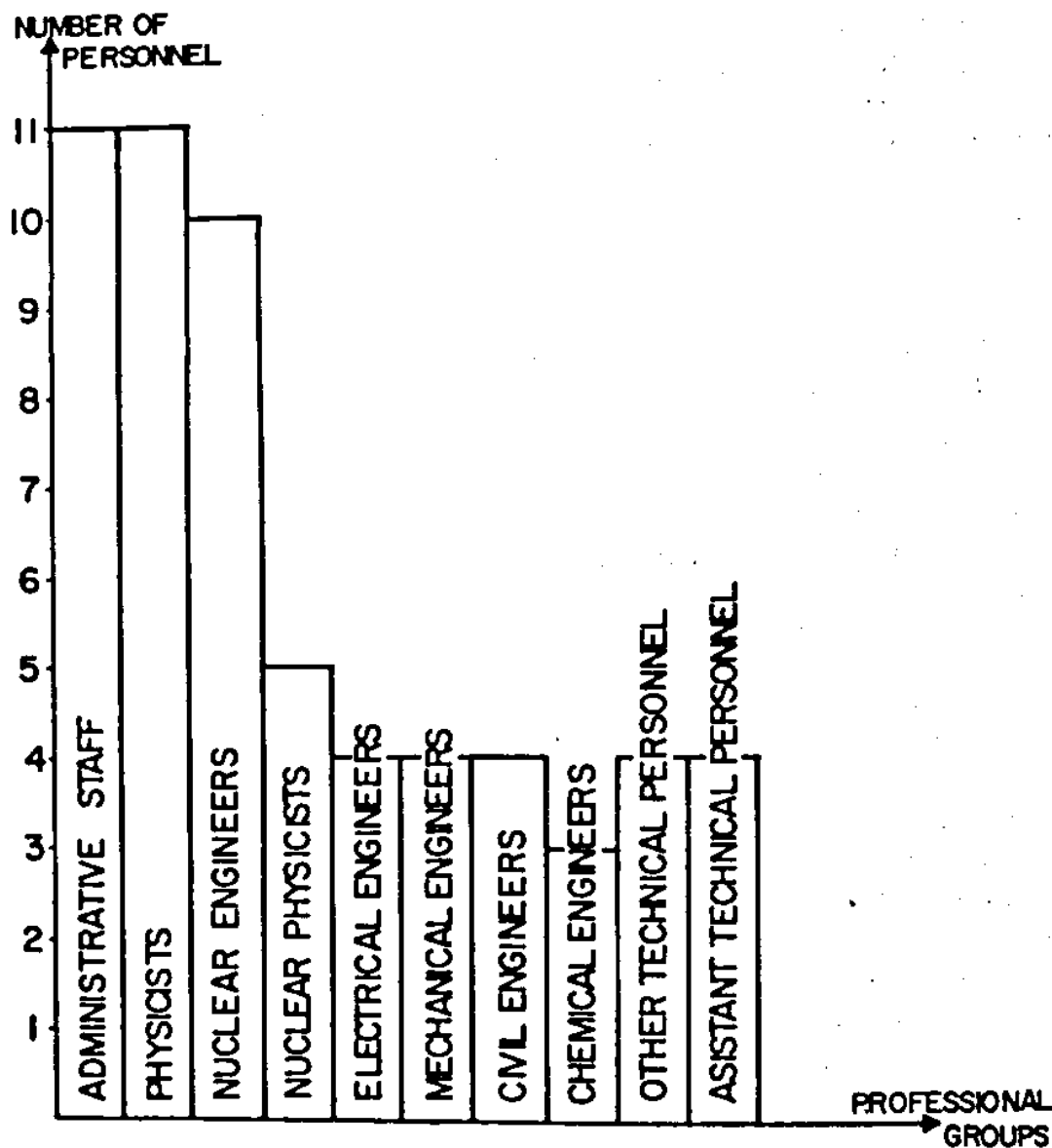
Fig.1 illustrates the number of the staff of Nuclear Energy Division and their distribution to professional groups, as of 1 January 1977. Considering the personnel working on the construction site and cooperatively working on nuclear power projects in other Divisions of the Turkish Electricity Authority, the total number already exceeds 100 at this stage of the project.

### 3.2 Local Participation In Engineering and Management

In developing countries, very often, local participation in manufacturing and/or erection of components of a plant based on a new technology is much lower than the actual capabilities in the country. This can probably be explained by the insufficient local contribution in engineering and management services. A recent survey has clearly shown that the local share in manufacturing and erection of a conventional steam plant can be almost doubled given the availability of adequate local engineering and management services. Therefore, local participation in engineering and management services is considered as an essential prerequisite for an increased local participation in manufacturing and erection of components.

Local engineering and management services can be supplied by a team within the utility or by private and governmental organizations outside the utility. Governmental restrictions on payment conditions imposed in Turkey lead to an intermediate solution, namely: concentration of the management and supervision services within the utility, and the encouragement of local participation by private engineering companies outside the utility.

The establishment of a team capable of managing and supervising a nuclear power project itself needs a great deal of know-how and training. To achieve this goal, an extremely close cooperation is programmed between the staff of the Nuclear Energy Division and the Consulting-Engineering Consortium. Table 4 illustrates the distribution of work load between Consultant-Engineer and the local personnel during the first phase of the services prior to construction. Local contribution reaches 54% of the total.



*Fig. 1. Number and Professional Distribution of the Personnel in the Nuclear Energy Division of TEK*

As can be seen from Fig.2, local contribution increases in the second half of the period in accordance with the increased number and experience of the local personnel. After 18 months of application, we can definitely state that the distribution of work load has been kept at the programmed level, and the local personnel have accumulated an appreciable amount of experience.

Another important factor influencing the contribution of the utility in the management and supervision of the project is the extent to which the project is subdivided into main and auxiliary lots. A turn-key contract might reduce the risk of the utility appreciably.



Table 4. Distribution of Work - Between TEK and Consultant - Engineer

ITEM	TEK (MAN-MONTHS)	ENG (MAN-MONTHS)
REVIEW OF FEASIBILITY STUDY	2	6
BASIC LAYOUT	9	25
SITE INVESTIGATIONS	16	13
LICENCING CRITERIA	31	10
REFERENCE DESIGN	35	76
TURKISH MANUFACTURERS	14	8
MAIN BID DOCUMENTS	46	154
BID EVALUATION	45	48
DESIGN	358	199
FUEL MANAGEMENT	37	23
SPARE PARTS	3	3
COST ESTIMATES	38	8
CPM - PROGRAM	10	13
INSPECTION	11	9
SITE EQUIPMENT	5	5
CONSTRUCTION ARRENGMENTS	5	5
PSAR-PREPARATION	95	24
CONTRACT PREPARATION	14	21
PROJECT MANAGEMENT	66	57
	840	707

However, it reduces also the contribution of the utility. On the other hand, splitting the project into too many lots might increase the risk of the utility to an unacceptable level. Therefore, an intermediate solution is adopted by arranging the main installation in three lots namely: nuclear island and turbine island, both including erection and excluding civil works, and the main civil block. Infrastructures and auxiliary buildings and installations are to be handled in form of separate local contracts. The coordination between main and auxiliary lots requires a thorough understanding of interphase conditions, which provides a sound basis for learning both in technical and managerial aspects.

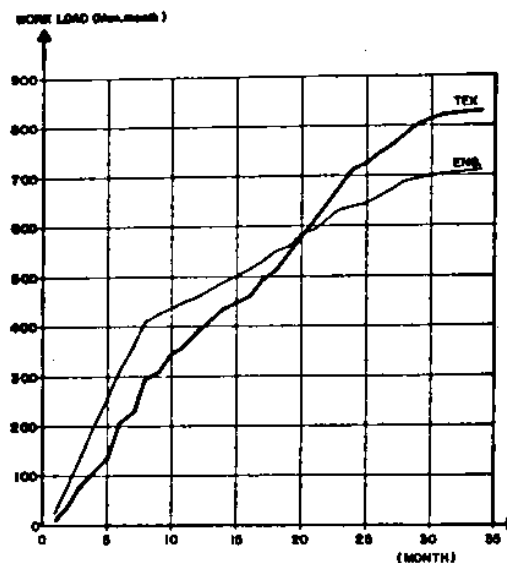


Fig. 2. Distribution of Work - Between TEK and Consultant - Engineer

In addition to direct participation of the utility, local engineering firms might be encouraged by obligatory requirements in bid specifications which oblige main contractors to subcontract certain engineering services to local firms. In this way, a direct transfer of know how from foreign to local engineering firms will be possible. Especially local civil engineering firms are now capable of cooperating effectively with foreign partners. Comparatively low salaries in Turkey also lead foreign firms to subcontract certain engineering and erection services to local firms.

### 3.3 Local Participation In Manufacturing of Components, Construction and Erection

Local participation in manufacturing of components, construction and erection might be possible in two ways:

- Already existing possibilities in the country
- Introduction into new fields.

Maximal use of already existing possibilities in the manufacturing of components, construction and erection is a very natural goal of each country, especially in developing countries in order to support the weak local industry and due to difficulties in the supply of foreign credits.

In Turkey, the existing production facilities are not yet equipped for a participation in the manufacture of heavy and complicated components. Therefore, only certain materials and auxiliary equipment and services which do not require a special skill might be supplied in the country for nuclear and turbine islands. In order to maximize the local participation, bid specifications oblige main contractors to investigate the possibilities of local supply thoroughly and subcontract such materials, equipment and services which can be supplied by local firms in Turkey. Hereby, the main contractor shall be responsi-

ble for the supervision, quality control and timely delivery of the local supply which protects the utility from undue risks. A comprehensive list of local manufacturers and construction firms is added to the bid specifications, in order to help foreign contractors judge local possibilities.

In contrast to nuclear and electro-mechanical equipment, a great part of the civil construction can be handled by the existing local firms. A foreign partner might only be necessary for the management and supervision services and for certain special constructions. Therefore, after the selection of the main contractors for nuclear and turbine islands, civil works of the main buildings will be covered by a separate contract, preferably to a local firm as main contractor together with foreign partners and/or subcontractors. As mentioned before, plant infrastructures and auxiliary buildings and installations will be handled, in any case, as separate local contracts.

Introduction of local manufacturers and construction firms into new fields can only be possible on a broad scale, if the utility itself undertakes the responsibility for the project management. Expectedly, foreign contractors would not easily undertake responsibility for local subcontractors to manufacture for the first time new equipment and construct a new component. On the other hand, a utility can only then accept such a risk if sufficient management, engineering and production capacities already exist in the country. Therefore, for the first nuclear power plant, it will be too optimistic to expect a high local participation in new fields and products. As a first step, the necessary management, engineering and production capacities must be developed according to a well-planned program. It will then be possible to contract separately such components which can be engineered and produced in the country by the aid of license agreements or even by being based on local designs and developments.

#### 4. CONCLUSIONS

Without well-planned steps in man-power training and development of local management, engineering and production capacities, transfer of a new technology would not be easily possible or would, at least, take a very long time. Consequently, such a country would depend on foreign management, engineering and production for an unacceptably long period. In developing countries, difficulties in finding sufficient foreign funds might, in the long run, restrict seriously a broad application of this new technology.

In Turkey, due to limited conventional energy resources, supply of the electrical energy for the rapidly growing industry will heavily depend on nuclear power plants after 1990. Turkish Electricity Authority, being responsible for the planning, erection and operation of the electric system in the country, has been working on its first 600 MWe nuclear power plant since 1972. This first unit is planned to be operative in 1984, followed by additional units with a 2-3 years time-lag up to 1990. Rapid transfer of nuclear technology is considered as an essential factor for the fulfillment of the future electricity generation program, heavily based on nuclear energy after the 1990s. Therefore, a broad train-

ing program has been started in order to develop within the utility a team capable of managing and supervising future projects without great foreign aid. Maximum participation of the local firms in the engineering and erection of the first nuclear power plant is encouraged by appropriate distribution of responsibilities between utility, foreign and local contractors.

Longer lead times for the realization of the project at initial stage and additional risks to be faced by a utility for a rapid transfer of nuclear technology will probably pay for themselves in the long run by a broader and more successful application in the country.

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## PLANNING EFFECTIVE NUCLEAR TECHNOLOGY TRANSFER AND THE PROJECT METHOD

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### ABSTRACT

Technology transfer includes a wide scope of activities ranging from formal advanced degree programs to on-the-job familiarization with process control. The methods utilized to accomplish the desired degree of technology transfer include all techniques by which information may be received through the senses. Lectures, reading, observation, participation in real or hypothetical operating situations and combinations of these have been used with varying degrees of success.

The extent of technology transfer achieved depends upon many factors including the interest, background, and motivation of the recipient, upon the experience and skill of the one providing the information, and upon the environment in which the transfer is taking place. In order to achieve the most cost-effective transfer at the level of transfer desired, methods of transfer must be optimized. Techniques and circumstances appropriate for learning to manipulate controls effectively and with the degree of insight that will insure safety are not necessarily those appropriate for the training of one who is to design modifications of the process or equipment to be controlled.

Technology transfer directed toward the overall planning function is probably the most involved of all, because of the wide scope of factors included. In the final analysis, the function requires a subtle combination of inductive and deductive reasoning.

In planning the methods of technology transfer to use in a specific situation, the five basic questions what, why, who, where and when should be answered.

With definitive answers to these questions established, the procedural question of how optimum transfer is to be accomplished may be undertaken within the constraints that apply. A decision-chart analysis is included to assist in the determination of recommended steps.

In the special case of nuclear technology transfer, the project method has certain advantages, for both the design function and the broader planning function. The effectiveness of the method is greatly increased if it is a real-life project and not simply an academic exercise. A specific project brings the learner close to reality and in so doing, uses the motivational factor, particularly if it relates to a system or situation about which the learner already has interest and background.

The resolution of the question of whether or not a specific country should embark on some aspect of nuclear energy application, the development of specifications for or the preliminary design of a multipurpose reactor for a specific geographical area are examples of projects that bring life to the understanding of principles. All members of a team working on a real design can be highly motivated and have the opportunity for developing the broad viewpoint that is one of the primary objectives of transfer.

Disadvantages of the method include the limited number of specific design opportunities, the tendency to specialize in one aspect at the expense of others, and the possible need for supplementary individualized instruction. Despite these disadvantages, the engineering adaptation of the project method is an effective means of technology transfer.

In its broadest sense, technology transfer includes a wide spectrum of activities ranging from on-the-job training in process control and operation of equipment to planning of large and complex projects. Nuclear technology covers the entire range from radiation monitoring to the planning of a nuclear agroindustrial complex. Obviously, no single method or technique for technology transfer will suffice over this range under all circumstances. All too often, the conditions cartooned in Fig. 1 prevail. If the technical knowledge or expertise of one person or group of persons is to be transferred effectively and economically to another person or group, thoughtful planning and consideration of methods is imperative.

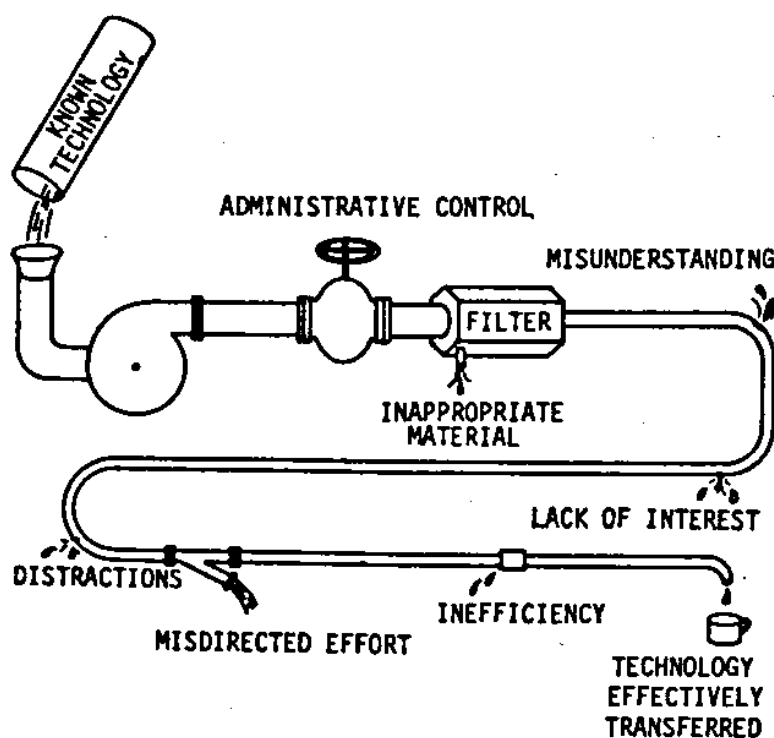
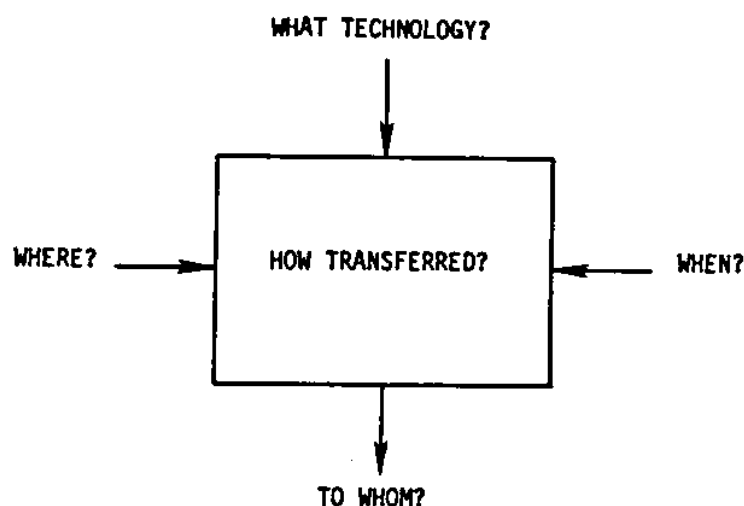


Fig. 1. The Technology Transfer Process

The external aspects of the planning for technology transfer include a consideration of the people involved (from whom to whom), what is to be transferred (skills, information, understanding), where the transfer is to take place (which country, field, plant, or office), when it is to occur and over how long a time span. The critical questions to be answered are indicated in Fig. 2.



*Fig. 2. Significant Factors in Technology Transfer*

The internal aspect of the design delineates the detail of how the transfer is to take place. Many methods and procedures are available or can be devised. The identification and development of the best "how" constitutes the optimization of the design of the transfer system. Before the question of how is addressed, the question of what should be answered.

Although many objectives of technology transfer programs could be cited, they can in general be classified into six groups.

The first group is one in which the objective is to transmit information in such a way that the recipient will have a general awareness of the topic under discussion. Newspapers and television usually convey information at this level. Often, a relatively small percentage of the information that is transferred in this way is retained by the recipient for more than a few hours. On the other hand, a forceful presentation can be made to transmit information that will last for years in the mind of the recipient.

A second general objective of technology transfer is to convey operating skills from individuals who are knowledgeable in the field to those who wish to acquire, for various reasons, those particular operation skills. The operating principles can be transmitted through discussion and operation manuals, but mastery of the skill and confidence in the



skill result from hands-on experience. One can read about how to drive an automobile, for example, but it is only after one has experienced the sensation and obtained the feedbacks that confidence can begin to be developed.

Another direction in which technology transfer may be directed is toward the development of analytical skills. This implies the capacity for a certain degree of analytical problem solving. In the development of this skill, the first step is to convey the basic principles underlying those skills. This may be done through a variety of methods. Lectures, discussion, reading, actual problem solving, video instruction, visual aids, and computer-aided instruction are all possibilities. The selection of the appropriate method in a specific situation depends upon a number of factors, as will be discussed later. This type of instruction is typical of that imparted at the beginning levels of a university program in engineering or technology.

Another possible objective of technology transfer is to develop in the recipient the ability or the skill to design. The information to be conveyed in this circumstance is the collection of appropriate design principles. These may be transferred through lectures, discussions, reading, specifications, and the various visual aids. In addition, actual experience in problem solving or in elementary design is a significant component of the technology transfer activity.

Beyond this point, the technology transfer may take one of two directions: research or planning experience. Although the two are not necessarily mutually exclusive, a transfer process which will develop the ability to conduct research is normally a very different process from that which is directed toward enabling the recipient to conduct large-scale planning.

It is the consensus of those working in the field that the ability to acquire research ability is developed through participation in research; so the conventional technology transfer in this area is accomplished by working as a member of a team to learn what the director of the team has to transmit. This embodies the basic attributes of a typical doctoral program in a university.

Although the particular abilities to be developed are quite different in the area of overall planning, the approach to technology transfer is much the same as it is for research. In this area also, the skills are transmitted through participation as a member of a team which is engaged in a planning exercise. However, information from any related fields such as economics and sociology must be incorporated into the technology transfer process in such a way that the recipient will be fully aware of the significance of these areas in addition to the purely technical area.

The overall relationships among these six general classifications of technology transfer are shown in the basic decision chart in Fig. 3. The start of all of the methods of technology transfer must be at the information-transmission level. If this level is adequate, then one proceeds to consider the details of an appropriate technology transfer process for this particular objective. If this level of comprehension is not adequate, then one goes on to the consideration of operating principles if operational skills are the prime

objective. If they are not the prime objective, but rather analytical skills are the objective, then one by-passes the operating principles and goes directly to basic principles. The analytical skills, which are the outcome of the technology transfer process associated with the transmission of basic principles, are the prerequisites to the next step, if it is desired, of the development of the skill to design. If ability to do technological design or detail design is the objective, then one proceeds to the technology transfer processes associated with that.

Beyond that point, as has already been stated, there are parallel paths of research experience and planning experience. These are depicted as the two bottom groups in Fig. 3.

With the objective established, the next step is the consideration of the details of the technology transfer process. These will differ for each of the six general areas of processes and are also controlled by certain limiting conditions or external aspects such as the people involved; the location or site of the transfer, with respect to country and physical locations such as field, plant, or office; when the technology transfer is to occur; over how long a time span; whether or not there are limiting dates that must be met; and the degree of complexity or the acceptable expense associated with the transfer process.

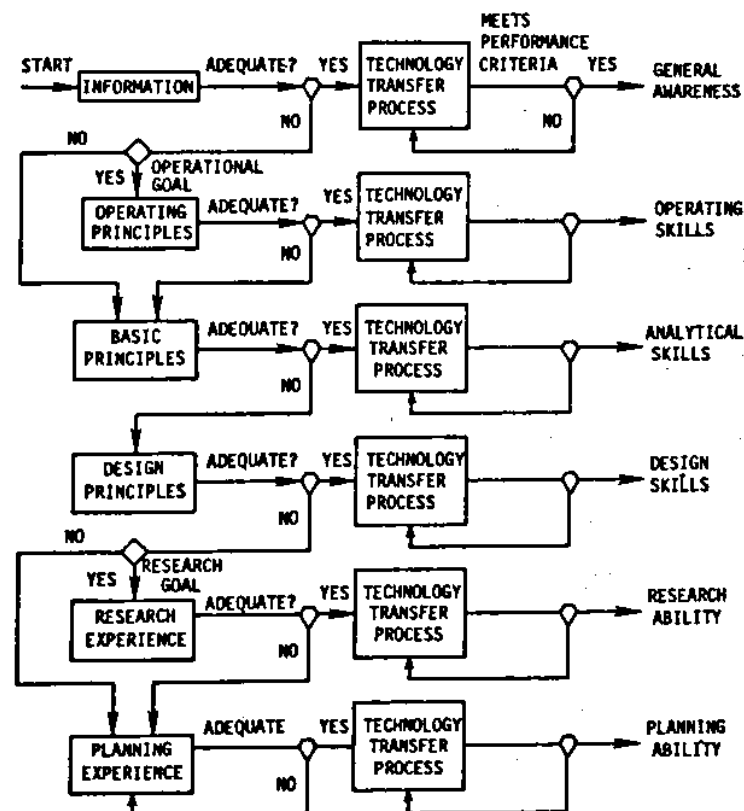


Fig. 3. Basic Decision Chart

The external factors, in reality, define the questions of what, who, where, and when associated with the technology transfer. Next, the all-important question of how the transfer is to be accomplished must be considered. This really constitutes the internal design of the technology transfer process.

Many methods are available for conveying information from one individual to another individual or a group of individuals. A few of these are noted in Fig. 4. In order to select the most suitable method among the many, the same approach may be employed that is used in solving any engineering problem. One of the first things to be done is to identify the principles that control the process. The principles underlying the learning process are not as explicit as Newton's second law of motion or the second law of thermodynamics. Nevertheless, underlying concepts may be identified.

Basically, information is transmitted and received in one of three ways noted in Fig. 5. It is received through the sense of sight, through the sense of hearing, and through the sense of touch. In the general area of nuclear technology transfer, the sense of smell and the sense of taste are relatively unimportant. There are times when it would be desirable to have a sense of intensity of radiation field, but this is one of the faculties that we have not developed.

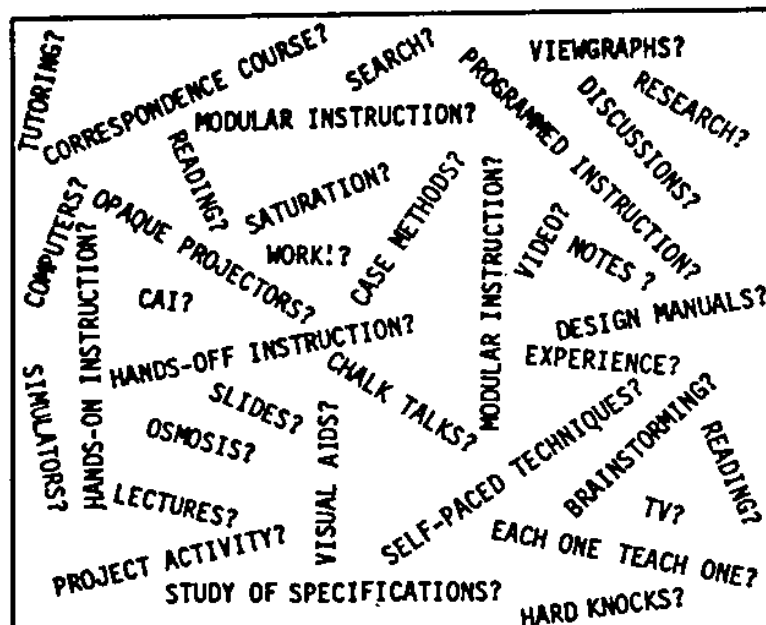


Fig. 4. The Grab Bag of Transfer Methods

INFORMATION TRANSFERRED BY :  
VISUAL STIMULI (SEEING)  
AUDITORY STIMULI (HEARING)  
TACTILE STIMULI (FEELING)  
EFFICIENCY OF TRANSFER DEPENDS UPON:  
PARTICIPATION OF RECIPIENT  
MOTIVATION TO LEARN  
CAPACITY FOR RECEIVING

*Fig. 5. Principles of Transfer*

Another principle that is involved is that the efficiency of the transfer process is directly dependent upon the degree of participation of the recipient. The degree of participation, in turn, is low if motivation is lacking and if the complexity of the presentation is so great that the material presented cannot be understood. Motivation is not solely the responsibility of the recipient. The process of transfer selected is a significant factor.

These factors suggest the following procedure. First, the appropriate level at which the material is to be presented must be established, taking into consideration the acceptable level. Next, the appropriate method of transfer is established by considering whether the material to be presented and the audience are best adapted to oral, visual, or tactile presentation, or a combination of these.

Then, methods must be devised to maintain interest at a high level. Throughout the transfer process optimum use should be made of feedback so that the process may be modified in order to increase efficiency and effectiveness. Feedback may be transmitted visually or orally. In a lecture or discussion situation, it is easy to tell when the attention of the recipient is wandering or when the material is not understood. The environment in which the transfer is taking place is important. Distractions should be minimized in order to increase the signal-to-noise ratio. Performance criteria include problem solving, question answering, and the degree of operational confidence that is evident. The attention span of the recipient relative to the particular technique utilized is a highly significant factor.

The foregoing factors associated with the technology transfer process may be combined in a process selection chart as shown in Fig. 6. The procedure requires an assessment of the receptivity of the individuals to whom the technology is to be transferred by means of auditory, visual, and tactile stimuli. The receptivity may be measured qualitatively or subjectively by the rate at which information is assimilated. It should be emphasized that this

rate is not necessarily any measure of intelligence. For example, one may assimilate rapidly what is spoken to them in one language and be completely unresponsive if a different language is used. In a completely academic situation, an index of receptivity or rate of assimilation of information may be obtained through performance in prerequisite class situations or through examination. Even then, the measures are not absolute. In a field situation, various means may be utilized to obtain a general indication of receptivity to the three types of stimuli through interviews, conferences, or discussions. Incomplete as the testing methods may be, they nevertheless serve to eliminate those methods which would prove to be completely ineffective or to indicate preliminary or remedial programs such as mastering a few key words or symbols before the technology transfer program is initiated.

One effective method of technology transfer that does not fall strictly within the system previously discussed is that of the project method. This, in effect, is a synthesis of the other methods indicated and will serve as an example of other technology transfer procedures that may be developed. In concept, the project method consists in making the trainee a member of a team that is working on a specific project. The degree of responsibility to be assumed by the trainee is consistent with his previous background and experience. For a new trainee, this responsibility would consist in essentially making the individual a helper so that the learning process would take place through assistance, observation, and informal instruction. This is the method commonly utilized by American industry in giving a new engineering undergraduate experience in the processes and procedures utilized in the particular industry.

RESPONSE TO STIMULI	REQUIRES FACILITY IN	RECEPTIVITY		
		RAPID ASSIMILATION		SLOW ASSIMILATION
AUDITORY STIMULI	ORAL COMMUNICATION	LECTURES RECORDINGS	REPETITIOUS VIA SOUND CASSETTES OR VIDEO DISCUSSIONS	LECTURES WITH GRAPHIC ARTS TUTORING
VISUAL STIMULI	WRITTEN GRAPHICAL OR MATHEMATICAL COMMUNICATION	PRINTED MATERIAL DIAGRAMS EQUATIONS	SUPPLEMENT TEXT WITH EXPLANATIONS VIDEO COMPUTER AIDED INSTRUCTION	GRAPHIC ILLUSTRATION WITH EXPLANATION VIDEO SELF-PACED INSTRUCTION
TACTILE STIMULI	MUSCULAR COORDINATION	DEMONSTRATIONS	INDIVIDUAL OPERATION SIMULATORS	CONTINUED PRACTICE

Fig. 6. Classification Based on Receptivity to Stimuli.

In an academic atmosphere, the project method may be used effectively, particularly at the graduate level, where an understanding of the interrelationships among the various factors involved in the design of a nuclear power plant is the objective. Here, the usual procedure may be that of assigning a class project on the development of a nuclear power plant to meet certain specified conditions and assigning to different members of the group specific responsibilities such as those associated with heat transfer, control, radiation protection, fuel handling, efficiency and costs. Although each member of the group has a specific responsibility, each one soon discovers that coordination of activities with other members of the group is absolutely essential. A specific advantage of the method is the insight that it provides into the overall functioning of the project, as an integrated unit and not as a compartmentalized group of special technologies.

Outside the academic environment, the experience may be obtained by working as a member of a project team in industry, where the motivational aspect may be strengthened by the knowledge that the project has real engineering significance. A variation on the project method is its use as a doctoral thesis. Under these circumstances, the candidate may be given the responsibility for the overall planning of a specific project such as an agroindustrial complex or a reactor unit adapted to the conditions in a particular country. Parallel team experience in research is possible in industry or a commercial or federal research laboratory.

In conclusion, it should be emphasized that technology transfer is a highly personal activity. Success or failure in technology transfer depends upon the skill with which the transfer materials are prepared with reference to the recipient. It depends upon the method utilized in the transmission of the information and it depends upon the background and interest of the one who is to receive the information. All the factors are interrelated and, as in the design of a complex electrical circuit, it is essential that the impedances of the various components be balanced. In other words, to be successful, the technology transfer process must be designed to balance the presentation against the receptivity of the recipient. A flow of mutual understanding is essential to achieve effective technology transfer.

## KUWAIT NUCLEAR POWER PROGRAM

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The first large-scale commercial electric power plant in Kuwait was partly put into operation in 1954. By 1955 the total installed capacity in the country was 30 MWe. In 20 years the total installed capacity reached 1346 MWe; an average of 21% annual increase over the 20 year period. Similarly, in 1955 the total installed capacity of the water desalination plants in Kuwait was 1.1 MG/day. It reached 60 MG/day by the year 1975; an average of 22% annual increase over the 20 year period. These figures reflect the rapid growth in population, expansion in services, industrialization and the continued rise in the standard of living. The average annual electricity (and energy in general) consumption per capita in Kuwait is approaching those in developed countries. However, the urban nature of the country, and the continued expansion in development, industrialization and service programs, coupled with a continued unnatural population growth, largely due to the influx of skilled and unskilled manpower to the country, will force a continued high rate of annual increase in installed capacities for electricity and fresh water generation. Fig. 1 shows the past and present projected average annual rate of increase in electricity and fresh water installed generating capacities; Fig. 2 shows the installed electricity and fresh water generating capacities required to meet the projected demands.

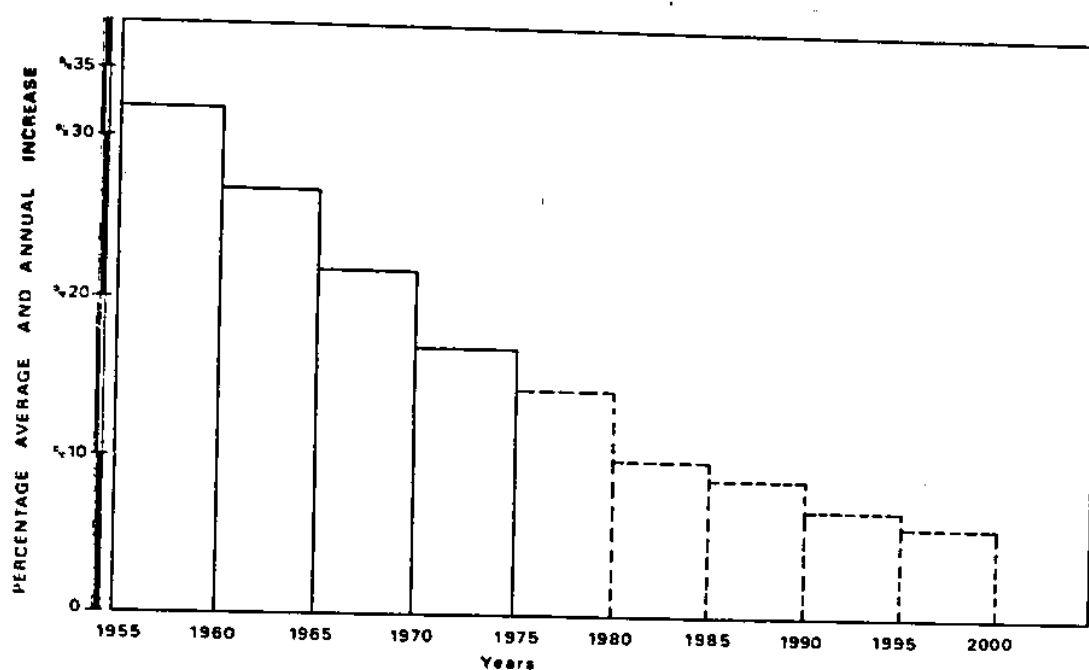
In the past all dual-purpose power plants (for generation of electricity and fresh water) utilized associated gas\* as the primary energy source. Associated gas is also utilized for reinjection into oil fields, and to produce liquified natural gas for domestic household and industrial utilization. With oil production levels stabilized around 2 million barrels/day in Kuwait after 1973, the amount of associated gas available could not meet the increasing demand in primary energy sources for power generation and industrial utilization.\*\* Alternative energy sources are therefore needed. Ministry of Electricity and Water (MEW) studies have shown that if oil was used as the only additional energy source to meet the demands of the projected expansion in electricity and fresh water installed generating capacities, a total of 91 million tons of oil will be required by the year 2000.

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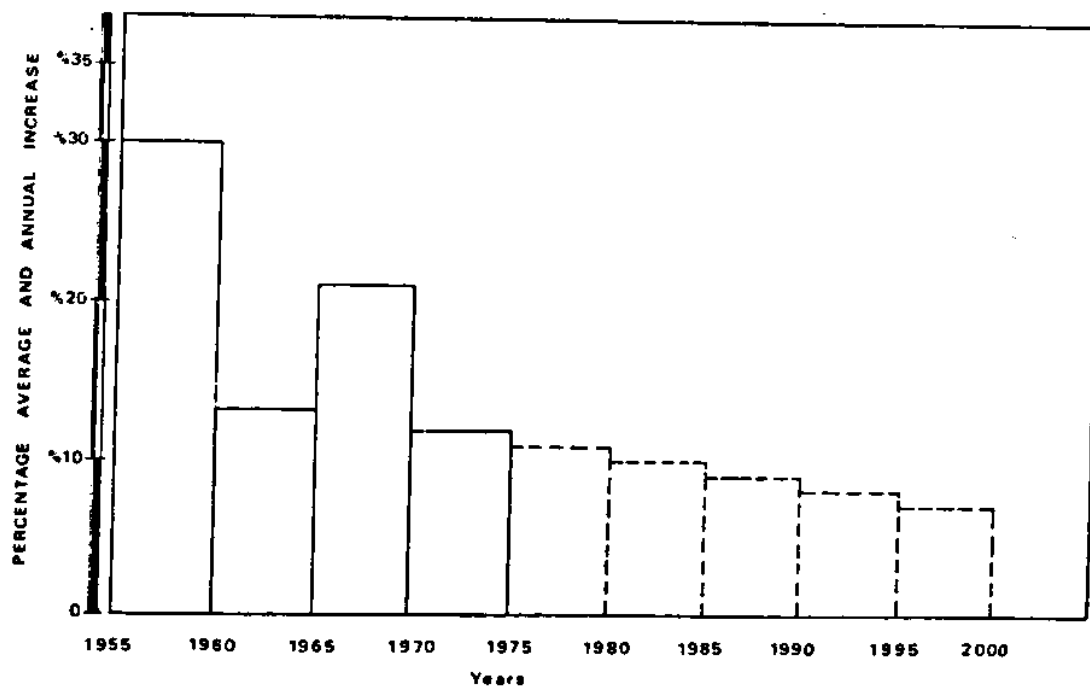
\*Kuwait, a major oil producer and exporter, has no exclusive gas fields. Gas is found associated with oil fields, and its production is directly related to oil production.

\*\*Max. associated gas available in a summer day is barely enough to operate 12000 MWe power plant associated with desalination plant of 45 MG/day capacity, which is below the maximum loads for 1976.

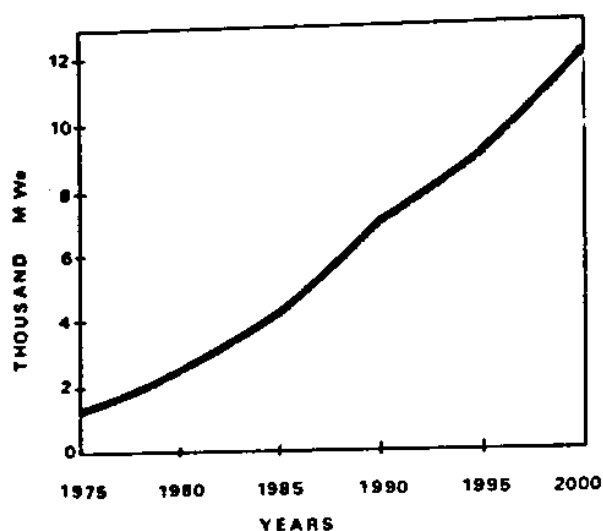




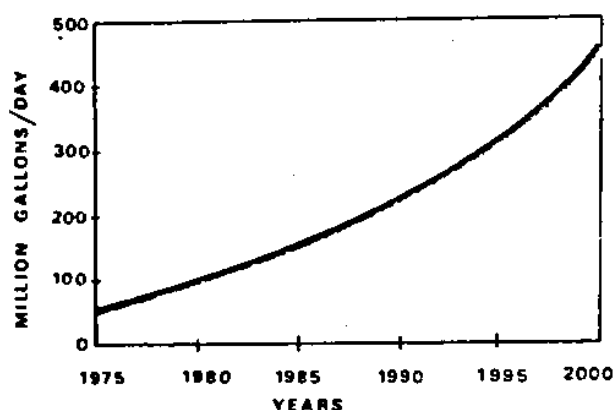
*Fig. 1 (a). Average Actual and Projected Annual Increase in Installed Generating Capacity of Electricity*



*Fig. 1 (b). Average Actual and Projected Annual Increase in Production Capacities of Distilled Water*



*Fig. 2 (a). Installed Generating Capacity of Electricity 1975 - 2000*



*Fig. 2 (b). Installed Production Capacity of Distilled Water 1975 - 2000*

The annual consumption of oil for power and water needs will reach 10 million tons/y by the year 2000, which constitute about 10% of the current annual production level.

Based on present and projected fuel prices and capital costs, recent comparative studies of electricity generation cost in developed oil-importing countries have indicated that nuclear generated electricity will be cheaper by at least 40% than that generated in fossil-fired (oil or coal) plants. Similar studies indicate that nuclear generated electricity is cheaper even in oil producing countries, such as Kuwait, with a break-even price for oil between \$ 8-10/barrel, depending on load factors and other local conditions.

Oil is a valuable commodity. It is currently the major income earner for Kuwait. However, it is a valuable raw material of finite magnitude and its use as an energy source should be contained and minimized world-wide. For those three reasons MEW is seriously considering a program calling for the gradual introduction of dual-purpose nuclear power plants to supplement oil-fired dual-purpose power plants currently being planned to meet future increased demand.

The size of the total installed capacity, base load and load factor in Kuwait, combined with restrictions on the size of the smallest commercial nuclear power plant available from suppliers, put a limit on the earliest date by which nuclear power plants could be introduced in Kuwait. Current projections indicate that a 600 MWe dual-purpose plant, the smallest size available on the commercial market, could be introduced in Kuwait around 1986. This is a feasible but tight schedule to work with. In table (1) we show MEW tentative schedule currently planned for introduction of nuclear power plants in Kuwait (Plan A). Figure 3a illustrates nuclear, oil and gas share, as primary energy sources, for electricity and fresh water generation according to the above schedule. Figure 3b illustrates the same for a nonnuclear alternative (Plan B). It was estimated that the total accumulative saving of annual operating costs resulting from adopting plan A over plan B over the period from 1986 to the year 2000 will amount to about K.D. 600 millions (equivalent to \$2 billions, in 1975 dollars), based on 1975 fuel prices and capital costs. This constitutes a 16% total saving over the same period.

It is evident from the above that the Kuwait proposed nuclear power program is an ambitious one. The proposed schedule in Table 1 is very tight indeed. To implement such a program requires extensive efforts and careful planning. A number of obstacles face such an ambitious program. These obstacles are common among all developing countries in their efforts to secure cheap electrical energy for the long term future. These obstacles include a shortage of trained and experienced manpower. Kuwait, because of its small size and limited population, suffers especially from this factor. Other factors include reluctance of developed supplier countries to allow a reasonably easy transfer of peaceful nuclear technologies and material to the developing countries, the non-availability of small and medium nuclear reactors of proven designs to suit the relatively small electrical networks of most developing countries, and complete reliance on a very small number of developed supplier countries for the nuclear fuel cycle.

To alleviate the problem of trained manpower needed for the program, and to ensure that the introduction of nuclear power plants to the country will not be on a black-box basis, an important cornerstone of the Kuwait nuclear program envisages the establishment of a small training power reactor to deliver steam to a turbo-generator of about 40 MWe and a distillation plant of about 10,000 Cu m/day. This training reactor will provide Kuwait with basic experience and training for the introduction of nuclear power into the country as a whole.

Preliminary inquiries sent to manufacturers have shown a serious interest on the part of at least five manufacturers in four countries to design, or modify existing designs, and manufacture such a reactor. Formal inquiries to these interested manufacturers have already gone out. On the basis of responses to those formal inquiries, a firm decision as to whether to proceed with this option, or to go directly to medium-scale commercial nuclear power reactor, will be made late this coming spring. If the decision is positive, it is hoped to have the training reactor operational during the early 80's, and to follow it by commercial size dual-purpose nuclear power plants in the latter 80's as outlined in table 1.

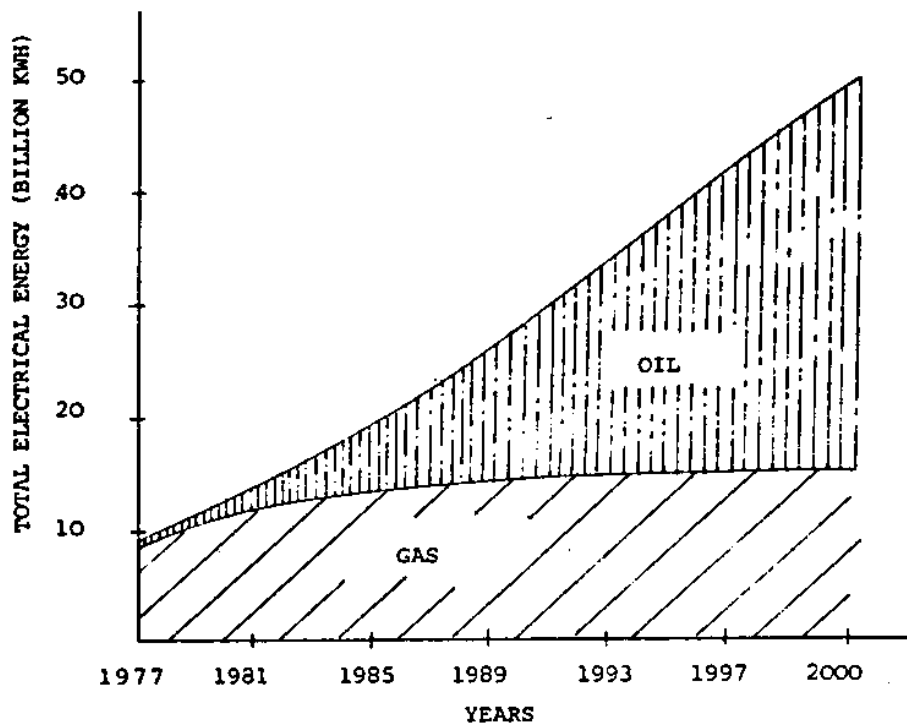


Fig. 3 (a). Plan I (Gas and Oil)

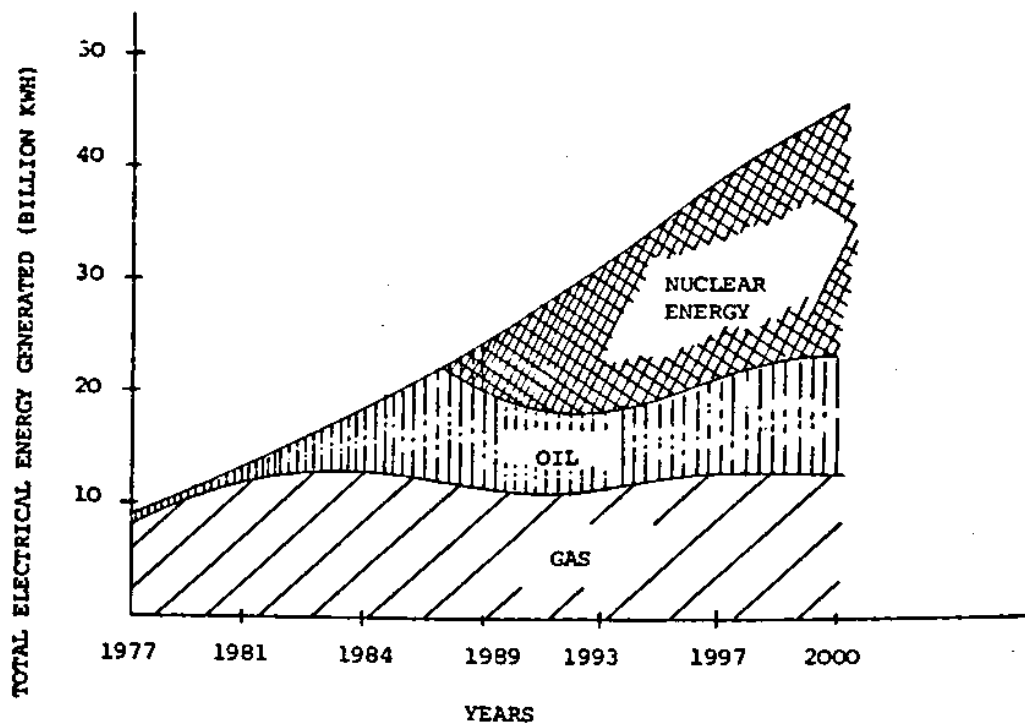


Fig. 3 (b). Plan II (Gas-Oil-Nuclear Energy)

Table 1. Schedule for Introduction of Dual-Purpose Nuclear Power Plants in Kuwait

Year	Unit #	Total capacity of unit in MWe Equivalent	Accumulative nuclear Percentage of total Installed Capacity
1983	0	50 MWe (for training purposes)	-
1986	1	600	13%
1989	2	600	20%
1991	3*	600	26%
1993	4*	600	30%
1996	5*	600	31%
1999	6*	600	30%

\* Units 3 and 4 could be substituted by one 1200 MWe units, similarly units 5 and 6 could be substituted by another 1200 MWe unit.

The plan allows for the installation of 4-6 commercial plants of about 3600 MWe total equivalent installed capacity by the year 2000. It is hoped that the proposed training reactor will serve as a regional training center serving the training needs of neighboring countries embarking on similar programs.

In this connection, at the recent General Conference of the International Atomic Energy Agency held in Brazil last September, Kuwait formally proposed the idea of establishing a number of Regional Nuclear Training Centers built around training power reactors similar to that being proposed for Kuwait to serve the needs of a number of groups of countries. Such Regional Training Centers could be jointly financed and operated with the help of the IAEA and will serve to graduate a continuous supply of trained teams of operators and technicians to man commercial nuclear power plants built in the region. Similarly, the problems of fuel availability and securing enrichment and reprocessing services for

the Kuwait proposed nuclear energy program could be alleviated with the establishment of region fuel cycle centers along the lines proposed and being developed by IAEA.

Up to this point all preliminary studies, planning and preparation for the Kuwait Nuclear Power Program have been carried out within MEW. A special Committee within the MEW, called Nuclear Energy Committee of Kuwait (NECK), was set up in 1974, to carry out the initial studies, plans and preparations. This committee is headed by His Excellency Abdulla Y. Al-Ghanim, the Minister of Electricity and Water with specialists and experts from MEW, Kuwait Institute for Scientific Research and Kuwait University. IAEA assistance was solicited and advice on program scope, legal aspects, safety and siting regulations was received. As the Nuclear Power program nears firm commitments and implementation, an independent nuclear energy authority will be set up in Kuwait to carry out the program. The plans for such an independent authority are well underway. IAEA was heavily consulted on the legal, structural and organizational aspects of this proposed authority.

# UNDP TECHNICAL ASSISTANCE FOR THE DEVELOPMENT OF NUCLEAR TECHNOLOGY IN ROMANIA

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## ABSTRACT

This paper presents the experience accumulated by the Institute of Nuclear Technology during four years of activity carried out in the framework of the UNDP technical assistance Project "Development of Nuclear Technology in Romania". The objectives of the Project and the achievements obtained are presented and the role played both by the foreign experts and by the fellowships in carrying out the practical problems of the working plan emphasized. There are also mentioned the difficulties met in expert recruitment, fellowship placement and getting the equipment, owing to the technological character of the Project objectives. Also underlined is the activity performed by IAEA as Executing Agency aiming at the right implementation of this Project.

## 1. INTRODUCTION

The economic and social development of Romania to high levels presupposes great efforts aimed at assuring a corresponding power production. Plans regarding power development of the country foresee that by 1990, approximately 20% of the electric power will be of nuclear origin, which means that by that time nuclear power stations amounting to a total power of about 6000 MWe will be put into commission.

The achievement of this program implies both a very important financial effort and a particularly consistent participation of the national industry in the construction of the nuclear power stations.

As regards the classical parts of these stations, Romanian industry has a long time experience, achieved by the construction of several thermoelectric stations, these being the basis of electric power production of the country at present.

Aimed at undertaking the specific aspects of nuclear energetics, there was set up in 1971 the Institute for Nuclear Technology (INT), of which the main task is to develop technological research activity in the field of designing and construction of nuclear reactor components, including fuel elements.

A successful accomplishment of these research programs presupposes mastering certain modern technologies as well as the presence of specialized equipment, which Romania had, at that time, only to a limited extent. The presence of some highly qualified foreign experts in the field was also considered necessary, so that together with Romanian special-



ists they may adapt the technological solutions verified at an international level, to the specific requirements of the National Nuclear Program.

It was in 1972 that UNDP agreed to award, through IAEA, technical assistance to the Institute for Nuclear Technologies, in the frame of a project entitled "Development of Nuclear Technology in Romania". The aim of this project is to support the technological research activity performed in INT aimed at producing nuclear power in Romania, by qualified experts, fellowships and supply of modern equipment.

## 2. STRUCTURE OF THE PROJECT

The Project elaborated by INT together with IAEA specialists, was submitted in July 1972 and was approved by UNDP, the Agency and the Romanian Government in January 1973. The document of the approved Project represented the basis of the whole activity performed during implementation period, though in the meantime some changes were necessary.

The Project is divided into the following main chapters: general information, objectives of the project, work plan, UNDP contribution (experts, subcontracts, fellowships and equipment), Government contribution, budget, as well as organizing and juridical aspects.

UNDP contribution was initially \$1,242,000 and it was foreseen that the ending date of the Project would be July 1975. But afterwards this figure was increased to \$1,434,507 and the final term was the end of 1977.

The reasons for these changes were mainly the following:

- Introduction in the work plan of some long-time experiments for irradiation testing of experimental fuel elements;
- difficulties in finding adequate subcontractors for providing experts, mainly for fuel, fuel elements and reactor components;
- difficulties in fellowships placement;
- long terms for delivery of main equipment and price increases.

In order to underline the importance of these changes, the budget in its initial and present form is presented in Table 1.

By the end of 1976 the project accomplishment was about 84%.

It was stipulated in the Project document that the management was to be assured by a foreign Project manager, performing his work in Romania and representing both UNDP and the Executing Agency. The INT director is the co-project manager. From May 1973 till December 1975, Dr. R. Lesser, an experienced specialist from the Institute of Transuranian Elements (Karlsruhe - FRG), was the Project manager. Before Mr. Lesser's arrival in Romania the management of the Project was assured by Mr. O.S. Plail from AERE Harwell, whose working system was based on short visits. After Mr. Lesser's leave, UNDP and IAEA considered that INT had accumulated enough experience so that for the following period the presence of another foreign Project manager was not necessary.

Project activity began in Bucharest at the temporary site of INT. At the same time important efforts were made by the Romanian Government who built a new INT site in

Pitești, this being supplied with modern equipment and facilities. At present the following laboratories are in operation: fuel elements, reactor components, corrosion, reactor physics, as well as a demonstration facility for zircaloy clad- $\text{UO}_2$  fuel elements. The construction of a 14 MWe Material Testing Reactor TRIGA type is under way and other facilities will soon be constructed, such as: labs for post-irradiation examination, halls for testing reactor components, multizonal zero-power reactor, a computer, etc.

Table 1. UNDP Project Budget

SUBJECT	INITIAL FORM \$	PRESENT FORM \$
EXPERTS	320,000	175,213
SUBCONTRACTS (EXPERTS AND IRRADIATION EXP. )	95,000	337,283
FELLOWSHIPS	234,600	261,486
EQUIPMENT	565,600	645,148
MISCELLANEOUS	27,000	15,377
TOTAL :	1,242,200	1,434,507

### 3. PROJECT IMPLEMENTATION

#### 3.1 Objectives of the Project and Achievements

Out of the large number of scientific and technological aspects of nuclear reactors there were undertaken in the first development phase only the following, which were in fact the main objectives of the UNDP Project :

- Development of the technology of  $\text{UO}_2$  sintered pellets from Romanian concentrates;
- Development of the technology of zircaloy clad- $\text{UO}_2$  fuel elements;
- Irradiation testing of nuclear materials and experimental fuel elements;
- Preliminary design of power reactor cores;
- Design, manufacture and testing of some power reactor components.

Till now the following progress has been achieved :

The technology for preparing  $\text{UO}_2$  powder starting from Romanian concentrates has been partially established, using the procedure based on ADU precipitation, as well as the technology for  $\text{UO}_2$  sintered pellets. Apparent methods for determining purity and physical-chemical properties of the  $\text{UO}_2$  powder and pellets have been also established. The accuracy of these analytical methods was checked up by comparing the determinations made in parallel on similar samples at INT and Nuclear Center abroad (KfK, CEN, Saclay, etc.) End-cap welding technology by the resistance and TIG procedures have been also assimilated and the corresponding NDT methods were established.

Based on experience accumulated during the laboratory researches, there has been

created a demonstration facility for manufacturing zircaloy clad- $\text{UO}_2$  fuel elements. Equipment for the demonstration facility was provided both by UNDP and Government contribution.

The activity performed in this demonstration facility was materialized by establishing the working procedures by which were manufactured quantities amounting to 100 kg of  $\text{UO}_2$  powders, pellets and rods for irradiation experiments.

Their characteristics are described in detail in the testing reports prepared during the irradiation campaigns.

The first rods irradiated up to 3000 MWd/t in BR-2, had an adequate behavior and are to be subjected to post-irradiation examination. The bundle of 19 rods, specially assembled for irradiation in MZFR, is at present behaving normally after 5 months of irradiation.

The tests performed in common by Romanian and foreign experts showed that the imposed technical specifications were rigorously fulfilled and at the same time the control methods used correspond to the international standards.

In the framework of the objective concerning reactor physics, specific computer codes have been intensively elaborated and on this basis the neutronic design of a multizonal zero-power reactor has been accomplished.

There were also performed preliminary reactor core calculations for a PHWR type, paying special attention to the estimation of neutronic and thermohydraulic parameters.

As far as reactor components are concerned some devices for testing stands were designed and manufactured. A 500 kW loop meant for heat transfer and hydrodynamic studies has been designed.

Various radiation detectors and electronic devices for the control system of power reactors were manufactured and tested.

Electrochemical methods for the corrosion studies of materials of nuclear interest were established and the design for a corrosion loop will shortly be issued.

### 3.2 Expert Assistance

Expert assistance has been an important tool in the achievement of the Project objectives. The funds foreseen now for the experts (including the Project manager) amount to 22.3% out of the total value of the Project.

It was initially planned that the experts' total mission duration would be 128 man/months, but in order to cope with this increase in costs it was necessary to reduce this to 104 man/months.

The expert recruitment was performed by IAEA based on "job descriptions" drawn up according to the needs coming from the Project work plan. The fields of activity, qualifications required, problems to be solved, as well as the staff and equipment available at INT, were mentioned.

The expert was supposed to know either English or French. I.N.T. made nomination proposals for expert posts any time possible.

IAEA recruited experts both on the basis of individual contracts and by concluding subcontracts with nuclear organizations from countries having a high experience in the nuclear field.

Such subcontracts have been concluded for the whole duration of the Project with FRG, Belgium, France, Sweden and Canada.

This subcontracting system began to be used in 1974 and had very good results as has been assured both the rhythmicity of the missions and uniformity of the information received.

The Project documents stipulated initially that the expert missions were to be 1-3 months duration but practically this was impossible. Then the system of dividing the activity period into more short term missions was adopted. This allowed both recruitment of some highly qualified but very busy specialists, and a better correlation with fellowship programs and equipment supply planning. Up to the present time 68 experts have worked at INT in the framework of the Project, performing 94 missions, whose duration varied between three days and one month.

The prolongation of the Project duration was also due to the difficulties met in finding experts for some specialties in the field of fuel elements technology and reactor components.

As far as the qualification of the experts who worked here is concerned it must be stated that in most cases the countries and subcontracting organizations sent very good specialists from research institutes with well-known traditions in the nuclear field.

Unfortunately experts from industrial units were not available.

The experts made an essential contribution to the accomplishment of the objectives of the work plan. Generally the expert was present at INT in the critical moments of the activity he offered assistance for. In the period between missions the experts had correspondence with INT specialists, so keeping informed of the development of the established work program. After each mission end the experts presented reports evaluated both by INT and IAEA.

### 3.3 Fellowship Program

The funds for this chapter represent 18.2% out of the total value of the Project. The total number of man/months initially foreseen had to be reduced during the Project implementation in order to deal with the increased cost of living in the host countries. Till now 40 people from INT have been trained, amounting to approximately 314 man/months.

Fellowship placement was made by the IAEA specialized office based on "Training Programs" issued by INT according to the Project document stipulations. During the implementation period some changes were made in the fellowship program, either as far as topic was concerned or by renouncing some positions. These changes were mainly due to the difficulties met in finding adequate training places for those fellows whose topic had a technological character.

It was not possible to find any fellowship place in factories.

Fellowship nomination was made by the Romanian Government by sending "Application

Forms" to IAEA. The candidates were submitted to an examination of the language knowledge requested by the host country.

The INT staff trained by UNDP contribution has played an important role in solving the problems raised by the Project implementation. Besides the knowledge in the field accumulated during their training period, the fellows could see how research work was organized and executed in well-known institutes. Whenever possible, training was performed in laboratories associated with respective topics. Beginning with 1974 the fellowship travel expenses were covered by INT. This allowed a more efficient utilization of the foreign currency funds representing UNDP contribution.

During their training all fellows presented "progress reports" evaluated by INT and IAEA. After finishing their training they also presented terminal reports.

### 3.4 Equipment and Material Supply

About 45% out of the Project total value was awarded to this chapter. Till now equipment and materials amounting to approximately \$610,000 have been supplied. This relatively large amount foreseen in the Project for this chapter allowed modern equipment to be obtained both for research laboratories and for the fuel elements demonstration facility.

Out of this equipment the most important are the following:

- equipment for continuous two-step precipitation of ADU;
- rotary furnace for calcination and reduction of uranium oxides;
- X-ray fluorescence spectrometer;
- resistance welding machine;
- rotative drum filter;
- semi-continuous high temperature sintering furnace;
- ultra-sonic testing equipment.

The particularly efficient activity of the IAEA specialized office which facilitated getting some very important equipment should also be underlined. At the same time a large number of necessary spare parts and devices were obtained very rapidly.

The drawing up of the equipment specifications was done by INT staff helped by experts.

But some difficulties in the activity of getting the equipment were still met, which had a negative influence upon the Project activity.

First we have to mention dollar devaluation and the increase of prices, which forced us to renounce getting some equipment through UNDP and to get them out of Government contribution. Second, the delivery terms for some basic equipment were subevaluated in the Project document and there were also delays in some equipment delivery, these being due to the supplier.

## **4. THE PART PLAYED BY I.A.E.A. IN THE PROJECT IMPLEMENTATION**

As executing Agency, I.A.E.A. made special efforts in order to assure a good imple-

mentation of this Project by which one tries to transfer some knowledge of nuclear technology from advanced countries. The IAEA specialized offices did their best to find the most ways so that under the conditions imposed by the limitations of the transfer of technology and Industrial Information, they could still recruit the necessary experts, place the fellows and get the equipment requested by the Project. So the subcontracts concluded by IAEA with nuclear organizations from advanced countries for providing experts, receiving fellows and performing irradiation tests were an important success.

## 5. REMARKS AND CONCLUSIONS

The UNDP Technical Assistance Project has allowed the INT staff to accumulate basic scientific and technological knowledge, in some fields of importance in nuclear power reactor accomplishment.

It must be also emphasized that the knowledge transfer achieved represents just a first step as we still meet major difficulties in establishing the details of the technological processes we are dealing with.

They are generated by the limits now in force in the world, as regards technology transfer. Under the conditions when the power requirement is ever greater and the primary resources more and more limited, an ever larger number of countries have to resort to nuclear energy, either making use of technology transfer, or by their own efforts.

The safety of nuclear power stations has become and continues to be a problem of the international community and the very severe steps taken till now for an ever higher safety level proved to be very good but very expensive.

It is also possible that, in the future, they will tend to be minimized to reduce expense, or to shorten the way for producing nuclear power, mainly when it is not possible to have an adequate technology transfer.

To solve this problem seems to be possible only by renouncing the limits now in force concerning the transfer of nuclear technology.

The role of the I.A.E.A. in supporting countries which start introducing nuclear power at an industrialized level may be increased. Both guidance and implementation of safeguards are of importance. This underlining of the importance of the role of the I.A.E.A. is becoming more and more necessary for the interests of the international community.

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# **METHODS OF TRANSFER OF NUCLEAR TECHNOLOGY**

## **PARALLEL SESSION**

**Co-Chairmen:** M. Simnad (*General Atomic/USA*)  
H. Mohammadi (*University of Shiraz/Iran*)



**GENERIC STANDARDIZATION PROGRAM  
AN EFFECTIVE MEANS TO TRANSFER  
NUCLEAR TECHNOLOGY**

**JOHN V. MOROWSKI**  
*International Area Operations*  
*Bechtel Power Corporation*  
*U.S.A.*



## **I. INTRODUCTION**

The transfer of nuclear technology addressed in this paper covers the knowledge and experience of an engineer/constructor from a sponsoring country in providing engineering, procurement, construction and overall management services to countries desiring to acquire modern technology. This need for technology transfer can best be met in two basic ways that complement each other very effectively.

- A. One is to "learn by doing." This technique emphasizes the involvement and participation of host country personnel in all aspects of engineering, procurement, construction and management of nuclear power projects.
- B. The second is to make existing technology available for transfer as a package. Our generic standardization program provides an excellent means of presenting existing technology in an easily transferable package to insure that the resultant project is receiving a proven and current state of the art and that it can be designed and constructed on a reasonable schedule. Generic standardization also insures that the cost and schedule impact of procured and installed equipment and materials is consistent with other plants of the same type and size. While one must avoid inflexible standardization, because it often requires a "take-it-or-leave-it" approach that is not useful for the transfer of technology, one must also avoid a lack of discipline in standardization which can lead to customized designs that require extensive personnel resources and involve high costs.

## **II. ISSUES IN THE TRANSFER OF TECHNOLOGY**

There are many vital issues that a country acquiring technology should consider in contracting for the transfer of nuclear technology. Some of these issues are as follows:

- A. Understanding National Goals. This involves a thorough understanding of the host country's short and long term goals, both in the expected progress of its program and in the attainment of technological self-sufficiency.
- B. Appraising National Technical Resources. This involves a realistic appraisal of the availability, competence and optimum deployment of resources available with-

In the country, particularly focusing on technical resources.

- C. Defining Licensing Requirements. This involves a reasonable definition of the safety and environmental licensing requirements and procedures in order to allow the host country to benefit from technology already developed by the sponsoring country.
- D. Grasping Project Magnitude. This involves an awareness of the total magnitude of a nuclear project and the need to properly integrate, through an effective project management system, all of the complexities of a project in order to insure the end product of a reliable power plant within budget and on schedule.
- E. Embracing "Learning by Doing". This involves a realization that technology transfer can best be learned "by doing" and that this can best be achieved by being part of a project team.
- F. The availability of experienced and adaptable personnel from the selected architect-engineer/constructor.
- G. A solid commitment by the architect-engineer/constructor to utilize continuous training and maximum involvement of host country personnel resources during the execution of the project.
- H. Equitable contract terms that recognize the value of the technology transfer and protect the proprietary interests of the architect-engineer/constructor.

### III. GENERIC NUCLEAR STANDARDIZATION

Bechtel's generic nuclear standardization program was initiated in early 1972 when it was realized that the design, construction and startup experience gained from many nuclear plants could be effectively combined into a generic nuclear standardization program. Unique among standardization concepts, one of the key objectives of Bechtel's standardization program was the recognition that standardization of an architect-engineer's design has to allow for (1) the competitive selection of major and auxiliary equipment, (2) the owner's unique economic and system requirements, and (3) the need for flexibility and adaptability to actual site conditions. Additionally, certain key, basic engineering and design documents must be available to each new project team to provide the momentum of a good front end engineering effort. This front end engineering is critical and must be essentially completed before the detailed civil, mechanical and electrical designs can be properly coordinated and scheduled. These key documents provide a solid project base and they minimize problems that host country personnel may encounter while working on the project.

To understand some of the difficulties of transferring nuclear technology, it may be helpful to examine a typical 1000 MWe nuclear plant with regard to the construction schedule, the manpower required, and the quantities of materials to be installed. Table I shows a listing of the approximate materials involved as well as the large quantity of drawings and specifications that must be engineered, and documents that must be managed.

Table 1. Quantity Listing for a Typical 1000 MWe Nuclear Plant Light Water Reactor

Items	Quantities	
	Non-Metric	Approx. Metric
Cubic yards of concrete	150 000	115 000 m <sup>3</sup>
Feet of large pipe (2½ in. and larger)	130 000	40 000 m
Feet of small pipe (2 in. and smaller)	150 000	46 000 m
Feet of cable	4 600 000	1 400 000 m
Feet of conduit and tray	440 000 / 65 000	134 000 / 20 000 m
Average no. of conductor/cable	3.6	
Connections	120 000	
Circuits	16 000	
Instruments	6 000 to 7 000	
Pieces of equipment	(major 350-400)	
Tons of structural steel (generic basis)	11 200	10 000 te
Field manual manhours (U.S. basis)	8 000 000	
Field nonmanual manhours (U.S. basis)	2 400 000	
Subcontract M.H.'s = (U.S. basis)	1 150 000	
Men in field (U.S. basis)	Av. 1150 Peak 1750	
Typical field schedule 1st conc to fuel load	60 months	
Plant area	140 000 ft <sup>2</sup>	13 000 m <sup>2</sup>
Plant volume	15 300 000 ft <sup>3</sup>	433 000 m <sup>3</sup>
Engineering drawings	7 000	
Piping drawings (orthographic)	650	
Piping iso drawings	150	
Vendor prints	40 000	
Purchase orders	400	
Specifications	350	
Schematic diagrams	900	
Systems for startup	110	
Pages in PSAR	4 500	
Pages in amendments	900	
Pages in FSAR	3 500	

#### A. Benefits To Host Country

There are four major benefits that explain why our comprehensive standardization program is an excellent means of bringing our engineering, construction and management experience to the host country.

1. Our approach encompasses all phases of a nuclear installation, and as such, it promotes an awareness and a perspective of the total process.
2. Our approach is an excellent way of quickly defining the technical scope of a new project, and this opens up all of the work and facilitates an orderly

and sequential engineering program.

3. Our approach represents an excellent training tool because it is basically discipline-oriented and it is arranged in successive levels of detail. This structure encourages and facilitates greater participation and absorption by host country personnel.
4. Our approach provides cross reference to all U.S. Codes, Standards and the Nuclear Regulatory Commission regulatory requirements. This allows for better understanding and acceptance and for timely adaptation to local licensing requirements.

**B. Key Elements Of Standardization**

The key elements of our program are:

1. Criteria development by participation in national and international committees. This allows general identification and understanding of criteria before the start of the design effort.
2. Criteria application in the form of codes and standards. This entails a thorough understanding and application of the governing codes, standards and regulatory guides and the application of their requirements.
3. Criteria application using topical reports. Topical reports describe sophisticated analysis and design solutions that have been approved by regulatory commissions, and they represent excellent methods for implementing criteria, standardizing designs, and preventing the reinventing of the wheel. Topicals referenced in safety analysis reports reduce review time and promote standardization. Examples of topical reports are listed in Table II.
4. Basic systems design using generic key design documents. These documents define plant systems and represent the basic design of the plant. Examples of these key documents are shown in Table III.  
Generic system descriptions and their associated flow diagrams, piping and instrumentation diagrams and control logics shorten much of the tedious preliminary design work and get a project off to a fast start. There are some 30 to 40 major electrical and mechanical systems that control the progress on physical layout of piping and electrical design work.
5. Physical layout using generic - modular plant arrangement. Although a standardization program involves more than the plant arrangement and its equipment, the arrangement is of vital concern to the owner, his engineer and contractors. The modular approach to structures and their relative arrangement is able to take advantage of site conditions and, at the same time, preserve, as a standard, the functional layout of the major equipment within each individual module. The arrangement of these modules with respect to each other is shown in Table IV. The plant arrangement shown in Table IV is for a peninsula type of arrangement of the turbine generator relative to the reactor. It is apparent that the individual modules can be

arranged as necessary and still preserve the standardization within individual modules.

Some of the major objectives in modularizing the plant arrangement are as follows:

- a. To incorporate, as the starting point for future projects, what has been learned from previous plant design experience.
  - b. To design a functional layout that is flexible and can accommodate such things as variable site conditions, all manufacturer's equipment and individual client preferences.
  - c. To insure implementation of licensing criteria and requirements in the physical plant layout.
  - d. To maximize construction access and construction schedule flexibility.
  - e. To maximize the ease of plant operations and maintenance.
6. The functional layout of each plant must be sufficiently flexible to accommodate all site conditions and all variations of manufacturer's equipment in accordance with each client's preferences. Equally important is the need to implement licensing criteria, such as electrical and equipment safety separation, while at the same time maximizing construction access and maintaining flexibility in the construction schedule.
  7. Procurement using standard equipment and materials specification.

#### IV. PLANT DESIGN MODELS

To prove that the standardization approach is practical and will result in a constructable plant that is operable and maintainable, a design basis scale model of the plant is used as a design tool. Models are increasingly being used in nuclear power plant work to facilitate design coordination, client reviews, and the training of plant personnel.

Perhaps the most important use of the project models in design coordination is the three dimensional review of the equipment and its location with respect to pipe breaks, pipe whip and fire hazards. The safety and reliability of vital systems is greatly enhanced by such reviews. Other advantages, such as locating pipe hangers and thermal and seismic restraints, and preparing piping isometric drawings directly from the model, are spin-off benefits from the use of design models. Finally, the model provides an invaluable tool in planning construction sequences, evaluating construction methods and solving construction problems.



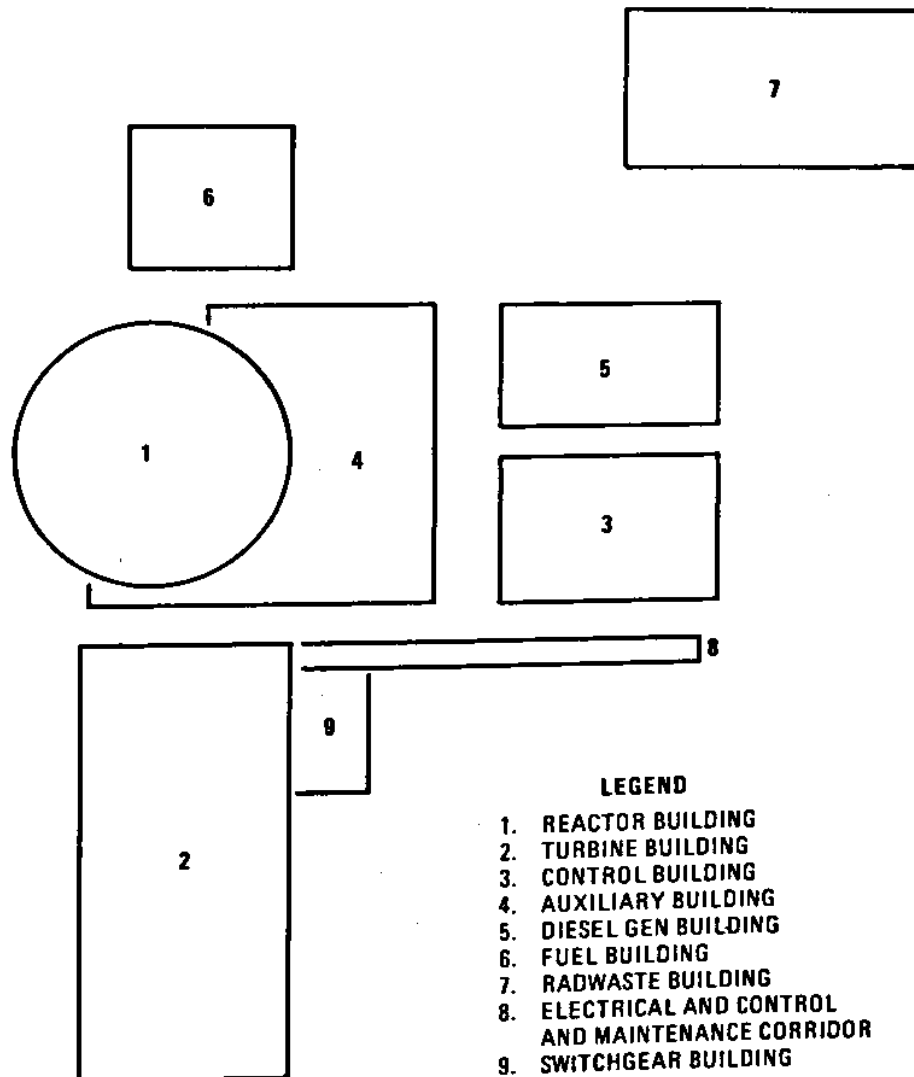
Table 2. Topical Reports Listing

Report	Title	Chronology
BC-TOP-1	Containment Building Liner Plate Design	Rev 0 to AEC, Oct 1969 Rev 1 to AEC, Jan 1973 Approved with conditions Feb 1974 Rev 2 Scheduled Sept 1974
BC-TOP-3	Tornado and extreme wind. Design criteria for nuclear power plants	Rev 0 to AEC, Mar 1970 Rev 1 to AEC, Jan 1973 Rev 2 to AEC, Dec 1973 AEC questions May 1974
BC-TOP-4	Seismic analysis of structures and equipment for nuclear power plants	Rev 0 to AEC, April 1971 Rev 1 to AEC, September 1972 Rev 2 submitted June 1974
BC-TOP-5	Prestressed concrete nuclear reactor containment structures	Rev 0 to AEC, Aug 1972 Rev 1 to AEC, Jan 1973 Rev 2 submitted July 1974
BC-TOP-7	Full scale buttress test for prestressed nuclear containment structures	Submitted to AEC, Aug 1971 Approved by AEC, Aug 1973
BC-TOP-8	Tendon end anchor reinforcement test	Submitted to AEC, Nov 1971 Approved by AEC, Aug 1973
BC-TOP-9	Design of structures for missile impact	Rev 0 to AEC, Nov 1972 Rev 1 to AEC, Aug 1973 AEC questions to Bechtel, May 1974
BN-TOP-1	Testing criteria for integrated leak rate testing of primary containment structures for nuclear power plants	Rev 0 to AEC, March 1972 Rev 1 to AEC, Nov 1972 Approved by AEC, Feb 1973
BN-TOP-2	Design for pipe break effects	Rev 0 to AEC, Sep 1972 Rev 1 to AEC, Sep 1973 Conditionally approved Feb 1974 Rev 2 approved June 1974
BN-TOP-3	Performance and sizing of dry pressure containments	Rev 0 to AEC, Jan 1973 AEC comments to Bechtel, Aug 1973 Rev 1 to AEC, Jan 1974 Rev 2 scheduled Sept 1974
BP-TOP-1	Seismic analysis of piping systems	Rev 0 to AEC, May 1973 AEC comments to Bechtel, Oct 1973 Response to AEC, Feb 1974 Awaiting AEC approval
BQ-TOP-1	Quality assurance program	Rev 0 submitted Jan 1974 AEC questions, May 1974 Response submitted June 1974 Approved May 1975

**Table 3. Generic Key Design Documents**

- SYSTEM DESCRIPTIONS
- SYSTEM FLOW DIAGRAMS
- SYSTEM P&ID'S
- SYSTEM CONTROL LOGIC DIAGRAMS
- ELECTRICAL SINGLE LINE DIAGRAM
- STANDARD SAFETY ANALYSIS REPORT (BESSAR)

**Table 4. Generic-Modular Plant Arrangement**



## **V. TECHNOLOGY TRANSFER EXPERIENCE**

Bechtel has had excellent experience in the application of this program on all of its current domestic projects, on two new projects in Spain, and on one in Taiwan. A key element in the transfer of technology is the use of a Phase I effort in our home office that brings together the client, his engineer (who will be doing the detail design), and the Bechtel personnel to form a cohesive and integrated design team. The Bechtel personnel assigned to the project form the basis of the project team that moves with the project to the host country to continue the learn-by-doing transfer of technology. The Phase I effort will vary depending on the needs of the client and the project, and usually consists of a 6-9 month effort.

Table V is an example of the Phase I accomplishments of three different projects. The accomplishments vary from project to project because they reflect the project's need to emphasize specific areas of work. For the most part, the scope of Phase I work considers the technology needs of the resources available in the host country. Then, the Phase II design activities and Phase III construction activities are implemented within the host country as part of an integrated team effort.

## **VI. OVERALL PROJECT MANAGEMENT**

The dominant element in the successful transfer of nuclear technology is to achieve the primary operating goal of the country acquiring the technology. That goal is to acquire a nuclear plant having the required level of quality at the earliest time and at the lowest cost. In order to achieve this goal, the host country owner or operator of the plant should become part of a project team and should function with a project manager as true partners having a common goal. The project management team provides a single integrated source of coordination and control of engineering, procurement, construction, quality assurance and startup services for the complete plant. The team can be a blend of sponsoring and host country personnel with an opportunity for growth of host country personnel who can learn large-scale, complex management techniques on a day-by-day one-on-one basis.

Table 5. Phase 1 Accomplishments

	1000 MWe PWR	1100 MWe PWR	950 MWe PWR
P&ID's			
Logic Diagrams	Complete for Ph I	Complete	Complete
Flow Diagrams	In Ph I Scope	In Ph II Scope	Not Reqd
Drawings & Sketches	Complete for Ph I	Complete for Ph I	Not Reqd
Specifications	365	359	335
Design Criteria	57	67	38
Studies & Calculations	117	92	73
System Descriptions	94	201	115
PSAR Draft	85	18	40
Project Schedules	Completed	Completed	Completed
Project Procedures	Prepared	Prepared	Prepared
Project Q/A Program	Prepared	Prepared	Prepared
Model (Design)	N.A.	N.A.	30% Complete
Scope of Services Manual	N.A.	N.A.	Completed
Control: Budget, Computer Cost, Scope Changes	N.A.	Implemented	Implemented

## METHODS AND PROBLEMS OF THE TRANSFER OF NUCLEAR TECHNOLOGY

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### ABSTRACT

Nuclear technology is typified not so much by the techniques utilized as by their application to the construction of a nuclear power plant. The main purpose of technology transfer is not generally to enable the receiving country to design and build its own plants, but to give it the means to operate the plants it acquires efficiently and economically.

At the same time, the transfer of technology initiates or accelerates diversified industrial development. This is essentially a consequence of personnel training and of the use of the capabilities of local contractors in the best position for fabricating nuclear equipment. But this stimulating effect does not make itself felt spontaneously. It needs to be organized, thus placing responsibility on the country receiving technology as well as on the country transmitting it. This is why cooperation in a spirit of mutual confidence and the will to attain a shared goal are required to accomplish the successful transfer of technology.

### 1. INTRODUCTION

What is termed "nuclear technology" is in fact the sum of a wide variety of industrial capabilities and know-how devoted specifically to the nuclear industry, but whose applications are not confined to this field only. It may be said that the same technique serves nuclear science, space exploration, petrochemical industry, aeronautical industry and many others. It is common knowledge that various branches of advanced technology are closely interdependent.

We also all know that, however great the effort put into its development, an advanced technology which has undergone controlled and resolute development can only survive and grow if there is not too great a gap between it and other industries. It can then join with them in a symbiotic relationship.

A new technology generates a new industry, but the new industry cannot exist in a vacuum. This is the case for nuclear industry. It needs customers; it also needs suppliers from whom it can draw its materials, equipment and processes. To get under way, it needs a solid and diversified industrial basis.

The transfer of nuclear technology from one country to another is always possible, but

how this is done and how well it works depends essentially on the technological and industrial level reached by the "receiving" country.

## 2. WHAT IS NUCLEAR TECHNOLOGY?

The most characteristic part of nuclear technology is that used for the design and construction of the NSSS. This holds true, of course, for the entire nuclear island.

Nuclear industry makes use of the whole range of sciences and techniques. Mechanical, thermal and hydraulic engineering and combinations of these, as well as knowledge of materials, structural design, neutronics, automatic control, high and low voltage applications, vibration analysis, and chemistry - these are some of the fields where the nuclear industry needs highly qualified specialists. To give an idea of the number of people involved, the Framatome engineering department employs one thousand persons (including five hundred scientists and engineers plus as many highly qualified technicians). These figures also give an idea of the complexity of the phenomena to be understood and controlled before an NSSS can be built.

But an NSSS is not only the result of hundreds of thousands of hours of engineering work, it is a system incorporating a range of equipment that requires particularly great care to build. The most outstanding example is heavy components.

These very large components have to be precision machines. Their assembly is not a simple task and welding is particularly difficult. In no other industry, to my knowledge, have such large and heavy components been manufactured and inspected with such great care. The most highly sophisticated control apparatus has been developed to detect the least flaw inside components up to a meter thick. The slightest variation in the composition of the metal is detected.

We might sometimes feel that regulatory requirements have possibly gone too far in this field. Yet they must be fulfilled and very high levels of quality reached for the heaviest as well as for the most intricate components, such as reactor vessel internals or fuel assemblies.

As effective as the means for production control may be, they are not considered sufficient proof that once a plant is built, it will be reliable and safe. The "quality" of the overall design of a nuclear steam supply system and of the related equipment must be demonstrated. The process by which this demonstration is made is called "Quality Assurance". There are few industries, with the exception of the space and aeronautics industries, where such strict programs have been set up as in the nuclear industry.

Application of quality assurance programs is very time consuming at all levels of design and production. They are extremely difficult to enforce, not so much for the main contractor, who is well aware of the motives behind them, but mainly with his subcontractors. Experience with nuclear engineering is acquired slowly and painstakingly.

Experience has also shown that a nuclear boiler takes 6 to 10 years to build, depending on the country and site. The supplier must therefore maintain control of a project

that stretches over such a long time that in most cases the teams that finish a project are not the same as those that started it. From this stem some exceedingly difficult management problems. Management techniques for large, highly complex and very long-term projects are certainly one of the important components of nuclear technology.

Nuclear industry can be described from many angles, and I have highlighted here the main points to be borne in mind when nuclear technology is to be transferred.

I would now like to add two points -

In some countries, nuclear industry has been at the stage of maturity for some years now. This means that, as techniques inevitably continue to develop, progress is sought in the improvement of existing technology (such as better performance, more economical operation), rather than in radical modification of the systems in themselves. This also means that the market has a tendency to greater stability. The number of nuclear power contractors on the world market is no longer very great and through the number of projects they carry out, the extent of their investments and their engineering knowhow, they acquire a wealth of experience that makes it difficult for new competitors to make a breakthrough on the market.

Technology comprises theoretical knowledge associated with know-how. Although theoretical knowledge may be transferred with relative ease, this is not so with experience. Theoretical knowledge can be transmitted directly, for he who acquires it does not need to transform it, but only to understand and assimilate it. Experience, on the contrary, can only be gained with time; errors of orientation must be avoided, development must go on steadily. Once the goal is established, one must strive to reach it with perseverance, without being put off by the inevitable setbacks encountered.

### 3. AIMS AND MEANS OF TRANSFER OF NUCLEAR TECHNOLOGY

Now, why should a country developing its industry try to acquire nuclear technology?

The most obvious reason that comes to mind is to set up an industry that will allow it eventually to build its own power plants. The way to this goal leads through intermediate and more directly accessible stages. But is this objective realistic?

I have already said how difficult it is for a new manufacturer to catch up on the long-standing experience of those who have already had contracts for scores of plants.

This situation is worsened by the increasing degree of complexity to which a nuclear power plant is subjected by safety requirements. A newcomer would have to master the most advanced design and construction techniques without going through the intermediate stage of gradual improvement of previously known techniques.

A good illustration is the piping support system. In 1965, nuclear piping systems were designed along the principles of those used in oil refineries or conventional power plants. Progressively, it was found necessary to take into consideration an ever greater number of phenomena, such as pipe whip in case of rupture, earthquakes, and various other causes for accident. Nowadays, the design and calculation of a nuclear plant piping



system, not to mention its construction, have become a highly sophisticated technique. The same holds true for most components of the NSSS and even the whole nuclear part of the power plant.

There is now every reason to believe that by about 1980-1985, the price to pay for joining the nuclear power plant contractors "club" will have become too high to set out on such an adventure, considering the necessarily limited number of plants to build.

However, a seemingly modest but more realistic goal, is to gain sufficient technical independence to be capable of operating the acquired nuclear power plants efficiently and economically. In reality this aim would be an ambitious one, and hence it would provide incentive. This may be achieved on a relatively short term, in about ten year's time, commensurate with the time it takes to design and build a nuclear power plant, from the day the contract is signed to the day the plant has been fully taken over by the owners.

The goal is in keeping with a goal of the authorities of the country investing in nuclear power plants: to ensure that the initial investment is profitable, that is, that the plants actually function for the entire life they were designed for. At the same time, the efforts made to reach the goal contribute to the spreading of technological progress and an acceleration in the country's industrial development.

Let us assume that this is the goal that has been chosen. There are two main consequences: first, teams with many difficult skills must be set up, which will be able to comprehend the operation of the plant down to the last detail, so that they can provide rational and scientific maintenance. Then, local industry must progress to the point where it can carry out fabrication and repair, and provide spare parts necessary to the maintenance or even the gradual improvement of the plant. In all this, local industry has to come up to the standard required for nuclear quality construction. This goal is ambitious and constructive, for it concerns all parts of the plant except the irremovable heavy components. In other words, there would be no point (and certainly no profit) in making a considerable effort to produce heavy components such as the reactor coolant system or the turbine generator, which will never need replacement. It would be far better to try to acquire the capability to fabricate the rest of the equipment, which represents over half the value of a plant and is made up of apparatus which will have to be partially replaced during the whole of plant life.

To opt for this goal would have another repercussion. Competent teams would be set up, capable of exercising positive control over the plant supplier. For to control intelligently does not consist in looking for errors in technical documents, but most of all in understanding the reasons for the way things have been designed, in discussing operational requirements adapted to the economic and social context, and in making relevant suggestions to the manufacturer. All of this enhances the task of control and makes it a useful complement to the role of the manufacturer.

I believe it is important to mention one last aspect: manufacture of the fuel assemblies. This is a component which, with the exception of the initial core, can be considered as a basic element of plant operation and maintenance. It is therefore legitimate for a country

building up its industry to ask itself when and how it should try to carry out its own fuel production. Technology transfer does not present a problem, but an investigation of this possibility should not neglect two important points: the manufacture of fuel would offer little employment and feedback to the local industry would be very slight.

Then in what stages can nuclear technology transfer take place?

We have seen that it can only be progressive, but nuclear power plants take so long to build that there is plenty of time to prepare the transfer.

The method is simple in principle. The way it is applied depends on the capabilities of the receiving country. First of all, it requires thorough analysis of the strong points of the industry, in order to make the best use of them in the first operations undertaken.

When local enterprise is considered capable and is specialized in certain types of equipment, it needs only to be initiated and trained to the special working conditions required by the nuclear industry. The experience of already qualified manufacturers can then be readily transmitted.

In any event, priority must be given to training personnel in many different specialties and at different levels, and it must be borne in mind that they will have to work together with compatible working methods. But the suggested scheme does not require the training of nearly as many persons as for a fully fledged nuclear industry capable of design and construction of complete plants. This goal is therefore within easier reach.

The problem of training lies differently with the various categories of personnel, that is, scientists, managerial staff, engineers, technicians and workers.

For scientists or managerial staff, universities and research facilities are available the world over. The theoretical knowledge the country will need at the outset can be transmitted to a selected group of individuals only. The training of engineers is more specific. It involves the transfer of nuclear technology as such, and can be accomplished in engineering schools and then in training programs with competent manufacturers.

The difficult point, which concerns the largest group, is training qualified technicians and highly skilled workers. For these, the quickest and most economical means is in technology centers, that is to say, workshops with many functions in which personnel receive training in basic techniques such as boilermaking, welding, electricity, electronics, precision mechanics and modern working methods in general.

The idea is to spread out the specialists trained in this way, not in pilot industries where they would remain among themselves and tend to form an isolated group but with selected contractors where they in turn would have the mission to bring about a change in mentality and bring the level of industry up to nuclear standard.

#### **4. CONDITIONS FOR SUCCESS**

If technology is to progress, then it is obviously necessary that qualified personnel be assigned to certain contractors, but this is not enough. They need adequate tools and they need contracts. During the first phase, they will have to devote their efforts to build-

ing prototypes, which open the way to qualification of their equipment and that of any sub-contractors they may have.

Once the equipment they build has been qualified, "real" orders are needed for equipment required for maintenance of nuclear power plants that have been purchased and are in operation.

Repercussions are soon felt in other areas: step by step, diversified industrial development can take place, based on more and more experienced contractors.

But another thing is needed to consolidate the development of these contractors: a sufficiently wide market.

Their efforts will pay, not through components or products of which few are made, but through such items as valves, piping, fittings, and other hardware, which, by virtue of their number, lifetime, low unit price and low investment have a more open market that already caters to the maintenance of other local plants.

It is also conceivable that neighboring countries starting to invest in nuclear industry might join together in a policy which will allow them to specialize their infant nuclear industries in manufacturing parts that will complement each other. In this way, each would have a larger market covering all the countries that are party to the agreement.

I would note in passing that this method is already used by industrialized countries. The growth of international trade and the specialization of production result in certain items being manufactured by a small number of contractors. This phenomenon is often hidden in industries that do not require heavy investment, by the fact that these companies establish more and more subsidiaries at different locations, which leads to reduced transportation costs, rationalized management, etc. But the fact remains that the mutual economic dependence of western countries is on the increase. This is positive, as long as their economic efficiency is improved by it.

I do not want to pass over the inevitable fact that the creation of a nuclear industry in a country where there is none will meet with great difficulties. Contractors have to be found who are prepared to set out on a road strewn with obstacles. Production is often difficult and subject to severe regulation, where the required quality is only reached through sustained effort, where the beginnings are thankless and in general not very profitable, in view of the risk taken. It is up to the governments to provide the assistance and incentive to develop the country's potential.

## **5. ASSISTANCE SUPPLIED BY THE PROVIDER OF TECHNOLOGY**

What can the companies and nations do who hold nuclear technology and are ready to help with its transfer?

In my view, the first essential step is to establish the legal framework for the provider of technology to transmit his knowledge to the contractors of the receiving country capable of producing nuclear equipment. This is done by awarding licenses for the manufacture of such equipment. If this is not sufficient for an effective transfer, as is generally the

case, other means of action should be undertaken to train engineers and technicians and to develop technical assistance at all manufacturing stages.

Engineers and management staff are trained in the licensor's facilities. Technical assistance can take on many forms, from advice on the choice of tools for the manufacture of new parts, to direct participation in the management of the contractor companies undertaking to apply this new technology. This can be done in any number of ways.

The provider of technology is also in a good position to open a market to local enterprise. Since he helps them to manufacture nuclear quality equipment, it is natural for him to include it in his proposals for construction of plants in the "receiver's" country. Such a policy does have its limitations, which result directly from the higher prices and longer schedules that the client will ultimately have to bear during the phase of local industry's adaptation to new technology.

In this respect, the conflict is inevitable between the desire of the client country to promote its infant nuclear industry and its desire to see to it that the plants it has ordered are built in as short a time as possible and at a price level comparable to that prevailing in technologically advanced countries.

Where the transfer of technology is economically worthwhile and technically feasible, the decision to organize it is a far-reaching one. It channels capital and industrial potential towards fast-developing and diversified activities. It can result in a real expansion of national capabilities, but only at the price of sustained effort.

To the countries that ask for assistance in building up their own nuclear industry, Framatome will reply unhesitatingly that they may be assured of its cooperation.

# **A PLAN FOR TRANSFER OF TECHNOLOGY IN NUCLEAR POWER PLANT DESIGN AND CONSTRUCTION TO DEVELOPING COUNTRIES.**

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## **ABSTRACT**

The installation of a nuclear power plant in a developing country in itself involves an extensive transfer of technology. However, to economically and safely operate the plant it is essential that transfer of technology is also carried out in a planned and systematic manner in the design and construction aspects of the plant. This should be with the aim of making the plant personnel capable of carrying out modifications, repairs, analysis and to some extent the design of systems or equipment. To achieve this a "specialists' core" should be developed, who should form the link, in the transfer of technology from the design and manufacturing facilities of the plant manufacturer to the developing country.

## **1. WHY TRANSFER TECHNOLOGY IN NUCLEAR POWER PLANT DESIGN AND CONSTRUCTION**

A nuclear power plant is a complex brought together and built by the application of various technologies. The state of this art, as it is at present, is in the process of development and still requires a large effort to learn from experience and carry out improvements. Indeed, it has been our experience at Kanupp during the last four or five years, that for economic and safe operation of a nuclear power plant in a technologically developing country, it is essential that all the applicable technologies are either available within the plant or within easy and quick reach of the plant personnel. A nuclear power plant cannot be operated on the basis of the information normally supplied in design descriptions, maintenance manuals or operation manuals. The developing country must, therefore, develop at least a minimum capability to provide the technological back-up to its nuclear plant operator that is normally available to the plant operator in a developed country from the large research institutions, design offices, industry, original equipment manufacturers etc.

It has been our experience that exchange of technical information and instruction between Pakistan and Canada, even with the use of direct telephone and telex is a painfully long process. Considerable time has to be spent in seeking of clarifications, further information etc. The penalty in operating time lost, as a result of this delay, can in the case of an incident which cannot be solved locally be at times colossal.

If a developing country ventures into a nuclear power program, without developing a minimum level of nuclear power plant related technology, it is liable not only to operate the plant uneconomically but also runs the risk of their unsafe operation. The development of this minimum level of local capability can best take place by the process of transfer of technology at the time of design, construction, commissioning and early stages of operation of the power plant. The aim of this transfer of technology is not necessarily to become independent of the nuclear power plant exporting countries, but is to ensure that facilities, capabilities and knowledge exist to operate the plant both economically and safely.

The type of technology required to be transferred into a developing country and to be sustained, encouraged and developed along with the development of a nuclear power program can be categorized as follows: -

**(a) Modifications:**

The nuclear power plant will, during the course of its operation, require modifications and improvements as a consequence of its own unique experience. The capability to carry out these modifications must be developed within the organization responsible for the operation of the plant. The trend to maintain status quo vis-a-vis the design of a plant as given by the original manufacturer, as is liable to occur in a developing country, must be curbed.

**(b) Repairs:**

The capability must be developed to be able to carry out repairs of equipment or components that may fail due to any of the possible causes without having to import experts. This will result not only in a reduction of downtime, but will also increase the local capability to understand the causes of failure and to take corrective action.

**(c) Analysis and Research:**

A nuclear power plant demands consistent review and analysis of its operating and maintenance techniques in the light of latest technological developments, behavior of installed equipment, its own unique experiences etc. Solution to these might require evolution of new procedures, installation of new equipment or components and research both in the plant itself or on test loops, rigs etc. The capability to carry out this analysis and research must be developed locally.

**(d) Design:**

It might be appreciated from the foregoing that the technology required to be transferred requires a deep insight into the design of a nuclear power plant. This ranges from the design aspects of the basic components to the design aspect of the sub-systems and complete systems. The transfer of technology, therefore, must begin at the design office of the nuclear plant manufacturer and encompass, wherever feasible, their manufacturing techniques. If this method of transfer of technology is pursued vigorously, in the long run the capability will automatically evolve of progressively designing and manufacturing components, systems etc. of a complete nuclear power station.



## **2. TRANSFER OF TECHNOLOGY - GIVE AND TAKE:**

Before we make a case for transfer of technology and plan its development, we have to ensure that the role of the "donor" country or countries i.e. the nuclear power plant exporting countries, is that of cooperation and understanding. For indeed, transfer of technology cannot take place if the donor countries are noncooperative. The erection of a nuclear power plant in a developing country in itself involves an extensive transfer of technology. The question then is: why should not the donor country help the recipient country to operate the plant both economically and safely? The donor countries stand to gain in the long term by transferring this technology, since in most developing countries cheap and reliable nuclear power is essential for economic development. Economic development leads to greater international trade which will be of mutual benefit to both the developing and the developed countries. Transfer of nuclear power technology, therefore, may be considered as an investment for larger trade by the developed countries in the developing country. Withholding this technology will benefit nobody since this technology can also be developed by local efforts, even though at great expense, once a developing country feels the necessity of it for its economic growth.

## **3. WASTE OF TRANSFERRED TECHNOLOGY:**

If a developing country embarks on a program of installing nuclear power stations without developing the essential local technology, this transferred technology may go to waste to a degree dependent on the local industrial and technological infrastructure. This waste can occur due to all or any of the following factors:

- (a) With the passage of time, local personnel involved in the initial stages of the plant will eventually disperse. This will seriously effect the pool of knowledge available within the plant and can result in its uneconomical and unsafe operation.
- (b) Whereas in nuclear power plant supplying countries constant research and improvement continue to be made to increase safety, reliability and economy, the power plant in a country without appropriately advancing technology will remain static and may become not only less competitive but prematurely obsolete.
- (c) All nuclear power plants require modifications, improvements and additions to suit their own unique local incidents or conditions. These cannot be carried out without a developing technological capability.
- (d) Unnecessary delays, with a heavy economic burden, in having to fall back on the original supplier to help in overcoming problems.
- (e) Poor operation and maintenance practices can creep in due to lack of knowledge and appreciation of special requirements.
- (f) With the passage of time the cost of original spare parts, because of obsolescence and other reasons, including nonavailability, will skyrocket. In certain cases



their supply will not be possible, putting a severe economic burden on plant operation.

#### 4. TRANSFER OF NUCLEAR POWER PLANT DESIGN AND CONSTRUCTION TECHNOLOGY - FORMATION OF A SPECIALISTS CORE:

For a developing country embarking on the setting up of a nuclear power plant or plants with the assistance of a developed country, many avenues are open for importing technology among which could be the following two extremes: -

- (a) Along with the import of the plant to also import the key men - decision makers - for the operation and maintenance of the plant. To continue to depend on the parent country for future modifications, improvements etc. and to leave the local technology to develop at its own pace along with the development of technology in the rest of the country.
- (b) Along with the import of the plant, to transfer technology so that eventually the plant can be operated without the inevitable delays caused by having to fall back on the original manufacturer in case of need and to be able to carry out improvements and additions necessary to keep the plant in economic and safe operational condition.

To follow the first extreme, no local effort is required. All that is required is the regular payment for services rendered. The problem of keeping the plant economically operational will be that of the foreign experts, they will make the efforts to improve and modify and they will learn - all at the expense of the technologically developing country. This, of course, cannot be accepted as a long term or even as a short term proposition.

The need, therefore, is to plan the import of nuclear technology along with the import of a nuclear power plant. This, our experience has shown, can best be achieved in the design and construction stage of the power plant.

The Pakistan Atomic Energy Commission, realizing the importance of this and with the cooperation of the prime contractor i.e. Canadian General Electric Co., for the Karachi Nuclear Power Plant (Kanupp) sent a team of ten engineers and scientists to the design office of the prime contractor immediately after signing of the contract in 1966. Each member of this "design team" was assigned different areas of the Kanupp design and they actively participated and contributed to the design of the plant and its equipment. The areas of design ranged from fuel design, fuel handling system design, reactor systems designs, nuclear safety, reactor physics to fuel scheduling etc. etc. Though it is now felt that the number of Pakistanis assigned to this "design team" was too small, the technical knowledge gained by these personnel as members of this team was put to great use by both the prime contractor and the operator of the plant. These persons, in their respective areas, played a key role in the commissioning of the plant and in solving problems in the early stages of the plant operation.

In this context mention may be made of the experience of Kanupp in two areas in which

there was a good participation of Pakistani engineers in the design stage: The fuel handling system in the Candu type of plants is considered quite delicate and requires a high level of technology to operate and maintain. This system has worked very well and to date the plant has never been derated or shutdown due to this system. The operating record of this system is similar to that in Canadian nuclear power plants. Since the very beginning of the operation of this plant this system has been operated and maintained by Pakistanis and a number of modifications have been instituted to improve the design. This excellent record is a matter of pride not only for a developing country like Pakistan but for the original manufacturer also. Another area from our experience that may be mentioned here, is that of fuel scheduling and management. For some time the fuelling schedule was sent by the Canadian General Electric Co., Canada, based on the operating data supplied to them. Fuel scheduling and management programs have now been developed by a team of Pakistanis led by a member of "design team" sent to Canada. These new programs have been very successful and the plant is operating and is being fuelled according to them.

It is, therefore, proposed that the transfer of nuclear power plant technology can only begin and must begin at the design office and at the works and plants of the manufacturers.

This transfer of technology should, therefore, begin by embarking on a plan to gradually and systematically produce a "specialists core" of design and production engineers who have been through phases of "retraining" in narrow specific fields applicable to the nuclear power plants. This "specialists core" of engineers and scientists should include enough personnel to cover all possible areas of a nuclear power plant design and fabrication. The range is vast and the aim should be to cover as great an area as possible and should not be limited to specific nuclear aspects only. All areas, even the balance of plant and conventional components must be covered. Manufacturing and design knowledge of these parts will be an asset at the time of maintenance and repair. This core of engineers and scientists should include persons with some basic experience in their respective areas so that they can "soak up" information easily. Each individual in this "core" should be given a specific area and a target to achieve within a time table. To begin with, they should be sent to the design offices of the manufacturers or the designers and should study and contribute as much as feasible to the design concept. They should then follow production of the item or component and learn and familiarize themselves with the various manufacturing stages. Whenever physically possible the members of this core must take part in the installation and commissioning of the components of systems they have been assigned.

Following the commissioning of the plant, the second phase of this "specialists core" begins. The members of this "core" should be located in the plant and analyse the operational experience of the equipment or system they specialize in. In case of faults, failures or breakdowns, these specialists will assist the operational and maintenance crews in the repairs. With their background knowledge these specialists can study and institute modifications as found necessary.

During this second phase, and even earlier in certain cases, these specialists should survey the capability of the local industry and research institutes to make components for

repair or replacements or carry out modifications of the areas they specialize in. This "core" can then recommend introduction of new industry or manufacturing facility or research efforts to assist the operation of the nuclear plant and also the local manufacture of components for subsequent plants. The recommendations of this "specialists core" will be based on actual solid experience and requirements and not on grandiose plans for industrialization of the country, as is liable to occur in a developing country, if the requirements are not well defined.

In the third phase of activity of this "specialists core", which should occur at about the time the operation of the nuclear power plant has stabilized and all the teething troubles resolved, the development of local technological capability should begin. This "core" by this time should have expanded to many monodiscipline design units - by the gradual addition of new members - with each unit responsible for one area of the plant design and manufacture such as nuclear pump design and manufacture, nuclear system design, heat exchanger and boiler design and manufacture, special valve design and manufacture, instrumentation, computer control etc. Each unit will now be responsible for the building up of facilities and knowledge for the step by step design and manufacture of the areas they specialize in. This local design and manufacture effort will be for the country's next or future nuclear power plants. These units can draw up a list of components and systems that can be designed and manufactured by local effort. The extent of local participation will depend on the amount of technology transferred and the industrial infrastructure available in the country. As more plants are built and if this involvement in design, construction and operation is kept up, the extent of local participation will continue to increase.

It has been noticed that in developing countries, technology has been transferred in many areas through individuals or through a specific item of equipment or plant but is not available nationally. It will be the purpose of this specialists core to search out individuals and equipment etc. for assistance, advice and use.

##### 5. LOCAL DEVELOPMENT FACTOR:

As has been discussed earlier, the development of local effort, by transfer of technology or otherwise, will be of great economic benefit to the operation of the plant. However, in the application of local effort, that is, local production and local design a certain economic burden, though small, will be added the cost of the plant. In the first local design effort, problems will arise. Though design defects occur in designs made by the most developed organizations, the designs made by local efforts will naturally invite more attention and, in case of faults, undue criticism. When components of a system are made locally, they may, because of the tooling costs and limited number, cost more than the equivalent imported from a developed country. The local development effort may on occasions delay the construction of the plant because of the "learning" process involved, much to the annoyance

of the national planners.

For the sake of transfer of technology and for the development of local technology in a developing country these aspects must be appreciated with understanding. This will be a small sacrifice for development.

## **TRANSFER OF NUCLEAR POWER TECHNOLOGY: A PRACTICAL APPROACH**

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### **ABSTRACT**

A developing country planning its first nuclear power plant will have two principal goals - to get the plant constructed and to acquire practical know-how on design and engineering as well as all aspects of project management in order to reduce to a minimum its dependence on foreign contractors for later plants. A great deal has been written on the subjects of feasibility studies, preplanning, and personnel requirements. However, very little has been said of the actual means by which technology transfer is to be achieved by a developing country.

The experience of many developing countries to date has been that the principal needs were personnel with practical experience in design engineering, plant operations, installation of plant equipment, and in project management. A practical means of acquiring this practical know-how through participation is presented in this paper. The owner's personnel who will participate in these activities are termed "engineering interns" (EI) and will be participating in actual design as working members of the contractor's staff team. Also pointed out are those areas in which the owner country EIs should acquire practical knowledge, and the organizational structure needed to achieve those goals. The various activities that are to be performed in the course of design and engineering of a nuclear plant are also discussed in detail.

Since the concept of technology transfer is a broad and complex one and cannot be treated in sufficient depth in a short paper, only one aspect of the overall technology program, namely the practical know-how of the design engineering and project management, is treated.

### **1. INTRODUCTION**

Extensive studies have been performed by the International Atomic Energy Agency (IAEA), and a variety of papers are available on the problems associated with introducing the first nuclear power plant and related technology into a developing country. The preplanning activities, general requirements, and feasibility studies have been considered and general methods suggested. However, very little has been said of the actual means of achieving the transfer of nuclear power technology; that is, the means of acquiring the necessary

know-how so as to enable the country to perform the tasks of engineering, installation, construction, and operation of the subsequent nuclear power plants with minimal reliance on foreign contractors.

Some of the means of acquiring this practical know-how are discussed in this paper. It is generally recognized that the most serious problems that developing countries have experienced in such projects to date have not been of the type that requires additional personnel with advanced academic training in nuclear science and technology. The most serious need has been for additional personnel with practical experience and training in design engineering, plant operations, and installation of nuclear plants, as well as all aspects of project management.

In order to focus our attention on the problems of actual means of acquiring the practical knowledge of the technology, we make certain assumptions about the status of the host country's nuclear program. The basic assumptions are the following:

- The country has an adequate educational foundation for training B.S. and M.S. level engineers and scientists.
- The country has completed the preplanning and feasibility-study phases of the nuclear power project.
- The country has established a firm long-range nuclear power program and has decided on a turnkey-type project for the first power plant.

Although the utility or government agency responsible for introducing the first nuclear power plant into the country would have planned the overall strategy of the technology transfer in the preplanning stage, the detailed planning and implementation of the plan start with the preparation of the bid specification documents and continue through the contract negotiation and to the completion of the project.

During the initial phase, at least, of a long-range national nuclear program, the only feasible and practical areas of meaningful technology transfer for a developing country are in design engineering, equipment installation, and project management rather than in the areas of design and manufacturing technology of hardware, such as nuclear steam supply system (NSSS) components or turbine-generator equipment. In other words, the effort should initially concentrate on those areas that are normally considered in the owner's and the engineer/constructor scopes and on certain limited areas of NSSS analysis.

In discussing the means of acquiring the practical know-how of the technology, the following three phases will be considered:

- Detailed Planning Phase: This phase starts with the preparation of the bid specification documents, which give detailed procedures and conditions for the participation of the owner-country personnel as "engineering interns" in the actual engineering, installation, and construction activities of the contractor as integral members of the respective contractor organization team. The owner country will have the most effective leverage to induce the potential contractor to agree to a technology transfer program during the contract negotiation.
- Implementation Phase: In this phase, a number of selected owner-country personnel,



the engineering interns, will be assigned to contractor organizations, each intern as a working member of a team.

- Application Phase: In this phase, the acquired practical knowledge of the engineering interns will be integrated into the project organization of the subsequent unit in an effective manner.

The most effective means of achieving these objectives are determined by examining the organizational forms and procedures and the functions and type of manpower required in each organizational entity.

## **2. PLANNING FOR THE FIRST NUCLEAR POWER PROJECT**

### **2.1 Special Problems in Developing Countries**

Nuclear power plants are extremely complex undertakings, and the importance of a substantial planning effort is widely recognized. However, careful planning for a first nuclear project in a developing country is more critical than for such a project in a developed country. Some of the more important differences are summarized below.

**2.1.1 The First Project** - The simple fact that the nuclear project is the first such project to be built in the country imposes significant inherent difficulties. Developed countries that now have at least one nuclear project have innumerable precedents and practices that facilitate succeeding projects.

**2.1.2 Imported Equipment and Services** - A nuclear unit in a developing country will require substantial purchases of foreign equipment and the use of foreign major contractors. Contracts for foreign equipment and services are necessarily more complex than those for domestic suppliers; the arrangements for financing are more complex; import licenses and customs may cause administrative delays; transport of heavy equipment is often a serious problem; the regulations, codes, and standards can be a problem in that they may conflict with those of the supplier country; resolution of matters relating to nuclear safety and licensing are generally more difficult; and other differences such as language and units of measure can cause problems.

**2.1.3 Infrastructure** - Probably the most serious difficulties facing most developing countries relate to uncertainties and deficiencies in the infrastructure necessary to support a nuclear project. Problem areas commonly include the supply of skilled labor and building materials, the availability of qualified subcontractors, the adequacy of road and rail transport to the site (particularly for heavy equipment), and the adequacy of port facilities.

**2.1.4 Organization and Responsibility** - The responsibility and authority of the organizations involved should be clearly defined in advance. This is a problem area that



is related more to the fact that the project is a first nuclear project in the country than the fact that the country is a developing country. The organizations most commonly involved include the owner-operator, the ministry responsible for industry, the ministry of finance or the central bank, and the agency responsible for the issuance of import licenses and custom clearances. All of these organizations will have significant influence on the ability of the owner to deal effectively with his prime contractor in negotiation of the contract and in execution of the project. Any lack of definition of responsibility and authority will result in increased costs and delays.

**2.1.5 Legislation and Insurance** - In many countries the necessary legislative basis for a nuclear program is not established until the first project is under way. Similarly, provisions for nuclear indemnification and insurance are often not established until the project has been started. In particular, contract negotiations for the nuclear plant can be greatly simplified if these areas are clearly established and understood in advance, preferably before the preparation of bid specifications.

**2.1.6 Regulations, Codes, and Standards** - Typically, preparation for a first nuclear project requires the formulation and promulgation of a substantial body of regulations, codes, and standards. In most developing countries there is a strong interest in maintaining effective competition between reactor suppliers from a number of different countries. As a result, the preparation of the regulations, codes, and standards is complicated because they must not impose any undue burden, or confer any undue advantage, on bidders from a particular country.

**2.1.7 Bilateral and Trilateral Agreements** - The construction of a first nuclear project will usually require at least one and possibly more bilateral and trilateral agreements covering, as a minimum, safeguards of nuclear materials. In many cases, agreements covering the supply of nuclear materials and/or enrichment will also be required. As in the case of legislation, it is important to do as much of the ground work as possible before the nuclear project is formally initiated. However, it is often not possible to enter into an agreement until the country supplying the nuclear steam supply system has been selected since the agreements will normally involve the specific country of supply.

## **2.2 Major Steps in Project Planning**

The actual planning of the nuclear program will vary widely in different countries. The unique circumstances in each country will influence the project itself and the planning for the project. However, certain basic considerations are common to almost all cases.

**2.2.1 Feasibility Studies** - In most cases the first formal planning effort carried out for a nuclear project is some form of feasibility study, often with the assistance of the IAEA.

Such studies are usually generalized evaluations of nuclear power plants. Their objective is to judge the probable economic competitiveness of a nuclear power plant in the circumstances of the specific country. They may include recommendations as to the structure and organization of the nuclear program, some evaluation of domestic participation and of manpower and training requirements, and rather specific recommendations in such areas as unit size and schedule.

**2.2.2 Preproject Planning** - One of the biggest problems in this early phase, particularly in developing countries, has been the tendency to spend very little money until the formal project has been initiated, a prime contractor selected, and foreign financing obtained. The reasons for this are apparent, but the results can often be damaging. A few million dollars spent in preproject planning and organization can save many tens of millions of dollars by avoiding later problems and delays.

**2.2.3 Planning the National Program** - In carrying out the project planning, it is important to distinguish between planning for the project and planning for the national nuclear program. Careful national planning should be carried out so that the first nuclear project is managed in accord with the long-term national objectives. Those who have the responsibility for planning and executing the first nuclear project should not also have the sometimes conflicting responsibility of establishing national program objectives. National policy should be formulated at appropriate policy-making levels within the government.

**2.2.4 Schedule** - One of the first and most important steps in planning for a nuclear project is to establish the project schedule. In the initial stages heavy emphasis should be placed on establishing detailed schedules for the owner's activities and the activities of the various interfacing agencies in the owner's government, that parallel the overall project schedule. It is extremely important, however, for the owner's project group to study carefully typical design and construction schedules so that the schedule of the owner's activities can be established.

**2.2.5 Nontechnical Areas** - The major nontechnical areas involved are finance, legal matters, purchasing, and administration, particularly contract administration. These areas need emphasis in planning, not because they are more important than the technical areas, but because the nontechnical aspects of a nuclear project are not as well understood and are often more difficult to deal with than the technical aspects. In addition, the most difficult nontechnical problems generally occur early in a project, but the technical workload reaches a maximum during the design phase. Formal training courses in the nontechnical areas are much more limited, and on-the-job training for individual staff members is more difficult to arrange in nontechnical than in technical areas. The problems in the nontechnical areas also tend to vary more widely from country to country than do the technical problems, so that it is more difficult to obtain assistance and guidance from other projects.

### 3. TECHNOLOGY TRANSFER THROUGH PARTICIPATION

#### 3.1 Objective, Concept and Methodology

3.1.1 Objective - The prime objective of a nuclear power technology transfer (in the restricted context of this paper) is to train sufficient manpower in all the necessary areas of design and engineering of a nuclear power plant, and thus minimize dependence on foreign contractors for later projects.

To do this, it is essential to establish a systematic and thorough program plan at a very early stage of the first nuclear project. It is also important that this program provide a maximum utilization of the limited domestic manpower and industrial resources without jeopardizing the construction of the first unit. It should be recognized that the objectives of constructing the first unit and the objectives of the technology transfer are out of phase in time and could be in conflict. The possibility of this conflict increases during the later stages of plant construction. This is especially true when the project organization responsible for the first nuclear unit is also responsible for the coordination of the technology transfer, which is a most likely situation in a developing country.

It is therefore extremely important to establish clearly the objectives and plans for the technology transfer functions of the project and convey the importance of this national goal, as early as possible, to all parties concerned, including the owner's project management and the contractor's project management.

3.1.2 Concept - In this paper the term "technology" is broadly interpreted to include all of the technical and nontechnical know-how that is required to design, engineer, construct, and operate a nuclear power plant. Some of the major nontechnical areas considered in this context are financing, legal matters, bid specification preparation, contract negotiation, and project management. These nontechnical aspects of a nuclear project are more difficult to deal with, and to train for, than the technical areas because they are not well understood and require extensive on-the-job experience in actual situations.

During the initial phase of a long-range national nuclear power program, the only feasible and practical areas in which meaningful technology transfer can be achieved are plant design and engineering and project management rather than equipment manufacturing. The actual construction activities are usually considered separately from the design and engineering activities and are not considered here in any detail.

The concept of technology transfer explored in this paper is how a developing country embarked on a first nuclear power plant project can forge a national design and engineering group staffed with experienced engineers and train enough experienced project management personnel by the end of the first project. The ultimate goal of this technology transfer program is to become independent of foreign contractors for subsequent nuclear power plant projects.

**3.1.3 Methodology** - The most practical and proven approach to the optimum utilization of limited manpower and resources in a technology transfer program is the project management approach, in which the available resources are effectively organized and allocated with a single purpose in mind.

Regardless of which government or private agency has the lead responsibility for constructing the country's first nuclear power plant, establishment of a self-contained project organization is the essential first step. The project group should be charged with the responsibilities of planning and executing the various activities necessary for a successful nuclear program, including the transfer of technology.

In a developing country it is neither practical nor necessary to staff the project group from the beginning with a large number of engineers with nuclear experience. In practice, only a few key members in each of the major discipline areas need have any previous nuclear experience. With a team of engineers well qualified in engineering basics, these few lead engineers would become the nucleus of the project engineering group.

It is interesting to note that even in the advanced countries, a typical architect/engineer (A/E) engineering group is formed around a few key lead engineers in each discipline area. Furthermore, even in an experienced large A/E firm, technology transfer is continuously taking place on a small scale within the company organization. For example, when an A/E firm organizes a new project group for a newly won nuclear contract, the nucleus of the new group is often formed by taking the number 2 man or even the number 1 man of each discipline section from the previous ongoing project to head a section of the new project group. Besides these key lead engineers, only a small fraction of the project team need to have previous nuclear experience. It is true, however, that these A/E firms have large functional support groups, staffed with experienced engineers, to provide analytical and design support to a project team.

A similar approach can be employed as a practical means of nuclear technology transfer in a developing country embarked on its first nuclear project. The practical means of acquiring the know-how will be explored by examining the type of organizational structures required, the manpower requirements, and the functions of each organizational entity.

### **3.2 Development of Detailed Program Plans**

There are three phases in achieving the objectives of technology transfer. They are the detailed planning phase, starting with the bid specification activities; the implementation phase, starting with the contract signing; and the application phase, starting with the organization for the second project. As shown in Figure 3-1 and discussed in Subsection 3.3.3.2, the detailed planning for the technology transfer starts during the project initiation phase of the nuclear program, during which the bid specification documents for the first unit are prepared.

The bid specification document should include a section in which the technology trans-

fer program is specified in detail. A detailed plan should include the following specific points :

1. Objectives of the program - The objectives are to acquire the know-how through actual participation in the design and engineering of the plant and in project management.
2. Means of actual participation - The "engineering interns" (owner's personnel) are to be assigned to appropriate contractor's home offices. The EIs will participate in actual design and engineering activities under the supervision of contractor's lead engineers as working members of the contractor's team.
3. Qualifications of the EIs - In general, an EI should have a B.S. or M.S. degree in one of the engineering or scientific disciplines.
4. Limits of authority - The owner personnel EIs should have no decision-making authority as the owner's representatives, except in very special circumstances.
5. Financial arrangement - The personal expenses of the EIs should be entirely borne by the owner country.
6. Contractor's obligations - The contractor should provide the EIs with appropriate facilities and supplies necessary to perform their duties.
7. Breakdown of areas of participation - All areas of design and engineering should be covered, including the project and construction management activities. An example is shown in Figure 3-2.
8. Number of participants - The number of owner personnel assigned to the contractor's facilities as EIs will depend on the scope of the owner's technology transfer program and should be decided by mutual agreement with the contractor. An example of the minimum number of EIs in each area is shown in Figure 3-2.
9. Duration of assignment - The duration of assignment for the EIs will depend on the assigned field. In general, the length of assignment will range from one to three years.
10. Terms and conditions - The terms and conditions of the technology transfer program should be clearly specified in the bid specification document so as to provide a common basis for bidding and evaluation.

In addition to describing the details of the program, the bid specification documents should also clearly convey the importance that the owner places on the program in evaluating the tendered bids.

It is at this stage that the owner can effectively exercise his leverage to obtain the most favorable agreement from the prospective contractor to implement the owner's technology transfer plans.

It should be pointed out, however, that the contractor also could benefit from the engineering-intern program. In reality, the contractor is gaining valuable engineering manpower and services free of charge in the form of well-qualified engineering interns. Therefore, the contractor should carefully plan his manpower requirements to take advantage of this program.

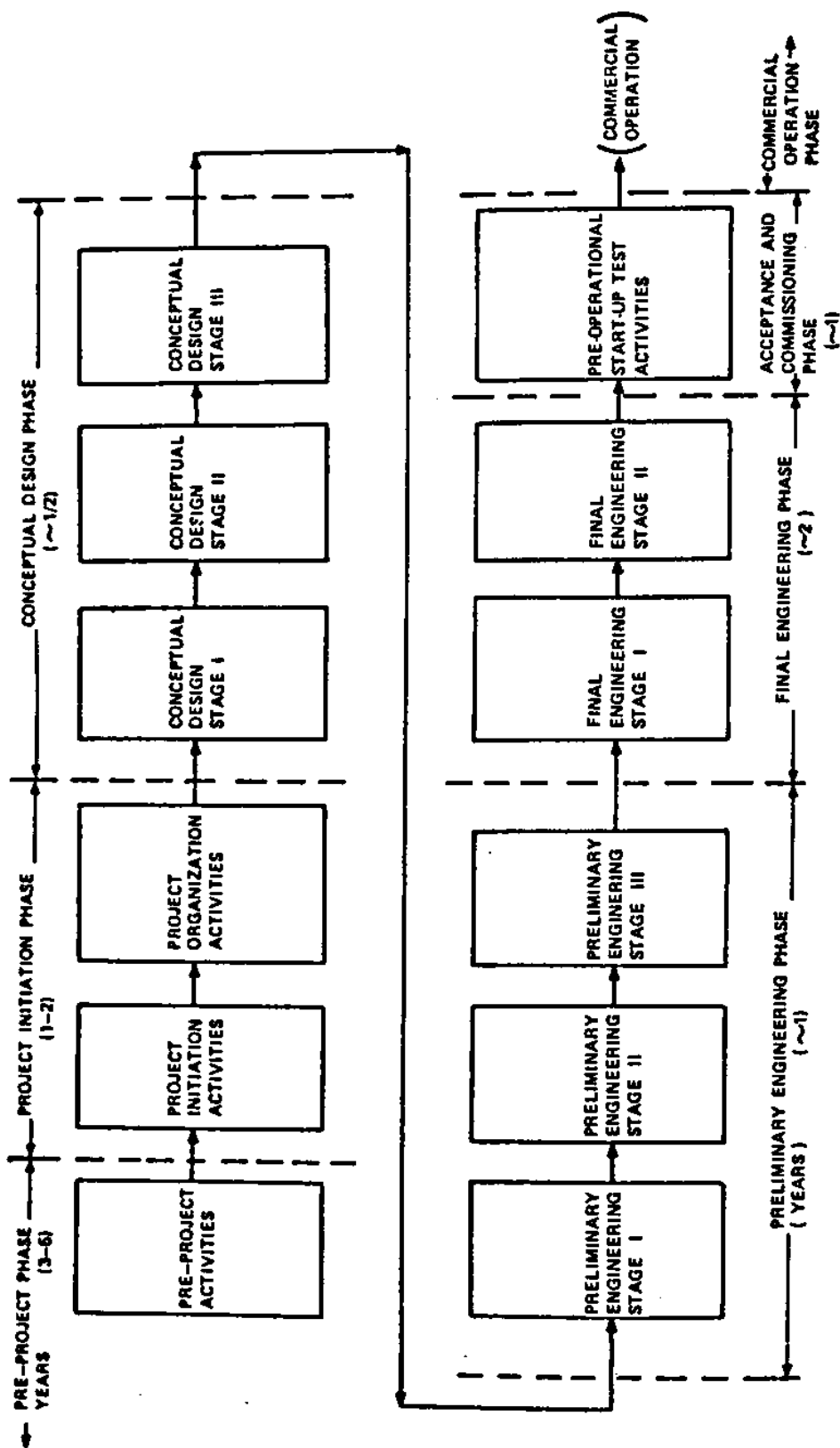


Fig. 3-1. Engineering and Design Activities of a Nuclear Power Plant Project

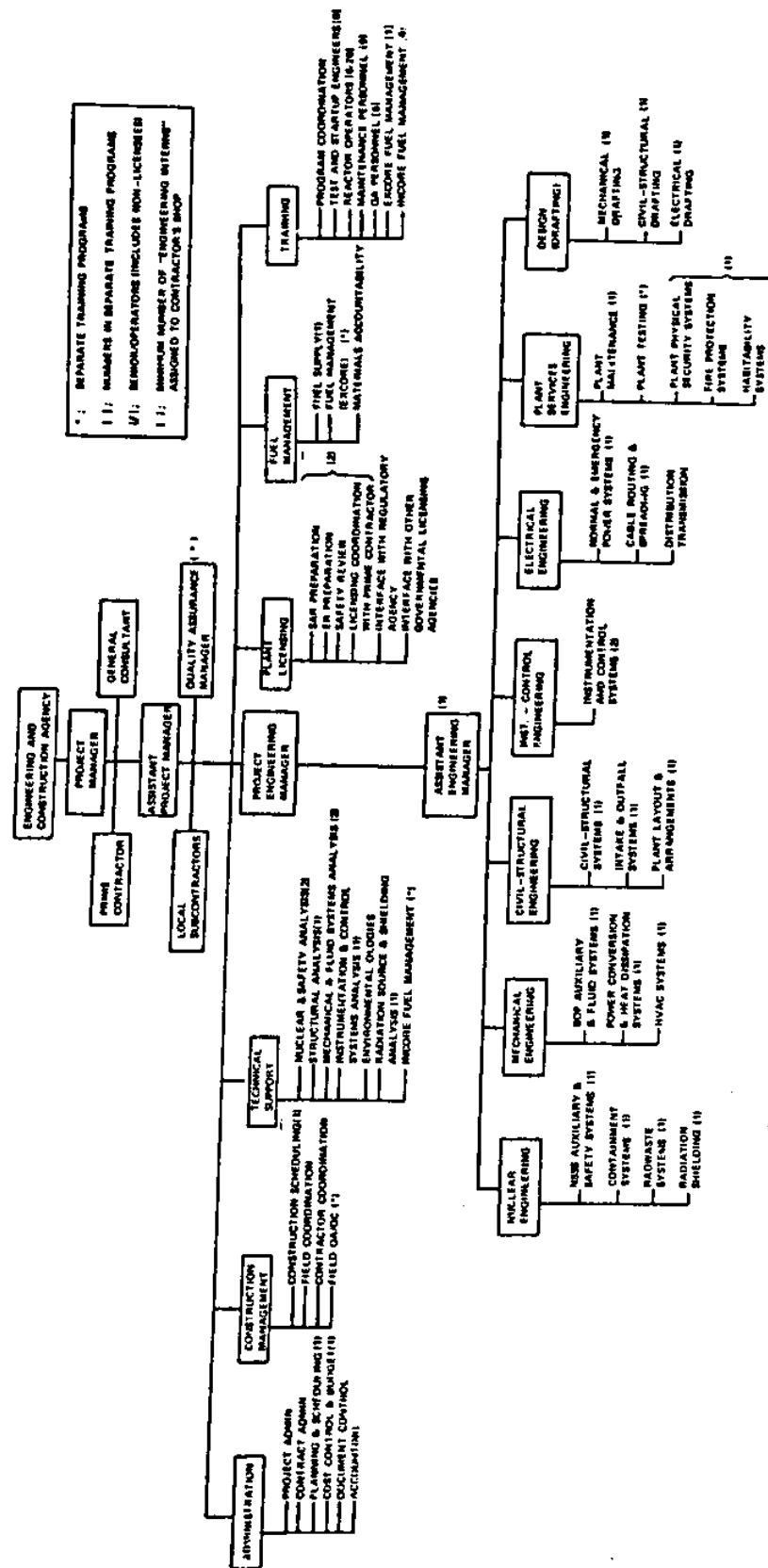


Fig. 3-2. Typical Project Organization and Engineering Interns Required for a Nuclear Technology Transfer Program



### **3.3 Implementation of the Program Plans**

Implementation of the program plans for technology transfer begins with the signing of the contract. As soon as the contract is signed, the owner-country's EIs are to be assigned to appropriate posts in the home offices of the prime contractor (NSSS supplier) and the engineer-constructor subcontractor.

**3.3.1 Activities of EIs at the NSSS Supplier (Prime Contractor)** - In a turnkey-type contract, the NSSS supplier customarily becomes the prime contractor and assumes the overall project management responsibilities.

The EIs assigned to this post are primarily concerned with the acquisition of know-how in the following areas:

1. All aspects of project management.
2. Analytical methods, including thermal-hydraulics, reactor core analysis, and various safety analyses.
3. Analysis of NSSS systems design, including fluid systems, instrumentation and control systems, primary auxiliary systems, and engineered safety features.
4. Licensing activities related to the NSSS and preparation of the NSSS section of the Safety Analysis Report.
5. The NSSS portions of preoperational and startup testing procedures.
6. Training of reactor operators, including simulator training.

**3.3.2 Activities of EIs at Engineer-Constructors (Subcontractors)** - The engineer-constructor, who is a subcontractor to the prime contractor, is responsible for the design and engineering of the plant and frequently also for plant construction.

The EIs assigned to this post are primarily concerned with the acquisition of know-how in the following areas:

1. Project engineering management.
2. Construction management
3. All phases of plant design and engineering, including the conceptual, preliminary, and final detail engineering of the complete plant.
4. Balance-of-plant systems design and engineering, including auxiliary systems, power conversion systems, radioactive waste systems, cooling water systems, and containment systems.
5. Analytical methods for off-site dose calculation, shielding calculation, containment pressure and temperature transient analysis, structural and seismic analyses, and other safety-related analyses.
6. Plant licensing activities, including the preparation of the Safety Analysis Report and the Environmental Report, if required.
7. Quality assurance procedures and field quality control activities.
8. Plant preoperational and startup test procedures.
9. Design drafting activities.

**3.3.3 Nature and Sequence of Project Activities** - The project activities required during nuclear power plant design, engineering, and construction can be categorized into several phases according to the sequence and the time period in which these activities are to be performed. The various phases are listed below. (Figure 3-1 shows the time periods and duration of each phase).

1. Preproject Phase
2. Project initiation phase
3. Conceptual design phase
4. Preliminary design and engineering phase
5. Final design and engineering phase
6. Commissioning and acceptance phase
7. Commercial operation phase

Many of the activities in each phase may require simultaneous action by various groups of the project organization.

**3.3.3.1 Preproject Phase** - This phase typically begins approximately five years before the signing of the contract for the first nuclear plant and continues until the project is officially initiated with the signing of that contract. The major activities to be performed during this phase are the following:

1. Survey of national power needs
2. Establishment of a national nuclear power program
3. Selection of consultants
4. Establishment of a nuclear regulatory agency
5. Promulgation of nuclear safety rules and regulations
6. Establishment of a nuclear power planning agency
7. Performance of a nuclear power feasibility study
8. Obtaining government approval for the nation's first nuclear power project
9. Survey for the potential plant site
10. Survey of the domestic industry participation capability
11. Formulation of the general strategy for technology transfer.
12. Exploration of project financing schemes

**3.3.3.2 Project Initiation Phase** - This phase begins approximately one to two years before the signing of the contract and consists of two stages.

In the first stage of the project initiation phase the major activities are as follows.

1. Selection of general consultant for the project
2. Survey of the available reactor types
3. Selection of the plant site
4. Definition of the general criteria for the proposed power plant
5. Preparation of the bid specification documents

6. Preparation of detailed plans for technology transfer
7. Evaluation of bids received
8. Prime contractor selection (turn-key)
9. Negotiation of final contract
10. Obtaining financing for the project

The second stage of the project initiation phase is concerned with actually organizing the project team and begins immediately after the contract signing. The major activities to be performed during this stage are the following:

1. Formation of the project organization
2. Personnel assignment and recruiting
3. Preparation of
  - . Administrative procedures
  - . Document control procedures
  - . Project filing procedures
  - . Other necessary procedures
4. Establishment of interface with other governmental agencies
5. Establishment of interfaces among the prime contractor, local or foreign subcontractors, and the general consultant
6. Establishment of the quality assurance program
7. Initiation of implementation of technology transfer program by assigning the engineering interns

**3.3.3.3 Selection of Consultants** - Selecting a consulting firm for the project could be the single most important step during the project initiation phase of a nuclear project. Because of the extent to which a developing country must depend on the advice and assistance of the consultants, and the effects of this advice on the future course of the entire project, the owner country should exercise extreme caution in choosing the very first consultant of the project.

(a) **Limitations of a Consultant** - The consultant that the owner country needs in this early stage of the project is a general consultant firm that is broadly experienced in all aspects of nuclear projects in a developing country. In seeking the consultant, it is important to recognize that there are certain limitations on the services that an outside consultant can provide to the owner. Some of these major limitations are the following:

1. Ability to perform interface functions with various governmental agencies of the owner country.
2. Ability to evaluate societal impact, such as the values placed by the society on the cultural, economic, environmental, and safety aspects of the nuclear program.
3. A detailed knowledge of the local infrastructure, including such areas as capabilities, limitations, and relative costs.

In general, therefore, it is not practical to delegate major decisions or policy matters to a consultant or the contractor; these matters must be determined by the owner's organization.

**3.3.3.4 Bid Specification and Bid Evaluation** - Other Important activities that the owner's project group must perform during this project initiation phase are the preparation of bid specification documents and evaluation of the tendered bids from prospective contractors.

- (a) **Preparation of Bid Specification Documents** - The preparation of bid specification documents usually requires assistance from the general consultant. If the owner country lacks the necessary experience and personnel, the general consultant could assume the principal role and prepare the documents with the help of the owner's staff. This task could be performed either in the owner's country or at the home office of the general consultant. However, from the point of view of technology transfer, it is better to perform this task in the owner's country, so as to maximize participation by the owner's staff.

Experienced consultant personnel would be assigned to each major area of activity, such as the reactor system, turbine-generator, and balance-of-plant systems, to supervise the owner personnel in preparing the documents.

- (b) **Evaluation of Bids** - Evaluation of the tendered bids requires intensive and concentrated efforts in a relatively short time period of three to four months. This activity, therefore, requires a large number of experienced experts in several areas. For this reason it is impractical to attempt to evaluate bids with the limited number of experienced personnel available within the owner's project group. A more practical and efficient way is to rely on the full resources and experiences of the general consultant. For the purpose of technology transfer, the owner country should assign several key personnel to the general consultant's home office to participate in each area of evaluation. For the bid evaluation activity the staff members needed are those with the most experience in the following areas:

1. Terms and conditions of contract and financial negotiations
2. NSSS and associated primary auxiliary systems.
3. Balance-of-plant and associated auxiliary systems
4. Turbine-generator systems
5. Mechanical and fluid systems
6. Civil-structural engineering systems
7. Instrumentation and control and electrical systems
8. Fuel management
9. Plant operation and maintenance

Following the evaluation of bids and the selection of the prospective contractor, the owner must exercise the final judgement as to the acceptability of the terms and conditions

of the proposed contract, as well as the technical services and options. The general consultant could again provide valuable service in assisting the owner in actual contract negotiations. For the top management personnel of the owner, the know-how of negotiating the technical and financial terms and conditions of a contract is another necessary skill to be acquired by participation.

**3.3.3.5 Project Organization** – Up to the point of signing the contract, the owner's project organization has consisted of a relatively small group of senior personnel who were mainly involved in preproject and project initiation activities.

However, during the second stage of the project initiation phase, it is necessary to establish a formal project organization, staffed with sufficient qualified personnel to carry out various activities of design, engineering, and constructing a nuclear power plant.

From the technology transfer point of view, the most efficient organization would be the one that combines the best features of a typical utility organization with those of an engineer-constructor (E-C) project organization. Such an organization is shown in Figure 3-3. Figure 3-2 is a detailed version of Figure 3-3.

A well conceived project organization is an essential first step for the technology transfer program, as well as being a necessary requirement for managing the construction of the nation's first nuclear power plant. Since the project engineering organization portion of the owner country's project organization shown in Figure 3-2 is similar to that of an E-C project organization, the engineering interns (EIs) of the owner country can be assigned to the corresponding E-C contractor's group. The minimum number of EIs required in each area is shown in parentheses in Figure 3-2.

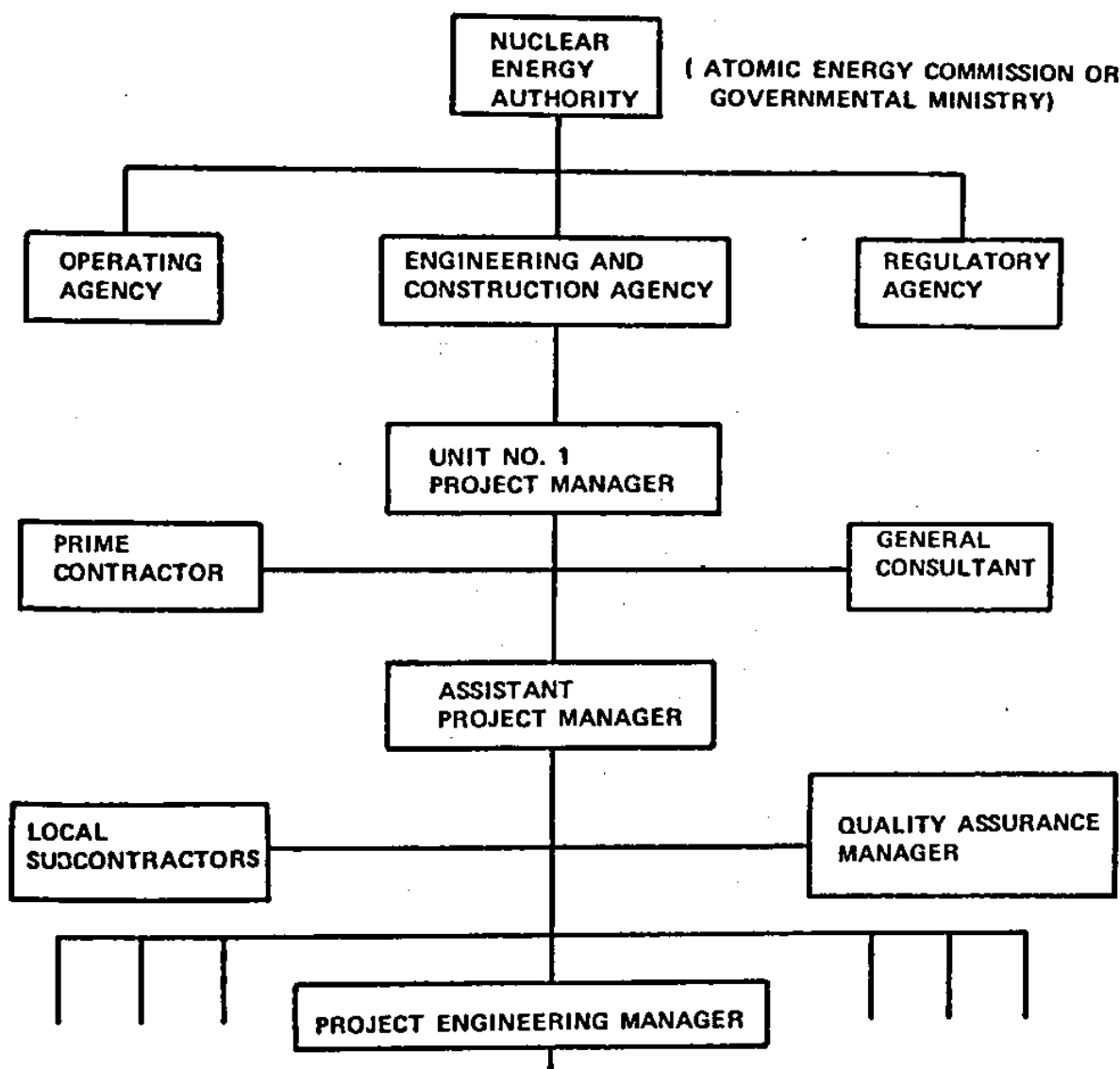
In this organizational structure, the country's regulatory activities and plant operating activities are separated from the activities of plant engineering and construction under their own agencies. These agencies are, however, all under a single national authority, which could be either the atomic energy commission of the nation or a ministry of the government. The agency for the engineering and construction could be further subdivided into two separate agencies for engineering and construction, if the country's participation in the actual construction of the plant is extensive. Examples of this type of organizational structure are those of Iran and Pakistan, where AEOL and PAEC are the principal authorities of the country's nuclear power programs.

An alternative to the above-mentioned organizational structure is shown in Figure 3-4. In this organizational structure, the engineering and construction and the operating activities are carried out within a single agency. For example, a national utility or a consortium of private utilities may have both the engineering and construction responsibility and the plant operating responsibility as well. Examples of this type of organizational structure are the Tennessee Valley Authority (TVA) in the United States and the Korea Electric Company (KECO) in the Republic of Korea.

Regardless of which alternative overall organizational structure a developing country may adopt, the organizational structure for the project's engineering and design activities

will resemble that shown in Figure 3-2. Details of the project engineering organization and its staffing requirements are discussed in Section 3.3.4.

**3.3.3.6 Conceptual Design Phase** - During the conceptual design phase, efforts are initiated to assimilate all major vendor data packages, especially those for the NSSS and turbine-generator, and to establish various project procedures. Major objectives of the activities during this phase of the project are to establish common ground rules among the various contractors and the owner's project office, and to formulate a consistent set of plant requirements, design criteria and bases, and the schedule and budget of the engineering tasks.



*Fig. 3-3. A Typical Nuclear Power Program Organization of a Developing Country*

The primary concern to the EIs during this phase of the project is to become familiar with the process by which the conceptual design of a nuclear plant is being carried out in various groups of the E-C project organization. In this regard, EIs should concentrate on learning the type of basic information required, the scope and extent of the interfacing required with other groups, and the importance of the initial formulation of a design concept. An ill-conceived initial design concept could have far reaching adverse effects on the economic and technical performance of the entire plant.

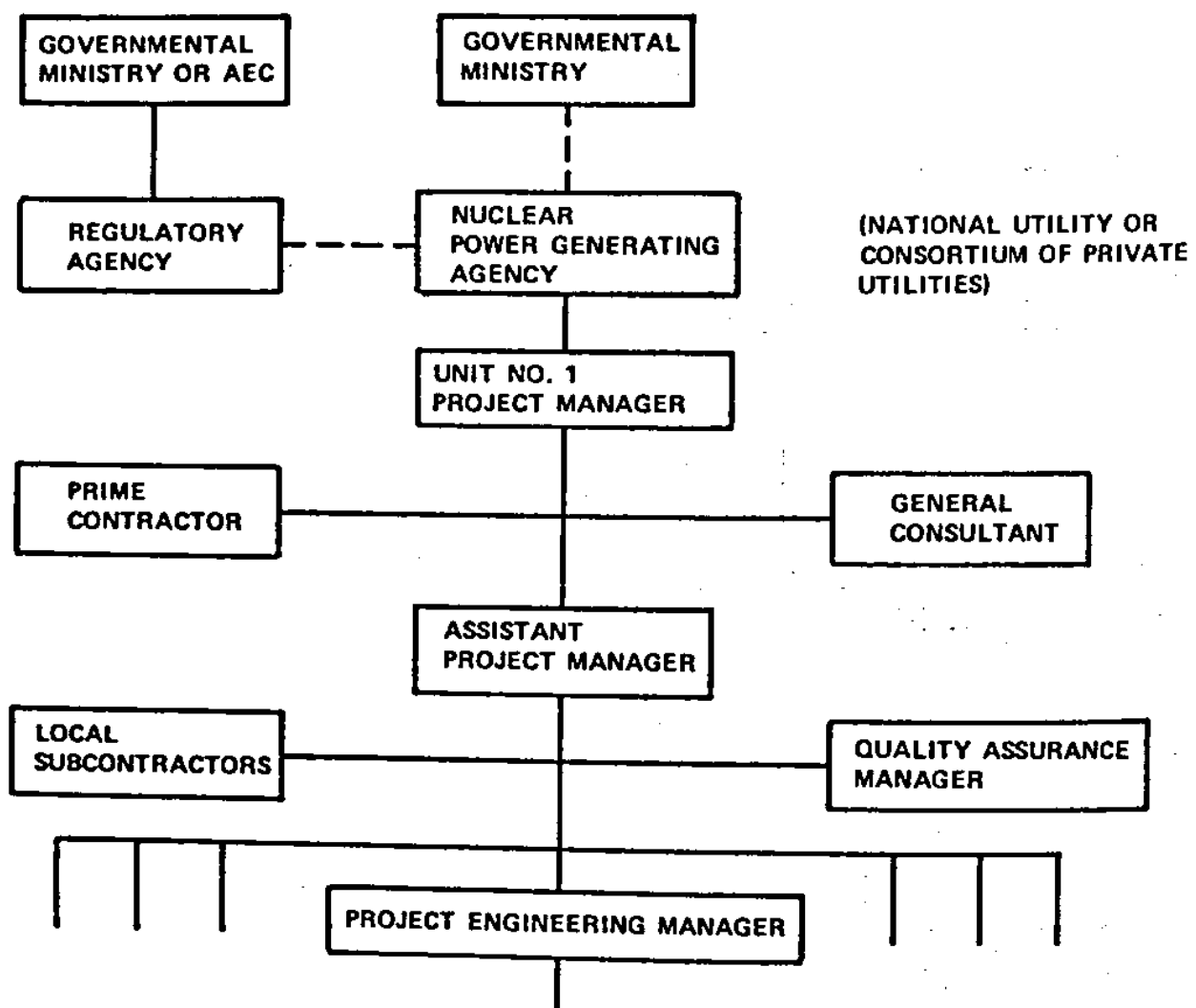


Fig. 3-4. An Alternate Nuclear Power Program Organization of a Developing Country



There are commonly three stages in the conceptual design phase of a nuclear power project, spanning a period of approximately  $\frac{1}{2}$  to 1 year. The activities grouped in each stage are in accordance with the approximate time frame in which they occur in the development of a nuclear plant engineering project.

(a) Conceptual Design Phase (Stage I) - The major activities performed during the initial stage of the conceptual design phase are the following:

1. Define system interfaces
2. Define plant design features
3. Identify design criteria, codes and standards
4. Identify required environmental and site data
5. Identify NSSS and turbine-generator data
6. Identify and initiate scoping and parametric studies for various design parameters
7. The EIs actively participate in all phases of engineering and design activities at various assigned posts in contractor's home offices

(b) Conceptual Design Phase (Stage II) - The major activities performed during the second stage of the conceptual design phase are the following:

1. Define project engineering task scopes for various engineering discipline groups.
2. Prepare:
  - Project milestone schedule
  - Preliminary cost estimates
  - Preliminary equipment list
3. Initiate conceptual plant general arrangements.
4. Define requirements for detailed supporting analyses:
  - Safety-related analyses
  - Accident analyses for the Preliminary Safety Analysis Report (PSAR)
  - Plant performance analyses
  - Environmental Impact analyses
5. Prepare project engineering task CPM.
6. Prepare PSAR and Environmental Report (ER) task CPM
7. Initiate preparation of conceptual design description
8. Prepare detail plans for special training programs in:
  - Core management training
  - Quality assurance training
  - Startup and preoperational testing training
  - Reactor operator training
  - Maintenance personnel training

(c) **Conceptual Design Phase (Stage III)** - The major activities performed during the third stage of the conceptual design phase are as follows:

1. Establish preliminary project engineering task budget and schedule
2. Complete conceptual plant general arrangement
3. Complete conceptual design description
4. Review the conceptual plant design for conformance to design criteria and plant specific requirements
5. Review for additional manpower requirements
6. Initiate PSAR and ER efforts

**3.3.3.7 Preliminary Engineering Phase** - The conceptual design phase officially ends and the preliminary engineering phase begins when the owner-country reviews and concurs with the plant features, design criteria and bases, rules and procedures, and the project schedule and budget.

Whatever is agreed on during this review and concurrence phase becomes the basis on which the project and plant design will proceed. Any change from these agreed-on bases will require management approval by both the contractor and the owner, so that no arbitrary changes or even additional optimization study are made that could lead to deviation from the agreed-on procedures or design. After the acceptance of the conceptual design by the owner, the plant design will proceed to the next phase, during which the conceptual design is translated into the preliminary engineering of the detailed design.

Staffing of the contractor's project engineering organization is greatly increased during this phase, and many relatively inexperienced engineers are assimilated into the organization under the supervision of experienced lead engineers.

The major objectives of the EIs during this phase of their assignment are to acquire the actual engineering and design know-how of plant engineering by actually performing the work as members of the discipline team. The most important thing for the EIs to remember is that the sole purpose of their Internship is to gain practical know-how of plant engineering and not to provide owner's input to the contractor's engineering efforts. The contractor's lead engineers will have absolute authority over the EIs on all technical matters.

Activities during the preliminary engineering phase are subdivided into three stages according to approximate time frames and sequence of performance:

(a) **Preliminary Engineering Phase (Stage I)** - The major activities in this stage of the preliminary engineering phase are:

1. Update project cost estimates
2. Prepare preliminary piping and instrumentation diagrams
3. Prepare preliminary plant general arrangements
4. Perform project design review
5. Continue PSAR and ER efforts
6. Update project engineering and design task budget and schedule

7. Initiate detailed supporting analyses
8. Initiate detailed review of plant licensability and PSAR and ER materials

(b) Preliminary Engineering Phase (Stage II) - The major activities of this stage are:

1. Complete plant general arrangements
2. Complete piping and instrumentation diagrams
3. Complete first draft of PSAR and ER
4. Continue detailed supporting analyses
5. Prepare preliminary construction package
6. Prepare preliminary schedule for equipment purchase
7. Revise equipment list
8. Complete preliminary plant design description
9. Review and revise PSAR and ER

(c) Preliminary Engineering Phase (Stage III) - The major activities in this stage are:

1. Submit PSAR and ER to regulatory agency for construction permit
2. Perform project design review
3. Continue with detailed supporting analyses
4. Review and update project schedule and budget
5. Prepare preliminary construction CPM
6. Initiate detailed engineering and design
7. Complete site-related "ology" studies

**3.3.3.8 Final Engineering Phase** - In this phase the engineering and design activities initiated in the preliminary engineering phase are continued and the designs updated and finalized.

The major activities of the EIs during this phase will be continued participation in the detailed design and engineering of the plant. One of the most important areas of understanding to be gained by the EIs during this phase of the project engineering activities is the understanding of detailed design review procedures and interface requirements among various discipline groups, and of the scope and depth of these views. This understanding can be gained only by actually participating in the contractor's design review meetings.

It is also during this phase that the owner's various formal training programs must be initiated. Some of these training courses will require several months, while others will require several weeks to complete.

Activities in this phase are also subdivided into two stages:

(a) Final Engineering Phase (Stage I) - Some of the major activities performed during this stage of the final engineering phase are the following:

1. Detailed final engineering and designs for plant systems and structures
2. Detailed analyses for:
  - Safety and accident analyses
  - System performance analyses

- Seismic design analyses
  - Piping and stress analyses
  - Structural analyses
  - Radiation transport and shielding analyses
  - Environmental impact analyses, etc.
3. Review and update project schedule and budget
  4. Review and update quality assurance program
  5. Prepare final engineering task CPM
  6. Prepare detailed construction CPM
  7. Perform plant engineering and design reviews
  8. Perform project licensing review
  9. Initiate FSAR and FER efforts

(b) **Final Engineering Phase (Stage II)** - The major activities during this stage of the final engineering phase are:

1. Continue detailed plant engineering and design
2. Complete supporting analyses
3. Submit FSAR and FER to regulatory agency for operating license
4. Review and update construction schedule
5. Prepare for preoperational testing
6. Prepare for fuel loading activities
7. Prepare for startup testing

**3.3.3.9 Preoperational and Startup Testing Phase** - Preoperational testing follows the construction proof testing, in which system flushing, strength testing, and electrical and instrument checks are performed to ensure that the systems and components have been installed in a proper manner. This proof testing of construction should begin at least one and a half years prior to the fuel loading.

The preoperational tests, which begin at least thirteen months prior to the fuel loading, are the functional testing of individual systems and subsystems to demonstrate their capability to meet prescribed performance requirements.

The plant startup testing, which begins with the loading of fuel, is the integrated testing of plant systems to verify overall plant operation. The fuel loading and the startup testing last approximately six months. Because of the complexity of preparing and implementing many hundreds of procedures, the planning of these activities must begin four to five years prior to the actual fuel loading.

Moreover, the plant personnel for these testing activities must be trained through a formal training program that is conducted either by the prime contractor (NSSS supplier) or by a consultant firm.

Some of the major activities to be performed during this last phase of a nuclear project are :

1. Complete detailed planning and scheduling for various tests
2. Complete various test procedures
3. Complete fuel loading procedures
4. Establish security plan
5. Perform hydraulic leak testing
6. Perform electrical testing
7. Perform preoperational testing
8. Perform initial fuel loading
9. Establish radiation control procedures
10. Perform startup testing
11. Complete operating procedures

### 3.4 Project Organization and Staffing Requirements

The project organization shown in Figure 3-2 is an example of the type of organization required for designing, engineering, and constructing a nuclear power plant. As can be seen from the figure, the staffing requirement for a nuclear project organization is a formidable one, especially in a developing country where the availability of experienced engineers is very limited. The number of personnel required to fully staff a project organization like the one shown in Figure 3-2 is approximately 200 to 250. The numbers shown in parentheses in the figure are the minimum numbers of EIs required in each field. This minimum number is over thirty, not counting the personnel required for such formal training as reactor operators, plant maintenance personnel, preoperational test personnel, and startup test personnel training.

There are many functional groups within the organization besides the central project engineering organization headed by a project engineering manager. Under the project engineering manager are several discipline groups, each headed by a principal discipline engineer. For a developing country embarked on its first nuclear project, it is neither practical nor necessary to fully staff every position in the organization chart. Since the primary functions of the owner's project engineering personnel during the first nuclear project are mainly to review and become familiar with the design and functions of the plant systems rather than to actually design and engineer the plant, it is necessary to staff each discipline group with only a few qualified engineers in addition to the EIs.

### 3.5 Formal Training Programs

There are certain areas for which formal training programs are necessary both for the operation and maintenance of the plant and for technology transfer.

**3.5.1 Reactor Operator Training Program** - The training program for reactor operators consists of both off-site and on-site training and is customarily conducted by the prime

contractor (NSSS supplier) or by an outside consultant firm.

**3.5.1.1 Off-Site Operator Training Program** - Both the plant management personnel who will not be directly involved with the plant controls and the future reactor control operators participate in an off-site training program approximately 36 weeks long. This training program is initiated approximately three years prior to the loading of fuel. The areas of instruction are:

1. Nuclear fundamentals and plant operations
2. Plant systems function and operations
3. Plant simulator training

**3.5.1.2 On-Site Operator Training Program** - The prospective reactor operators are required to participate in approximately 44 weeks of on-site training in addition to the off-site program.

This program is designed for the reactor operators who must obtain a hot license. This training starts approximately 18 months before the fuel is loaded and continues through the startup testing phase of the project.

**3.5.2 Maintenance Personnel Training Program** - The maintenance personnel training program is initiated one to two years prior to the fuel loading. This program could be conducted either by the contractor or by a consultant firm and consists of the following training programs:

1. Mechanical maintenance personnel
2. Electrical maintenance personnel
3. Instrumentation and control maintenance personnel
4. Health physics technician
5. Nuclear plant chemistry technician
6. Turbine-generator maintenance personnel
7. Turbine-generator control technician
8. Plant computer software
9. Plant computer hardware
10. Other equipment maintenance

**3.5.3 Fuel Management Training Program** - The fuel management training is provided for qualified personnel with either a nuclear engineering or a nuclear science degree and consists of in-core and ex-core fuel management training. These programs are usually conducted by a qualified consultant firm.

**3.5.3.1 Ex-Core Fuel Management Training** - This program provides formal training in the field of fuel procurement, fuel economics, and the general subject of out-of-core fuel management. This course lasts from a week to several weeks.

**3.5.3.2 In-Core Fuel Management Training Program** - This program provides a formal training in the field of core management. This course usually lasts approximately nine months and must be initiated about two years prior to the fuel loading.

This training program will provide the owner personnel with the following capabilities:

1. Independent monitoring of the core performance
2. Evaluation of in-core fuel management alternatives
3. Independent planning and optimization of refueling strategy
4. Preparation of reload fuel specifications
5. Operation of associated computer programs

**3.5.4. Quality Assurance/Quality Control Training Program** - A quality assurance training program is usually conducted by a consultant firm and provides the owner's personnel with training in the planning and preparation of owner's QA/QC programs, procedures of audit, evaluation, and reporting of audit results of the contractor's QA/QC programs, including the on-site programs.

### **3.6 Application Phase of the Technology Transfer Program**

The final phase of a technology transfer program is the application phase, in which the acquired know-how is put to use in an effective manner for the country's later nuclear projects. The most effective way in which to achieve this final goal is to replicate the first plant for the later units. Replication of the first unit will enable the owner country to fully utilize the newly acquired technology and to reduce dependence on foreign contractors for design and engineering.

It is also necessary to fully staff the project organization chart shown in Figure 3-2, in order to perform independent design and engineering of the succeeding plants and to reap the fullest extent of benefits from the technology transfer program. The owner country will, however, still require a certain amount of assistance from foreign contractors, particularly in plant hardware and in the actual construction of the plant.

In performing the design and engineering of the second unit, the owner country will most likely require the services of a few experienced foreign engineers to act as consultants to various engineering discipline groups of the project organization.



## TECHNOLOGY TRANSFER IN NUCLEAR POWER IN THE PHILIPPINES

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### ABSTRACT

The Philippine Atomic Energy Commission (PAEC), since its creation in 1958, has been the prime mover in local activities on nuclear development in the country that led to the implementation of the country's first nuclear power plant project. The preparatory activities include the establishment of a research reactor, technical and economic feasibility studies on nuclear power in Luzon, plant site selection and nuclear manpower training.

The power plant project is currently the responsibility of the National Power Corporation (NPC) with the PAEC exercising regulatory responsibility over the project. Ebasco Overseas Corporation is serving as consultant to NPC and Westinghouse International Projects Company as the prime contractor for the nuclear power plant.

A uranium exploration program has been initiated. Studies are currently being undertaken for the recovery of the uranium found in low concentrations associated with economic base metals.

Assistance has been received by the Philippine government in the different activities related to nuclear power development. The greater part of the technology transfer has been effected through assistance given by the International Atomic Energy Agency and the United States government.

### 1. INTRODUCTION

The first International conference on the peaceful uses of atomic energy, held in Geneva, Switzerland in 1954, marked the initial exposure of the Philippines to international transfer of nuclear technology. Realizing the advantages offered by the new energy source, particularly the good prospects of nuclear power for electricity generation, the Philippine government immediately arranged for the training of some government technical personnel at national laboratories in the United States and at the same time negotiated for a bilateral cooperation agreement with the United States government on the peaceful uses of atomic energy. This agreement was signed in October 1955.

When the Philippine Atomic Energy Commission (PAEC) was created by law in 1958, the handful of government personnel thus far trained in nuclear science and engineering became the Commission's initial technical staff. This group worked on a program of PAEC activities, the more notable of which were the following :

1. Establishment of the 1000 kW nuclear research reactor facility.
2. Initiation of a nuclear research and development program with activities and projects centering around the research reactor facility.
3. Nuclear manpower development through local training and foreign fellowship programs.

Among the intended purposes of the research reactor was its use as a training facility for graduate studies in nuclear engineering and future nuclear power plant operating personnel. Nuclear power plant feasibility studies were programed as part of the research and development efforts. In order to generate and develop the local manpower needed in the various nuclear activities, a nuclear manpower training program was started immediately.

## 2. ESTABLISHMENT OF THE RESEARCH REACTOR FACILITY

### 2.1 Initial Training of Reactor Personnel

Upon signing of the reactor supply contract, with the International General Electric Company, three PAEC technical staff members were sent to the reactor manufacturer's facilities in California for training in reactor facility design and to coordinate the reactor pool and building design with that of the reactor system being done by the manufacturer. This arrangement afforded the Filipino designers an initial appreciation of the stringent requirements of nuclear reactor systems such as leak tightness of the reactor pool and reactor building for radiation safety, required air changes and flow directions in the building ventilation system especially where radioactive areas are involved, earthquake consideration, reactor cooling and shielding requirements under emergency situations, and other design aspects. Meanwhile, other scientists and engineers were sent for training in various fields, such as health physics in England and Australia, reactor operation, hazards evaluation and plant supervision in the United States, and observation and participation in the fuel loading and initial criticality experiments for the Taiwan research reactor.

### 2.2 Local Activities

The reactor building design was continued in the Philippines with the assistance of an expert from the International Atomic Energy Agency (IAEA). Additional experts were recruited during various stages of reactor facility construction such as for the establishment of health physics laboratories, reactor control and instrumentation, reactor start-up and reactor experiments. These experts were mainly provided by the IAEA and the University of Virginia. For the welding of the reactor pool aluminum liner, two local technicians were given on-the-job training and proficiency tests in aluminum welding at the local U.S. Air Force base. Techniques in radiographic examination of aluminum welded joints were taught by PAEC to the reactor pool contractor's personnel. In a similar manner, PAEC

electronics technicians were given courses and pointers in nuclear instrumentation servicing and maintenance.

The preparation and training given to PAEC personnel and the assistance provided by foreign experts made possible the attainment of initial criticality of the research reactor on August 23, 1963 by an all-Filipino reactor team. This kind of orientation and nuclear consciousness among PAEC personnel continued to be observed to the extent that, for the past nearly 14 years of reactor operation, there has been no reactor incident or release of radioactivity from the reactor facility. As of the end of 1976, some 13,399.15 MW hours of energy release were logged for the reactor and at least 42\* engineers given special training in nuclear technology.

### 3. STUDIES ON NUCLEAR POWER

#### 3.1 Preliminary Assistance Mission

Upon request of the Philippine Government, the IAEA sent a three-man Mission to the Philippines in October 1960 to undertake a survey of the prospects of nuclear power in the country within the decade of the 1960's. The Mission looked into the country's economic growth pattern, structure of power demand and supply in the Luzon\*\*Electric System Grid, forecast of local demands for the decade under study, availability of energy sources, and trends in fuel oil prices and generating plant costs. The Mission report, which was submitted to the Philippine government in September 1961, indicated that a nuclear power station of 2 x 100 MWe units installed in the Manila area in 1967-68 might be competitive with an oil-fired station of the same size and that there appeared to be ample justification for giving serious thought to the installation of a nuclear power plant in the Luzon Grid.

Encouraged by the IAEA Mission report, the PAEC initiated the formation of an inter-organizational Ad-Hoc Committee on Nuclear Power Study with membership coming from the PAEC, National Power Corporation (NPC) and Bureau of Mines representing the government sector and representatives of the Manila Electric Company (Meralco), Philippine Electric Plant Operators Association and the Philippine Chamber of Industries for the private sector. The Committee's main task was to advise the PAEC Commissioner on the timing for the introduction of nuclear power in the Luzon Grid.

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\* 22 Engineers out of these are no longer with PAEC.

\*\* Luzon is the largest and most densely populated island in the Philippines. It contains the metro Manila area where a majority of the industrial and commercial establishments are located.

### **3.2 Pre-Investment Study**

The Committee's recommendations to the PAEC led to the initiation of a UNDP-IAEA supported "Pre-Investment Study on Power, including Nuclear Power in Luzon" in early 1964. This was a 2-year project the primary objective of which was the development of an optimum generating capacity expansion program for the Luzon Grid for a 10-year period (1965-1975) including the consideration of nuclear power plant additions, if economically feasible. The study was undertaken by an American consulting architect-engineer organization, as a contractor to IAEA, in cooperation with some government and private entities in the Philippines.

The first phase of the project was a comprehensive power market survey in the Luzon area, the results of which indicated a load growth rate of 12.7% per year. Taking into consideration the operating conventional hydro and oil-fired power plants as well as those already under construction, the study indicated the need for an additional 1000 MW thermal capacity by 1975 which could either be nuclear or conventional. In the second phase, the economics of conventional and nuclear power plants were studied. The fixed charges for the large capital investment of the nuclear plant were shown to be capable of being compensated by annual fuel-cost savings to be derived, such that after 1979 some \$14 Million net operating savings could be effected from the operation of the nuclear power plant.

While the study was being undertaken, several engineers of the PAEC, NPC and Meralco were sent abroad for graduate studies in nuclear engineering as well as on-the-job training in reactor safety analysis, power system planning, nuclear power plant construction and operation.

The results of the Pre-Investment Study were endorsed to Meralco in 1967, which was then the only utility with an electric system large enough to absorb generating units of 300 MW capacity. After some study, the company signified its intention to "go nuclear" by requesting for international tenders for a 300 MW nuclear power plant and an oil-fired unit of the same capacity. The specifications and bid analysis were done for Meralco by a foreign architect-engineering firm. Reacting swiftly to this move of Meralco, the local oil companies offered to the utility a proposal for a long-term oil supply at very low prices. The large capital investment called for by the nuclear plant as well as the attractive offer of the oil companies influenced Meralco's decision to defer the introduction of a nuclear plant in its generating system. In the meantime, Meralco requested the PAEC to conduct a course on nuclear reactor technology for ten Meralco engineers who were groomed to constitute the nuclear group within the organization.

### **3.3 Atomic Energy Liability Act**

A significant result of the Pre-Investment Study was the enactment of the Philippine Nuclear Liability Act by the Philippine Congress in 1968. Close collaboration of the legal staff members of IAEA and PAEC facilitated the early completion of the legislative documents that

were presented to the Congress.

The Act essentially established a policy of the government on the development and use of atomic energy for power generation by setting the maximum liability of the government for damages resulting from nuclear incidents and concurrently laying down the rules and procedures for filing, establishing and satisfying claims for such damages.

### 3.4 Feasibility Study

Notwithstanding Meralco's decision to postpone the construction of a nuclear power plant, the President of the Philippines created in 1971, a Coordinating Committee for Nuclear Power Study in order to prepare the ground-work for a thorough feasibility study on nuclear power in Luzon. The government was already interested in having a study made so that, should nuclear power generation be again shown to be technically feasible as well as economically competitive with conventional plants, the study might be used in the loan negotiations with banking institutions for financing of the project. This resulted in the second UNDP-IAEA supported project on the "Feasibility Study for a Nuclear Power Plant in Luzon". The study was divided into two parts, namely:

- (1) Plant site selection, and
- (2) Techno-economic study

On the site selection, a team of PAEC, NPC and Meralco engineers had previously narrowed down the candidate sites to only four in number, and established their tentative order of priority. Subsequently, a 3-man IAEA Mission was sent to the Philippines in March 1972 to evaluate the data gathered for the sites. The Mission's activities included a thorough review of the historical data of natural disasters in the country such as earthquakes, tsunamis, typhoons, etc., as well as actual site visits and observations. The Mission eventually recommended the final selection between two sites only. Thereafter, the technical staff of the Coordinating Committee carried out sea water measurements and geological investigations at these two candidate sites in order to gain time for the collection of site data should nuclear power plants be established at these sites.

The techno-economic phase of the study was given by IAEA under contract to the joint team of Electrowatt Engineering Service and Sargent and Lundy, consulting engineering organizations based in Switzerland and United States, respectively. It was decided to confine the study to light water reactor systems only and to the two sites selected in order to limit the time and expenses to be incurred within the budgeted UNDP support. Moreover, light water reactor types have the most number of reactor-years of operation and were already demonstrated to be relatively safe and clean systems.

The study again demonstrated the technical and economic feasibility of a 600 MW nuclear power generating unit in the Luzon Grid. The preferred site was Bagac, in the province of Bataan, facing the China Sea.

## **4. IMPLEMENTATION OF THE NUCLEAR POWER PLANT PROJECT**

### **4.1 NPC and PAEC Assignments**

The Feasibility Study Report was submitted by the UNDP to the Philippine Government on 31 July 1973. Upon receipt of the report, the President of the Philippines decided to implement the nuclear power plant project with a single unit of 600 MW electric generating capacity. A pertinent Presidential Decree giving the NPC the sole authority to undertake the generating capacity additions in the Island grids became the basis of a concurrent Presidential directive entrusting the construction and operation of the nuclear power plant to the Corporation. The PAEC retained regulatory responsibility over the power plant project. Accordingly, the NPC and PAEC restructured their respective organizational units to cope with these new assignments. At NPC, a Special Projects Group to which the Nuclear Power Division belongs was organized while a Department of Nuclear Regulations and Safeguards was created at PAEC. The initial staff of NPC's Nuclear Power Division was recruited from among the PAEC nuclear-trained manpower. Five other NPC engineers were sent to PAEC to attend the Commission's Reactor Technology Course, which was similar to the course previously given to the Meralco engineers.

### **4.2 NPC Contract Negotiations**

The NPC negotiated and eventually signed contracts with Ebasco Overseas Corporation and Westinghouse International Projects Company. Ebasco agreed to provide consulting and engineering services to NPC in the following areas or activities:

- (a) Nuclear plant vendor contract services
- (b) Plant site investigation
- (c) Preparation of Environmental Report
- (d) Review of Preliminary Safety Analysis Report that will be submitted by the nuclear plant vendor
- (e) Cost Engineering services
- (f) Development of the NPC Quality Assurance Program
- (g) Field Non-destructive Examination services
- (h) Vendor quality compliance verification services
- (i) In-service inspection services
- (j) Fuel management services
- (k) Training of NPC personnel in the review of the plant engineering design.

Ebasco undertook a detailed study of the geography, geology and seismology of the Bagac site and other possible nearby areas. The investigation showed that another location, Napot Point in the town of Morong, which is about 15 kilometers north of Bagac, and also along the China Sea coastline, had better geography and geological structure. This made NPC decide to locate the plant in this new site. The Consultants have so far submitted



the Preliminary Site Investigation Report (PSIR), practically completed the gathering of site data needed for the engineering design of the plant and are expected to submit shortly to NPC the Environmental Report (ER). They are currently assisting NPC in the continuing collection of data on site meteorology, hydrology, terrestrial and marine ecosystems as well as in the development of the NPC quality assurance program. Other NPC staff engineers are already programmed for training by Ebasco in the design review of the civil, structural, mechanical and electrical engineering aspects of the power plant.

Westinghouse International Projects Company contracted for the supply, construction, installation, testing and start-up of the nuclear power plant on a turn-key basis. The scope of supply of equipment and services include the :

- (a) Nuclear Steam Supply System,
- (b) Turbine-Generator System,
- (c) Balance of Plant,
- (d) Fabrication of the nuclear fuel elements for the initial core,
- (e) Main power transformers and switchyard,
- (f) Site construction facilities,
- (g) Marine docking, loading and unloading facilities,
- (h) Plant architectural and engineering design services,
- (i) Project management,
- (j) Construction management,
- (k) Start-up services,
- (l) Local civil works, electrical and mechanical equipment erection,
- (m) Option for long-term fuel fabrication services, and
- (n) Training of NPC plant operators.

Westinghouse, together with Burns and Roe Company, are currently proceeding with the design of the plant systems and structures, including the electrical switchyard, pump-house, cooling water intake and outlet structures. It has sub-contracted the civil, electrical, mechanical and erection works, and the housing facility construction with local engineering groups. The site construction activities as of the present have so far been limited to site grading and excavation for the building foundations and the construction of bunkhouses and supervisory staff houses.

Westinghouse is expected to submit soon the Preliminary Safety Analysis Report (PSAR) and its own Quality Assurance Program for the project.

#### **4.3 Regulatory Activities**

On the regulatory side, the PAEC has defined the requisite permits and licenses that are going to be issued to allow NPC to proceed with certain phases of plant construction and operation. The requisite documents for the corresponding permits and licenses are:

- (a) the PSIR for the issuance of the Provisional Permit;
- (b) the PSAR and ER for the issuance of the Construction Permit; and



- (c) the Final Safety Analysis Report for the Issuance of the operating license at a specified initial power level.

After review of the PSIR, the PAEC has issued a Provisional Permit to NPC on December 20, 1976. This permit allowed the NPC to construct the reactor building and fuel element pool storage foundations up to the ground (grade) level only. Additional construction of the structures above ground level, equipment erection, system component installation, and testing but excluding nuclear fuel loading will be authorized upon Issuance of the Construction Permit. However, this permit will be issued only after PAEC has reviewed the submitted PSAR, ER and QA program and is satisfied that the reactor facility will be designed safely and is not expected to release radioactivity that may endanger the public and the environment.

The PAEC has requested the IAEA for technical assistance in the (a) review of the PSAR, ER, QA program and other technical documents submitted by NPC for the safety evaluation of the nuclear power plant and (b) QA audit and inspection during plant construction. Additional expert or staff assistance will be requested from IAEA as the plant construction progresses until the plant becomes operational.

## 5. URANIUM EXPLORATION AND RECOVERY

Another important aspect considered in the studies on nuclear power is the availability of indigenous sources of nuclear fuel materials. Although the international market price of uranium was still very low and appeared to be stable, the Philippine government, nevertheless, considered it prudent to undertake a survey of uranium availability in the country. In the latter part of 1963, an expert in nuclear raw material prospecting was sent by IAEA for this purpose. The expert assisted the Bureau of Mines (BM) for one month in the conduct of a nationwide radiometric survey. These efforts led to the information that radioactive anomalies existed in a mining district in southern Luzon. Detailed ground investigations and core drillings confirmed the presence of uranium in low concentrations associated with some economic base metals. Another expert was requested from IAEA in 1968 to train PAEC scientists in geochemical and neutron activation analysis of local uranium bearing ores.

The PAEC has been making attempts to produce yellow cake from the mined ores at its small uranium processing laboratory. IAEA expert assistance was also provided in late 1975 in these initial efforts. Another expert is expected to be assigned for a six-month duration in 1977 for the development of techniques for the semi-commercial processing of uranium ores.

The IAEA technical assistance given for this activity included, in addition to the expert services, some equipment, special materials and training fellowships.

In order to encourage active participation of the private mining companies in the program for exploration and mining of nuclear fuel minerals, the Philippine government is already developing some incentives in the form of awards, tax exemption privileges, technical and financial assistance to be given to interested organizations. The PAEC has

recently concluded a 5-week course on uranium and thorium prospecting for personnel of the BM and private mining companies. Lecturers in this course were the former IAEA trained fellows.

## 6. MANPOWER DEVELOPMENT FOR NUCLEAR POWER

### 6.1 Foreign Training

The PAEC nuclear training programs have been primarily intended for the development of requisite local manpower in the promotion of peaceful nuclear activities. In nuclear power development, some 187 foreign fellowship training grants were obtained for the period 1955-1976, representing about 30 percent of all the grants received by the Philippines. These are broken down as follows :

	<u>Fellowship Grants Awarded</u>		
	PAEC	NON-PAEC	TOTAL
Uranium Prospecting, Mining & Processing	8	4	12
Nuclear Engineering/Nuclear Technology	16	19	35
Nuclear Chemical Engineering	2	1	3
Nuclear Materials Technology	1	2	3
Reactor Engineering	4	17	21
Reactor Control & Instrumentation	11	2	13
Nuclear Plant Construction	9	13	22
Nuclear Safety	6	16	22
Safety Standards/Procedures Development	5	7	12
Reactor Safety Evaluation	5	--	5
Radiation Protection	10	7	17
Radwaste Management	5	3	8
Fuel Reprocessing	1	--	1
Environmental Protection	8	5	13
TOTALS	91	96	187

The fellowship awards to PAEC were for academic and on-the-job training programs, which enabled some PAEC personnel to attain graduate academic degrees. The non-PAEC grants were non-formal and on-the-job training slots awarded mainly to Meralco, NPC and university professors. Because of the long time lag between training completion and the implementation of the nuclear power plant project, more than 70% of these trained personnel have either left the country or diverted into other areas of endeavor.

## **6.2 Local Training**

The PAEC also initiated local training programs utilizing two approaches namely: formal university education and PAEC-conducted training courses. A graduate program leading to a Master of Engineering (Atomic Energy) degree was offered at the University of the Philippines (U.P.) in 1962 with the teaching staff for the nuclear courses taken from the PAEC scientists and visiting professors from the University of Virginia. This program did not attract graduate students since there were no immediate prospects for the initiation of the nuclear power plant project at that time. Only nine graduate students obtained their master degrees, three of whom went to the United States for further studies, and received doctoral degrees.

This U.P. graduate program was revived in 1976 with the course offering modified for the grant of the degree of Master of Science in Nuclear Engineering. The program is assured of financial support from PAEC and NPC. In addition, the PAEC has offered the services of its graduate degree holders as professorial lecturers and the use of its laboratory courses.

During the first semester of the current academic year only five graduate students came from NPC and one from PAEC. In the second semester, eleven students enrolled in the program, of which five came from NPC, three from PAEC and three were privately supported. It is expected that, with the much publicized nuclear power plant project, more graduate students will be going into the nuclear engineering program as well as in other graduate nuclear science courses already being considered.

## CONTRACTING OF NUCLEAR POWER STATIONS AND TRANSFER OF KNOW-HOW

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### 1. INTRODUCTION

Nuclear power stations have been built in a wide variety of different ways. At one extreme a single contractor has been given complete responsibility to design, build and commission a complete nuclear station, handing it over to the owner only when it is running. At the other extreme the owner has bought only the basic hardware of the Nuclear Steam Supply System from the reactor vendor, designing the rest of the power station and buying all other equipment himself. The purpose of this paper is to highlight the potentials of different types of contracts and contracting procedures as far as transfer of nuclear technology is concerned.

Basically there are three different types of contract approaches which have been applied so far for nuclear power stations, namely:

1. **TURNKEY APPROACH**, where a single contractor or a consortium of contractors takes the overall responsibility for the whole works.
2. **SPLIT-PACKAGE APPROACH**, where the overall responsibility is divided between a relatively small number of contractors, each building a large section of the works.
3. **MULTI CONTRACT APPROACH**, where the owner or his architect-engineer (A/E) assumes overall responsibility for engineering the station, issuing a large number of contracts.

So far, for a first nuclear power station in a country almost always - even in the US - a turnkey contracting approach has been followed. However, the risks of going non-turnkey are reduced as the owner gains experience. A non-turnkey approach is possible even for a first station if an experienced Architect-Engineer is employed. A final selection of the contract approach should, therefore, be made once all salient factors have been carefully evaluated. These factors are:

- potential vendors and their particular experiences and attributes
- government and industrial relationships
- competitive considerations
- foreign financing possibilities
- planning and implementation of the project and subsequent projects

- development of national industry and engineering capability.

The objectives of most utilities entering the nuclear field are:

- to build a station to the required schedule which will produce electricity at as low a price as is consistent with adequate safety and an acceptable environmental impact;
- to make the maximum reasonable use of domestic resources in construction;
- to gain experience from the project so that future stations can, if necessary, be better adapted to the needs of the country and depend less on foreign expertise and hardware.

The latter two points determine the amount of technology transfer that can be obtained in building nuclear power stations.

## 2. PROJECT APPROACH STRATEGIES

### 2.1 General

The development of a project approach strategy covers in particular the following:

- determination to carry out an open or limited bidding competition or to go in for a negotiated contract;
- determination of contract type;
- determination of contracting procedure.

Great attention should be paid to developing and selecting for each project the most suitable project approach strategy. It is obvious that for the first nuclear project all factors have to be evaluated in depth, whereas for subsequent units the evaluation can be limited to those factors which have changed in the meantime.

The decision to carry out an open or limited bidding competition or to go in for a negotiated contract is largely influenced by the political situation and/or financing possibilities and to a lesser degree by a particular market situation. It is felt that the negotiated contract, compared with the open or limited bidding procedure can bring the same or even better results as far as transfer of nuclear technology is concerned, if adequate attention has been given to this matter during the contract negotiations.

The contract types and contracting procedures which can be considered for a nuclear power station have been summarized in Fig. 1 and are briefly commented on hereafter:

### 2.2 Turnkey Contracts

**2.2.1 Types of Turnkey Contracts.** Basically, one distinguishes between the following types of turnkey approaches (Fig. 2):

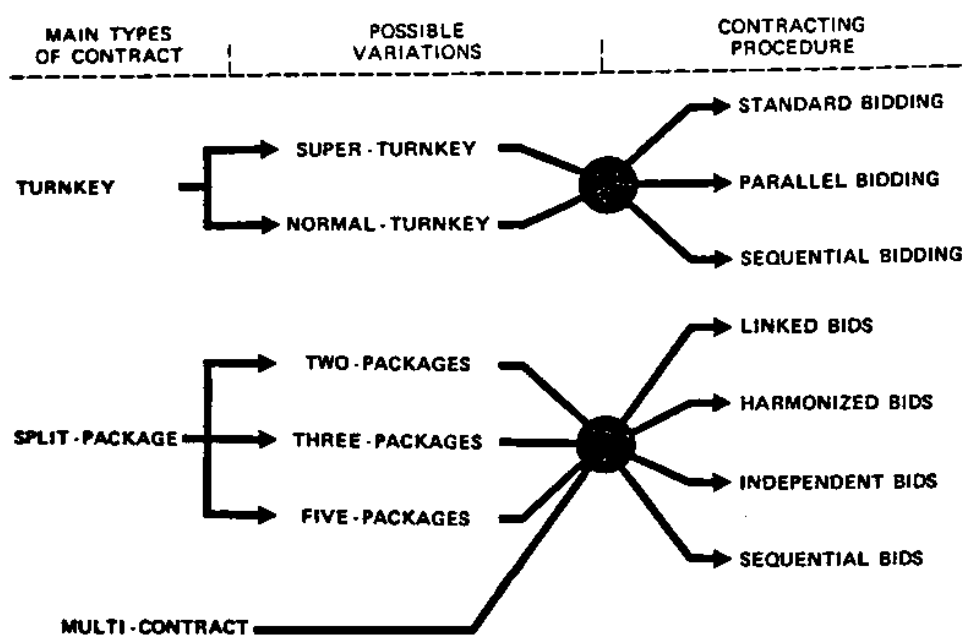
- Super turnkey
- Normal turnkey.

**(a) Super Turnkey**

This term is used when a single contract is placed covering the whole nuclear power station. It also usually implies minimum involvement on the part of the owner in influencing or approving design so that the whole responsibility for the success of the project is placed upon the contractor. This approach is particularly suitable for utilities with little technical strength in the nuclear field as has been the case in the past in Germany, Austria, Switzerland and Holland and in less well developed countries.

**(b) Normal Turnkey**

This term is used to describe a contract placed for a nuclear power plant where the utility supplies all peripheral items of the plant (10-20% of plant costs). It is usual for owners with nuclear experience or greater competence in conventional power stations to wish to influence and approve the design of the plant to a greater extent than for the super turnkey contracts as well as taking full responsibility for the owner's scope himself. The owner's scope can, however, differ substantially, depending on the engineering capability within the utility. This approach means a closer involvement of the owner in the detailed engineering of the station and increased local participation in the owner's scope.



*Fig. 1. Contract Types and Contracting Procedures*

**2.2.2 Contracting Procedures for Turnkey Contracts.** The bidding and contracting procedure for getting to a turnkey contract can have major effects on some of the features of such contracts in particular as far as the competitive situation and the team-up of reactor and turbine supplier or the turnkey supplier and civil contractor are concerned.

(a) Normal Bidding

The normal procedure for bidding for a turnkey plant is for a reactor vendor to get together with a turbine vendor, sometimes from within their own firm or group, and a civil contractor to submit a firm price bid for a complete nuclear power station. The main disadvantages of the normal bidding procedure are:

- the combination of reactor and turbine vendor might not give the best technical solution
- the competitive situation is restricted and potential vendors might be excluded.

(b) Parallel Bidding

Under this procedure separate bids are received from the reactor vendor for a nuclear island and from the turbine vendor for a turbine island. When the assessment of the various bids has been completed, the favored contractors are asked to get together to harmonize their bids at the interface and then to submit a new combined bid for a turnkey contract.

The experience with this procedure has not been too good due to the fact that marrying two vendors is time consuming and gives opportunities for price adjustments.

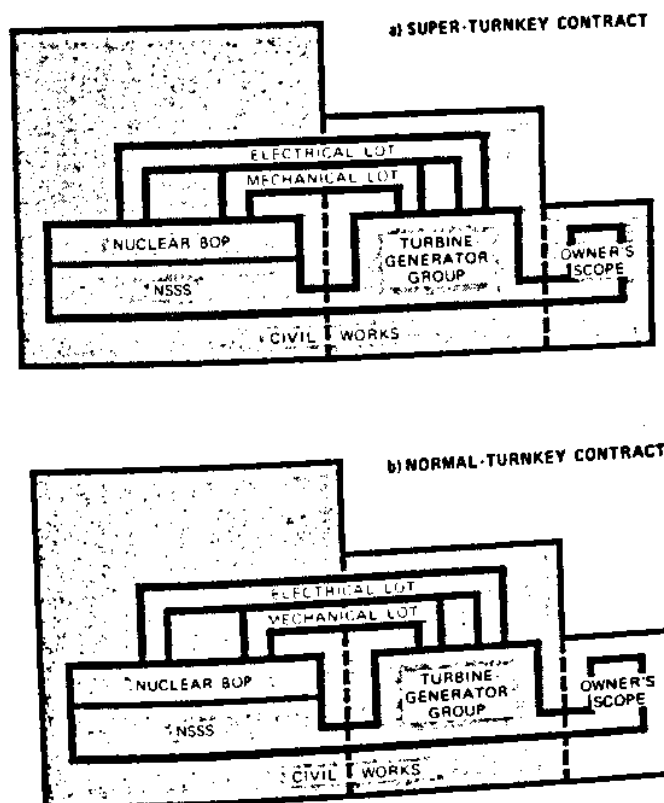


Fig. 2. Types of Turnkey Contracts



### (c) Sequential Bidding

This approach recognizes the fact that the reactor is more complex than the turbine and that interface requirements, electrical and control system designs, etc. tend to be dominated by reactor rather than turbine requirements. Bids are therefore invited from reactor vendors, either alone or in conjunction with architect-engineers for a nuclear island.

Bid evaluation will proceed in the usual way until negotiations with the favored reactor vendor reach the letter of intent stage. Then bids are invited for the supply and erection of the turbo-generator and for the civil design and construction.

The successful reactor bidder should then form a consortium to build the station with the selected turbine supplier and the civil contractor.

A formal contract would then be signed between the owner and the newly formed consortium. This contract would be for the turnkey construction of a complete power station.

This contract procedure is, however, a time consuming process but if initiated at the right time, gives more flexibility to select the right reactor and turbine vendor.

## 2.3 Split-Package Contracts

**2.3.1 Types of Split-Package Contracts** (Fig. 3). The term "Package" is used herein to describe a functionally complete part of a nuclear power station for which a single contractor takes overall responsibility to design, supply, construct and set to work. The split-package approach has been applied to a great extent to the construction of conventional thermal power stations in Europe but until now not so much for nuclear power stations.

Basically, one distinguishes the following types of split-package approaches:

- two package approach
- three package approach
- five package approach.

#### (a) The Two Package Approach

Under this approach, the two main contracts (excluding the owner's scope) are for a nuclear island and a turbine island. By dividing the main plant into two packages, a higher degree of competition and technical choice can be effected. This approach has, however, two main difficulties. One is the problem of harmonizing the interfaces and the other arises from the problems of having two civil contractors close to one another. This can be avoided if each bidder is asked to select his civil contractor later by a sequential bidding technique. The bidding for the civil works can then be arranged so as to choose a single civil contractor for both halves of the station.

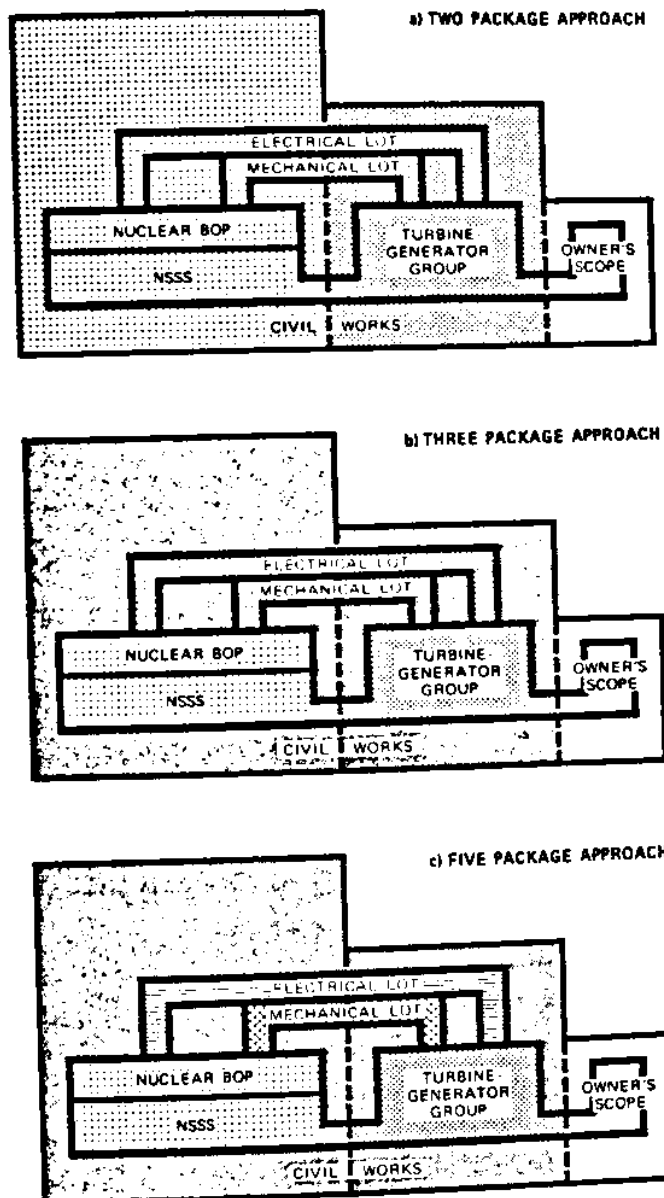


Fig. 3. Split Package Approach Options

(b) The Three Package Approach

This approach separates the civil works from both the nuclear and turbine islands and makes them a separate contract placed directly by the owner. This approach has, apart from the problem related to civil work, the same positive and negative features of the two package approach, i.e. it does not ease the problems associated with the interface between reactor and turbine.

(c) The Five Package Approach

In this approach the problems associated with the matching of the interface

between the nuclear island and thermal island is reduced by the owner taking direct responsibility for much of the mechanical and electrical equipment which links them. The initial bidding is then for nuclear and thermal lots each with reduced extents of supply compared with the corresponding island. When the two main plant contractors have been chosen the owner (or his architect-engineer) issues appropriate bid invitations for civil, mechanical and electrical lots to complete the power station. In practice the electrical and mechanical lots may be let as a number of separate contracts over an extended period of time.

**2.3.2 Contracting Procedures.** As for turnkey contracts, although to a lesser extent, the bidding and contracting procedure for getting to the contracts for the different packages can have major effects on some of the features of this approach in particular as far as the interfaces and the selection of the civil contractor are concerned.

**(a) Linked Bids**

Under the split-package types of contract the interface problems represent a risk to the owner of extra costs and delay. One way to avoid this while keeping separate contracts is to invite linked bids for the nuclear island and the turbine island. Under this scheme pairs of reactor and turbine vendors are asked to submit bids for their respective islands together with a guarantee that the interface problems have been considered before the bids were submitted and that pairs of bids are compatible and together form a complete power station. This arrangement appears to offer little advantage over a turnkey bid since the owner's freedom to select turbine and reactor separately has been lost.

**(b) Independent Bids harmonized by Vendors**

Under this proposal the reactor and turbine vendors will submit independent bids in response to an enquiry which specifies the interface. When the favored bidders have been identified, instead of asking them to form a consortium, they are asked merely to harmonize their interfaces and then to quote any cost variation involved in this.

**(c) Independent Bids (Customer Engineered)**

This is the most normal type of split-package approach and the one where the customer really starts to take responsibility for many aspects of the design of the station. Bidding is similar to that described in the previous section but the customer takes it upon himself to negotiate any necessary amendments to the interface directly with each bidder.

**(d) Sequential Bidding**

If time permits, a sequential bidding procedure can be utilized for the split-package approaches. In this case bids will first be invited and assessed for the nuclear island (with or without civil works) or nuclear lot. The bid specification for the turbine island or thermal lot can then be issued with much better defined interfaces.

## 2.4 Multi Contract Approach

The multi contract approach is now the normal way of contracting in the USA and in a similar way is also adopted in Spain, Belgium and some other countries. Under it the customer, or more usually his architect-engineer invites bids for a NSSS and turbine, selects the preferred bids, places contracts and then designs the balance-of-plant around this equipment. He will produce a very large part of the safety report and supervise construction, usually erecting the plant himself. This option clearly gives the maximum opportunity to the customer to select the plant which suits him and to influence the design as he would wish. It also gives him, if his architect-engineer is a good one, the best chance of having a minimum cost plant. On the other hand, it gives him or his architect-engineer the maximum amount of work and responsibility and the minimum protection if things go wrong, and if the station is late or does not behave well.

In principle, the same bidding procedures can be applied as for the split-package approach options. The interface problems between the two main vendors are however limited to the main steam and feedwater conditions so that there is no particular need to have linked or harmonized bids.

## 3. TRANSFER OF TECHNOLOGY AND LOCAL PARTICIPATION

### 3.1 General

In all countries which have introduced, or are introducing, nuclear power, the participation and development of local industrial, contracting and engineering organizations is considered to be of much importance.

It is evident that very many factors influence the degree of local participation that can be achieved, or is desirable. Technical capability, commercial and cost consideration, foreign exchange, as well as political factors, can have an important bearing on the final outcome. The influence of project approach in local participation cannot be generalized upon, since much will depend on the attitude of foreign plant suppliers and the ability of local organizations to meet their requirements.

For any contracting strategy the importance put upon local participation must be spelled out in detail in the bid specification. Bidders must then be asked to be specific about local participation in their bids wherever possible and if vague promises of a certain percentage local participation are made these should be investigated in detail during pre-contract negotiations and preferably converted into firm commitments with penalties attached for nonfulfillment.

### 3.2 Turnkey Approach

The turnkey approach gives, by nature, a more restricted possibility for technology transfer, because the whole responsibility for technical performance, costs, guarantees

and construction time has been given to the general contractor. This is in particular the case for development of and use of existing local industry for the supply of materials. The development and use of local engineering capabilities and capacities depends very much on the general contractor selected and the emphasis which is placed on this matter in the contract.

Some vendors have little desire to sell more than the NSSS and turbine-generators from their own factories, so that they can achieve as high a local content with a turnkey bid as can be achieved by any other contractual procedure. However, other vendors undoubtedly have a greater desire to sell their own equipment, especially in the electrical field, and this is likely to lead to relatively low local contents in their case for a turnkey contract.

The utility may gain adequate experience from a turnkey approach but this depends very much on the owner's scope and the extent to which design review and QA and QC will be carried out by the utility.

Local participation as regards supply of materials and manpower can in the case of a turnkey contract considerably be enhanced if the utility is willing to ease the contractual conditions in favor of increased local participation, and if this is properly laid down in the contract.

In order to increase local participation, it might be necessary to include in the contract a very detailed pricing of the whole power station, in order to compare bids of local suppliers with the costs originally included for the same equipment in the contract. Also, careful attention has to be given to delivery times of local suppliers which might not be the same as the times foreseen by the general contractor in his construction schedule.

As a whole, it can be said that with turnkey contracts, a high degree of local participation is more difficult to achieve but that it can be enhanced by more flexible types of contracts where the risks of costs, delays and guarantees for the general contractor are limited, if local suppliers are considered.

A turnkey supplier will normally try to use a local civil contractor if there is one of adequate capability.

### 3.3 Split-Package Approach

The two and three package approaches as discussed in this paper are merely intended to give the right combination of reactor and turbine vendor and not so much to increase local participation, unless there is a local turbine manufacturer to be considered. The approaches are, as regards local participation and technology transfer, very similar to the turnkey approach.

A real improvement in local participation can be obtained in moving to the five package approach, whereby the nuclear and turbine lot are limited with regard to equipment, to those parts which cannot be manufactured in the country itself, and the other packages are divided in lots which can be rendered to the local industry. The participation of local

industry is much more under the control of the utility than in case of turnkey contract. Further, the utility will have a much bigger influence on the station design and the learning effect will be substantial.

The utility plays a more active role compared with the turnkey or two or three package approaches where his role is largely limited to reviewing other designs. This will however depend on the extent to which he uses the services of an architect-engineer. The effort and manpower involved for the utility is considerable, even if an architect-engineer is employed and the overall management as well as the selection of the contractors of the main lots is a key issue for the overall success of the project with such an approach. It is clear that the risks involved for the utility are greater and that normally such an approach is only selected if the utility has experience with this approach for thermal power stations.

### **3.4 Multi-Contract Approach**

This approach enlarges the possibility for local participation and development of engineering know-how, even more. The participation of local industry is very much under the control of the utility, the influence on station design can be great and learning effect will be substantial.

The effect and manpower involvement on the side of the utility is still larger than for a split-package approach, since the detailed engineering of most of the plant, as well as erection and testing are now part of the utility's responsibility. The need for competent architect-engineers is evident. The whole success of this approach depends, however, on picking the right architect-engineer and the right split-up of management and engineering responsibilities between the A/E and the local engineering companies. This approach gives great possibilities of local engineering companies to develop their know-how in collaborating with the A/E. The attitude and experience of the latter to local participation and development of engineering know-how is, however, an important requisite for its success.

The engineering capacities required for such an approach are very big and therefore the development of the local capacity should be in line with the nuclear program in a country. Unless one sees good possibilities for rendering engineering services abroad one must be careful to develop only so much engineering capacity at the utility and the local engineers as required on a long-term basis.

## **4. CONCLUSIONS**

The maximum local participation that can be achieved in any country is determined by the capability of local industry and by the willingness of the owner to achieve high levels of local participation, even at the expense of higher costs and perhaps higher risk of poor performance.

Once the owner has clearly specified his requirements what will in fact be achieved will depend in a turnkey contract on:

- the skill of a turnkey bidder, main contractor or architect-engineer in finding and evaluating potential local sources of supply
- the willingness of turnkey bidders or main contractors to accept these local suppliers if that involves extra costs, extra risk, or less work to put into their own factories.

This situation can significantly be improved by moving to a split-package solution, but it must be remarked that the local participation achieved may still be well below the theoretical maximum.

Even greater control over local content is obtained by moving to the multi-contract approach though much will then depend on the skill and willingness of the A/E in finding and evaluating local firms.

As regards engineering know-how the turnkey approach can bring the utility adequate experience, if this is properly considered in the contract and if the utility is led by a competent consulting engineer.

Transfer of engineering know-how to local engineering companies is more difficult to realize with a turnkey contract, in particular with vendors who have themselves a large engineering potential.

The split-package and multi-contract approaches are definitely more suitable for local development of engineering know-how. The selection between the split-package and multicontract approach largely depends on the potential vendors, and not on the degree of difference between the two approaches as regards local participation and development of industry and engineering companies.



## **A PRACTICAL APPROACH TO THE TRANSFER OF NUCLEAR TECHNOLOGY**

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### **ABSTRACT**

Sweden's nuclear energy program is based almost entirely on national efforts. High national ambitions together with limited manpower resources require an efficient system for the transfer of knowhow. This system may be of interest to other countries facing a rapid nuclear expansion.

### **1. INTRODUCTION**

There is a tendency among the industrialized nations to look upon the developing countries as being rather homogeneous. But there are large differences indeed - differences in ultimate and long-range needs as well as in the approaches applied to fulfill these needs. We are aware of the differences and of how important it is to take them into consideration. However, at the same time, their importance should not be exaggerated. The different needs do not necessarily mean different approaches. For instance, Iran has been foresighted and started to develop and exploit new energy sources as a substitute for the precious natural resources presently being used. Sweden has developed its nuclear energy program along very much the same lines in order to preserve the few remaining waterfalls as well as to help in the international oil conservation efforts.

It is against this background that one should consider the question of the transfer of technical knowhow. The detailed structure of a technology transfer program depends on a multitude of factors which vary from one country to another. Thus, it is not merely sufficient to have the resources. It is also necessary to be flexible in adapting these resources to the needs of the receiving party. Sweden is a small nation, but a nation with both the resources and the flexibility required to make a successful program of value to both parties.

A modular approach is used in the scheduling of such a program. This entails the implementation of a number of independent subprograms, which may be combined to meet the wishes and needs of almost any country.

Because Sweden is a small nation, it is also easier for the receiving party to influence the program when the parties do not differ widely in terms of strength.

What then can Sweden offer? The nuclear energy program of Sweden is unlike that of other small countries in that it is based to a great extent on national efforts. The only step in the fuel-cycle that has not at all been considered for domestic implementation is uranium enrichment. Uranium mining has long been carried out on an experimental scale; a fuel factory is in operation; the Swedish reactor of BWR type, of which four units have been operating successfully for many years, is of entirely domestic design; and a Government body is studying the details of the conditions for a national fuel reprocessing and waste disposal program.

If we should like once more to compare Iran and Sweden on the basis of the above remarks, we find that, for different reasons, both nations have limited resources, but both have also managed to establish an ambitious nuclear energy program.

How then should nuclear technology knowhow be transferred? It is our opinion that the most efficient way for both parties would be for the technology transfer to be carried out in parallel with Swedish deliveries for domestic nuclear power plants.

## 2. ASEA-ATOM

ASEA-ATOM, whose capital stock is equally owned by ASEA and the Swedish State, began its activities in January, 1969. The creation of ASEA-ATOM led to the concentration in a single company of the industrial efforts that had previously been carried out by ASEA's Nuclear Department and AB Atomenergi.

Since filing its first patent application in the nuclear power field in 1947, ASEA has developed its own boiling water reactor design. ASEA-ATOM is now the only company outside the United States that can offer complete commercial nuclear power plants with boiling water reactors, without having to resort to foreign licenses.

The final goal of the technology transfer should be that the receiving party is capable of constructing nuclear power plants on its own within the framework of a license agreement.

We have considered different ways of implementing such a transfer of technology from Sweden to a receiving party. The basic idea is that the engineers in the receiving country should work within the supplier's organization and also with other bodies in his country during all phases of the construction of nuclear power plants. During this period the responsibility for the delivery of the nuclear reactor plants should rest with the supplier. In this way the domestic engineers would be given ample time and opportunities to assimilate the technology involved.

For subsequent plants a company in the receiving country should act as main contractor and the Swedish assistance could be limited to the provision of knowhow in the form of a normal license agreement. The overwhelming part of the work would then consequently take place without any active assistance from Sweden. On the other hand, such

an agreement would allow the domestic company to consult appropriate Swedish bodies on a case-by-case basis. The Swedish involvement could be adjusted on each occasion to match actual needs.

Throughout the period of the license agreement, there should be a two-way exchange of information. Sweden should thus be notified about the experience gained by the company in the receiving country. This will maximize the mutual benefits of the exchange of information between the two equal partners.

The reactor technology knowhow to be transferred can briefly be summarized as follows:

- Specification of components
- Quality control
- Functional analysis of systems
- Licensing procedures and documents
- Procurement of equipment
- Project planning and implementation
- Installation of equipment
- Plant start-up and commissioning
- Plant operation and maintenance

The above-mentioned areas are those that are directly related to the construction of nuclear power plants. In all these areas Sweden is willing to let engineers from the receiving country work in the offices and laboratories of ASEA-ATOM.

This knowhow is, of course, highly proprietary by nature and can only be provided by means of a license agreement between the relevant organization in the receiving country and ASEA-ATOM.

It should also be pointed out that Sweden is in the position to provide extensive training assistance of a more general kind. Some examples are given below.

### 3. AB ATOMENERGI

AB Atomenergi is a State-owned research organization with approximately 1000 employees. Its headquarters are situated at Studsvik, south of Stockholm, and the company has at its disposal very sophisticated experimental facilities for nuclear power research and development.

By tradition AB Atomenergi is strongly oriented towards educational activities. As an example, the company for many years has been organizing comprehensive basic courses in reactor technology for university graduates. These courses, like all other main courses, may be held in English for foreign students.

AB Atomenergi can also provide high-level education on a more individual basis. Each year a number of foreign students prepare their doctoral theses in fields like reactor physics, heat transfer and nuclear metallurgy at the company.

#### **4. AB KARNKRAFTUTBILDNING (AKU)**

AKU (Nuclear Power Training Center) was established in 1972 by the three Swedish power utilities that own and operate nuclear power plants.

AKU offers services in training of the operating personnel at nuclear power plants. The company has built a nuclear training center, the main feature of which is a large, full-scale nuclear power plant simulator. This is the first full-scale simulator of its kind to have been built in Europe. It was delivered by ASEA and ASEA-ATOM.

This basic theoretical training of future operators is accomplished by using the AKU self-instructional training package. Through careful arrangement of text, sound and pictures, it has been possible to reduce the need for teachers to a minimum.

#### **5. TRAINING AT SWEDISH NUCLEAR POWER PLANTS**

As a complement to the services that AKU can offer, trainees can be given the opportunity to work at Swedish nuclear power plants in operation. This applies not only to reactor operators but also to chief engineers, health physicists, maintenance personnel, etc.

#### **6. TRAINING AT SWEDISH MANUFACTURING COMPANIES**

Engineers from foreign countries can also obtain training by working with Swedish manufacturing companies. The company of primary interest in this respect would, of course, be ASEA-ATOM. However, other manufacturers may also be attractive to engineers.

#### **7. PARTICIPATION IN SAFETY RESEARCH PROGRAM**

Safety procedures and the implementation of various codes and standards constitute a most important part of a national nuclear program. The licensing body in Sweden, the Swedish Nuclear Inspectorate (SKI), is sponsoring an extensive safety research program, which is being carried out at AB Atomenergi. The results of these experiments, many of which are unique, are directly used by SKI in its evaluation of the applicant's safety analyses. One way of familiarizing trainees with safety analysis studies related to licensing procedures would be to let them participate in this safety research program at Studsvik.

#### **8. SUMMARY**

These examples of possible Swedish assistance in education and training should in no way be regarded as complete. On the contrary, additional alternatives exist and could be discussed.

The fundamental idea in the Swedish approach to the nuclear technology transfer

**problem is:**

- (a) the existence of independent training packages covering most areas of interest**
- (b) the possibilities to combine these independent packages to meet the needs of the receiving country**
- (c) the technology is transferred between equal parties.**

# TECHNOLOGY TRANSFER FOR DESIGN AND MANUFACTURE OF HEAVY NUCLEAR COMPONENTS FOR LIGHT WATER REACTORS

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## ABSTRACT

A firm entering today's heavy nuclear component business will probably find it necessary to up-grade its previous technology. It may also wish to provide for continued input of updated technical information. This paper describes the transfer of such nuclear component technology between Combustion Engineering, Inc. in the U.S.A. and Uddcomb Sweden A.B. of Sweden. The numerous communication and training methods used are described. Many examples of specific information and assistance interchanges are described. The paper is based on practical experience and is written from the viewpoint of the recipient firm since the Author served on the staff of Uddcomb for several years.

## 1. INTRODUCTION

A joint venture firm, Uddcomb Sweden AB, was formed in mid-1969 between Combustion Engineering, Inc. (C-E), Uddeholm (A Swedish steel firm) and the Swedish Government (Statsforetag AB) to design, manufacture, and erect heavy nuclear components plus chemical and special process pressure vessels for the Swedish and European market. Uddcomb is the only such supplier in Scandinavia.

Uddcomb was new to the nuclear component business and wished to make as much as possible of Combustion Engineering's experience in the design, manufacture, and erection of nuclear components, so besides being involved in a joint venture with C-E, Uddcomb had a license agreement with C-E that included technical assistance.

In an enterprise such as this, the importance of communication and proper use of the relayed information cannot be over-emphasized. To accomplish this, Uddcomb had requested that an experienced C-E technical supervisor (referred to as a "resident" here\*) join its staff for several years. There were three primary reasons for this request:

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\*The Author served on the staff of Uddcomb as the "resident" in the capacity of Assistant Technical Director for a two year period during 1972, '73 and '74.

- 1 Establish and stimulate the flow of technical information between C-E and Uddcomb during the critical start-up period of the new manufacturing facility.
- 2 Provide technical input and personnel training to facilitate Uddcomb's entrance into the nuclear steam generator business. (This was necessary due to the unique aspects of steam generator design, fabrication, and warranty responsibility when compared to reactor pressure vessels.)
- 3 Organize an advanced engineering (or Proposition Engineering Group). The function of this group would be to provide a strong technical coordinating function during bid (tender) preparation. Such a function is normal in most nuclear component firms to clearly define the scope of work and to cause a minimum of disturbance to line functions during bid preparation.

To avoid confusion by referring to the two parties by names visually and phonetically alike ("licensor" and "licensee") and to emphasize the importance of communication the licensor will be referred to here as the "sender" and the licensee as the "receiver".

## 2. HISTORY AND BACKGROUND

Uddcomb's initial operations were located in Degefors in central Sweden at the Uddeholm facility, but in a "land locked" shipping situation. Thus shortly thereafter, a search for a deep water (ice free) harbor location commenced to overcome the transport problems of the anticipated 8m outside diameter X 600 metric ton vessels.

Uddeholm brought to the venture a background of pressure vessel and heat exchanger experience so important at the outset (including trained engineers and craftsmen, heavy machining equipment and general welding and support equipment). C-E brought fifteen years of nuclear component technical experience and support manpower. The Swedish Government brought financial backing, management support and a desire to support the development of nuclear power in Sweden.

When Uddcomb was formed in 1969, orders for two new Swedish Nuclear Stations Oskarshamn II and Barseback I, had just been placed. Uddcomb received the order to furnish the BWR vessels for both. The plans were for initial fabrication to commence at Uddeholm's Degefors facility with final assembly at the yet-to-be selected deep water harbor. Thus the selection of the new plant site, plant layout, heavy equipment ordering and plant construction occur in parallel with initial vessel design and construction. C-E provided essential technical support and guidance in this process to make Uddcomb's present Karlskrona plant 100% operational. In early 1972, with a minimum of schedule interference, the vessel sub-assemblies, personnel, and certain equipment were transferred from Degefors to the newly completed plant on the Baltic at Karlskrona. By mid 1972, this transition was complete and the author (resident) arrived in Karlskrona.



### 3. EXCHANGE OF TECHNICAL INFORMATION

#### 3.1 External: With the Sender's Organization

It is essential that the sender provide the receiver with up-to-date technical information and also keep him aware of the increasing pool of technical information which is continually being developed. The system set up must be capable of handling both large bulk quantities of mail (blue prints, manuals, etc.) and electronic communication (TLX and telephone). The majority of communications will normally be via TLX and telephone since quick turn-around is essential. Frequently a special courier must be used to expedite bulk shipments or when special instructions are desired.

A technical information library was maintained at the receiver's facility. These technical documents were up-dated periodically by the sender through a routine distribution system to the receiver. The following "off-the-shelf" sender documents were maintained in the technical information library:

- Nuclear quality assurance manual
- Design engineering standards manual
- Structural (and thermal analysis) standards
- Detailed material purchase specifications
- Detailed process specifications (non-destructive testing and special shop processes)
- Nuclear fabrication practice manual (Detailed instruction for performing special shop operations)
- Detailed welding procedures production control manual
- Typical field instruction and operating manual (for each type of component)
- Typical fabrication schedule networks (for each type of component)
- Typical stress analysis reports (for each type of component)
- Complete bound sets of fabrication drawings for:
  - (a) Typical PWR vessels
  - (b) Typical BWR vessels
  - (c) Typical steam generators
  - (d) Typical pressurizer
- Technical computer program listing

Particular questions will frequently arise at the receiver's facility for which a highly specialized and rapid transmittal of information is vital. These questions cover many disciplines, including engineering, metallurgy, materials selection manufacturing, non destructive testing, and field problems. Consequently, contact must be made with various departments of the sender. In this instance, the departments were located at two facilities: one in Chattanooga, Tennessee and the other in Windsor, Connecticut. Because of the experience of the resident within his own company, he could quickly determine which departments and individuals within the sender's organization had the proper information. Communication would then be made by telex or telephone.

### 3.2 Internal: Within the Receiver's Organization

Good external communication is only part of the total communications requirement. The information must be dispersed to the proper people in the receiver's organization. To do this, means were set up to stimulate the resident and the receiver's staff to contact each other on a regular routine basis, and not just on emergency requests. The formal methods used were to have the resident attend staff meetings, attend departmental meetings, and conduct training programs. Perhaps just as important as the formal methods was the informal - indeed friendly - relationship that was established between the resident and the receiver.

Thus the receiver's personnel must be kept aware of what is technically available, and must not be reluctant to request assistance and/or information. This cannot be over-emphasized if the receiver is to gain full benefit from the relationship and the sender is to be able to fulfill his obligations.

## 4. TRAINING

The training or educational activities carried out by the receiver were a significant factor in the technical exchange benefits. Such training fell into several categories:

### 4.1 Residence at the Sender's Domestic U. S. A. Facility by Receiver's Technicians

This type of training was extremely effective and was generally performed as "on the job training" where the resident performed an active role as a temporary member of the sender's staff. The technologies for which this method was used and duration were:

<u>Technology</u>	<u>Training</u>	<u>Duration</u>
Structural Engineer	Stress analysis and steam generator performance analysis	1 year
Manufacturing Engineer	Steam generator manufacturing techniques	1 year
Quality Assurance Engineer	Quality control systems and non-destructive testing techniques	6 months
Radiograph Technician	Radiographic equipment operation	1 month
Welding Engineer	Welding techniques and welding equipment development	3 months

### 4.2 Seminars

Periodically, the sender sponsored a seminar customized for key receiver technicians. The format was based approximately 50% on receiver suggestions and current problems and

50% on the sender's "new" information. These seminars lasted three to four days including extensive shop observation tours. In addition, the sender occasionally conducted more specialized seminars encompassing several nuclear (and non-nuclear licensees) on a selected subject of common interest, e.g. welding techniques and problems.

#### 4.3 Manager Tours

To complement the seminars discussed above, visits by the receiver's Manager were frequently arranged to provide an overview of the particular Manager's activities and overall organization functioning. The emphasis during such visits would be in the management, organization, staffing, and long range planning areas.

#### 4.4 Steam Generator Technology Education

As mentioned earlier, one of the receiver's principle long range objectives (successfully accomplished) was to enter the steam generator business. The resident conducted an intensive education program for the receiver's engineers, technicians, and shop supervision on this subject prior to receipt of orders. This training included:

- (a) Color slide presentations showing step by step construction of a typical steam generator.
- (b) Discussions of steam generator operation theory and performance characteristics.
- (c) Emphasis on areas where steam generator materials and manufacturing differed from the more familiar reactor vessels.
- (d) Discussions of special equipment and non-destructive testing required for steam generators.

These programs were offered to all levels of management, shop foremen, and technicians as part of a familiarization program. Benefits were immediately evident during the steam generator bid (tender) preparation period prior to receiving actual orders and, of course, in execution of current steam generator orders for KWU and WENESE.

The receiver's background (at Uddeholm) in heat exchanger design and manufacture provided fertile ground for this educational program.

#### 4.5 License Familiarization

An important training function as part of a technical exchange program was to assure that all levels of the receiver's supervisors and technicians were aware of the provisions of the technical exchange agreement with the sender. This is essential to encourage use of the agreement and in some cases, to assure that all were aware of its existence. This was accomplished by two steps.

Step 1 - Since technical exchange agreements are frequently a semi-formal document

written by lawyers, a simplified one page summary of the agreement's provisions was prepared and given wide distribution.

Step 2 - Discussion groups and seminars were conducted by the resident to explain the provisions of the agreement based on the summary published in Step 1.

#### 4.6 Sponsoring Students

At the request of the receiver, the sender sponsored numerous third and fourth year University Engineering students for summer "on-the-job" training at the sender's nuclear facilities. These students, on graduation, were given special consideration for employment by the receiver.

### 5. UP-GRADING OF PRIOR EXPERIENCE

What sort of prior experience is required to successfully undertake the design and manufacturing of heavy nuclear components? Obviously, such a transition is much easier and more feasible for a manufacturer of large chemical pressure vessels than for a textile manufacturer. There are certain technologies and skills that are basic to the design and manufacture of all nuclear components. These are listed below. In addition, there must be experienced people having these backgrounds available or a source for recruiting and training such talent:

Project management	Planning & supervision
Pressure vessel and civil engineers	Structural design and calculation
Metallurgists	Analysis of material and welding problems
Qualified welders	Pressure boundary welds
Machinists	Operation of large machine tools
Non-Destructive testing personnel	Testing and interpretation of radiography, ultrasonic, testing, magnetic particle testing, and dye penetrant testing.

Nuclear component manufacturers have traditionally come from five heavy manufacturing industries: boiler manufacturers, chemical pressure vessel manufacturers, shipyards, marine diesel manufacturers and heavy steel plate or forging manufacturers. These industries offer a combination of a source of the manpower talent listed above plus partially suitable facilities. In Tables IA and IB, these five types of industries versus the Talent and Facilities usually available are shown.

Thus, it can be seen that most of these basic industries *when combined with an experienced source of nuclear component technical information* offer a sound basis and high probability for success for entering the nuclear component business.

Table 1-A. Facilities

TALENT AND/OR PERSONNEL	Boiler Mfgs.	Chemical Pressure Vessel Mfgs.	Ship-yards	Marine Diesel Mfgs.	Heavy Steel Plate &/or Forging Mfgs.
Project management	X	X	X		
Pressure vessel and civil engrs.	X	X	X		
Metallurgists	X	X			X
Machinists	X	X	X	X	X
Welders	X	X	X		
NDE personnel (non-destructive examination)	X	X	X	X	X

Table 1-B. Facilities

FACILITIES	Boiler Mfgs.	Chemical Pressure Vessel Mfgs.	Ship-yards	Marine Diesel Mfgs.	Heavy Steel Plate &/or Forging Mfgs.
Material testing laboratories	X	X	X		X
Large machine tools				X	X
Large automatic welding equipment	X	X			
Large stress relief furnaces	X	X			X
Heavy cranes	X	X	X	X	X
Water shipping access			X	X	

## 6. PROBLEMS

All nuclear component manufacturing operations will encounter certain problems. It is difficult to present a discussion of these in general terms since they are usually unique and highly specialized. A firm entering the business, however, will probably encounter certain problems which can be categorized:

### 6.1 Large Component Size

Whereas in the early 1960s, nuclear systems were nominally 375 MWe (requiring PWR Vessels 140 inches inside diameters with 125 MWe steam generators or BWR Vessels 180 inches inside diameter), an entrant into today's nuclear component business is faced with nominally 1200 MWe systems which require:

<u>Inside Diameters (or Capacity)</u>	<u>Component</u>	<u>Weight (Maximum)</u>
173" - 196"	PWR Vessels	400 Tons
251" - 265"	BWR Vessels	650 Tons
300 - 600 MWe	Steam Generators	650 Tons

Although this large size and weight extrapolation may at first seem awesome, the new entrant can be consoled by a number of facts:

- (1) The basic materials have not changed since the 1960s; they have simply gotten thicker and require tighter inspection standards.
- (2) The basic designs have not changed significantly from the 1960s.
- (3) The basic facilities and equipment required have not changed significantly from the 1960; they have, however, gotten larger (to handle larger sizes, weights, and produce greater output).
- (4) The basic manufacturing and inspection methods have not changed significantly since the 1960s; higher quality, greater productivity, and more thorough inspection is required, however.
- (5) The basic design methods are similar to the 1960s; a greater depth and sophistication in stress analysis and fracture mechanics is required, however.

The increased component size has caused several specific changes in engineering and manufacturing methods:

- (a) Thicker steam generator tube sheets and larger number of tubes require tape (numerically) controlled multi-spindle tube sheet drilling machines.
- (b) The larger number of steam generator tubes requires automated tube expanding and tube to tube sheet welding equipment.
- (c) Thicker flanges and larger studs require trepanning equipment for flange stud holes.

- (d) Increased steam generator capacity requires higher capacity steam separators.
- (e) Increased reactor vessel sizes require well deposited cladding equipment with high surface area coverage rates.
- (f) Thicker vessel shells require higher deposition rate welding equipment.
- (g) Stricter inspection requirements require increased use of ultrasonic testing techniques.
- (h) Lower safety factors combined with increased safety demands have necessitated greater sophistication in stress analysis and fracture mechanics.
- (i) Requirements for in-service ultrasonic examination have necessitated certain changes in design configurations for accessibility considerations.

## 6.2 Mixing of Codes and Design Specifications

The European market usually requires a nuclear component supplier to furnish components to several countries. This presents several basic problems (and costs) which a U.S. supplier does not normally encounter. These problems generally involve language differences and the requirement to work to several different codes and specifications in all technical departments of the Company.

In the case of the receiver, which is typical, three customers were involved covering a wide range of requirements as listed in Table II.

Due to highly specialized and nationalized requirements of each of these different customers it is frequently necessary to organize and subdivide the technical (and commercial) departments of a firm along customer rather than the traditional product lines.

## 6.3 Single-point Contact

It is highly recommended that both the receiver and the sender establish a single-point contact to act as a clearing house for technical information. These individuals should be fluent in the common language selected for communication and be highly knowledgeable regarding the other firm's technical operations.

The assignment of this single-point contact (and communicator) by the receiver will tend to encourage requests by the technical staff. It will also allow a more efficient expediting and dissemination of information.

## 6.4 Priorities

The sender's staff is frequently fully occupied with routine work and special problems. Thus, the receiver may have difficulty obtaining adequate priority and a prompt response to his requests. It is therefore important that a clear understanding exist between both parties regarding turn-around time and priority to be given requests from the receiver.



Table 2. Mixing of Customer Requirements

CUSTOMER	COUNTRY	TYPE SYSTEM	COMPONENT	SIZE	FORMAL TECHNICAL LANGUAGE	CODE SPECIFICATIONS
ASEA-ATOM	Sweden	BWR	Reactor Vessel	204"-251" (5.2-6.4 M)	English	ASME Section III, Swedish Pressure Vessel Code, plus Swedish State Power Board extra requirements
			Core Internals	204"-251" (5.2-6.4 M)		
Westing-house WNESE	Belgium	PWR	Reactor Vessel	157" (4.0 M)	English	ASME Section III plus Swedish State Power Board extra requirements
			Pressurizer	84"		
			Steam Generators	(2.15 M) 250 MWe capacity		
KWU Kraftwerk Union A.G.	West Germany	PWR (Siemens)	Reactor Vessel	196" (5.0 M)	German	A.D. Merkblatt (German Pressure Vessel Code) plus extra TÜV and KWU specification requirements
			Steam Generators	300 MWe capacity		
		BWR (AEG)	Reactor Vessel	263" (6.7 M)		

### 6.5 Mixing of Nuclear and Non-Nuclear Vessels

It is frequently the case for an entrant to the nuclear component business to design and fabricate a mixture of both nuclear and non-nuclear pressure vessels. This is frequently necessary due to:

- (a) Limited volume of nuclear work at the outset requiring a supplement of non-nuclear work to fully utilize the facilities.

- (b) A gradual evolution into the nuclear component work from a background of non-nuclear pressure vessels.

This mixing does not normally create any major problem. The design engineering function can readily be adapted since they are already working to several customer specifications and design codes which have evolved from the non-nuclear vessel era. The manufacturing operations are similar for the two types of components. It is in the quality assurance area that care must be exercised to properly separate the widely different quality standards between the two component types.

## 7. SPECIFIC EXAMPLES OF TECHNICAL ASSISTANCE AND INFORMATION EXCHANGE

It may be of interest to the reader to review typical specific examples of information and assistance furnished to the receiver by the sender as part of the technical assistance agreement. This list covers a wide variety of technical and software subjects plus, in some instances, actually furnishing fabrication materials:

- 1) Advice (and expediting assistance) in selection and purchase of heavy shop equipment.
- 2) Consultation on shop expansion plans.
- 3) Consultation in obtaining ASME Section III Nuclear Stamp.
- 4) Use of the sender's patents.
- 5) Special stress analysis assistance.
- 6) Use of cost reduction ideas.
- 7) Furnish materials from the sender's stock (due to receiver or vendor procurement problems):
  - (a) Large quantities of Inconel welding electrodes
  - (b) Nozzle forgings
  - (c) Special Inconel forgings
- 8) Repair custom electronic equipment.
- 9) Supervisor job descriptions.
- 10) Shop fixture and tooling drawings.
- 11) Field erection information.
- 12) Optical tooling information.
- 13) Special test laboratory reports.
- 14) Welding problem evaluation.
- 15) Perform laboratory testing for clad bond.
- 16) Quotations for special sub-contract manufacturing.
- 17) In-service inspection information.
- 18) Strip cladding equipment information and welding procedures (stainless steel and Inconel).

- 19) Manpower planning information.
- 20) Vessel shipping and outdoor storage protection information.
- 21) Shop facility capability (output) predictions.
- 22) Techniques for "freezing" PWR CRDM mechanisms housings into closure head.
- 23) Automatic nozzle welding equipment information.
- 24) Technical review and comments to bid specifications.
- 25) Assistance in developing "Up-John" (or vertical progression) welding; in lieu of electroslag welding.
- 26) Special technical advice on requirements for reactor vessel "O" ring seals.

Much of the above assistance and communication is highly dependent on the degree of similarity between the operations of the sender and the receiver. For this reason, it is highly recommended that a firm entering the nuclear component business give serious consideration to achieving "technical standardization" with the more experienced firm with which it is associated. This technical standardization would tend to create a common ground in:

- Use of similar design and construction
- Use of similar materials
- Use of similar major manufacturing equipment
- Use of similar welding and other manufacturing techniques
- Use of similar inspection equipment and techniques

Obviously these similarities will cause better communications between technicians and can even allow immediate furnishing by the sender of welding materials and equipment parts by air freight. Naturally, different economic conditions and a desire to use local manufactured materials and equipment can modify this "standardization" objective.

## 8. BENEFITS OF TECHNOLOGICAL EXCHANGE

To an entrant into the nuclear component business, the advantages of having direct technical access to a highly experienced nuclear component firm are extremely beneficial and in many cases mandatory. In addition to the specific examples described earlier, the following general benefits will usually automatically become available:

- (a) The receiver will have direct access to 15 to 20 years of the sender's hard earned experience.
- (b) The receiver is permitted to expend a minimum of his resources, effort, and capital on Research and Development.
- (c) The receiver can minimize his staff since "peak load" assistance can be provided by the sender.
- (d) The receiver is provided with a potential source of highly experienced technical and management personnel for possible overseas assignment in the event assistance is required.

- (e) The receiver has available a potential source for specialized sub-contract manufacturing assistance in the event of severe problems or equipment failure.
- (f) The receiver can avoid (and not repeat) problems or errors experienced by the sender.
- (g) Frequently the sender's experience with a common customer can be used to mediate or resolve problems.
- (h) Perhaps most important, a firm with limited nuclear experience will gain a greatly increased credibility with his customers if he has provided for technical access to and assistance from an experienced nuclear component manufacturer.

## 9. SUMMARY

The author trusts that the contents of this paper, when viewed through the eyes of a new or potential entrant into the nuclear component business, will offer sound suggestions for establishing a basis for the Transfer of Technology. The relationship described herein between Uddcomb and C-E has been a practical, working and viable basis for interchange of technical information. Each such relationship, however, must be specially "tailored" to suit the experience and technical resources of both the sender and receiver of nuclear component technology.

## A STRATEGY OF IMPROVING NUCLEAR TECHNOLOGY TRANSFER PROCESSES BASED ON FIELD EXPERIENCE

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### ABSTRACT

A critique of earlier approaches of transfer of nuclear technology is made on the basis of past experience in earlier programs. Unsuccessful implementation of many of the plans to transfer nuclear technology require assessment of the pitfalls of those plans and development of a novel approach to realize future plans. A strategy is developed here to improve nuclear technology transfer processes within the framework of economic development theories. Recommendations were made for strategies to accumulate the human capital and to devise efficacious plans. The role of information availability is considered, giving an outline for methods of acquisition of data and required knowledge. Participation of countries benefiting from the transfer program in sharing the financial risk is found to be essential for success of nuclear projects.

### 1. PREAMBLE

Attempts made to identify complications associated with the nuclear technology transfer process tend to overlook the real causes of failure of earlier programs. Most of the earlier studies are limited to exploring whether or not it is feasible, at this time, to establish media for global exploitation of nuclear energy. Others have concentrated on educational affairs or on blaming the status quo of economic, social, political, and human development.<sup>(1,2)</sup> Also there is a tendency to base recommendations on prima facie information and purely presumptuous data.<sup>(3)</sup> Thus far, no attempts were made to synthesize plausible modifications for present strategies of nuclear energy transfer. Here, an ex post facto assessment of earlier projects is made and a novel approach is presented to solve recognized and anticipated problems which are likely to develop in the transfer process taking into account mutual interests of both the contributing and the recipient countries. The Schumpeter theory of economic development<sup>(4)</sup> is used as a framework for the interpretation of field observations.

## 2. FRAMEWORK

The Schumpeterian theory makes distinction between two states: a dynamic state identified by a great flux of technology transfer and a circular flow state characteristic of the antique Oikenwirtschaft or household economy. Innovating entrepreneurs are the channels through which transition can be made from the statics circular flow to the dynamic state. Statics is not a state of stationary equilibrium and hence it may include growth of technology. Growth here is limited to increase in physical production and associated economic return. In contrast to dynamics, statics refers to the basic state of technology, production and economy and identifies that state of absence of economic agents that can stimulate technical progress. Those agents are the innovating entrepreneurs. Appearance of entrepreneurship results in an upswing of technology and causes a sudden change in the prevalent static state of the economy. The upswing is sustained by creation of new entrepreneurs even if their contribution is limited to imitation of earlier innovators. Eventually, the system again reaches a circular flow state after a certain level of development has been achieved. The measure of technical changes introduced through adaptation and innovation and of the effectiveness of transfer of technology processes is the associated economic developments.

A distinction must also be made between inventions and innovation. Inventions have no immediate economic significance since there exists always a reservoir of technical inventions and hence increase in the invention rate does not imply growth in the transfer of technology. Innovations, on the other hand, are the application of inventions through the use of new combinations of technological factors by entrepreneurs to increase economic productivity. This distinction between invention and innovation as an element in transfer of new technologies has not been realized by planners in developing economies. Often a transfer of technology program is launched with all emphases placed on encouragement of inventions and generation of new untested ideas. Consequently, many of the conceived ideas have no impact on technological development. This is despite the false belief that such ideas are achievements of goals of development. Unless the idea is transferred from a concept to a real product or to a tool for technological growth it is unlikely that this idea will be relevant to development. For example: many of the developing countries have contributed to the scientific world a wealth of theoretical work on nuclear scattering and interaction between particles yet the nuclear industry in those countries is of no existence. Moreover, the role of inventors usually falls short when it comes to adaption of imported nuclear technology. This observation does not undermine the value of basic work in science and physics which is necessary but not satisfactory for technology transfer.

The innovation process can be enhanced by the transfer of new technology, by a new method of production, by the exploration of new resources, by entering a new market, and by a change in the organizational structure of one or more of the existing industries. The motives which create entrepreneurs and make innovation possible are a complex combination of sociological and psychological factors and are not limited to economic gain. Although

personal morale is important, esprit de corps plays the major role in motivating innovating entrepreneurs.

Evidently, innovations in this framework open up new investment possibilities through technological development and hence stimulate economic growth and result in more capital accumulation. This is opposite to the conception that capital investments induce innovation which is stressed in modern economic theories. <sup>(5)</sup> Recent evidence in several developing countries shows that the presence of large capital investments did not stimulate innovations or accelerate the transfer of technology process.

### 3. HUMAN CAPITAL

Human capital is a major element of the nuclear technology transfer strategies since the initial conditions are set up by careful assessment of local skills. Decision-making must be founded on accurate statistics of requirements and proportions of engineers, technicians, managers and maintenance and operation personnel. Specific skills must be provided via practical field work, actual participation in all phases of nuclear projects, involvement in tasks wherein quality assurance and high quality workmanship are emphasized and practice of the art of innovation even through imitation. Creation of innovating entrepreneurs is the backbone of viable transfer processes. Underutilization of local manpower is likely to slow down the process and to deteriorate the competence of newly developed skills. Corrective policies are needed to exploit indigenous technologies even at the expense of high social cost in the short term. Issues such as inadequacy of available human capital, barriers between local and technological cultures and brain drain must be analyzed as technical problems rather than socioeconomical paradoxes. The transfer process is endangered by present emphasis on education in terms of increase in college degree holders, of production of bureaucrats with life-guaranteed jobs and of establishing a hierarchy based on academic degrees. In contrast, a viable transfer of nuclear technology program requires emphasis on competence, innovation, and on systems of liability, penalty and reward.

### 4. PLANNING

Planning must be done with due patience for long periods without major disruptions using calculated feedback reiterations. Stability and continuity are important elements of success. The decision-maker must employ systematic and scientific methodologies in designing and implementing strategies. This requires a high degree of technical sophistication. Limiting decision-making to political domains infested by transients induces confusion and obstructs the flow of the transfer process.

Many of the unsuccessful plans were made on the spur of the moment under the effect of national slogans or the desire to imitate. Some decision-makers overestimate the capability of their nations and overlook the nature of evolution and its implications for the



transfer of new technologies. Acquiring skills necessary for development of nuclear technology and execution of nuclear projects has to go through an evaluation process which cannot be bridged by rushing into decisions or by increase in the budget. The socioeconomical and technological systems are not flexible enough to accommodate fast changes.

Careful planning requires setting up long term goals and short term objectives which are realistic enough to warrant no drastic changes in the future. Then financial and human capabilities have to be precisely assessed to provide schedules and identify the requirements of implementation of the project at hand. Examination of viable alternate approaches needs to be considered before decisions are made. When gambles are involved, weighted risks and benefits must be calculated. Motivation of the people involved has to be factored in the plan as opposed to the erroneous assumption that people will always do what they are told exactly as expected. Distinction must be made between patriotic duties and participation in the technological expansion of the country. Moral codes can often provide incentive to contribute to the growth and development. However, this is not the case if the goals are not clearly understood and appreciated by individuals. National slogans may increase production, however, they can hardly induce innovations unless personal motivation is stressed.

## 5. INFORMATION

For a specific nuclear project in a given location, language barriers between persons in charge must be eliminated and means of communication must be improved. A program is required for translation, adaptation of foreign experts to working environment and mutual understanding between the management at different levels. Adequate information flow must be made to support the transfer activities. Books, references and current literature need to be available and to be within the financial capability of local technical people. This may require subsidizing and printing of special nonexpensive editions of basic resources.

Plans for information acquisition are often made by non-technical personnel who are not involved in the projects. Hence, the value of availability of information when needed is undermined. Keeping abreast with new developments in the specific field of interest and other related fields is essential in invoking innovation and progress. Increased communication and exchange of information between countries is also a vital part of the transfer of nuclear technology due to its novelty.

## 6. FINANCE

Financial participation of recipients in the transfer projects is likely to enhance the chance of success at the expense of elongating the period of achieving specific national goals. Pools of nations or local private enterprises may be formed to share the economic risk involved since the magnitude of investment is usually beyond the capability of a single small country.

## 7. CONCLUSIONS

A realistic approach based on technical analysis of the problem of transfer of nuclear technology involves the basic elements described above. Those apply in many aspects to both the contributing and recipient countries. The payoff in the long run of following these guidelines would include avoidance of the setback suffered by early and recent programs.

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## THE CONSULTANT, AS AN OUTSTANDING MEANS FOR TRANSFERRING NUCLEAR TECHNOLOGY

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### 1. INTRODUCTION

The transfer of technology is historically a basic activity within mankind, either down generations or between contemporaneous individuals or groups: Iran is certainly an outstanding illustration, over millenia, of both these kinds of transfers. Such transfers have been achieved by all conceivable means, from peaceful diffusion to devastating invasions, from purchasing to spying and robbery, from forced displacement of people to more subtle brain drains. However, this paper concentrates on an instrument for transferring technology which seems to me a true invention of our modern age: the Consultant. Such an invention is certainly connected with the ever increasing complexity of a number of recent technologies, and the corresponding importance of the "know-how", which prevents them from being readily understandable and practicable - and also to the large amount of money they involve and the corresponding necessary prudence in making decisions: nuclear technology is certainly a fine example of these two features of modern industrial achievements. Since, in addition, a world-wide diffusion of nuclear technology is needed (as shown, for instance, by the IAEA nuclear market surveys), many countries have to face this peak technology when industrialization is just starting and technical background is insufficient. Therefore, there is no wonder that the use of consultants in the nuclear field is a well established practice.

From this starting point, the intent of this paper is to outline the specific aspects of technology transfers involved in the complex relations established between an organization in charge of the early stages of the introduction of nuclear power in a developing country and the consultant this organization has hired. After having reviewed the various aspects of consulting services, this paper will outline which transfers of technology they implement. Then, specific points of interest will be emphasized before reaching a conclusion.

### 2. THE VARIOUS ASPECTS OF CONSULTING SERVICES AND CORRESPONDING TRANSFERS OF TECHNOLOGY

We mentioned above that the intervention of consultants in the nuclear field is justified by the specific character of the nuclear projects. This specific character may be briefly highlighted by the following examples, both in the early decision-making process and

during the implementation of the projects:

- nuclear projects imply heavy financial commitments and long-term planning, both problems which, in the world's present economical situation, are difficult to solve
- nuclear power has become a sensitive political problem, both in foreign affairs and in home policy
- safety and licensing requirements are overwhelming burdens
- the introduction of nuclear power, especially in only slightly industrialized countries, requires in many areas preparatory actions and implies pitfalls that have to be identified and faced in advance.
- a number of technical decisions (such as selection of reactor type and of safety criteria) considerably influence the costs and also have long-term effects: such decisions have therefore to be carefully weighed
- the construction of a safe and reliable power plant, even built by experienced companies of world-wide reputation, inevitably means a large involvement of the Owner. It also implies a high degree of financial risk.
- the operation of a nuclear plant requires trained operating and maintenance personnel, capable of making the best use of this sophisticated instrument.
- the introduction of nuclear power, on the other hand, offers an outstanding opportunity to develop the receiving country's expertise in many areas: management, engineering, construction and industry. This opportunity must be seized by developing countries.

This short summary shows that a number of organizations have to take part in the process of introducing and constructing nuclear plants and that a considerable amount of experience is required from all partners in their long-term decisions as well as in their day-to-day action. Such experience obviously cannot exist in all its aspects within all the participating organizations in a country just starting (or even just considering) going nuclear. For instance:

- In the early stage, there could be a lack of qualified personnel for properly advising Government and Utility executive levels and providing them with the background information needed for making right decisions
- In the implementation stage, there will most probably be a lack of experienced personnel within the Utility, even if a complete turn-key contract is adopted, to carry out without undue risks the tasks which in any case fall upon the Utility, such as:
  - preparation of the bid specification
  - evaluation of the bids
  - writing and managing the contract
  - supervision of the general contractor
  - preparing itself to the full take-over of the plant and the corresponding responsibilities and abilities
  - fuel cycle policy

Regulatory and Licensing aspects need high level teams for properly selecting the criteria to be met and exercising judgement on how these criteria are fulfilled by the builders: such personnel usually does not exist when nuclear power is just being introduced.

These examples, to which many others could be added, fully justify the need for support from outside consultants having a large practical experience of nuclear projects in all aspects and therefore in a position to dig out of the best location in the international nuclear community and experience the specific information needed for the project.

The consulting services may widely vary according to the specific needs:

- assignment of experts to review work already done by others or to give advice before decisions are made
- specialized services in spot areas
- technical assistance covering the complete project.

Usually, there is a combination of these services: a main consultant is hired for the complete project, in association with expert or specialized services in specific areas, either under the main consultant's responsibility or under the Utility's direct control in coordination with the main consultant.

At this point, having reviewed the special character of nuclear projects, the corresponding need for outside assistance from experienced consultants, the different possibilities for their intervention, we shall now list in more detail the main scope of services assignable to a consultant hired for a complete nuclear project and outline the corresponding transfers of technology achieved by this consultant: this analysis results in the matrix given in Table 1, in which the intensity of the dotted lines illustrates the degree of the various transfers mentioned, thus permitting allocation of a "factor of merit" to each of these transfers.

The table shows that the largest transfer from the Consultant to the Owner is the transfer of international experience in nearly all aspects of the nuclear projects; as a matter of fact, this transfer is certainly the consultant's most important function, in particular because:

- it shortens by years the Owner's learning period
- it avoids a tremendous number of mistakes or misjudgements.

Other special features are dealt with in the next paragraph. However, one aspect of a consultant's work warrants special emphasis: the transfer of manufacturing know-how to local industry. The fact that, in Table 1, this aspect got the poorest factor of merit only reflects the fact that it is of little importance to the Owner. But, from the Country's point of view, this aspect is certainly of greatest importance for making best use of nuclear power for sponsoring the Country's industrial capabilities.

Table 1. Transfers of Technology Achieved by a Consultant

TRANSFER OF TECHNOLOGY	CONSULTING SERVICES		Transfer of world - wide nuclear experience	Transfer of management techniques	Transfer of nuclear engineering techniques	Transfer of nuclear construction experience	Transfer of specific nuclear techniques	Transfer of nuclear manufacturing know-how
	Assistance in basic decisions	Assistance in project planning						
	Siting Plant size Advisable reactor types Advisable suppliers Fuel cycle Waste management Safety criteria Cost estimates Financing	Personnel planning List and logics of actions Quality assurance Cash flows						
	Project organization Engineering procedures Scheduling methods Cost control methods Change control methods Reporting methods							
	Breakdown into contracts Invitation to bids Bid evaluation and selection Contract and specifications Supplier supervision							
	Main technical options Judgement on provenness Selection of codes, standards Selection of safety criteria Interpretation of foreign codes and criteria Adaptation of standard plants to local Decision on changes Decision on abnormalities C.A. and C.C. methods Owner's engineering work Pre-up test organization Start-up test organization Spare part policy Expert services							
	Qualification investigations Degree of participation Form of participation Collaboration with foreign industry Training of specialized workmanship Consulting services to local industry							
	Local licensing Authorities Foreign licensing Authorities Public							
	Training of individuals Training of teams							
	Insurance Legal							
Factor of merit			44	20	30	37	28	10

Our company has been involved for years in consulting services to a foreign country for the construction of a nuclear plant, comprising:

- in the form of a joint team in our own country, the project engineering of the plant up to the purchase specifications
- in the form of technical assistance to the project team in the foreign country, a participation in the implementation of the construction both as regards management and technical aspects
- participation in a complete survey of local industry to evaluate on a realistic basis their actual capabilities
- recommendations regarding the manufacture of components and the participation of local industry along the following options:
  - . complete fabrication abroad
  - . fabrication of a prototype abroad and line-production by local industry, with technical assistance or license from abroad
  - . materials or standard components to be purchased abroad for local manufacture of equipment
  - . training of local workmanship (mainly welders) either abroad or locally by foreign instructors.

Of course, this is an extreme case which means that priority is given to learning and training and that a long construction period is therefore allowed - which is usually contrary to a Utility's selfish point of view. But this example has the advantage of showing the extent of transfers of technology which can be achieved by consultants, the benefits which can be derived from the introduction of nuclear power - and also to illustrate the fact that a Country's general interest can conflict with a Utility's legitimate desire to have its plant built as soon as possible by the most reliable manufacturers.

### 3. SPECIFIC FEATURES

The transfer of technology achieved by a consultant can be considered from another point of view, the methods of transfer.

The usual methods for transferring technology from developed to developing countries are the following:

- information
- training of individuals
- training of teams
- joint ventures
- purchase of engineering from abroad
- know-how transfer agreements between foreign and local entities
- license agreements between foreign and local industry
- industrialization through local subsidiaries of foreign companies driving forward



the local industry

- purchase of equipment for future local duplication
- purchase of turn-key plants to save time - and learn later
- Joint Research and Development agreements between developed and developing countries
- transfer of technology centers

This provides another means for measuring the completeness of the consultant's action since, in the above list, consulting services have the advantage of offering the benefits of the first six methods and can also take care of the others, involving third parties. This remark illustrates three facts:

- the consultant transfers its own nuclear know-how (enriched, as previously mentioned, by its international nuclear experience)
- this know-how is a part of the nuclear know-how to be expected from the use of nuclear power, in addition to the builder's know-how and the general background know-how which is needed in support of nuclear projects
- the consultant may provide advice on the transfer of know-how from others and even be in charge of managing an integrated transfer of know-how, from all sources, as required by the customer: this brings us back to the example already quoted, where our company was involved in a comprehensive technical assistance contract from project engineering to managing local industry training.

As a matter of fact, in nuclear technology, one should emphasize the importance of the know-how, which can be defined as a mixture of basic knowledge, plus practical knowledge, plus applied methods, plus experience gained from both successes and mistakes - and also as a diffuse knowledge, held by teams, not by individuals, and which can neither be comprehensively documented nor taught in schools or universities. It results that the only practical method for transferring nuclear know-how is a joint work (preferably in integrated teams) in which nuclear technology is practiced in common between those who possess the know-how and those who want to acquire it: it is not the exact definition of a consultant's assignment, in which the consultant never works in place of his customer, but side by side with him, thus ensuring efficient training and paving the way to future independence.

This close contact between consultant and customer is also a factor of success in that the consultant is in a position to better understand the customer's situation and social and cultural background. This understanding is a condition for success since the consultant acts as a sort of "interpreter" between two spheres differing from the technical and cultural points of view: this means that the consultant should be capable of transforming his own "message" (i.e. his know-how) into a language fully understandable by the "receiver" (i.e. the customer). This particularly well emphasizes two features of equal importance for the qualification of a consultant:

- technical knowledge, know-how based on practical experience, introduction in

the international nuclear world

readiness and capability to reach a good understanding with the customer, in order to ensure a successful transfer of his own knowledge and know-how under conditions that are always specific to one customer and country.

One can also briefly mention that, from the role of an "interpreter", the consultant can shift to the role of an "adapter" to the extent that, again in order to best conform to local conditions, the consultant may have either to adapt his own methods or to advise adapting the purchased plant: of course, the basic concepts of the plant systems must remain unchanged, but adaptations of non-essential or non-safety-related concepts to local technology or to local social environments are in many cases desirable and possible. As an example, industrialized western countries have generally developed their industry and their industrial products by favoring investments rather than manpower: obviously most developing countries have the reverse approach, resulting in the need for adaptations of purchased plants. Such adaptation should of course be carefully evaluated to make sure that they do not impair the provenness of the plant and its operating standards: the consultant's advice in such an evaluation is certainly essential.

#### 4. CONCLUSION

The man-to-man contact, which we have referred to as the main characteristic of a consultant's work with respect to the customer, certainly results in the best chances for a straightforward acquisition of nuclear technology, by giving access to:

- the consultant's experience and know-how
- the international nuclear experience made accessible through the worldwide activity of every qualified consultant, through the consultant's connections in the nuclear business and also through the fact that the consultant normally uses an information system which enables him to pick-up processed useful information out of the redundant and multi-source worldwide nuclear information flow.

Furthermore, the consultant's way of cooperation with the customer fully meets the basic requirements for every type of transfer of technology: training people (individuals and teamwork), preparing them for the changes brought in by the new technology, educating them for technical and professional behavior in view of this new technology - in most areas by using the best educational method: the possibility for trial and error processes under the consultant's supervision.

Therefore, one can say that using consultants in the nuclear field is certainly the best compromise between conflicting concerns in developing countries: quickly acquiring new technologies and learning from them without money and time-consuming mistakes or groping.

Of course, this paper leaves untouched basic problems connected with large-scale transfers of new technologies:

- for the vendor, what is the impact on his own country and economy of such transfers?
- for the purchaser, what sort of society is he contributing to, by acquiring foreign technology: to what extent is he prepared to have the local structures modified by new technologies which will inevitably have a snow-ball effect and will introduce a new kind of culture?
- for both, what sort of new international order are such transfers promoting?

These questions require careful evaluation without yielding to a sort of fatality resulting from the combination of an instinctive need for an immediately lucrative undertaking on one side and of an unconsidered avidity for any new technology on the other side: this is the only valid course leading to an orderly world status.

## A BELGIAN EXPERIENCE IN NUCLEAR TECHNOLOGY TRANSFER

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### ABSTRACT

Nuclear technology transfer involves ultimately nuclear industry. Reactor fuel and core management is a field where some know-how can be exchanged between core designer and reactor operator to both partners' benefit. A collaboration scheme in that area is strongly supported by the easy access to experimental tools, such as a small operating LWR and a critical facility. Belgium has a quite unique position in this respect.

Nuclear technology transfer is achieved by several complementary means such as education, training on the job, publications, seminars, grant of licenses, exchange of knowhow and other things.

Education and training are quite well covered nowadays as concerns individuals. Good academic courses are available and the many nuclear research centers offer a wide spectrum of opportunities to acquire the proper level of basic knowledge in a particular field. Ultimately however, technology transfer touches upon industry which operates the different nuclear processes and to which belong the specialist teams with their know-how.

It is shown here, through twenty years of experience by a Belgian company in the nuclear field, how this technology transfer can be achieved by industry, and what schemes might be introduced to facilitate the communication of know-how in specific areas.

Belgium was the first small country to face the problem of getting nuclear know-how from the large countries where it had been developed. Belgium has since pursued an intensive nuclear program which leads industry to develop its own know-how. This step forward has developed a new situation where Belgian industry is now in a position to transfer nuclear technology.

Going nuclear means for any country the setting up of a complete structure. The education system must provide adequate means for nuclear specialization. Research centers dedicated to the nuclear field are needed to operate research and testing reactors as well as the sophisticated laboratories. Training facilities are required for reactor operation and the performance of tasks involved in the fuel cycle. Architect engineering capability has to be developed for construction of nuclear plants. Process engineering should be available in particular areas and fuel management is a field of utmost importance. The

listing is impressive and for a country starting a nuclear program choices must be exercised, priorities must be given in order to reach step by step the level of technical knowledge required.

As concerns fuel cycle, it is quite normal that once nuclear power plants are installed, the very next step should be to aim at what is often called "some" fuel cycle independence. This will be concentrated on below.

Belgonucleaire has had experience in fuel cycle training in three directions: facilities operation, facilities construction and reactor fuel management. These three types of concerns have led to different schemes of training and technology transfer.

Facilities operation was dealt with by direct integration of individuals in the operating teams. Formation is very specific and aims at giving practice to people already well aware of the processes involved. Such training has been going on for years in different fields like reactor physics and fuel fabrication. This has been done in very close collaboration with the CEN/SCK, the Belgian nuclear national research center on whose grounds facilities are built.

Construction of facilities affords a good opportunity for engineering capability transfer. The best experience so far was to integrate a team, not individuals, in a project of concern to them. This kind of approach has the advantage of giving a complete picture of the project without impeding the project schedule.

Reactor fuel management techniques need a more elaborate scheme for truly efficient know-how transfer. Methods of analysis, computer codes and the overall process of decision can only be assimilated by a complete ad hoc education program. Moreover, this effort is not valuable if some formal transfer of right to use these methods and codes is not provided. Such a program has been defined at Belgonucleaire which, as designer and supplier of core reloads, is in a favorable position to give more valuable material than universities which are lacking some important codes and big reactor vendors who, for commercial tactics, do not want to transfer this know-how.

The Belgonucleaire program on reactor fuel management is based on the assumption that the great responsibility must be assumed by the reactor operator. Good, efficient and economic core management can only be achieved by acquisition of the proper know-how. It requires the reactor operator to be in a position where he can get his nuclear fuel from the manufacturer with the minimum guarantee including good workmanship. This position might appear at first glance difficult to reach but one should view the fuelling problem in the right perspective. What appears difficult to achieve under present technical and commercial conditions is a realistic objective considering the time range available to reactor operators. This achievement took 20 years for a country like Belgium; it would take about half that period of time for a program which started today. It would take even shorter if technology transfer could be arranged satisfactorily.

What is the advantage of self-reliance in core management? First, improved operation reliability and a higher maneuverability of the nuclear power stations thanks to better knowledge of core performance and characteristics. Second, better commercial conditions

from the fuel manufacturers who must assume a smaller responsibility linked to their supply. It is a matter of fact that the penalty in case of fuel failure bears always very highly on the reactor operator whatever the guarantees provided by the fuel manufacturer. It is thus to the operator's advantage to take the risks he would mostly assume anyway. Moreover this kind of fuel responsibility is only a small part of the overall responsibility for the plant operation.

The problem raised by that approach lies in the fact that the reactor operator must get sufficient know-how. That is where technology transfer comes into play. To start the process, one should find someone who has and who will transfer proper know-how. At a later stage, this know-how must be kept alive and take benefit of the operating experience.

It is Belgonucleaire's opinion that the best scheme to reach both aims is a long-term collaboration scheme where the know-how supplier would in fact exchange his present know-how with the future know-how acquired by the reactor operator. Thus, it is not a one-way technology transfer and both partners do take advantage as time goes on. The scheme bears in itself the needed stability to achieve the set goals with both partners sharing balanced responsibility at the start as well as in the future.

To be able to support such a program, the supplier should at best have an easy access to several tools among which a flexible critical facility, test rigs, a small operating LWR reactor and elaborate computer facilities. It should also be strongly involved in fuel R & D and hold an up-to-date position in the field.

It is a matter of fact that Belgium has a quite unique position in this respect. As is well known, most of these facilities are in operation at the Mol CEN/SCK national research center. Belgonucleaire has used these tools for years and has developed through R & D work on fuel design and irradiations the ability required for fuel supply to power reactors.

Except for the particular approach proposed, that is, a collaboration scheme with a two way know-how transfer, the program of actions would not differ in any way from the general schedule offered today on the market. It would involve education in depth of the reactor operator people, participation from the start in core-management work, implementation of computing hardware and software, follow-up of fuel irradiations and any other service as required by the reactor fuel operation.

Because such a program can be offered to different reactor operators, it is not linked to any particular party and could be extended in some cases to several partners who took the decision to share their efforts to gain time and knowledge.