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**TECHNICAL NOTES**

**of the**

**OPERATIONAL SAFETY REVIEW TEAM MISSION**

**to**

**BUSHEHR**

**NUCLEAR POWER PLANT**

**Iran**

**29 September - 16 October 2018**

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**PREAMBLE**

This report presents the results of the IAEA Operational Safety Review Team (OSART) review of Bushehr Nuclear Power Plant, Iran. It includes recommendations for improvements affecting operational safety for consideration by the responsible Iranian authorities and identifies good practices for consideration by other nuclear power plants. Each recommendation, suggestion, and good practice is identified by a unique number to facilitate communication and tracking.

Any use of or reference to this report that may be made by the competent Iranian organizations is solely their responsibility.

**FOREWORD**

**By the Director General**

The IAEA Operational Safety Review Team (OSART) programme assists Member States to enhance safe operation of nuclear power plants. Although good design, manufacture and construction are prerequisites, safety also depends on the ability of operating personnel and their conscientiousness in discharging their responsibilities. Through the OSART programme, the IAEA facilitates the exchange of knowledge and experience between team members who are drawn from different Member States, and plant personnel. It is intended that such advice and assistance should be used to enhance nuclear safety in all countries that operate nuclear power plants.

An OSART mission, carried out only at the request of the relevant Member State, is directed towards a review of items essential to operational safety. The mission can be tailored to the particular needs of a plant. A full scope review would cover eleven operational areas: leadership and management for safety; training and qualification; operations; maintenance; technical support; operating experience feedback; radiation protection; chemistry; emergency preparedness and response, accident management and human technology organization. Depending on individual needs, the OSART review can be directed to a few areas of special interest or cover the full range of review topics.

Essential features of the work of the OSART team members and their plant counterparts are the comparison of a plant's operational practices with best international practices and the joint search for ways in which operational safety can be enhanced. The IAEA Safety Series documents, including the Safety Standards and the Basic Safety Standards for Radiation Protection, and the expertise of the OSART team members form the bases for the evaluation. The OSART methods involve not only the examination of documents and the interviewing of staff but also reviewing the quality of performance. It is recognized that different approaches are available to an operating organization for achieving its safety objectives. Proposals for further enhancement of operational safety may reflect good practices observed at other nuclear power plants.

An important aspect of the OSART review is the identification of areas that should be improved and the formulation of corresponding proposals. In developing its view, the OSART team discusses its findings with the operating organization and considers additional comments made by plant counterparts. Implementation of any recommendations or suggestions, after consideration by the operating organization and adaptation to particular conditions, is entirely discretionary.

An OSART mission is not a regulatory inspection to determine compliance with national safety requirements nor is it a substitute for an exhaustive assessment of a plant's overall safety status, a requirement normally placed on the respective power plant or utility by the regulatory body. Each review starts with the expectation that the plant meets the safety requirements of the country concerned. An OSART mission attempts neither to evaluate the overall safety of the plant nor to rank its safety performance against that of other plants reviewed. The review represents a `snapshot in time'; at any time after the completion of the mission care must be exercised when considering the conclusions drawn since programmes at nuclear power plants are constantly evolving and being enhanced. To infer judgements that were not intended would be a misinterpretation of this report.

The report that follows presents the conclusions of the OSART review, including good practices and proposals for enhanced operational safety, for consideration by the Member State and its competent authorities.

**EXECUTIVE SUMMARY**

This report describes the results of the OSART mission conducted at Bushehr Nuclear Power Plant, Iran from 29 September to 16 October 2018.

The purpose of an OSART mission is to review the operational safety performance of a nuclear power plant against the IAEA safety standards, make recommendations and suggestions for further improvement and identify good practices that can be shared with nuclear power plants (NPPs) around the world.

This OSART mission reviewed ten areas: Leadership and Management for Safety; Training and Qualification; Operations; Maintenance; Technical Support; Operating Experience Feedback; Radiation Protection; Chemistry; Emergency Preparedness & Response and Accident Management.

The mission was coordinated by an IAEA Team Leader and Deputy Team Leader and the team was composed of experts from Armenia, Belgium, Brazil, China, France, Hungary, Slovenia, Sweden, IAEA staff members and an Observer from China. The collective nuclear power experience of the team was approximately 310 years.

The team identified 12 issues, resulting in 6 recommendations, and 6 suggestions. 4 good practices were also identified.

Several areas of good performance were noted, including the following:

* The plant has in-house research and development and failure assessment capabilities and is also able to design and manufacture robots used for remote surveillance activities.
* The plant has developed a simple modification to the primary system chemistry monitoring system that provides quicker and more precise results while reducing radiation dose.
* The plant has developed a simulator that enhances their capability to train people to diagnose faults on the fire detection and protection systems.
* Before and during simulator training, a psychology specialist evaluates the performance and medical and psychological records of Main Control Room staff.

The most significant recommendations made by the team were:

* The plant should establish and implement a comprehensive severe accident management programme.
* The reinforcement of management expectations in the field should be enhanced to ensure these are fully understood and implemented by the plant personnel and contractors.
* The plant should improve its arrangements for adequacy of corrective actions and their timely implementation to prevent occurrence of similar events.
* The plant should ensure rigorous implementation of fire prevention and mitigation measures to ensure the safety of personnel and plant reliability.

Bushehr NPP management expressed their commitment to address the issues identified and invited a follow up visit in about eighteen months to review progress.

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# INTRODUCTION AND MAIN CONCLUSIONS

**INTRODUCTION**

At the request of the government of Iran, an IAEA Operational Safety Review Team (OSART) of international experts visited Bushehr Nuclear Power Plant from 29 September to 16 October 2018. The purpose of the mission was to review operating practices in the areas of Leadership and Management for Safety, Training and Qualification, Operations, Maintenance, Technical Support, Operating Experience Feedback, Radiation Protection, Chemistry, Emergency Preparedness & Response and Accident Management. In addition, an exchange of technical experience and knowledge took place between the experts and their plant counterparts on how the common goal of excellence in operational safety could be further pursued.

The Bushehr Nuclear Power Plant is located in Bushehr County, Iran, 17 kilometres southeast of the city of Bushehr, between the fishing villages of Halileh and Bandargeh on the Persian Gulf, and around 1000 kilometres south of Tehran.

The plant is operated by the Nuclear Power Production and Development Company of Iran (NPPD), an entity wholly owned by the government of Iran and based in Tehran.

The Bushehr Nuclear Power Plant site was originally anticipated to comprise two units each consisting of a 1213 MWe KWU Pressurized Water Reactor connected to a single turbine generator, plus the necessary ancillary equipment. Construction started in May 1975 but was suspended for several years before restarting in 1998 following an agreement reached with a Russian supplier. The plant design was adapted to house a single VVER 1000 reactor with a nominal net output of 915 MWe. This unit is now known as BNPP-1.

It is not planned to complete the second of the two originally planned units, though it was partially constructed. However, the procurement and construction of another two units has been officially launched. These will be known as BNPP-2 and 3 and are expected to be commissioned in the mid-2020s.

BNNP-1 initial criticality was achieved in May 2011; the main generator was first connected to the local power grid in September 2011 and the unit was declared ready for commercial operation in September 2013. The first refuelling and maintenance outage took place in February 2014.

The plant obtains significant support from managerially independent organizations such as the original equipment manufacturers and a maintenance and repair organization known as TAPNA (which is also a subsidiary of NPPD). Technical support for the plant is provided by technical support organizations (TSOs) consisting of in-house (internal) and external providers. The internal TSO within BNPP-1 primarily provides system engineering functions, while the internal TSO at the corporate office (NPPD) provides policies, oversight and licensing interface. The internal TSO at the plant has a permeated structure with one division assigned as the design authority. The head of that division is also responsible for technical interface with the external TSOs which consist of responsible designers, among others. Most of the design engineering technical support functions are provided by the external TSOs. Also within the operating organization (NPPD), there are several domestic organizations led by a semi-external TSO, TAVANA, which is solely dedicated to providing technical support to the plant. IAEA also offers support to NPPD and BNPP-1 through a Technical Cooperation programme agreed with Iran.

INRA: the Iran Nuclear Regulatory Authority, exercises state supervision of the safe use of nuclear power in Iran, and is the licensing authority. The National Nuclear Safety Department (NNSD), an agency of INRA, provides hands on supervision of regulatory compliance. NNSD has an on-site office at BNPP-1.

The Bushehr OSART mission was the 203rd in the programme, which began in 1982. The team was composed of experts from Armenia, Belgium, Brazil, China, France, Hungary, Slovenia, Sweden, IAEA staff members and an Observer from China. The collective nuclear power experience of the team was approximately 310 years.

Before visiting the plant, the team studied information provided by the IAEA and the BNPP-1 to familiarize themselves with the plant's main features and operating performance, staff organization and responsibilities, and important programmes and procedures. During the mission, the team reviewed many of the plant's programmes and procedures in depth, examined indicators of the plant's performance, observed work in progress, and held in-depth discussions with plant personnel.

Throughout the review, there was useful exchange of information between the OSART experts and plant personnel. Emphasis was placed on assessing the effectiveness of programmes in achieving the expected levels of operational safety rather than simply the content of programmes. The conclusions of the OSART team were based on the plant's performance compared with the IAEA’s safety standards and good international practices.

The following report is produced to summarize the findings in the review scope, as described in the OSART Guidelines document. The text reflects only those areas where the team considers that a Recommendation, a Suggestion, an Encouragement, a Good Practice or a Good Performance is appropriate. In all other areas of the review scope, where the review did not reveal further safety conclusions at the time of the review, no text is included. This is reflected in the report by the omission of some paragraph numbers where no text is required.

**MAIN CONCLUSIONS**

The OSART team concluded that the managers of the Bushehr NPP are committed to improving the operational safety and reliability of their plant.

The team identified 12 issues, resulting in 6 recommendations, and 6 suggestions. 4 good practices were also identified.

The team found several areas of good performance, including the following:

* The plant has in-house research and development and failure assessment capabilities and is also able to design and manufacture robots used for remote surveillance activities.
* The plant has developed a simple modification to the primary system chemistry monitoring system that provides quicker and more precise results while reducing radiation dose.
* The plant has developed a simulator that enhances their capability to train people to diagnose faults on the fire detection and protection systems.
* Before and during simulator training, a psychology specialist evaluates the performance and medical and psychological records of Main Control Room staff.

The most significant recommendations made by the team were:

* The plant should establish and implement a comprehensive severe accident management programme
* The reinforcement of management expectations in the field should be enhanced to ensure these are fully understood and implemented by the plant personnel and contractors.
* The plant should improve its arrangements for adequacy of corrective actions and their timely implementation to prevent occurrence of similar events.
* The plant should ensure rigorous implementation of the fire prevention and mitigation measures to ensure the safety of personnel and plant reliability.

Bushehr management expressed a determination to address the team’s proposals for improvement and indicated a willingness to accept a follow up visit in about eighteen months.

# 1. LEADERSHIP AND MANAGEMENT FOR SAFETY

1.1. LEADERSHIP FOR SAFETY

The plant checks that managers are regularly in the field to assess and discuss conduct of work and compliance with management expectations and objectives. Walk downs in the field for senior and line managers are planned and monitored in a logbook and feedback on the results is provided. The managers and leaders demonstrate shared values and expectations, and support attitudes and behaviours that result in a sustainable safety culture. The team observed reinforcement of expectations regarding use of Personal Protection Equipment (PPE), coaching and adherence to rules. The process to foster the expectations through the whole organization is precisely monitored and personnel demonstrating exemplary behaviours are rewarded. However, the team also observed that expectations are not always well-known, understood and consistently reinforced. The team made a recommendation in this area.

The senior management team communicates the integrated policy, safety objectives and goals to staff and interested parties. Regular meetings with senior management regarding safety are held (meetings are monitored in compliance with the plant’s ‘ethical guide’) and other communication methods are used such as posters, booklets, intranet pages and induction training. The team observed regular briefings made in the field by management to support and reinforce the safety policy, goals and objectives in day-to-day activities. However, the senior management level does not always proactively address identified challenges to continuously improve the safety and reliability of the plant. The team made a suggestion in this area.

Managers and leaders use feedback on safety performance within their area of responsibility and share this information across the organization to ensure continuous improvement. Recognition for good results and good performance is given regularly. Safety culture thinking sessions take place between staff and the plant Director. Open discussion is encouraged during this these sessions. The coaching of line managers by a senior manager is used to clarify expectations and demonstrate a strong commitment to nuclear safety. The plant Director encourages his team to promote the use of feedback within the whole organization and the quantity and quality of the feedback is assessed. The ‘Operational Technical Decision’ meeting on technical issues related to safety is an opportunity to share important decisions before implementation. Records of this meeting contain events, scenarios and decisions.

1.2. INTEGRATED MANAGEMENT SYSTEM

The project for implementation of an Integrated Management System (IMS) is in progress, being monitored and deployed with the support of an external consultant. A programme of training in the processes is complete, including risk assessment. The integrated policy is established without major key indicators, resulting in some lack of integration and difficulty to assess efficiency.

1.4. DOCUMENT AND RECORD MANAGEMENT

The control of documentation, records and reports is established and implemented in accordance with the plant procedure ‘Instruction for incoming control’. The issue, validation, approval, dissemination, review and periodic updating of documentation, records and reports is made in conformity with the plant procedures ‘Procedure for life cycling Technical documentation’, ‘Instruction for update, cancel, and destruction of documentation’, ‘Instruction for registering and storage of documentation’. The management of documents is meets international standards.

1.5. INTERFACES AND RELATIONSHIPS

For all modifications needing organizational change or the adaptation of human resources the approval of NPPD is mandatory. The plant’s procurement process takes into account the financial effects of changing expectations, for example in the case of the new integrated policy. Communication with the public and other interested parties about the operation of BNPP-1 and any notable events are made. Information regarding environment effects is provided to the public by the regulator.

1.6. GRADED APPROACH

The site understands and uses a graded approach in various areas such as:

* Implementing the Systemic Approach to Training.
* Decision making process and use of external resources, in different fields if necessary.
* Temporary modifications.
* Identification of jobs and tasks important to safety and which are subject to complementary psychological assessment.
* Psychological assessment of certain personnel (which the team recognized this as a good practice).

1.7. HUMAN FACTORS MANAGEMENT

Assessment and monitoring is made about expected behaviours resulting in continuous improvement and this has been correlated with an observed decrease in human error direct cause in events. The team encouraged the plant to not consider human error as a root cause.

1.8. CONTINUOUS IMPROVEMENT/LEARNING ORGANIZATION (MONITORING AND ASSESSMENT)

The plant uses self-assessments, internal and national assessment by NPPD and regulatory representatives, and also by WANO or using other assessments required for ISO certifications such as 9001, 14001 45001). The team encouraged the plant to organize benchmarks on a regular basis to keep informed of current best practices.

Regarding contractual requirement between NPPD and BNPP all external or independent corrective actions must be implemented with due diligence. The organization checks that managers are aware of the results of audits and oversight monitoring activities, and use the results of those activities to improve safety. The weak points identified by the previous assessment are ‘Problem identification and resolution’; ‘Management accountability’; ‘Continuous improvement learning’; and ‘Work process’. The team encouraged the plant to further focus on improving these areas.

1.9 SAFETY CULTURE

A strong safety culture is composed of many attributes that collectively demonstrate the approach to promoting a safe working environment within an organisation. The IAEA promotes 5 broad safety culture characteristics:

1. leadership for safety is clear,
2. accountability for safety is clear,
3. safety is integrated into all activities,
4. safety is a clearly recognized value, and
5. safety is learning driven.

During the OSART mission, the overall experience of the team was utilized to capture those behaviours, attitudes and practices that characterize the safety culture in place at the plant. The team identified many facts related to strengths and weaknesses in performance potentially affecting safety culture that could assist management to improve safety culture at the plant.

With respect to observed strengths, the team identified that the plant management has demonstrated a strong willingness to understand how safety could be improved through the OSART process in comparison with WANO peer review [1]. The team also noted strong relationships between BNNP-1 and TSOs to ensure services related to plant safety are available. In addition, the team noted examples where leaders and managers coached individuals to enhance their performance [1], [4].

There are attributes that the team believed could be strengthened to improve the overall safety culture and safety performance at the plant. The team observed several cases of human behaviour deficiencies not being promptly identified and challenged, for example in fire safety issues in the field [1], [2], [4]. The team also noted that the operating organization did not always address operating experience in time to prevent repeat events [1], [5]. Finally, the team encouraged the senior management team to create and communicate a compelling long-term vision for improving safety in the operating organization [1], [2], [3], [4], and encourage plant personnel to take more accountability for day to day compliance [2], [4].

**DETAILED LEADERSHIP AND MANAGEMENT FOR SAFETY FINDINGS**

1.1. LEADERSHIP FOR SAFETY

**1.1(1) Issue**: The senior management level does not always proactively address identified challenges to continuously improve the safety and reliability of the plant.

The team noted the following:

* The Integrated Management System is not yet fully implemented.
* The Ageing Management Programme does not include all critical systems.
* Severe Accident Management Guides are not yet available.
* The plant does not have an integrated planning system covering all testing and maintenance activities for the entire organization.
* Concerning the setting and monitoring of Key Performances Indicators (KPI), the team observed:
	+ The Process for key indicators does not integrate the need for leading indicators that improve foresight seeing and efficiency.
	+ Plant key safety indicators do not include an indicator for monitoring event recurrence.
	+ The indicators for the quality of maintenance and the effectiveness of the work management process, are not discussed at senior management level.
	+ There is no KPI related to contamination events of personnel in the set of KPIs discussed at senior management level.
	+ Leading performances indicators for monitoring operating experience performance have not been fully established.

Without a proactive approach to identified challenges, the senior management level might miss opportunities to improve the safety and reliability of the plant.

**Suggestion**: The senior management level should proactively address identified challenges to continuously improve the safety and reliability of the plant.

**IAEA Bases:**

GSR Part 2

4.3. Goals, strategies, plans and objectives for the organization shall be developed in such a manner that safety is not compromised by other priorities.

4.4. Senior management shall ensure that measurable safety goals that are in line with these strategies, plans and objectives are established at various levels in the organization.

SSR 2/2 Rev. 1

4.35. Monitoring of safety performance shall include the monitoring of: personnel performance; attitudes to safety; response to infringements of safety; and violations of operational limits and conditions, operating procedures, regulations and licence conditions. The monitoring of plant conditions, activities and attitudes of personnel shall be supported by systematic walkdowns of the plant by the plant managers.

**1.1(2) Issue**: Management expectations are not always consistently reinforced in the field to ensure their understanding and implementation by the plant personnel and contractors.

The team noted deviations for management expectations in the following areas:

* Radiation protection (See Radiation Protection 7.3);
* Material condition (See Maintenance 4.6);
* Housekeeping, industrial safety, personal behaviour.

Without management expectations sufficiently reinforced in the field, they might not be fully understood and implemented by the plant personnel and contractors.

**Recommendation**: The reinforcement of management expectations in the field should be enhanced to ensure they are fully understood and implemented by the plant personnel and contractors.

**IAEA Bases:**

GSR Part 2

3.3. Managers at all levels in the organization: (a) Shall encourage and support all individuals in achieving safety goals and performing their tasks safely.

SSR-2/2 Rev. 1

4.35. Monitoring of safety performance shall include the monitoring of: personnel performance; attitudes to safety; response to infringements of safety; and violations of operational limits and conditions, operating procedures, regulations and license conditions. The monitoring of plant conditions, activities and attitudes of personnel shall be supported by systematic walk downs of the plant by the plant managers.

NS-G-2.4

3.6. The operating organization should establish high performance standards for all activities relating to safe operation of a plant, and should effectively communicate these standards throughout the organization. All levels of management should promote and require consistent adherence to these high standards. Management of the operating organization should foster a working environment that encourages the achievement of high standards in safe operation of the plant

# 2. TRAINING AND QUALIFICATIONS

2.1. ORGANIZATION AND FUNCTIONS

The Department of Human Resources and Training Centre is under the authority of the Managing Director, and the Head of the department reports directly to him. The number of staff in the Human Resources and Training Centre is currently 59 with training services from contractors. Most of the Human Resources and Training Centre staff are classified as experts or technicians; the difference is that some tasks require higher level (Degree level) technical knowledge; others, such as planning or scheduling of training do not. Internal and external technical organizations provide special training for certification of BNPP personnel.

The goals and objectives of the plant training are set by NPPD in the field of human resources with inputs from the plant. Examples of goals are: the requirement to use the Systematic Approach to Training (SAT); monitoring of staff performance; developing skills and knowledge of staff; and focus on succession planning. The goals are reviewed every three years.

BNPP-1 Human Resources and Training Centre have applied a customized Systematic Approach to Training (SAT). The plant has implemented this makes extensive use of lessons learned from Job and Task Analyses (JTA) made by other NPPs and IAEA recommendations. The team considered this a good performance.

The plant has a Training and Qualification Steering Committee that take the lead in approving the development of training, including training needs analysis and identification of any external support. The committee meets to review training programmes and personnel training needs, performance of training activities, and also considers performance indicators, related to training programme implementation. The report includes corrective actions. All managers are responsible for assessing training needs in their own areas; some of them participate in classroom training and offer their experience. This participation is not systematically applied to ensure that all managers have monitored goals for attendance at training and the team encouraged the plant to ensure that the conduct of training is monitored and evaluated systematically by managers at all levels,.

2.2. QUALIFICATION AND TRAINING OF PERSONNEL

The procedures cover test item development, for the initial, enabling, and final examinations of BNPP staff.

The procedure ‘Technical Requirements for Test Items for Entry Level Tests and Final Exams’ also specifies the existence of a database with questions, for oral and written examinations. The procedure recommends developing, for each training objective and enabling training objective, test items for entry and final knowledge level control. After each course related to the authorization of licensed staff such as Control Room Operator (CRO) and Unit Shift Supervisor (USS), a written examination is performed. There are 11 courses required for CRO authorization. The final exam is oral and is conducted with the participation of NPP management and the regulatory body (INRA) management.

The plant has a succession plan for qualified instructors which considers movement and retirement of personnel. Instructors receive initial training and are assigned time in the field to retain and enhance their competence as instructors. Satisfying the demand for instructors is a Performance Indicator in the annual review report.

The plant ensures that each contractor has the necessary qualifications and training for the job performed, by requesting a set of documents, in accordance with national regulations. A file for each contractor is sent for approval to INRA.

The Human Resources and Training Centre has well equipped training facilities and classes, including a Full Scope Simulator (FSS), and laboratories that reproduce actual plant conditions for: chemistry, radiation protection, emergency preparedness and industrial safety. There is a procedure for control of the FSS configuration, and a procedure for the updating the hardware and software. At the FSS 39 exercise scenarios are used in examinations, including one for Station Black Out – total loss of power supply from external sources, turbo generator, and loss of emergency diesel generators. Up to 76 scenarios have been developed and are planned for verification.

The team observed two FSS exercises, including a drill for Emergency Response by a main control room (MCR) crew. Several concerns were raised about the manner in which the main control room licensed personnel reacted to alarms. The team made a suggestion that the plant should consider enhancing alarm response management in the simulator.

During a class for advanced training related to Design and Operation of Snubbers, the instructor displayed good teaching skills, a questioning attitude and promoted a good learning atmosphere. Technical reference materials, including drawings and video projector, were available to the trainees. Two mobile telephones held by trainees rang during the course class. There were no signs in classrooms to communicate management expectations for attending the training courses. The team encouraged the plant to set clear expectations regarding use of mobile phones during training.

Before and during simulator training, a plant psychology specialist made an evaluation of the performance and checked the medical and psychological records of the MCR staff, using a checklist. BNPP-1 has a procedure for this psychological evaluation. The team recognized this as a good practice.

2.3. RECORDS AND REPORTS

The training record-keeping facility comprises 2 rooms, one being a library, and the other a repository for personnel records and training programs, where only authorized personnel can enter. The personnel records include the personnel data and training results. There is a database for use by training personnel, with results of examinations, and the date of the next examination for reauthorization. The database also specifies the number and types of certificates held by each person. The training course database specifies for each course the applicable revision.

2.4. USE OF PSA AND PSR

There is a course titled ‘Nuclear Safety Assurance’ dedicated for personnel working in the Nuclear Safety Department and other related disciplines, which provides information related to the use of Probabilistic Safety Assessment results for determination of the plant safety status. In case of modifications to the installed equipment, or to plant documents, or any plant reference document, these modifications result in revisions to the training materials.

**DETAILED TRAINING AND QUALIFICATION FINDINGS**

2.2. QUALIFICATION AND TRAINING OF PERSONNEL

**2.2(1) Issue**: Alarm response management in the simulator is not sufficiently robust.

The team noted the following:

* For a number of alarms, the Control Room Operator (CRO) did not use the Signalization response procedure, and the response was done by memory.
* The response to panel alarms was delayed in several cases. Some alarms were observed promptly by the Unit Shift Supervisor who then notified the reactor operator(s).
* During refresher training of control room shift personnel, for a number of alarms, the CRO did not request the Alarm Response Procedure or Signalization Response Procedure.
* Several alarms were lit but no action was taken by the operators.

Without a robust alarm response management in the simulator, the diagnostic and teamwork skills of operators are not effectively strengthened.

**Suggestion**: The plant should consider implementing a more robust alarm response management in simulator training.

**IAEA bases:**

NS-G-2.8

5.17. Control room operators should also be trained in plant diagnostics, control actions, administrative tasks and human factors such as attitudes and human–machine and human–human (teamwork) interfaces. Shift supervisors should additionally be trained in supervisory techniques and communication skills. Their training should, in general, be more broadly based than that of other operators.

**2.2(a) Good Practice**

Application of medical and psychological ‘fitness for duty’ examinations in the recruitment and examinations of personnel with tasks important for nuclear safety.

The objective of the medical and psychological ‘fitness for duty’ reviews in the recruitment and examination of plant personnel with positions and tasks important for nuclear safety (such as main control room staff and some management positions), is to acquire and maintain competent human resources for ensuring the safety of the plant. The psychological examinations are designed and performed so that competencies needed in these positions are confirmed with different psychological examinations and tools, and measured by international standards. The assessment includes: test of cognitive abilities using test of vital signs of the central nervous system; various methods to test non–verbal intelligence, reaction time, sustained attention, distance, time estimation and attention; personality dimensions and compatibility of these with the job; and determination of psychological health.

Benefits:

* Assessment of abilities, personality traits and behaviours
* High validity, minimizing errors, accurate measurement of response time of the candidates
* Comparison of individual's result with normal results, and with each other, for use in deciding optimal shift crew composition, considerations for promotion and succession planning
* Enhanced organization of workshops on safety culture using the results of psychological examinations
* Development of personal psychological interventions and cognitive rehabilitation

# 3. OPERATIONS

3.3. OPERATING RULES AND PROCEDURES

The plant has implemented effective arrangements to ensure that the Operating Limits and Conditions (OLC) are understood and followed by the MCR staff. All entries into OLC are properly logged by the operators. The surveillance programme covers all safety systems and clear acceptance criteria exist.

There are numerous graphics, parameters and maps in the operating procedures (OP) to support operators in their activities. A color-coding system is used to divide operational procedures into relevant groups for ease of use. All the necessary procedures are accessible at all operational work places. The team identified some deficiencies related to OP, such as an incomplete diesel generator field operator check-list and an unauthorized operator aid on a safety related chiller. The team encouraged the plant to improve the operating procedures.

The team observed, during emergency training, that plant management regularly briefed main control room (MCR) personnel regarding Safety Culture, the priority of safety, the Stop-Think-Act-Review (STAR) principle and team work. The team considered this a good performance.

3.4. CONDUCT OF OPERATIONS

The plant has achieved many positive results in the conduct of operations. Additional personnel are provided to mitigate operators' load during scheduled outages. First line supervision and managerial walk-downs are conducted to ensure that plant conditions are meet expectations. However, the team identified several cases when adverse conditions of equipment were not previously identified or recorded. It is expected that equipment is labelled and any deficiencies recorded in logbooks. However, the team found 15 missing labels, unrecorded. The team made a suggestion in this area.

The plant’s shift personnel perform regular walkdowns according to specific operational procedures. These procedures define the scope and frequency of the walkdowns, and how results should be documented. Based on these procedures walkdowns routes and checklists are developed, based on the safety significance of possible failures of systems and equipment. However, there is no uniform approach to the development of the walkdowns procedures and checklists, nor in the scope of control or expectations for recording the results. The walkdown procedures have different names, different statuses in the documentation hierarchy and a different relation to management processes. The team encouraged the plant to improve these procedures.

3.6. FIRE PREVENTION AND PROTECTION PROGRAMME

The plant has implemented a comprehensive fire protection programme. The organizational chart of the plant for fire safety provides management and control of fire safety issues. The roles and responsibilities are defined. However, during the review, weaknesses were observed by the team regarding operation and maintenance of fire doors and unsealed penetrations as fire barriers. The team made a recommendation in this area.

Based on operating and maintenance experience the plant has designed an Automatic Fire Protection System (AFPS) simulator. The main objectives of the simulator are to facilitate detection of AFPS equipment defects, perform incoming controls and acceptance tests of components and spare parts and help train operating and maintenance personnel. The team recognized this as a good practice.

The plant has established a continuing training programme for the residents of the camps and settlements near the plant in order to familiarize and educate them regarding fire safety. This programme includes fire safety training and instructions for the use of fire extinguishing equipment. Another objective of this training programme is minimizing the risk of fire in the neighbourhood of the plant. The team considered this a good performance.

The plant was not able to present the team with a fire hazard analysis report, but instead referred to the FSAR (Final Safety Analysis Report). The FSAR sections containing the results and conclusions of hazard analysis have been presented. Based on interviews with responsible officials, NPPD as the operating organization is responsible for all safety analyses, including fire hazards analyses, which should be reviewed as part of Periodic Safety Review in 2023. In accordance with NNSD` regulation ‘General Safety Regulation for Nuclear Facilities and Activities’ (requirement 32 i.32.2) Periodic Safety Review ‘*shall be performed periodically, at least every ten years*’. According to IAEA Safety Guide SSG-25, hazard analyses, including fire hazard analyses, are one of the safety factors which should be reviewed as part of Periodic Safety Review. However the ‘Long term modification programme for BNNP’ 1420 – LTS - 05 contains only one activity regarding Periodic Safety Review: Ageing. The NPPD plans to carry out the Periodic Safety Review were not been demonstrated to the team and it was unclear who will be responsible for performing or reviewing the hazard analysis. The team encouraged the plant to resolve this.

**DETAILED OPERATIONS FINDINGS**

3.4. CONDUCT OF OPERATIONS

**3.4(1) Issue:** Management expectations for the identification and reporting of deficiencies are not always followed in the field.

The team noted the following:

Labelling

* Missing label on a turbine electrical box at turbine hall 15.25m,
* Missing label on a pressure gauge at turbine hall 8.30m in room 1ZF-04.21/3,
* 2 missing labels on valves belong to low pressure air pipeline in room ZF07.12-F07.58,
* Missing label on valve belongs to hot water system UW-16 pipeline at turbine hall,
* Missing label on intermediate cooling system VH25S002 at turbine hall,
* Missing label on intermediate cooling system VH12S001 at turbine hall,
* Missing label on intermediate cooling system valve before VH40S001 at turbine hall,
* 7 missing labels on hot water system UW pipelines at turbine hall -6m.

Indicate equipment status

* Gauge low pressure steam10RA30P511 read 0 bars because the gauge was isolated. The field operator opened the valve, and revealed a coupling leak. This problem had not been reported in the logbook,
* Gauge 10SH73P501 read too high pressure - over the maximum 250 kPa. It was reported earlier, but had not been tagged,
* UV62S457 has a partly damaged thermal insulation which was not tagged.
* The oil level in the bearings of safety related spent fuel pool pump TH18D001 (1. safety train, 2. safety class) was not visible (possibly too full or too empty). This defect had not been reported.

Housekeeping

* A bolt, washer and other discarded object on the floor in Fyrquel oil tank room at turbine hall +6.50m,
* There are discarded bolts under the pump UD55D001.

Without adequate attention to the identification and reporting of deficiencies operational safety could be jeopardized.

**Suggestion:** The plant should consider reinforcing the management expectations for identification and reporting deficiencies in the field.

**IAEA Basis:**

SSR 2/2 Rev. 1

7.10. Administrative controls shall be established to ensure that operational premises and equipment are maintained, well lit and accessible, and that temporary storage is controlled and limited. Equipment that is degraded (owing to leaks, corrosion spots, loose parts or damaged thermal insulation, for example) shall be identified and reported and deficiencies shall be corrected in a timely manner.

NS-G-2.14

4.36. Deterioration in material conditions of any kind, corrosion, leakage from components, accumulation of boric acid, excessive vibration, unfamiliar noise, inadequate labelling, foreign bodies and deficiencies necessitating maintenance or other action.

4.49. The shift crews should routinely monitor the conditions of systems and components and should record appropriately the plant status and parameters and all automatic or manual acts. Every change in the status of systems or components should be appropriately documented and should be communicated to the main control room in a timely manner.

5.1. A consistent labelling system for the plant should be established, implemented and continuously maintained throughout the lifetime of the plant. It should be ensured that the system is well known by the staff. The system should permit the unambiguous identification of every individual component in the plant. In addition to the labelling of plant components, labelling of the doors and compartments of the plant should be regarded as part of the same system.

3.6. FIRE PREVENTION AND PROTECTION PROGRAMME

**3.6(1) Issue**: The plant measures for fire prevention and mitigation are not always fully implemented to ensure the safety of personnel, plant safety and reliability.

The team noted the following:

* One out of two emergency exits to the stairwell from 2nd floor of ZU10 was found locked.
* Throughout the mission a significant number of deviations related to fire doors was observed:
	+ Plant personnel passing through open fire doors did not close them.
	+ In the EDG 1 building, although handles of two fire doors were in the closed position; both fire doors were opened (5-6 cm) (instructions say the fire doors must be closed and locked).
	+ In a diesel generator building, both of the double fire doors at the entrance were found opened without any plant personnel in the area.
	+ At the entrance of the RCA, the fire door did not close due to a malfunction.
	+ At locations ZY-03.29 and ZC-08.53, two fire doors did not close automatically.
	+ Some fire doors did not to have gaskets; that would inhibit the spread of smoke.
* In the turbine hall, there was no seal against the propagation of a fire in a penetration through the wall of room 1ZF-02.22a which house a tank containing ‘Fyrquel®’ hydraulic fluid.
* Two penetrations through the wall of room ZY-03.07/2 were not sealed to inhibit the propagation of fire.
* In the EPD calibration room ZC2-405, a penetration through the wall of this room had been open for over a month, decreasing the level of protection against the propagation of a fire.

Without rigorous implementation of fire prevention and mitigation measures, the safety of personnel and plant reliability may be compromised.

**Recommendation**: The plant should ensure rigorous implementation of the fire prevention and mitigation to ensure the safety of personnel and plant reliability.

**IAEA Bases:**

SSR 2/2 Rev. 1

5.21. The arrangements for ensuring fire safety made by the operating organization shall cover the following: adequate management for fire safety; preventing fires from starting; detecting and extinguishing quickly any fires that do start; preventing the spread of those fires that have not been extinguished; and providing protection from fire for structures, systems and components that are necessary to shut down the plant safely. Such arrangements shall include, but are not limited to:

(a) Application of the principle of defence in depth;

(b) Control of combustible materials and ignition sources, in particular during outages;

(c) Inspection, maintenance and testing of fire protection measures;

(d) Establishment of a manual fire fighting capability;

(e) Assignment of responsibilities and training and exercising of plant personnel;

(f) Assessment of the impact of plant modifications on fire safety measures.

NS-G-2.14

4.36. Factors that should typically be noted by shift personnel include:

* Deviations in fire protection, such as deterioration in fire protection systems and the status of fire doors, accumulations of materials posing fire hazards such as wood, paper or refuse and oil leakages, or industrial safety problems such as leakages of fire resistant hydraulic fluid, hazardous equipment and trip hazards;

7.2. The comprehensive work control system should cover any authorizations, permits and certificates necessary for ensuring safety in the work area and for preventing work activities from having undue effects on safety. The following specific matters should be considered:

* Control of fire hazards;

**3.6(a) Good practice**

Based on operating and maintenance experience the plant has designed an Automatic Fire Protection System (AFPS) simulator. The main objectives of the simulator are to facilitate detection of AFPS equipment defects, perform incoming controls and acceptance tests of components and spare parts and help train operating and maintenance personnel. The team recognized this as a good practice.



*Figure 1: Simulator of AFPS for BNPP*

# 4. MAINTENANCE

4.1 ORGANIZATION AND FUNCTIONS

There is a clear structure in management procedures describing the maintenance process and requirements. Maintenance personnel are aware of their roles, responsibilities and the associated risks.

4.2. MAINTENANCE FACILITIES AND EQUIPMENT

The plant has established a customized system for controlling the circulation of tools, in accordance with the technical requirements and needs of the plant, to comply with the Foreign Material Exclusion (FME) requirements. The plant has allocated 13-digit barcodes to tools and engraved them on tools, providing all specifications and allowing their use to be tracked. Furthermore, the plant uses FME checklists rigorously before and after maintenance activities, ensuring material accounting. The team considered this as a good performance.

4.6. MATERIAL CONDITIONS

The team noted several deficiencies regarding corrosion and leakage, as well as degraded, deficient or worn-out material conditions, such as cable sheaths, thermal insulation and pipes containing chemicals. The team made a suggestion in this area.

4.7. WORK CONTROL

BNPP-1 has adopted a regime including preventive, corrective and predictive maintenance. However, the plant does not have an integrated long-term planning process covering all testing and maintenance activities for the entire organization. This could allow conflicting execution of tests or maintenance activities on safety related equipment, as well as to the simultaneous execution of tests and/or work orders in different safety trains. This also makes it more difficult for Operations to maintain a good overview of the availability of safety related equipment at all times. The team encouraged the plant to establish an integrated work management process to prevent such safety breaches.

The plant is developing a set of key performance indicators (KPI), to be able to monitor the quality of maintenance work and the effectiveness of the work management process. However, at the time of the review in October 2018, only 6 of the 14 planned KPIs were defined and implemented. The KPIs already implemented that give a good indication of the quality of maintenance activities and the effectiveness of the work management process (compliance with preventive maintenance planning, maintenance rework, ratio of corrective maintenance to planned activities) are not monitored at senior management level. The team encouraged the plant to further develop the necessary KPIs in the maintenance and repair domain, and to implement and monitor leading performance indicators on maintenance quality and work management effectiveness at senior management level.

An extensive training and qualification programme for all maintenance personnel is in place. An individual work passport is issued to every worker, containing all applicable qualifications necessary to perform assigned tasks. The team observed that the completeness and validity of these qualifications was verified before the start of maintenance activities. The team considered this a good performance.

**DETAILED MAINTENANCE FINDINGS**

4.6. MATERIAL CONDITIONS

**4.6(1) Issue:** The plant’s arrangements for monitoring material condition do not always ensure that degradation is identified, reported and corrected in a timely manner.

The team noted the following:

Corrosion:

* Corrosion was visible on piping containing cooling water in radiation measurement equipment at the ZC-09.82 room.
* Corrosion was visible on surface of a flange of pipework used to transfer sulphuric acid and sodium hydroxide from delivery vehicles to tanks inside building ZG.1
* Corrosion was observed on the drain pipe of the UF ventilation system, caused by sulphuric acid liquid spills.
* Corrosion was observed under the condensate sampling cabinets in the main turbine hall basement.
* An unpainted and rusty surface was observed at the compensator of pipeline number 02.03.01 in the radiological controlled area.

Leakage:

* Three leaks caused by condensate induced corrosion were observed in the radiological controlled area (ZC-06.35).
* Several leaks were observed in the area of UW-16 pipeline (ZF).
* Traces of oil observed in the area of Turbine bearing oil tank sampling point (F04.21, ZF/SC21S104)

The team also noted the following:

* The plant’s diesel generator (DG) control centre is cooled by an additional air conditioning UV45D677. At the connection point, the electrical cable is missing a part of its jacket.
* One of the electrical cables associated with the protection system of diesel generator is GY11D402 is heavily worn.
* Several devices for measuring the X and Y displacements in the main turbine hall have missing pointers.
* The thermal insulation close to the valve SN40S810 in the main turbine hall was degraded.
* At the high-pressure turbine in the main turbine hall, several conduits were not properly fastened.

Without adequate arrangements for monitoring the material condition, the identification, the reporting and the correction of degradation may not happen in a timely manner.

**Suggestion:** The plant should consider enhancing the arrangements for monitoring material condition to ensure that degradation is identified, reported and corrected in a timely manner.

**IAEA Bases:**

SSR-2/2 Rev. 1

7.10. Administrative controls shall be established to ensure that operational premises and equipment are maintained, well-lit and accessible, and that temporary storage is controlled and limited. Equipment that is degraded (owing to leaks, corrosion spots, loose parts or damaged thermal insulation, for example) shall be identified and reported and deficiencies shall be corrected in a timely manner.

NS-G-2.6

10.2. The systems and components of the plant should be examined for possible deterioration so as to assess whether they are acceptable for continued safe operation of the plant or whether remedial measures should be taken. Emphasis should be placed on examination of the pressure boundaries of the primary and secondary coolant systems, because of their importance to safety and the possible severity of the consequences of failure.

# 5. TECHNICAL SUPPORT

5.1. ORGANIZATION AND FUNCTIONS

Although there are several areas where design knowledge and expertise is acquired and maintained by the in-house (internal) TSO (for example core design, in-service inspection and probabilistic safety analysis), the team identified an issue regarding the sufficiency of design knowledge and expertise within the operating organization. The main areas of concern were noted as:

* Provision of daily technical advice and guidance to operations, to ensure safe and reliable operational decisions;
* Provision of urgent technical assessments, advice and guidance during off-normal operations, particularly for event evaluations and accident assessments;
* Taking prompt compensatory measures (e.g. technical solutions, temporary physical or administrative changes in accordance with the design basis) that could be put in place to establish or restore satisfactory system, structure and component (SSC) status and condition of affected SSCs;
* Requesting, acquiring, interpreting and applying design services from external technical support organizations as an informed customer.

The team made a suggestion to consider enhancement of in-house technical support in these areas.

The internal TSO prepares and maintains job descriptions for each engineer/scientist. This also includes their responsibilities for activities outside normal operations in addition to those for normal duties. This ensures adequate technical advice is available during outside normal operations, such as refuelling and maintenance outages. The team noted this as a good performance.

5.4. AGEING MANAGEMENT

A plant ageing management programme (AMP) for ten critical systems has been established and will be implemented once all aspects and roles responsibilities are well communicated throughout the organization. However the scope of a typical AMP in the nuclear power industry is broader than those ten critical systems in the plant’s current AMP scope. The team encouraged the plant to consider broadening the scope of AMP to other systems that may include critical plant assets as well as safety systems.

5.6. SURVEILLANCE PROGRAMME

The plant’s ISI/NDE/NDT/DT programme is recognized by the team for its well-established capabilities, including its self-sufficient high-level expertise and qualified staff, as well as a comprehensive research and development department to design and manufacture tools and develop new methods. The team recognized the breadth and scope of the programme as a good practice.

5.7.PLANT MODIFICATION SYSTEM

The plant’s modification (also known as ‘modernization’) process follows two main procedures: one for permanent modifications (based on IAEA’s NS-G-2.3 and Technical Report Series (TRS) No. 317 guidance) and another for temporary modifications. A graded approach is used and temporary modifications do not have the same requirements as permanent modifications which may result in deficiencies in implementation of temporary modifications. The team encouraged the plant to consider treating temporary modifications in a similar manner to permanent modifications regarding the assessment of safety significance, including the assessment of cumulative effects, as suggested by the IAEA guidelines and technical and programmatic reports.

The team also noted that the plant’s equipment qualification process relies on the initial qualifications that were established by the responsible designer at the design stage. This process does not include a programmatic approach to upgrade, preserve and review equipment qualification within (and by) the operating organization. The team encouraged the plant to consider establishing an in-house equipment qualification programme that is based on the IAEA guidelines and technical and programmatic reports.

**DETAILED TECHNICAL SUPPORT FINDINGS**

5.1. ORGANIZATION AND FUNCTIONS

**5.1(1) Issue:** The knowledge and expertise within the operating organization regarding the plant design is not always sufficient to provide compelling technical advice and ensure that external TSO (Technical Support Organization) have delivered appropriate information related to safety.

Although there are several areas where the design knowledge and expertise is acquired and maintained by the internal technical support organization (for example core design, in-service inspection, and probabilistic safety analysis), the team observed the following:

* The responsible designer(s) have not turned over the design calculations nor their associated elements (such as design inputs and assumptions, applicability range of methods and tools, and elaboration of results) to the operating organization. Rather, the operating organization possesses only the operational limits, conditions and procedures that were derived from the design calculations. The lack of access to design calculations limits the capability of in-house engineers to understand and question the design.
* All technical support activities concerning the design calculations and other design activities of Safety Class 2 and 3 system, structures and components (SSCs) are outsourced to the responsible designers which requires sufficient expertise and knowledge to review and approve their deliverables.
* The equipment qualification process relies on the initial qualifications that were established by the responsible designer at the design stage, and there is no formal and programmatic approach to upgrade, preserve and review equipment qualification within the operating organization.
* The internal expertise and experience for developing ageing management programme and examination of the underlying design knowledge is limited. Therefore, a third-party review for adequacy and completeness check was needed.

Without the required knowledge and expertise and in-house technical decisions and assessments of external TSO products might not be suitable to ensure plant safety.

**Suggestion:** The plant should consider enhancing its in-house efforts and expertise regarding the design to ensure that its technical advice and information from external TSO is appropriate for plant safety.

**IAEA Bases:**

SSR-2/1 Rev. 1

3.6. The formally designated entity shall ensure that the plant design meets the acceptance criteria for safety, reliability and quality in accordance with relevant national and international codes and standards, laws and regulations. A series of tasks and functions shall be established and implemented to ensure the following:

[…] (f) That the necessary engineering expertise and scientific and technical knowledge are maintained within the operating organization; […].

* 1. The management system, as an integrated set of interrelated or interacting components for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective manner, shall include the following activities:

[…] (f) Design integrity, which includes maintaining a formally designated entity that has overall responsibility for the continuing integrity of the plant design throughout its lifetime, and managing the interfaces and lines of communication with the responsible designers and equipment suppliers contributing to this continuing integrity [Ref. 2, SSR-2/1].

5.6. SURVEILLANCE PROGRAMME

**5.6(a) Good practice:** Establishment of the in-house Research and Development Team and the Assessment Approval Committee for non-destructive and destructive examinations, failure analyses, as well as design and manufacturing of robots to be used in surveillance and recovery activities.

**Benefits:** The following activities by the Research and Development Team support the plant’s operational safety:

* Rapid initial study of potential causes of various defects and failures for any equipment.
* Provision of scientific conclusions and technical reports on the root causes of failures and sharing the identified issues and findings with other institutions and universities for further study and potential research.
* Establishment of a common platform and language between universities, institutes and non-nuclear industries.
* Studies of operational experience of other nuclear power plants and starting projects with cooperation from academia and institutions to explore appropriate measure against the possibility of similar events.
* Conceptualize, propose, design and cooperate with the companies that manufacture inspection equipment which are suitable for use in BNPP conditions. For example, a robotic vehicle was manufactured for inspection within the spent fuel pool and reactor vessel and another for the search and recovery of parts that fall into the primary circuit.

# 6. OPERATING EXPERIENCE FEEDBACK

6.1. ORGANIZATION AND FUNCTIONS

All personnel, including managers and contractors, are systematically trained on the reporting and use of operating experience. Management expectations and specific issues related to operating experience are delivered to the staff through extensive initial and annual continuing training. In addition, a significant number of professional staff, as well as managers, have been trained on investigation techniques. The team considered this as a good performance.

6.2. REPORTING OF OPERATING EXPERIENCE

The plant has recently implemented an intranet based software named ‘OPEX’ to manage event reporting, screening, tracking of corrective actions, dissemination and use of operating experience. This new system facilitates reporting of all types of issues and is accessible to all plant personnel. The analysis reports of internal as well as external operating experience are readily available for easy access and use. Moreover, the system enables a systematic verification of the use of operating experience by relevant personnel. Currently, the system is being populated with previous operating experience information.

6.3. SOURCES OF OPERATING EXPERIENCE

The major source of information about external operating experience is WANO Moscow Centre. At the time of the mission, the plant did not have access to the IAEA International Reporting System for Operating Experience.

Operating Experience sources include feedback from operators of conventional plants in the country. This feedback facilitates performance improvement by BNPP-1, especially in conventional areas like electrical systems or turbine-generators.

6.5. INVESTIGATION AND ANALYSIS

All significant events (classified at the plant as perturbations and deviations) and low-level events are investigated using ASSET methodology which is no longer supported by the IAEA. Several workshops and technical support missions have been organised, with the support of WANO and IAEA, to improve the quality of event investigations. In collaboration with Rosenergoatom, the plant is currently implementing an extensive project to introduce a new investigation methodology, together with its technical support organisation TAVANA.

Although improvements in the management of near misses have been made, the existing trend analysis methods are not sufficient to enable timely identification of deteriorating performance and associated corrective actions. The team encouraged the plant to continue improving the management of near misses by adopting a comprehensive trending process.

6.6. CORRECTIVE ACTIONS

Corrective actions resulting from analyses of operating experience are developed and approved by the relevant investigation committee. In some of the reviewed event reports, organizational factors contributing to human errors and the extent of the problem were not addressed with appropriate and timely corrective actions. Corrective actions are tracked to completion by the operating experience group and their status is reported to management on a weekly basis. At the time of the mission, several corrective actions were found to be implemented with a significant delay since the event occurrence. The team made a recommendation in this area.

6.9. EFFECTIVENESS REVIEW OF THE OPERATING EXPERIENCE PROGRAMME

The overall self-assessment strategy at the plant includes detailed semi-annual surveys with broad participation of the plant staff; departmental self-assessments performed by multidisciplinary teams; and annual statistical reports and corporate assessments resulting in a number of important improvements of Operating Experience programme effectiveness. However, current performance indicators in this area are only lagging. The team encouraged the plant to adopt more leading performance indicators, for example reporting of near misses by individual departments, average age of event investigations, average age of near misses or status of corrective actions taken to low level events.

6.10.USE OF PSA AND PSR

Significant plant events are evaluated using a PSA model. The use of PSA based on event analysis provides a numerical value for the risk significance of an operational event. It is also used to increase the understanding of the plant vulnerabilities given the event occurrence. The team considered the use of PSA in event investigation process as a good performance.

**DETAILED OPERATING EXPERIENCE FINDINGS**

6.6. CORRECTIVE ACTIONS

**6.6(1) Issue:** some of the plant’s arrangements for adequacy of corrective actions and their timely implementation are not sufficient to prevent occurrence of similar events.

The team noted the following:

* In two reviewed 2016 significant events, an error made by an individual was identified as a root cause. The organizational factors contributing to such errors were not evaluated in a sufficient manner. As an example, the organizational factors contributing to the human errors in the 2016 event ‘The spurious actuation of a boron injection pump’ were not evaluated in the event analysis report. These organizational factors could include work scheduling; personnel training on error reduction tools or human-machine interface.
* In several reviewed events, the corrective actions were implemented with a significant delay since their occurrence:
* An event with similar human performance deficiencies as those observed in the boron injection event occurred two years earlier. One of the corrective actions taken to address the root cause of the previous event was not completed at the time of event recurrence.
* Three significant events occurred at the plant in February 2018. The final investigation reports of those events were approved by the Investigation Committee in June 2018. Relevant operations staff were not familiarized with the reports until the end of September 2018.
* One of the corrective actions for the event ‘Disconnection of 400 kV lines because of fire in the area below the lines’ from September 2016 was to revise a procedure for dealing with failures of turbine systems. The deadline for the corrective action was in 2016. The procedure was revised at the beginning of October 2018.
* A corrective action to develop a procedure for monitoring neutron flux by both available ranges was taken in response to the event occurred in February 2018: ‘Reactor protection system actuation at minimal controlled power’. The corrective action was to address human performance issue identified in the event analysis; however, at the time of the mission in October 2018, briefing of relevant personnel about the lessons learned had not been done.
* In the reviewed event reports, the concepts of extent of cause and extent of condition were not consistently used to identify corrective actions preventing event recurrence in the same or similar systems and processes.

Without appropriate arrangements for adequacy of corrective actions, and their timely implementation, similar events can reoccur.

**Recommendation:** The plant should improve its arrangements for adequacy of corrective actions and their timely implementation to prevent occurrence of similar events.

**IAEA Bases:**

SSR 2/2 Rev. 1

5.30. As a result of the investigation of events, clear recommendations shall be developed for the responsible managers, who shall take appropriate corrective actions in due time to avoid any recurrence of the events. Corrective actions shall be prioritized, scheduled and effectively implemented and shall be reviewed for their effectiveness. Operating personnel shall be briefed on events of relevance and shall take the necessary corrective actions to make their recurrence less likely.

NS-G-2.11

2.5. The organization that operates a nuclear installation should maintain an effective system for the collection and analysis of operational experience and should promptly disseminate safety significant information among its own staff…

5.2. The development of recommended corrective actions following an event investigation should be directed towards the root causes and the contributory causes, and should be aimed at strengthening the weakened or breached barriers that failed to prevent the event. Personnel at nuclear installations are responsible for implementing corrective actions promptly and effectively.

5.5. A number of important factors should be taken into account when determining corrective actions. These should include the need for:
—Restoring or maintaining the desired level of nuclear safety;
—Addressing human and organizational factors;
—Considering the implications of the action for existing documentation and for operational aspects.

I.8 (4) The relevant corrective actions are implemented promptly enough to prevent the recurrence of similar events that could be caused by underlying root causes of the same category.

III.15. The analysis of events relating to human characteristics should include the causes and circumstances of any problems with human performance that contributed to the event…There may have been errors and human performance related issues in the areas of procedures, training, communication, engineering for human factors and the human–machine interface, management and supervision. The analysis should be sufficient to categorize the human performance issues…

GS-G-3.1

6.71 Senior management should ensure that corrective actions are subjected to approval, prioritized and completed in a timely manner on the basis of their significance. Managers should be held accountable for meeting due dates for corrective actions. Extensions or exceptions to due dates for completing corrective action should be controlled and should be made only in response to new issues of higher priority.

# 7. RADIATION PROTECTION

7.1. ORGANIZATION AND FUNCTIONS

There is a clear structure in management procedures describing the radiation protection process and requirements. Radiation Safety personnel are aware of their roles, responsibilities and the associated risks. However, at senior management level, there are no performance indicators regarding individual dose and personnel contamination events. The team encouraged the plant to develop and monitor leading performance indicators.

7.2. RADIATION PROTECTION POLICY

The Radiation Safety group holds a wide set of records, logbooks and procedures. The team evaluated these records, logbooks and procedures to be completely and correctly filled out and filed.

A training and qualification process for all radiation safety staff is in place; however, some recent developments in the industry might be missed. Therefore, the team encouraged the plant to seek out benchmarking opportunities on a regular basis to keep informed of current international best practices regarding radiation safety.

7.3. RADIATION WORK CONTROL

The team acknowledged that the collective dose and personal contamination events at the plant are relatively low. However, the team observed some deficiencies in the control of radiation and contamination. The plant does not always take the necessary measures to minimize the risks resulting from radiation exposure and contamination for the personnel. The team made a recommendation in this area.

The team observed the monitoring of the radiation and contamination levels, prior to the start of maintenance works, and considered this according to international standards.

Although the use of radiation work permits for works with significant radiation risk is well implemented, the team encouraged the plant to develop an integrated system to manage all tests and maintenance related activities.

The plant has developed a tool to display radiation and contamination levels in different locations of the Radiation Controlled Area (RCA). This information is available at the entrance of the RCA and on the plant’s intranet. The team considered this a good performance.

7.4. CONTROL OF OCCUPATIONAL EXPOSURE

The plant does not measure the isotopes that are present in the oxide layer at the inside of the pipes of all circuits with primary water and which contribute to the main source term for radiation exposure in the radiation controlled area. The team encouraged the plant to further investigate means to decrease the radiation source term.

7.5. RADIATION PROTECTION INSTRUMENTATION, PROTECTIVE CLOTHING AND FACILITIES

The Radiation Safety group of the plant includes a maintenance and repair group for all radiation monitoring equipment. The plant has taken action to develop tools to improve the effectiveness and thus also the collective dose for the functional testing of the online radiation monitoring system. The team considered this as a good performance.

The team observed some checklists that do not contain acceptance criteria. The team encouraged the plant to include these to improve quality control.

The team observed the activities of the radiochemistry laboratory, and considered the performance, knowledge and experience of its staff met international standards.

The plant’s health physics group provides all information related to individual exposures to all personnel via the internal intranet. The team considered this as a good performance.

7.6. RADIOACTIVE WASTE MANAGEMENT AND DISCHARGES

A robust control and measurement system for radioactive waste is installed at the plant, enabling most necessary operator actions to be carried out by remote control. The team considered this as a good performance.

The plant has developed a software tool to manage all aspects related to the production, inventory, measurement, storage and transport of all solid radioactive waste. The team considered this as a good performance.

The plant’s off-site environmental protection and monitoring laboratory succeeded in becoming a member of the ALMERA network (Analytical Laboratories for the measurement of Environmental Radioactivity), established by the IAEA. The team considered this as a good performance.

**DETAILED RADIATION PROTECTION FINDINGS**

7.3. RADIATION WORK CONTROL

**7.3(1) Issue**: The plant’s expectations and work practices related to radiation and contamination control do not always ensure that the risks for the personnel are minimized.

The team noted the following:

* The plant’s constraint for the yearly equivalent dose of the lens of the eye is – based on the prescription of the regulatory body – 150 mSv, whereas the prescribed equivalent dose limit according to ICRP and GSR Part 3 is 20 mSv per year, averaged over 5 consecutive years (100 mSv over 5 years) with a limit of 50 mSv in a single year.
* The daily dose limit for workers in the radiation controlled area (RCA) is 0.2 mSv and specifically for shift personnel 0.5 mSv. The measured average individual dose in the last quarter of 2017 and second quarter of 2018 (periods of normal operation) was 0.01 mSv, much lower than the defined dose constraints.
* The maximum yearly individual dose obtained in 2016 (2.48 mSv) and 2017 (4.33 mSv) is much lower than the individual exposure constraint determined by the plant (16 mSv), whereas the yearly limit imposed by the regulatory body is 50 mSv (with an investigation level of 6 mSv).
* The personal contamination monitors currently present at the exit of the radiation controlled area (RCA) do not monitor the whole body.
* Although contamination measurements are performed at the exit of the RCA, the plant does yet not have small item monitors for this purpose.
* The plant does not monitor the global α-activity in the primary water, to assess fully the contamination risk during work on components in contact with this water.
* There is no signage present either at the entrance or exit of the waste management control room to clarify the expectation on wearing protective equipment.
* There is no contamination check prior to entrance to the waste management control room, which is considered as clean, though entrance is possible from a potentially contaminated zone.
* The expectations for wearing gloves and other protective equipment in uncontaminated areas of the RCA are not clear, causing people to both wear and not wear gloves and other protective equipment in these areas.
* Hand and foot monitors are present at several places in the RCA; however, no clear barrier between the possible contaminated zone and the ‘clean’ side is present.
* One person was observed to still wear his protective equipment (gloves, mask and protective apron) in a ‘clean’ part of the RCA after taking a radioactive sample.
* The key performance indicators discussed at senior management level do not contain any leading indicators regarding radiation exposure and contamination of the personnel.
* For the clearance of materials or waste, the control of the absence of loose contamination is only performed after the direct gamma and beta radiation measurements.
* Upon leaving the RCA, the plant’s expectation is that personnel wash their hands prior to the first personal contamination measurement. Although several hand and feet contamination measurements are installed in the RCA, the plant might miss opportunities to detect loose hand contamination and remove the origin of that contamination.

Without clear expectations and the right work practices in the radiation controlled area, radiation dose or contamination events might not be minimized.

**Recommendation**: The plant should set and monitor clear expectations and work practices related to radiation and contamination control to ensure that the risks for the personnel are minimized.

**IAEA Bases:**

GSR Part 3

III.1 – For occupational exposure of workers over the age of 18 years, the dose limits are:
(b) An equivalent dose to the lens of the eye of 20 mSv per year averaged over five consecutive years (100 mSv in 5 years) and of 50 mSv in any single year.

2.42. The relevant principal parties shall establish and implement a protection and safety programme that is appropriate for the exposure situation. The protection and safety programme:
(b) Shall apply measures for protection and safety that are commensurate with the radiation risks associated with the exposure situation and that are adequate to ensure compliance with the requirements of these Standards.

3.77. Employers, registrants and licensees: (b) Shall establish and use, as appropriate, constraints as part of optimization of protection and safety.

3.90. Registrants and licensees:
(d) Shall establish measures for protection and safety, including, as appropriate, physical measures to control the spread of contamination and local rules and procedures for controlled areas.
(g) Shall provide, as appropriate, at exits from controlled areas:
(i) Equipment for monitoring for contamination of skin and clothing;
(ii) Equipment for monitoring for contamination of any objects or material being removed from the area;

RS-G-1.1

4.1. Optimization of protection needs to be considered at all stages of the life of equipment and installations, in relation to both normal and potential exposures. As a consequence, all situations — from design, through operation to decommissioning and waste management — should be considered in the optimization procedure.

4.20. Dose constraints should be used prospectively in optimizing radiation protection in various situations encountered in planning and executing tasks, and in designing facilities or equipment. They should therefore be set on a case-by-case basis according to the specific characteristics of the exposure situation.

4.21. The process of deriving a dose constraint for any specific situation should include a review of operating experience and feedback from similar situations if possible, and considerations of economic, social and technical factors. For occupational exposure, the experience with well managed operations is of particular importance in setting constraints, as it should be for implementing the optimization principle in general.

NS-G-2.7

2.14. The optimization of protection and safety measures, or the application of the ALARA principle (to keep doses as low as reasonably achievable, economic and social factors being taken into account), should be carried out at all stages during the lifetime of the equipment and installations. In the optimization, all relevant factors should be taken into account.

3.3. The operating organization ‘shall designate as a controlled area any area in which specific protective measures or safety provisions are or could be required for:
(a) controlling normal exposures or preventing the spread of contamination during normal working conditions; and
(b) preventing or limiting the extent of potential exposures.’

3.11. Changing areas shall be provided, as appropriate, at the entrances to and exits from those zones which are contaminated or may become contaminated. Changing areas should be designed to prevent the spread of contamination by means of partition into a clean side and a potentially contaminated side.

3.12. Equipment is required to be provided, as appropriate, for the monitoring of persons at exits from controlled areas in order to ensure that contamination levels on their clothing and body surfaces are below a specified level.

3.13. Before items are removed from any contamination zone, and in any case before they are removed from controlled areas, they are required to be monitored as appropriate (Ref. [2], para. I.23) and suitable measures should be taken to avoid undue radiation hazards.

3.20. Investigation levels for individual doses and intakes should be set by the management on the basis of expected levels of individual dose. Investigation levels for workplace monitoring should be set on the basis of the expected levels of dose rate and contamination and operational experience.

3.77. The buildup of radioactive residues in piping and components of the primary system can be reduced by maintaining close control over the selection of materials and chemical parameters. In the design and the operation of the reactor, attention should be paid to ensuring that materials and chemical parameters are specified and controlled so as to minimize the production and buildup of radionuclides.

# 8. CHEMISTRY

8.1. ORGANIZATION AND FUNCTIONS

A water chemistry diagram which summarizes chemistry limits, plant conditions and required actions when chemistry deviates from acceptable ranges for all plant states was developed in 2017 by the chemistry shift supervisor. This diagram was posted in the walls of offices, laboratories and control room for better understanding by the staff. This initiative was recognised by the team as a good performance.

8.2. CHEMISTRY PROGRAMME

The plant has a good understanding of all potential internal/external biases on analytical measurements and on equipment calibration. Many examples of mitigating measures were observed by the team (for example independent reference material; quality control samples & blanks; monthly checks of operator bias; quality charts control; and isolated rooms to protect equipment from environmental bias). However, the team observed several occasions where surface corrosion was present on laboratory equipment and instruments. Potential introduction of impurities might affect accuracy of measurements related to water-chemistry monitoring. The team made a suggestion in this area.

The plant experience of participating in blind tests with external laboratories is limited to Iranian organizations not belonging to the nuclear field. The team encouraged the plant to participate in international proficiency testing to better assess the quality of chemical analysis (for instance through ASTM standards network or with Russian plant laboratories).

The plant routinely (once per day) uses grab sampling of the primary circuit to support adjustment of the water-chemistry regime. A new measurement system installed by the plant optimizes the measurement performance and reduces the personnel radiation dose intake. The team recognized this as a good practice.

8.5. LABORATORIES, EQUIPMENT AND INSTRUMENTS

All necessary equipment is available in the laboratories with enough redundancy. However, performance of measurements could be improved using more modern instruments. The plant has started to replace some of the instruments related to important safety parameters monitoring (for example measurement of boric acid concentration in primary circuit using an automatic titration method). The team encouraged the plant to implement the current 4 years replacement plan of laboratory instruments as scheduled.

A post-accident sampling system and corresponding procedure is available at the laboratories and is applicable to both liquid and gas samples. The system was reviewed in 2018 to address concerns with its usability. However, the procedure in place does not address its applicability for different high activity levels of the sample, as well as the uncertainties related to its use. The team encouraged the plant to re-evaluate and, if appropriate, modify the procedure to analyse highly radioactive samples in post-accident situations.

8.7. MANAGEMENT OF CHEMISTRY DATA

All measured values are reported by the day-based and shift-based laboratory teams from the laboratory log books to the plant database. This database is accessible on-line for technical and engineering division, senior engineers and supervisors. Measurements outside the normal range are highlighted in red to facilitate the quick identification and correction of deviations. The team considered this as a good performance.

8.9. QUALITY CONTROL OF CHEMICALS AND OTHER SUBSTANCES

The plant has a procedure in place for quality control of incoming chemicals (supplier specifications check; random sample analysis before storage; and systematic sample analysis before transfer to the plant) and the labelling system in place allows to identify designated use of samples and their usability (unique code number on sampling bottles; expiration date on chemicals). However, the identification numbers of sampling bottle caps are hand-written with fading ink. The team encouraged the plant to use another method with less risk of cross-contamination between bottles in case of bottle cap exchange.

Chemicals are segregated and stored according to the Russian Norm (ND-5124) defining maximum quantities allowed for toxic or flammable materials. Ten cabinets are used in the main chemical storage room of the daily laboratories to separate chemicals according to their material safety datasheets. However, the segregation rules are not always applied inside laboratory rooms where small chemical quantities are stored for daily use. The team encouraged the plant to follow international laboratory practices and clarify storage rules for small chemical quantities.

**DETAILED CHEMISTRY FINDINGS**

8.2. CHEMISTRY PROGRAMME

**8.2(a) Issue**: chemistry instruments and equipment are not always maintained in good condition to ensure accurate analyses.

The team noted the following:

* Primary water circuit (ZC/825): corrosion inside analytical equipment (small oxidation layer below measurement cell of spectrophotometer, corrosion on hinges of Nitrogen/Carbon analyzer door).
* Demineralized water control laboratory (ZG.0/302): corrosion inside fume-hoods and on external part of fume hood ventilation exhaust.
* Secondary water circuit control laboratory (ZF/351): corrosion on external surface of ventilation exhaust for fume hood.

Without good condition of instruments and equipment, the accuracy of measurements for chemistry monitoring purposes might be affected by the introduction of disturbing impurities.

**Suggestion**: consideration should be given to maintain the condition of chemistry instruments and equipment to ensure accurate analyses.

**IAEA Bases:**

SSG-13

6.35. All laboratory instruments and equipment should be in good condition in order to provide accurate and reliable analytical data for monitoring purposes. The condition of such instruments and equipment should be ensured by a documented maintenance plan and a regular calibration plan.

NS-G-2-14

6.20. Plant housekeeping should maintain good conditions for operation in all working areas. Working areas should be kept up to standard, well lit, clean of lubricants, chemicals or other leakage and free of debris; the intrusion of foreign objects should be prevented and an environment should be created in which all deviations from normal conditions are easily identifiable (such as small leaks, corrosion spots, loose parts, unauthorized temporary modifications and damaged insulation). The effects of the intrusion of foreign objects or the long term effects of environmental conditions (i.e. temperature effects or corrosion effects or other degradations in the plant that may affect the long term reliability of plant equipment or structures) should be evaluated as part of the plant housekeeping programme.

**8.5(1) Good Practice**

Sampling of primary circuit water is performed once per day by the shift laboratory personnel using a sampling glove-box to analyse oxygen and hydrogen concentration. A feed-through line has been designed and manufactured to connect the inside of the sampling glove box with a portable gas analyzer located outside the glove-box. This modification allows a more precise and rapid analysis which minimizes the operator’s dose intake but still provides effective support for the adjustment of the water-chemistry regime.



Sampling box (before modification by the plant): O2/H2 manual measurement



Sampling box (after modification by the plant): O2/H2 measurement with portable equipment

# 9. EMERGENCY PLANNING AND PREPAREDNESS

9.1. ORGANIZATION AND FUNCTIONS

Agreements are in place to support the plant from Bushehr province for medical emergency services; emergency evacuation; emergency accommodation; public training and awareness, telecommunications; transportation and traffic control; and for rescue and fire fighting. A new off-site emergency plan was approved by provincial government and put in place recently. A new on-site emergency plan, in line with 2015 national regulation for on-site plans, was recently approved by the plant and will be put in place after approval by the regulatory body. The team encouraged the plant to bring this plan formally into force at an early date and update all relevant emergency related procedures and training programmes.

Emergency planning and response arrangements are based on hazard assessment described in the Final Safety Analysis Report (FSAR) for Design Basis Accidents and some Beyond Design Basis Accidents. Results of the analyses give estimated releases of radionuclides to the containment and environment as well as prediction of doses to the population. Hazard assessments for the cases of low probability events, including early containment failure or containment bypass are not available. The team encouraged the plant to expand the hazard assessments and consider all potential hazards, including accidents with early containment failure or bypass.

Evacuation of on-site personnel is done in two steps. First, using the dedicated buses of the plant, transporting evacuees to a Precautionary Planning Zone (PAZ) checkpoint at 5 km, where contamination measurements are performed and initial decontamination is carried out if needed. Second, another set of buses from Bushehr province transporting evacuees to predetermined locations outside a 30-km radius from the plant. This arrangement is intended to prevent potential spread of contamination; however, it could introduce delays in evacuation**.** The team encouraged the plant to study possibilities for optimized evacuation of on-site personnel.

9.2. EMERGENCY RESPONSE

The plant has various facilities that intended for use by the emergency response personnel during an emergency including after a radioactive release. These include the main control room, the back-up control room and the local emergency response centre, located in shielded buildings, and the on-site and off-site emergency response centres. However, these facilities do not satisfy all the requirements for long term effective implementation of the emergency response actions and protection of personnel in case of all accidents. The team made a recommendation in this area.

Criteria for identification, notification and activation of emergency situations are clearly defined in a decision chart in the on-site emergency plan. The criteria are based on elevated levels of gamma dose and iodine concentration in air in the plant’s controlled areas, at the site and in the PAZ. The team encouraged the plant to expand these criteria to include other plant status indicators (critical safety function indicators), such as containment high-range gamma dose rate; pressure; hydrogen concentration; temperature; high-range post-accident sampling and reactor vessel water level.

The plant uses two software tools for the assessment of radiological conditions during an emergency, based on pre-calculated scenarios, and for proposing actions for the protection of personnel and population. As a backup, the plant uses a manual procedure on paper. The team considered this as good performance.

The on-site emergency plan describes for several specialised emergency operation teams how to deal with immediate mitigation actions during an emergency, for example to repair safety equipment and systems; to decontaminate; to fight fire; and to provide medical support. Safety teams can provide situation analysis and plant status; radiation situation analysis and on-site and off-site radiation monitoring. Response teams have procedures for their work and are trained in their use. All personnel with duties under the on-site emergency plan are selected based on individual knowledge, competences and experience for their tasks, and fitness for duty under stress conditions which is determined by a medical exam including a psychological test. The team considered this as a good performance.

All members of emergency operating teams receive, in addition to the basic training, training in: emergency preparedness and response; the classification of emergencies; personal protection equipment; dosimetry; equipment for radiation measurement; decontamination; fire fighting; first aid and their tasks during emergency. This is followed by practical exercises and drills. The Crisis management team receives additional training on roles and functions of local emergency response centre. Shift personnel receive training similar to emergency operating teams and additional certified training. All training is recorded in individuals’ training passport, tracked in the central training data base and evaluated by EPR training officer. The team considered this as a good performance.

9.3. EMERGENCY PREPAREDNESS

Emergency assembly points exist in some buildings on site with instructions for the evacuees. The team noted some deficiencies, for example: not all assembly points have dedicated telephone to contact emergency crisis centre or evacuation committee; no continuous radiation monitoring; no dedicated battery lights; no stretcher for medical evacuation; no first aid kit; no stable iodine pills and water; no identification signs for alert, site emergency or general emergency on the poster with emergency instructions. The team encouraged the plant to enhance assembly points with all necessary equipment and instructions.

An exercise programme to test response arrangements and capabilities exists for individuals, groups, between the groups and with the off-site actors. Procedures cover exercise planning, conduct, assessment and reporting. After the assessment of exercises, areas for improvements are identified and recommendations made to the participants. The plant has well prepared documents for planning, conducting and assessing exercises to test emergency preparedness. The team considered this as good performance.

All emergency centres have comprehensive and redundant communications systems and means (at site and to off-site), connected to backup power supplies. In addition, Bushehr province is able to provide mobile telecommunication units to support emergency response centres. All emergency centres have access to 150 plant parameters from main control room. The team considered this as a good performance.

For decontamination of a larger number of persons, including injured persons, the plant has a special decontamination container with showers; water; its own electric generator; and a supply of towels and clean clothes, that can be towed with a truck to any location on-site or off-site if needed.

**DETAILED EMERGENCY PLANNING AND PREPAREDNESS FINDINGS**

9.2. EMERGENCY RESPONSE

**9.2(1) Issue**: The plant’s emergency facilities are not sufficiently protected and equipped to ensure long term effective implementation of the emergency response actions and protection of the personnel.

The team noted the following:

* The On-site back-up emergency response centre in the main administrative building (ZV1) has an air supply system filtered for aerosols but not for Iodine. There is no analysis to assess performance of the system for cases of prolonged releases.
* The On-site back-up emergency response centre has limited fire resistance, for example most internal doors are wooden.
* The Off-site back-up Emergency Response Centre (OERC) has no filtered air supply system.
* All emergency response centres have very limited supply of water and food.
* Redundant aerosol and charcoal filter systems for the main control room (MCR), backup control room and Local Emergency Response Centre (LERC) in the ZX building are designed for Beyond Design Basis Accident (BDBA, FSAR 15.3.4). In the event of a large radioactive release air can be supplied from compressed air cylinders to the MCR, backup control room and LERC for 6 to 24 hours. There is no analysis to assess the response of these filter systems to a prolonged radioactive release during some BDBAs or severe accidents.
* Currently, in case of emergency, ten specialized emergency operation teams will gather at the ground floor of the large maintenance shop in the ZL-0 building which has no post-accident habitability. The plant has plans for a future design of a bunkered building with filtered air supply system, able to accommodate all specialized emergency operation teams and additional 300 persons.

Without providing sufficiently protected and equipped emergency facilities the effective implementation of the emergency response actions may be compromised, including protection of personnel.

**Recommendation:** The plant should provide sufficiently protected and equipped emergency facilities to ensure long term effective implementation of the emergency response actions and protection of personnel in case of all accidents.

**IAEA Bases:**

GSR Part 7

5.7. Facilities, instruments, tools, equipment, documentation and communication systems to be used in an emergency, including those needed for off-site communication and for the accident management programme, shall be kept available. They shall be maintained in good operational condition in such a manner that they are unlikely to be affected by, or made unavailable by, accidents. The operating organization shall ensure that relevant information on safety parameters is available in the emergency response facilities and locations, as appropriate, and that communication between the control rooms and these facilities and locations is effective in the event of an accident [2]. These capabilities shall be tested periodically.

5.52. The operating organization and response organizations shall ensure that arrangements are in place for the protection of emergency workers and protection of helpers in an emergency for the range of anticipated hazardous conditions in which they might have to perform response functions. These arrangements, as a minimum, shall include:

6.22. Adequate tools, instruments, supplies, equipment, communication systems, facilities and documentation (such as documentation of procedures, checklists, manuals, telephone numbers and email addresses) shall be provided for performing the functions specified in Section 5. These items and facilities shall be selected or designed to be operational under the conditions (such as radiological conditions, working conditions and environmental conditions) that could be encountered in the emergency response, and to be compatible with other procedures and equipment for the response (e.g. compatible with the communication frequencies used by other response organizations), as appropriate. These support items shall be located or provided in a manner that allows their effective use under the emergency conditions postulated.

6.25. For facilities in category I, emergency response facilities separate from the control room and supplementary control room shall be provided so that:

(a) Technical support can be provided to the operating personnel in the control room in an emergency (from a technical support centre).

(b) Operational control by personnel performing tasks at or near the facility can be maintained (from an operational support centre).

(c) The on-site emergency response is managed (from an emergency centre).

These emergency response facilities shall operate as an integrated system in support of the emergency response, without conflicting with one another’s functions, and shall provide reasonable assurance of being operable and habitable under a range of postulated hazardous conditions, including conditions not considered in the design.

NS-G-2.15

3.53. In the development of procedures and guidelines, account should be taken of the habitability of the control room and the accessibility of other relevant areas, such as the technical support centre or areas for local actions.

3.96. The accessibility and habitability of the physical locations of the teams of evaluators and implementers as well as of emergency director under the severe accident conditions should be checked and maintained.

# 10. ACCIDENT MANAGEMENT

10.1. ORGANIZATION AND FUNCTIONS

The plant has a training programme which addresses Beyond Design Basis Accidents (BDBA) and guidelines. Since the plant has not yet developed strategies to cope with severe accidents, the staff engaged with the key functions in the accident management programme have not been trained in severe accident progression and associated phenomena. The team encouraged the plant to train the technical support centre evaluators, decision makers and implementers on severe accident phenomena.

10.2. OVERVIEW OF THE SEVERE ACCIDENT MANAGEMENT PROGRAMME

The plant’s arrangements for accident management do not fully address the mitigation of severe accidents. For example, Severe Accident Management Guidelines (SAMGs) are not yet available at the plant. The strategy for venting the containment in case of overpressure lacks an analytical basis for quantifying its consequences, and hydrogen management strategies are not yet considered even though the plant has identified the inadequacy of the Passive Autocatalytic Recombiners (PARs) currently installed. The team made a recommendation in this area.

The plant has a contract in place with external partners for the delivery of SAMGs, as well as symptom based Emergency Operating Procedures (EOPs); delivery is expected by the end of 2021, and in parallel to this a re-evaluation of the initial stress tests that were finalized in 2012 is being performed. Prior to delivery of the SAMGs, the team encouraged the plant to proactively address the already identified issues, as well as the upcoming ones.

Examples of supported actions may be to update the current BDBA guidelines:

* With information on severe accidents, e.g. the anticipated evolution of a severe accident, associated phenomena and consequences.
* With diagnosis (identification) of the risk of hydrogen explosion and management of the containment spray system in such conditions.
* By complementing the strategy on containment venting with information on the foreseen consequences to the containment, relevant equipment, and to the environment (expected releases).
* With alternative ways to depressurize the primary and secondary circuits.
* With alternative ways to measure or estimate vital parameters such as reactor vessel water level that might not be available or reliable under severe accident condition.

10.8. USE OF PSA, PSR AND OEF

There are currently no SAMGs at the plant hence no PSA studies related to SAM strategies have been performed. In contrast, based on the current BNPP-1 procedures and design, a Level 2 PSA has been developed for the determination of the full spectrum of possible challenge mechanisms during a severe accident progression, quantification of containment damage states and associated consequences. The Level 1 and 2 PSAs are well developed and will be used for the development and verification of the SAMGs. The team identified this as a good performance.

**DETAILED ACCIDENT MANAGEMENT FINDINGS**

10.2. OVERVIEW OF THE SEVERE ACCIDENT MANAGEMENT PROGRAMME

**10.2(1) Issue**: The plant’s arrangements for accident management do not fully address the mitigation of severe accidents.

The team noted the following:

* Currently, there are no Severe Accident Management Guidelines available at the plant. The plant has a contract in place for the delivery of Severe Accident Management Programme but it will not be implemented before the end of 2021.
* The plant has Beyond Design Basis Accident (BDBA) guidelines with the aim to prevent severe core damage, as well as mitigate the consequences in case of failure to prevent a severe accident. However, the only mitigative strategy provided concerns containment venting.
* Regarding the strategy for venting the containment to the stack in case of overpressure the team observed the following:
	+ No guidelines on the negative effects of venting the containment and its implications on the Emergency Response Organization are available to support the decision-making process.
	+ No analyses were performed for determining the set points for optimal venting operation, for assessing the stack filter effectiveness under severe accident conditions and for estimating the expected radioactive releases.
* Although a mobile diesel generator is in place and the instructions for its operation were developed, its possible deployment is not included in the BDBA guidelines.
* Passive autocatalytic recombiners (PARs) in the containment are dimensioned and qualified only for Design Basis Accidents. Although the plant already identified this issue; it has not yet estimated the number of additional PARs needed to cope with severe accidents, and no strategies have been developed for the management of the hydrogen concentration in the containment for the current plant configuration.
* The decision makers, the implementers and the technical support group that evaluates and recommends recovery actions during an emergency situation, have not received training on severe accident phenomena.
* The plant does not currently use symptom based emergency procedures for BDBAs, only using event based ones.

Without a comprehensive accident management designed to mitigate the consequences of a severe accident, the plant might not efficiently minimize the release of radioactive materials and its consequences to the personnel, the public and the environment.

**Recommendation**: The plant should establish and implement a comprehensive severe accident management programme.

**IAEA Bases:**

SSR-2/2 Rev. 1

5.8. An accident management programme shall be established that covers the preparatory measures, procedures and guidelines, and equipment that are necessary for preventing the progression of accidents, including accidents more severe than design basis accidents, and for mitigating their consequences if they do occur. The accident management programme shall be documented and shall be periodically reviewed and as necessary revised.

5.9. Arrangements for accident management shall provide the operating staff with appropriate competence, systems and technical support. These arrangements and relevant guidance shall be available before the commencement of fuel loading, shall be validated and shall then be periodically tested as far as practicable in exercises and used in training and drills [1, 6]. In addition, arrangements shall be made, as part of the accident management programme and the emergency plan, to expand the emergency arrangements, where necessary, to include the responsibility for long term actions.

NS-G-2.2

8.4. For anticipated operational occurrences and accident conditions, the Ops should provide instructions for the recovery. For design basis accidents (DBAs), these procedures to keep the plant state within specified limits may be event based or symptom based. For beyond design basis conditions, the instructions will be symptom based; that is, they will use parameters indicating the plant state to identify optimum recovery routes for the operator without the need for accident diagnosis.

NS-G-2.15

2.2. Reference [6] establishes the following requirements on severe accident management and accident management in the operation of nuclear power plants:

‘Plant staff shall receive instructions in the management of accidents beyond the design basis. The training of operating personnel shall ensure their familiarity with the symptoms of accidents beyond the design basis and with the procedures for accident management’ ‘Emergency operating procedures or guidance for managing severe accidents shall be developed’.

2.12. In view of the uncertainties involved in severe accidents, severe accident management guidance should be developed for all physically identifiable challenge mechanisms for which the development of severe accident management guidance is feasible; severe accident management guidance should be developed irrespective of predicted frequencies of occurrence of the challenge.

2.31. Accident management guidance should be an integral part of the overall emergency arrangements at a nuclear power plant. The execution of the severe accident management guidance is the responsibility of the emergency response organization at the plant or the utility. Roles and responsibilities for the different members of the emergency response organization involved in accident management should be clearly defined and coordination among them should be ensured.

3.64. For the mitigatory domain, in upgrading equipment the focus should be placed on preservation of the containment function and, in particular, the following functions should be taken account of:

* Containment isolation in a severe accident, including bypass prevention;
* Monitoring parameters in the containment, allowing an early diagnosis of the unit status including the concentration of fission products and hydrogen;
* Ensuring the leak tightness of the containment, including preservation of the functionality of isolation devices, penetrations and personnel locks, for a reasonable time after a severe accident;
* Management of pressure and temperature in the containment by means of a containment heat removal system;
* Control of the concentration of combustible gases, fission products and other materials released during severe accidents;
* Containment overpressure and under pressure protection;
* Prevention of high pressure core-melt scenarios;
* Prevention of vessel melt through;
* Prevention and mitigation of containment basemat melt through by the molten core;
* Monitoring and control of containment leakages.

3.128. In addition to accident analysis in the areas of neutronics, thermohydraulic, core degradation, etc., structural analysis should be performed for phenomena that present mechanical loads. (For example, if hydrogen combustion is calculated to occur, combustion loads should be calculated and it should be investigated whether the containment or other relevant structures will survive the loads. Often, the capability of structures to accommodate the loads is presented as a fragility curve depicting probability of failure).

3.115. Analysis of a potential beyond design basis accident or severe accident sequence typically has one of the following objectives: (1) formulation of the technical basis for development of strategies, procedures or guidance; (2) demonstration of the acceptability of design solutions to support the selected strategies, procedures and guidelines in accordance with the established criteria; or (3) determination of the reference source terms for emergency plans. While the basic approach (the use of best estimate analysis) is the same for all three objectives, the scope and assumptions for various applications of the analysis will be different for each objective. Later stages of the analysis aim to provide only analytical support for accident management.

3.122. In the second step of the analysis of a potential beyond design basis accident or severe accident sequence, the effectiveness of proposed strategies and their potential negative consequences52 should be investigated. The analysis performed at this step should also support development of the actual procedures and guidelines, since proper set points to initiate, throttle or terminate actions need to be determined. The potential availability and functionality of equipment and instrumentation, as well as the habitability of workplaces under the prevailing accident conditions, should be investigated.

3.104. For each group involved in accident management, including the management of the operating organization and other decision-making levels, and also, where applicable, regulatory personnel, specific objectives and training needs should be defined. The training should be commensurate with the tasks and responsibilities of the functions; hence, in-depth training should be provided for the key functions in the severe accident management programme, that is, the technical support centre evaluators, decision makers and implementers. Regulators, where they participate in utility decisions, should be trained so that they fully understand the basis of proposed utility decisions.

# DEFINITIONS

**Recommendation**

A recommendation is advice on what improvements in operational safety should be made in that activity or programme that has been evaluated. It is based on IAEA Safety Standards or proven, good international practices and addresses the root causes rather than the symptoms of the identified concern. It very often illustrates a proven method of striving for excellence, which reaches beyond minimum requirements. Recommendations are specific, realistic and designed to result in tangible improvements. Absence of recommendations can be interpreted as performance corresponding with proven international practices.

**Suggestion**

A suggestion is either an additional proposal in conjunction with a recommendation or may stand on its own following a discussion of the pertinent background. It may indirectly contribute to improvements in operational safety but is primarily intended to make a good performance more effective, to indicate useful expansions to existing programmes and to point out possible superior alternatives to ongoing work. In general, it is designed to stimulate the plant management and supporting staff to continue to consider ways and means for enhancing performance.

*Note: if an item is not well based enough to meet the criteria of a ‘suggestion’, but the expert or the team feels that mentioning it is still desirable, the given topic may be described in the text of the report using the phrase ‘encouragement’ (e.g. The team encouraged the plant to…).*

**Good practice**

A good practice is an outstanding and proven performance, programme, activity or equipment in use that contributes directly or indirectly to operational safety and sustained good performance. A good practice is markedly superior to that observed elsewhere, not just the fulfilment of current requirements or expectations. It should be superior enough and have broad application to be brought to the attention of other nuclear power plants and be worthy of their consideration in the general drive for excellence. A good practice has the following characteristics:

* novel;
* has a proven benefit;
* replicable (it can be used at other plants);
* does not contradict an issue.

The attributes of a given ‘good practice’ (e.g. whether it is well implemented, or cost effective, or creative, or it has good results) should be explicitly stated in the description of the ‘good practice’.

*Note: An item may not meet all the criteria of a ‘good practice’, but still be worthy to take note of. In this case it may be referred as a ‘good performance’, and may be documented in the text of the report. A good performance is a superior objective that has been achieved or a good technique or programme that contributes directly or indirectly to operational safety and sustained good performance, that works well at the plant. However, it might not be necessary to recommend its adoption by other nuclear power plants, because of financial considerations, differences in design or other reasons.*

# LIST OF IAEA REFERENCES (BASIS)

***Safety Standards***

* + **SF-1**; Fundamental Safety Principles (Safety Fundamentals)
	+ **SSR-2/2 Rev.1**; Safety of Nuclear Power Plants: Commissioning and Operation (Specific Safety Requirements)
	+ **GSR Part 2;** Leadership and Management for Safety (General Safety Requirements)
	+ **GSR Part 3;** Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards
	+ **GSR Part 7;** Preparedness and Response for a Nuclear or Radiological Emergency (General Safety Requirements)
	+ **SSR-2/1 Rev.1**; Safety of Nuclear Power Plants: Design (Specific Safety Requirements)
	+ **NS-G-1.1**; Software for Computer Based Systems Important to Safety in Nuclear Power Plants (Safety Guide)
	+ **NS-G-2.1**; Fire Safety in the Operation of Nuclear Power Plans (Safety Guide)
	+ **NS-G-2.2**; Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants (Safety Guide)
	+ **NS-G-2.3**; Modifications to Nuclear Power Plants (Safety Guide)
	+ **NS-G-2.4**; The Operating Organization for Nuclear Power Plants (Safety Guide)
	+ **NS-G-2.5**; Core Management and Fuel Handling for Nuclear Power Plants (Safety Guide)
	+ **NS-G-2.6**; Maintenance, Surveillance and In-service Inspection in Nuclear Power Plants (Safety Guide)
	+ **NS-G-2.7**; Radiation Protection and Radioactive Waste Management in the Operation of Nuclear Power Plants (Safety Guide)
	+ **NS-G-2.8**; Recruitment, Qualification and Training of Personnel for Nuclear Power Plants (Safety Guide)
	+ **NS-G-2.9**; Commissioning for Nuclear Power Plants (Safety Guide)
	+ **NS-G-2.11**; A System for the Feedback of Experience from Events in Nuclear Installations (Safety Guide**)**
	+ **NS-G-2.12**; Ageing Management for Nuclear Power Plants (Safety Guide)
	+ **NS-G-2.13**; Evaluation of Seismic Safety for Existing Nuclear Installations(Safety Guide)
	+ **NS-G-2.14**[;Conduct of Operations at Nuclear Power Plants (Safety Guide)](file:///S%3A%5CSengoku%5CMaterials%20for%20OSART%20Prep.2007-7%5CPublication%5CDS347draft32007-03-01.pdf)
	+ **NS-G-2.15**; Severe Accident Management Programmes for Nuclear Power Plants (Safety Guide)
	+ **SSG**-**13**;[Chemistry Programme for Water Cooled Nuclear Power Plants (Specific Safety Guide)](file:///S%3A%5CSengoku%5CMaterials%20for%20OSART%20Prep.2007-7%5CPublication%5CDS388_DRAFT_3_050706.pdf)
	+ **SSG**-**25**;[Periodic Safety Review for Nuclear Power Plants (Specific Safety Guide)](file:///S%3A%5CSengoku%5CMaterials%20for%20OSART%20Prep.2007-7%5CPublication%5CDS388_DRAFT_3_050706.pdf)
	+ **GSR Part 1**; Governmental, Legal and Regulatory Framework for Safety (General Safety Requirements)
	+ **GSR Part 4**; Safety Assessment for Facilities and Activities (General Safety Requirements)
	+ **GS-G-4.1**; Format and Content of the Safety Analysis report for Nuclear Power Plants (Safety Guide)
	+ **SSG-2**; Deterministic Safety Analysis for Nuclear Power Plants (Specific Safety Guide)
	+ **SSG-3**; Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants (Specific Safety Guide)
	+ **SSG-4**; Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants (Specific Safety Guide)
	+ **GSR Part 5**; Predisposal Management of Radioactive Waste (General Safety Requirements)
	+ **GS-G-2.1**; Arrangement for Preparedness for a Nuclear or Radiological Emergency(Safety Guide)
	+ **GSG-2**; Criteria for Use in Preparedness and Response for a Nuclear and Radiological Emergency (General Safety Guide)
	+ **GS-G-3.1**; Application of the Management System for Facilities and Activities(Safety Guide)
	+ **GS-G-3.5**; The Management System for Nuclear Installations (Safety Guide)
	+ **RS-G-1.1**; Occupational Radiation Protection (Safety Guide)
	+ **RS-G-1.2**; Assessment of Occupational Exposure Due to Intakes of Radio­nuclides (Safety Guide)
	+ **RS-G-1.3**; Assessment of Occupational Exposure Due to External Sources of Radiation (Safety Guide)
	+ **RS-G-1.8**; Environmental and Source Monitoring for Purposes of Radiation Protection (Safety Guide)
	+ **SSR**-**5;** Disposal of Radioactive Waste (Specific Safety Requirements)
	+ **GSG-1** Classification of Radioactive Waste (General Safety Guide)
	+ **WS-G-6.1**; Storage of Radioactive Waste (Safety Guide)
	+ **WS-G**-**2.5**; Predisposal Management of Low and Intermediate Level Radioactive Waste (Safety Guide)

***INSAG, Safety Report Series***

* + **INSAG-4**; Safety Culture
	+ **INSAG-10**; Defence in Depth in Nuclear Safety
	+ **INSAG-12**; Basic Safety Principles for Nuclear Power Plants, 75-INSAG-3 Rev.1
	+ **INSAG-13**; Management of Operational Safety in Nuclear Power Plants
	+ **INSAG-14**; Safe Management of the Operating Lifetimes of Nuclear Power Plants
	+ **INSAG-15**; Key Practical Issues In Strengthening Safety Culture
	+ **INSAG-16**; Maintaining Knowledge, Training and Infrastructure for Research and Development in Nuclear Safety
	+ **INSAG-17**; Independence in Regulatory Decision Making
	+ **INSAG-18**; Managing Change in the Nuclear Industry: The Effects on Safety
	+ **INSAG-19**; Maintaining the Design Integrity of Nuclear Installations throughout their Operating Life
	+ **INSAG-20**; Stakeholder Involvement in Nuclear Issues
	+ **INSAG-23**; Improving the International System for Operating Experience Feedback
	+ **INSAG-25**; A Framework for an Integrated Risk Informed Decision-Making Process
	+ **Safety Report Series No.11**; Developing Safety Culture in Nuclear Activities Practical Suggestions to Assist Progress
	+ **Safety Report Series No.21**; Optimization of Radiation Protection in the Control of Occupational Exposure
	+ **Safety Report Series No.48**; Development and Review of Plant Specific Emergency Operating Procedures
	+ **Safety Report Series No. 57**; Safe Long-Term Operation of Nuclear Power Plants

***Other IAEA Publications***

* + **IAEA Safety Glossary Terminology** used in nuclear safety and radiation protection 2007 Edition
	+ **Services series No.12**; OSART Guidelines
	+ **EPR-ENATOM-2002**; Emergency Notification and Assistance Technical Operations Manual
	+ **EPR-METHOD-2003**; Method for developing arrangements for response to a nuclear or radiological emergency, (Updating IAEA-TECDOC-953)
	+ **EPR-EXERCISE-2005**; Preparation, Conduct and Evaluation of Exercises to Test Preparedness for a Nuclear or Radiological Emergency
	+ **EPR-NPP PPA 2013**; Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor

***International Labour Office publications on industrial safety***

* + **ILO-OSH 2001**; Guidelines on occupational safety and health management systems (ILO guideline)
	+ **Safety and health in construction** (ILO code of practice)
	+ **Safety in the use of chemicals at work** (ILO code of practice)

# TEAM COMPOSITION OF THE OSART MISSION

**TARREN Peter – IAEA**

Team Leader

Years of nuclear experience: 40

**CAVELLEC Ronan – IAEA**

Deputy Team Leader

Years of nuclear experience: 20

**KONTZLER Fabien**

Company: Electricité de France

Years of nuclear experience: 8

Review area: Leadership and Management for Safety

**BOGDAN Daniel**

Company: National Commission for Nuclear Activities Control

Years of nuclear experience: 24

Review area: Training and Qualification

**KEREKES Zoltan**

Company: MVM Paks NPP Ltd.

Years of nuclear experience: 22

Review area: Operations 1

**HOVHANNISYAN Artur**

Company: RAOS Project Oy

Years of nuclear experience: 23

Review area: Operations 2

**WU Chao**

Company: China Power Operations Co. Ltd.

Years of nuclear experience: 22

Review area: Maintenance

**KILIC Arif Nesimi**

Company: IAEA

Years of nuclear experience: 28

Review area: Technical Support

**ZAHRADKA Dian**

Company: IAEA

Years of nuclear experience: 25

Review area: Operating Experience Feedback

**WYCKMANS Rikkert**

Company: ENGIE Electrabel, Doel NPP

Years of nuclear experience: 18

Review area: Radiation Protection

**AMARAGGI David**

Company: IAEA

Years of nuclear experience: 23

Review area: Chemistry

**GREGORIC Miroslav**

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Years of nuclear experience: 40

Review area: Emergency Preparedness & Response

**HANSSON CONCILIO Roberta**

Company: Vattenfall AB

Years of nuclear experience: 20

Review area: Accident Management

**HE Xia**

Company: Manager assistant, Wuhan university

Years of nuclear experience: 4

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