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SIGNIFICANT OPERATING EXPERIENCE REPORT

SOER | 2013-1

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Operator Fundamentals Weaknesses

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WANO Significant Operating Experience Reports (SOERs) are written to facilitate the sharing of valuable learning points gained from the operating experience of WANO members. This WANO SOER is based on the Institute of Nuclear Power Operations INPO Event Report IER L1-11-3, "Weaknesses in Operator Fundamentals". This SOER describes an adverse trend in operator fundamentals that may be a precursor to events of greater consequence. This document provides recommendations that require both immediate attention and ongoing actions.

WANO MEMBERS ARE EXPECTED TO CLOSELY REVIEW THIS WANO SOER IN LIGHT OF THEIR OWN PLANT PROCEDURES, POLICIES AND PRACTICES TO DETERMINE HOW THIS OPERATING EXPERIENCE CAN BE APPLIED AT THEIR PLANTS TO IMPROVE SAFETY FURTHER. IMPLEMENTATION OF THE RECOMMENDATIONS CONTAINED IN THIS REPORT WILL BE EVALUATED DURING WANO PEER REVIEWS FROM AUGUST 2013.

Summary

Several significant events have occurred that highlight weaknesses in the knowledge, skills, behaviours and practices essential for operators to operate the plant safely and effectively – operator fundamentals. In some cases, individuals caused events during operations activities. In other instances, individuals did not mitigate the effects of power transients. Events include reactor trips, loss of reactor coolant system inventory, unplanned reactivity additions and damage to plant equipment.

In the past, industry efforts to improve operator fundamentals resulted in short-term reductions in the number of significant events and reactor trips caused or complicated by weaknesses in operator fundamental performance. However, these efforts were not sustainable because the actions taken and lessons learned were not well incorporated into operational standards, training, and management systems. As a result, events caused by weaknesses in the use of operator fundamentals continue to occur too frequently.

Analysis of recent events and their causes identified several underlying reasons for operator fundamental weaknesses. These reasons include the following:

- Operators are not sufficiently focused on understanding the technical aspects of the task to complement the use of human performance techniques.
- An imbalance exists between 'training on task' implementation and training on integrated system knowledge, the technical basis for procedures, the reasons for operational practices and power plant fundamentals.
- Risk recognition and mitigation are not used effectively to supplement the requirement to follow approved processes and procedures and ensure activities are completed event-free.
- Training techniques and needs have not been adjusted to account for operators having fewer opportunities to experience plant transients, safety system operation and other abnormal / unusual evolutions because plants in general are operating more reliably.

This SOER establishes actions to help members to self-assess the effectiveness of operator fundamentals and training programmes at their stations. This SOER also establishes actions to ensure operator fundamentals are well ingrained in and rigorously applied by operators.

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Recommendations that each WANO member is expected to address

The following recommendations are intended to address the causes and contributors to operator fundamentals weaknesses and lead to effective, sustainable corrective actions:

1. Conduct a self-assessment of operations training programmes.

Conduct a self-assessment of the operations training programmes using '*Self-Assessment Guide: Assessing Training Effectiveness in Addressing Operator Fundamentals'*, May 2011, to understand fully their effectiveness of training on the subject of operator fundamentals[1]. Develop corrective actions based on the results of the self-assessment to improve the quality of operator fundamentals training.

2. Perform a self-assessment of operator fundamentals as practiced.

Perform a self-assessment of operator fundamentals using '*Self-Assessment Guide to Operator Fundamentals'*, June 2011, to identify gaps that could cause events or reduce crew effectiveness when responding to a transient. Use the results of the self-assessment to develop corrective actions designed to better focus training and coaching of operators on identified weaknesses.

3. Implement effective organisation and leader behaviours.

Implement the following organisation and leader behaviours and practices to establish and reinforce operator fundamentals:

a. Clearly define, communicate, and make readily available for operator reference the fundamentals using the '*Your Role in Operator Fundamentals'* document.

b. Ensure initial and continuing training for operators provides them with a thorough understanding of plant design, engineering principles and sciences to complement task requirements. Ensure methods such as open-ended questioning, discussions, walkdowns and dynamic learning activities are used to establish, refresh, reinforce and test this knowledge.

c. Actively monitor and engage operators to improve the application of their fundamentals through in-field coaching. Ensure active monitoring includes the following goals and attributes:

- Make changing behaviours the primary objective, with capturing and trending data a secondary, but still important objective.
- Include thorough, probing inquiries or questions as part of any observation to assess the operator's level of attention on the task, thinking process, level of task understanding and state-of-mind. Pre-job briefings provide an excellent opportunity to gauge an operator's knowledge of an upcoming task. In addition, observe visible behaviours, such as having the procedure in-hand, self-checking and placekeeping.
- Promote, reinforce and reward behaviours that support a culture of understanding on how the plant works and why it works that way. Encourage the use of a questioning attitude and reward conservative decision-making.

[1] The linked documents in Recommendations 1, 2 and 3 are located on the WANO website in the Guidelines and Good Practices Section under Industry Guidance and Reference Documents.

- Build in follow-up activities to ensure identified gaps are addressed in a timely manner and are shared across crews and departments to promote learning and improvement.

d. Ensure individuals in the operations line of responsibility (for example, shift manager, operations manager, plant manager and site vice president) actively monitor key operator fundamental activities at an appropriate frequency. This would include activities such as reactivity changes, field operator rounds, crew responses to simulated transients, surveillance tests and infrequently performed tasks.

e. Ensure operator performance is closely reviewed after significant plant transients and trips to identify potential weaknesses in behaviours, knowledge and practices.

4. **Establish and maintain training and programmes that support effective control room teamwork.**

a. Training should include the importance of staying in your assigned role, of challenging other team members who do not meet the intent of their roles or who step out of their role and of working together to control and monitor the plant effectively.

b. Crew composition assignments for each operating team should be structured such that there is a good mix of new and experienced operators on each crew with complementary backgrounds and personalities.

c. Ensure members of a newly constituted crew train together before assuming control room duties, and evaluate personnel returning from lengthy off-shift assignments before they resume control room duties.

d. Ensure the shift manager leads, sets high standards, encourages the crew members to be critical of their performance and develops timely and effective actions to continuously improve crew performance.

5. To ensure sustainability of the above actions, use corrective actions, performance indicators and self-assessments to identify, track and trend the effective application of operator fundamentals.

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Discussion

Operator fundamentals are defined as the essential knowledge, skills, behaviours and practices that individuals and operating crews need to apply to operate the plant effectively. The fundamentals that all operators should demonstrate are as follows:

- Monitor plant indications and conditions closely.
- Control plant evolutions precisely.
- Establish a bias for a conservative approach to plant operations.
- Work effectively as a team.
- Have a solid understanding of plant design and system interrelationships.

Appropriate use of operator fundamentals, combined with the proper use of operating procedures and human performance techniques, could have prevented or mitigated the impact of events described in this SOER.

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Operator Fundamentals

Monitor plant indications and conditions closely

1. Monitoring plant indications or parameters requires the full attention of operators, who must continuously analyse indications to determine if the plant is operating as expected. This is true even for operators in plants of more recent design that rely more on digital screens and comprehensive alarm systems to monitor the plant status. Properly monitoring indications requires teamwork within the operating crew to effectively communicate information and coordinate any required actions. However, it is not enough to read the gauge, take the logs or watch the trend. Operators must fully understand what they are monitoring, know when actions are necessary and recognise when to involve supervisors. Operators must also be familiar with plant equipment and component fundamentals, system operation and integrated plant response to interpret accurately the monitored indicator. As a minimum, effective operators do the following when monitoring the plant:

    a. Monitor plant indicators at a frequency based on their importance and procedural requirement, as it pertains to plant conditions, and communicate the status to the operating crew when necessary by describing the indicator, its value, trend and action needed or taken.

    b. Increase the frequency of monitoring key indicators during transients.

    c. Identify slowly developing adverse trends.

    d. Validate the accuracy and proper function of indications through multiple independent means, if available, avoiding undue focus on any single indicator.

    e. Investigate and understand unexpected trends and alarms; take action to restore the system or indicator to normal and ask for assistance when needed.

    f. Increase monitoring, as appropriate, for any disabled alarm function.

2. Although numerous indications are monitored constantly, operators need to maintain the overall picture of plant conditions. For example, operators must maintain continuous awareness of reactor power and other parameters applicable to the particular reactor design, such as reactor pressure or water level. It is important for operators to understand which key parameters to monitor and to determine reactor and plant statuses following reactor power changes or during activities with a potential to affect reactor safety.

The following events emphasise the importance of properly monitoring plant parameters and continuously analysing indications to determine if the plant is operating as expected:

WER PAR 12-0102, 'Loss of inventory in the residual heat removal system', Asco Unit 1 (PWR, Spain)

While performing a surveillance test of semi-automatic recirculation channels, a motor-operated valve that operators had incorrectly verified as deenergised unexpectedly opened during the test. Despite three control room alarms (A sump high level, B sump high level and reactor coolant system low level) the fact that the valve was open went undetected by control room operators for several minutes. The open valve resulted in a loss of approximately 25 m^3 (6600 gallons) of water from the reactor coolant system. The event occurred with the unit in cold shutdown, at a reduced system inventory and with fuel in the reactor vessel.

EAR ATL 10-0003, 'Electrical fault complicated by equipment failure and inappropriate operator action leads to electrical distribution system damage, complicated trip and safety injection', H. B. Robinson Unit 2 (PWR, United States)

During an event, control room operators did not effectively monitor important control board indications and act promptly to control key plant parameters, contributing to an automatic safety injection actuation, an uncontrolled cooldown and a challenge to reactor coolant pump (RCP) seal cooling. Specifically, the crew did not identify that the volume control tank level was low until emergency procedures directed checking of the charging flow. At this time, the volume control tank was empty and the operating charging pump had lost suction, causing an inadequate seal injection flow and elevated RCP bearing water temperatures.

EAR PAR 12-0009, 'Low temperature overpressure protection system out of service in mode 4', Doel Unit 1 (PWR, Belgium)

Control room operators did not identify an alarm indicating that the low temperature overpressure protection was out of service. This resulted in the unit exceeding the action completion time in the technical specification. The event occurred during heatup after a refuelling outage when an instrumentation test, performed as part of a required surveillance, took the low temperature overpressure protection out of service. Approximately 46 hours following the test, operators discovered that the low temperature overpressure protection was still out of service. No formal instruction existed in the test procedure to tell operators to put the low temperature overpressure protection back into operation following the completion of the test.

SER 2009-3 'Human error during trip response results in inadvertent safety injection' Daya Bay Unit 2 (PWR, China)

In November 2007, with Daya Bay Unit 2 operating at full power, a maintenance error caused an automatic reactor trip and a loss of offsite power. A control room operator responding to the trip inadvertently opened valves that caused high-pressure safety injection flow to be directed into the reactor vessel. The control room crew took several actions not directed by procedures in their efforts to control the increasing primary system pressure and pressuriser level. It took one hour and 57 minutes to recognise that safety injection flow was directed to the reactor vessel.

WANO Peer Review Report Examples

The following examples are from recent WANO Peer Review reports and demonstrate that numerous problems still exist with operators properly monitoring plant parameters and continuously analysing indications to determine if the plant is operating as expected:

1. During a unit outage, operators did not notice that the reactor pool temperature slowly increased over three days from about 20°C to 54°C, resulting in an overflow of the pool. Control room operators regularly record the pool temperature.

2. A main control room operator closed an isolation valve downstream of train A of the reactor residual heat removal (RHR) system and it was not identified until seven hours following the event, when a night shift manager discovered it during a safety assessment. Successive rounds of operators, as well as the technical manager and shift supervisor of the following team did not detect an isolated train of RHR. This condition violated the technical specifications and indicated a lack of operator knowledge about the technical specifications' applicability to RHR.

3. On occasion, field operators have not properly responded to equipment oil levels that were out of range. For example, on Unit 1, the chemical and volume control charging pumps were respectively 35%, 50% and 25% above the maximum level. In another situation, on Unit 3's circulating water filtration system, one sight glass was completely empty of oil.

Control plant evolutions precisely

1. Accurate operating guidance, deep knowledge of integrated system operations and theory, use of human performance error prevention tools and attention to the task are essential in ensuring precise plant control.

2. The introduction and application of human performance tools in the 1990s have substantially improved operator performance when controlling the plant. However, along with human performance tools, operators are also expected to fully understand and anticipate the plant's response to actions, remain focused on the task, and know what to do if an unexpected response occurs. Therefore, operators should be well versed in the coordination of activities and understand how activities impact the plant. Conservative critical parameter limits and bands are set to ensure that the margin to an undesirable state is maintained. The level of complexity of any activity and an operator or crew's level of familiarity with the activity should be considered and additional controls or oversight implemented, if necessary.

3. Operators need to implement all four attributes of the human performance tool STAR (stop, think, act, review), with special emphasis on T (think) and R (review). Operators need to use all of their knowledge and skills to ensure the plant responds as expected and that indications are consistent with what is expected to occur based on the action taken. For example, when changing a system alignment, an operator checks for flow changes and verifies that indicated parameters, such as flow, motor amperage, level, pressure or power, change as expected.

4. Industry operating experience has shown two recurring problems regarding the use of procedures and human performance tools. First, operators followed procedures exactly as written, but did not adequately understand the evolution or have the necessary knowledge to know how the plant should respond to the situation or condition. In these cases, if the plant does not respond properly because of equipment problems or if the procedure is deficient, an event occurs. Second, many events have occurred when operators did not follow procedures as written, implemented evolutions with no procedure guidance or did not use human performance techniques properly to support procedure use. Precisely controlling the plant requires the thoughtful use of procedures and human performance tools, including the following fundamental behaviours and practices:

   a. Establish clear parameters and limits and then control the parameters within the specified bands and at specified rates.

   b. As allowed by pre-established operational procedures and guidance, anticipate automatic trips and operation of equipment protective features and take deliberate, manual actions to avoid challenging automatic actuations. Examples of protective features are turbine trips, reactor trips and other features intended to prevent damage to equipment. Manual action of safety system operation, such as closing isolation valves and starting safety systems, are governed by normal, emergency and abnormal operating procedures.

c. Verify and report automatic system actuations or responses, which include required operator actions if the plant has not responded as expected.

d. Ensure indications and plant conditions are appropriate for the applicable procedure before implementing it.

e. Know the basis for the procedure and each procedure step prior to performing an action or manipulating equipment. Operate the plant in accordance with approved and up-to-date operating procedures and information.

f. Know which steps could result in undesirable consequences if not performed correctly, and ensure appropriate contingencies are established.

g. Use formally approved labels and line-ups.

h. Track changes in system alignments.

The following events emphasise the importance of using procedures to operate the plant precisely and thoughtfully, to track system alignment changes and exercise proper configuration control to ensure awareness of plant status:

WER TYO 12-0122, 'Reactor trip on activation of secondary shutdown system on neutron power very high', Rajasthan Unit 5 (PHWR, India)

With reactor power being raised, a control room panel operator did not properly reference the startup procedure for required actions. As a result, when the reactor power exceeded 8% the reactor tripped on neutron power very high because the secondary shutdown system trip normal setpoint had not been reset as required. The event occurred following a controlled reduction in reactor power during emergency core cooling system and a reactor power setback testing. During the testing, reactor power was reduced to 0.1% and an automatic changeover of the secondary shutdown system trip setpoint to 8% power occurred.

MER MOW 08-0010, 'Reactor water entry into the feedwater equipment premises through valves disassembled for maintenance', Smolensk Unit 3 (LWGR, Russia)

Because they were not effectively tracking plant configuration status, main control room operators were unaware that maintenance work on two feedwater system valves precluded certain methods of adding makeup water to the steam drums. Subsequently when operators attempted to initiate makeup to the steam drums, using the normal method through the feedwater lines, a substantial spill of water into the feedwater equipment room occurred.

WER ATL 12-0465, 'Automatic reactor trip due to an inadvertent turbine trip signal during testing', South Texas Project Unit 1 (PWR, United States)

A reactor operator and control room supervisor missed the procedure step to block the turbine trip signal during a scheduled surveillance test, resulting in an automatic reactor trip. The operator inadvertently turned two pages at once, skipping the page that contained a critical procedure step designed to prevent a turbine trip and subsequent reactor trip during the test.

WER PAR 12-0193, 'Alignment error leading to the injection of boron into the primary circuit during a stretching cycle for 7 minutes', Cruas Unit 3 (PWR, France)

An alignment error resulting from performing a reactivity control operation from memory rather than using a procedure resulted in a reactor, near the end of core life, being shut down and causing an early entry into a refueling outage. As part of a makeup/discharge operation in the primary circuit, a control room operator initiated a dilution of 20 m3 without use of a procedure and manually directed the three-way valve to the boron recycle system. After the dilution, the valve and the water and boron makeup system were not placed into automatic makeup configuration as required. Because of this configuration, enough boron was injected into the primary system to preclude proper reactor operation and the shift manager ordered it to be shutdown.

WANO Peer Review Report Examples

The following examples are from recent WANO Peer Review reports and demonstrate that problems still exist with using procedures to operate the plant precisely and thoughtfully and tracking system alignment changes to ensure accurate turnovers of plant status:

1. A misaligned switch resulted in the Unit 1 containment spray system pump being deenergised and unavailable for use. Operators had incorrectly deenergised the pump during a procedural activity approximately one hour before discovering it was misaligned. An operator and a supervisor responsible for aligning and verifying that the switch was in the proper, energised position signed the governing procedure.

2. A main control room operator started a second component cooling water pump before the pre-job briefing for a residual heat removal surveillance test and before reaching the step in the procedure that directed starting the pump. In addition, the operator did not report starting the pump to the shift supervisor, so that the shift supervisor was unaware of the actual configuration of the plant.

Operate the plant with a conservative bias

1. Conservatism is a bias for action in the direction of plant safety, and includes maintaining a sufficient safety margin, as indicated by parameters. This behaviour also avoids challenging the plant and shows a clear desire to protect the reactor core. Conservatism prompts operators to reduce reactor power or shut down the reactor whenever the procedures, their training or their judgment indicates the need. It also prompts operators to stop and question the action they are about to take so that they do not proceed when uncertain. In addition, operators realise that actions allowed during some plant conditions may not be conservative during other plant conditions. Performing an action that produced a desirable effect in the past may produce an undesirable effect in a different situation.

2. Managers declare and strongly support the policy to act conservatively as it applies to reactor safety through frequent communication and reinforcement of this approach to operations. The message must emphasise conservative actions over production goals when reactor safety margins are involved. When faced with unknown or unexpected conditions, operators should feel empowered to reduce power or shutdown the reactor without fear of negative repercussions from senior managers. How the crew reacts to unknown or unexpected conditions and the decisions made by the operating crew determine the effectiveness of management's message. The following examples demonstrate a conservative bias for reactor safety:

    a. Equipment needed to support effective plant operation is available and is operating properly. This includes backup indications available, controllers in automatic and redundant equipment operational.

    b. Avoid multiple or concurrent activities with a potential to affect reactor safety.

c. Understand plant conditions, effectively control the plant and know the appropriate action to take when control of the plant or of a component cannot be maintained. This may mean stopping the evolution and involving supervisors.

d. Question conditions and situations that are out of the ordinary or unexpected, particularly if they could erode plant operating margins. Resolve these issues in a timely manner rather than continuing to operate the plant with the condition present.

e. Establish conservative operating bands for critical parameters to ensure that sufficient operating margins are maintained and undesirable conditions avoided.

f. Approach operating the reactor with an appropriate amount of scepticism and with well-developed contingency plans should an evolution not proceed as expected.

The following events highlight the need to operate the plant with a conservative bias and to approach each operation and control manipulation with thoughtful restraint:

MER ATL 12-0231, 'Automatic reactor trip on intermediate range monitor hi-hi set point during startup', Pilgrim Unit 1 (BWR, United States)

During reactor startup, control rods were withdrawn without adequately evaluating the impact the rod withdrawal would have on reactor power, resulting in an automatic reactor trip. With reactor thermal power at approximately 1.7 percent, the reactor tripped on hi-hi flux on both reactor protection system channels. Prior to the trip, operators took the reactor critical, reached the point of adding heat and established a heatup rate. During the heatup, operators observed the five-minute reactor coolant heatup indication reach 18°F (about 8°C), which they mistakenly believed corresponded to an approximate 216°F/hour (about 102°C/hour) heatup rate. The actual heatup rate was 50°F/hour (10°C/hour). In response, the shift manager directed operators to insert control rods to reduce the heatup rate. This direction did not include specific guidance or limitations regarding the extent rods were to be inserted. Five control rods were inserted from position 12 to 8 (10 notches) and resulted in the reactor being brought subcritical. Upon recognition that the heatup had stopped, operators withdrew control rods to re-establish a heatup. Four of the previously inserted control rods were withdrawn from position 8 to 12. During withdrawal of the fifth rod, an automatic reactor trip occurred because of hi-hi flux conditions.

WER MOW 13-0007 'Non-Permissible increasing of reactor power without available system SCORPIO for monitoring of reactor core' Dukovany Unit 3 (VVER, Czech Republic)

Despite conflicting indications of reactor power level between neutron flux detectors and other means, such as temperature measurements and steam flow, control room operators continued to increase power to support reactor physics testing. The result was exceeding the 35% operational power level allowed (by approximately 10%) without having the online core surveillance system (SCORPIO) in service and without full availability of in-core detectors. Once operators stopped and investigated why the power indicated by the neutron flux detectors did not match other indications of reactor power, they discovered a large number of flux detectors and two of three in-core cabling systems disconnected.

WANO Peer Review Report Examples

The following examples are taken from WANO Peer Review reports and demonstrate that numerous problems still exist with operating the plant using a conservative bias and approaching each operation and control manipulation with thoughtful restraint:

1. Operators caused a heat transport system (HTS) release outside containment when they did not adequately question the impact of a minor operating procedure (MOP) they developed to determine the position of a failed HTS motor operated valve. When operators executed the MOP, a water

hammer occurred that caused two relief valves to lift and fail, resulting in a 13,000-gallon HTS release to the containment recovery sump. Because they rationalised the task as minor, the operators did not consult supporting procedures and documentation to the extent necessary to understand fully the risk of implementing the actions they had developed for the existing plant conditions.

2. In May 2010, operators commenced an integrated emergency core cooling surveillance test without understanding the affected system configurations. As a result, operators did not respond to a lowering reactor water level that deviated 24 inches from the programme over a one-hour period. Furthermore, they did not stop the test when observed anomalies occurred, choosing instead to continue testing.

3. Operations personnel did not recognise the risk of performing a surveillance test on equipment that rendered one emergency diesel generator (EDG) inoperable while the other EDG was unavailable. If the second EDG had become unavailable because of the testing, outage risk would have changed from the lowest risk classification to the highest risk classification without contingency plans in place.

Work well as a team and communicate effectively, particularly during abnormal or emergency situations

1. The fundamentals discussed in the above sections are more effective when operating crews work together as a team. Effective teams include a thoughtful balance of backgrounds, experience, technical knowledge and personalities. Each member of the crew understands his or her assigned role and how the crew works together to respond to transients and evolutions. Members of an operating crew review, challenge and support each other's actions while maintaining their own unique role. In addition, operating crews do not hesitate to question or challenge supervisors if directions are given that may place the plant in an undesirable state. Being part of a successful operating crew means that each member of the team feels personally responsible for the successful outcome of the crew's efforts. Effective team skills and behaviours that contribute to a crew's success include the following:

    a. Ask questions to obtain the necessary information.

    b. Encourage a questioning attitude, and advocate a willingness and obligation for main control room personnel to question and challenge when an action appears inappropriate or when the expected action for a given condition is not taken.

    c. Resolve conflicts to achieve the best solutions and improve the effectiveness of the team.

    d. Seek to improve team performance by being critical of that performance when appropriate.

    e. Provide thorough and accurate turnovers during or at the end of a shift.

    f. Fulfil assigned roles, and do not assume another team role without a proper turnover.

2. Communication is an important aspect of teamwork. Members of crews should communicate clearly and regularly to share important information and clarify priorities. For example, at the beginning of a plant transient, operating crews monitor and communicate the value and trend of key parameters. Proper communications and information sharing allows the prioritisation of actions needed to protect the core and stabilise the reactor. Good communication improves crew alignment and allows an individual member of a crew to understand better plant conditions and their decision-making responsibilities. Effective crews also have a clearly defined communication standard and rigorously follow that standard.

3. Effective command and control and oversight are critical to good teamwork. Control room supervisors must use available resources thoughtfully to ensure operators correctly prioritise their actions to mitigate an event. Shift managers, control room supervisors and shift technical advisors need to perform their designated role and maintain a broad overview of a transient or evolution. They should

avoid becoming overly involved in the performance of any task that distracts them from fulfilling their oversight, leadership or advisory function.

The following are examples of a lack of questioning attitude, improper communications or the operating member of a crew stepping out of their role and becoming overly involved with specific activities or tasks, thereby diminishing overall teamwork:

SER 2012-3, 'Station blackout and loss of shutdown cooling event resulting from inadequate risk assessment', Kori Unit 1 (PWR, South Korea)

Control room personnel did not demonstrate the proper questioning attitude and willingness to challenge decisions by managers that placed the station in a more vulnerable condition as it relates to reactor safety. For example, two main control room operators discussed why the main generator relay testing was to be performed with the 354 kV line the only offsite power source, but did not raise this concern with the operations shift manager. During testing, a protective trip actuated causing a loss of off-site power, contributing to a station blackout and loss of shutdown cooling. A lack of willingness to question or challenge decisions made by senior managers also indicates a weakness in working effectively as team.

EAR ATL 10-0005, 'Overpower and overpressure trip during nuclear instrumentation calibration', Arkansas Nuclear One Unit 1(PWR, United States)

During the nuclear instrument calibration that led to the reactor trip, oversight and command and control effectiveness in the control room degraded because the assistant operations manager (AOM), operations shift manager (OSM), and control room supervisor (CRS) were performing tasks that detracted from their oversight functions. The CRS did not confirm that control room operators understood their individual responsibilities in support of the nuclear instrumentation calibration. The OSM was engaged in other ongoing activities in the control room, including voltage regulator testing. An AOM was in the control room during unit startup. However, at the time of the nuclear instrumentation calibration, he was coordinating a conference call with other site managers.

MER MOW 12-0028, 'Two control rod housing failures caused by internal dynamic forces generated during hydraulic testing of the reactor coolant system', Kalinin Unit 3 (VVER, Russia)

Lack of communications among operators, combined with a failure to communicate the need to change operating procedures regarding the potential for gases to accumulate in the upper areas of the reactor during cold shutdown, contributed to two control rod-housing failures during hydraulic testing. With the unit in an outage, leaks from two control rod drive mechanisms developed during post-maintenance hydraulic testing of the reactor pressure vessel. The cause of the leak was determined to be a detonation of an explosive mixture of hydrogen gas in the upper portions of the mechanisms' housings. The hydrogen was present because operators did not properly vent the reactor pressure vessel. The need to vent the pressure vessel before performing the testing to remove hydrogen gas that may have accumulated was known by some of the more experienced operators, but not by those that performed the test.

WANO Peer Review Report Examples

The following examples from recent WANO Peer Review reports show that problems still exist with demonstrating a questioning attitude, communicating properly and with operating crew members stepping out of their role and becoming overly involved with specific activities or tasks:

1. During simulator training, operators on two different crews silenced alarms associated with failed recirculation pump seals without addressing or reporting them to the control room supervisor. In addition, the shift technical advisor did not fulfil his oversight role. These factors contributed to seal failures resulting in primary leaks in the drywell and an increasing drywell pressure before the operators isolated the reactor recirculation pump. The resultant high drywell pressure caused automatic safety system actuations and required the declaration of an emergency alert.

2. While attempting to perform an activity in the Unit 1 main control room, five different red alarms occurred and were reset (several times) without properly communicating the alarms to other crew members or checking the alarm response sheet. After finally checking the alarm response sheet, it was determined that the configuration of a system had to be changed in order to perform the activity.

Have a detailed understanding of plant design, system and component interactions and applicable theoretical or engineering principles

1. Operators should have a thorough understanding of the basis for their actions and the expected system response to those actions. They should pair their knowledge of system interactions with the procedural guidance provided to ensure successful outcomes. A detailed understanding of how the plant operates requires more than recognising plant conditions and following procedures as written. Operators with a detailed understanding of what is happening and why it is happening are more likely to recognise the added risk associated with reduced operating margins resulting from unusual or degraded plant conditions.

2. The applied science and engineering principles behind plant operations are understood and refreshed on a regular basis, including reactor physics, fluid flow, thermodynamics and electrical theory. This level of knowledge is broader than understanding component design and integrated operations. For example, licensed operators and shift technical advisors understand that a critical reactor at the point of adding heat (POAH) behaves much differently than a subcritical reactor in the intermediate range for the same rod pattern.

3. Behaviours and practices that promote a detailed understanding of plant design, engineering principles and sciences include the following:

    a. Before operating a component, understand how it functions and interacts with other components or systems.

    b. Understand the risk profile for the existing plant configuration, including the collective risk of having multiple, diverse components out of service or temporary modifications installed.

    c. Establish a learning environment among crew members that encourages questioning, challenging and reviewing information.

    d. Regularly review system drawings and diagrams with the intention of refreshing basic knowledge.

    e. Train using simulator scenarios that challenge the fundamental knowledge of plant design, engineering principles and sciences.

    f. Include plant design, engineering principles and sciences in continuing training of operators.

g. Regularly evaluate crew member knowledge of plant design, engineering principles and sciences.

h. Discuss expected system and parameter changes and their basis during pre-job briefings.

The following events demonstrate the undesired results that occur when operators attempt to use procedures or operate plant systems and equipment without understanding plant design, applicable engineering principles or sciences:

EAR TYO 12-0001, 'Operation of overpressure relief devices of moderator cover gas with reactor in shutdown state', Tarapur Unit 4, (PHWR, India)

With the unit in a shutdown condition, deuterium and oxygen re-combiners and the moderator cover gas recirculation were stopped and the system depressurised to perform maintenance activities without adequately determining the impact this condition would have on the plant. As a result of placing the unit in this configuration and the subsequent increase in conductivity of the moderator due to poison addition, a buildup of deuterium in the cover gas space occurred. The end result was a deuterium deflagration that caused all the over pressure relief devices of the calandria to rupture.

ENR ATL 11-0001, 'Reactivity management event', Millstone Unit 2 (PWR, United States)

During a turbine control valve test, the operator erroneously believed that he would lower turbine first-stage pressure by increasing turbine load. The shift technical advisor, acting as a peer-checker, and the unit supervisor both agreed with the operator that increasing turbine load would lower first-stage pressure. Although just-in-time training was conducted, operator knowledge deficiencies concerning the effect of turbine load changes on turbine first-stage pressure resulted in the incorrect operation of the load set pushbutton, causing an unplanned increase in reactor power.

MER TYO 12-0021, 'Reactor trip due to the condenser vacuum-low', Ulchin Unit 1 (PWR, South Korea)

The lack of knowledge by operators related to the automatic interlock function of the air exhaust shutoff valve and the auxiliary boiler contributed to a reactor trip from 100 percent power when main condenser vacuum was lost. The event occurred during performance testing of the auxiliary boiler, resulting in an automatic reactor trip when the interlock opened the valve unexpectedly.

WANO Peer Review Report Example

The following example is from a recent WANO Peer Review report and demonstrates that problems still exist with operating plant systems and equipment without adequately understanding the plant design, engineering principles or sciences involved:

Because of inadequate knowledge, field operators did not understand the need or reasons for manipulating inverter breakers in a specific order. As a result, a manual turbine trip and reactor shutdown occurred because of a sustained loss of 120 VAC electrical control power. The event occurred while restoring inverters to service and the alternate power supply breaker to an inverter was opened before normal power was available.

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Reinforcing Operator Fundamentals – the key to long-term sustainability

Managers and supervisors must effectively communicate, continuously monitor and reinforce operator fundamentals. Lack of focus on operator fundamentals can allow the standard for individual and crew behaviours and practices to decline. If this happens, undesirable or improper standards can become ingrained. Effective organisational and leadership behaviours and practices include, but are not limited to, the following:

1. Teach operators what the proper fundamentals are and how to use them. This should be in addition to normal operator training. It is about explaining the expectation of how to operate the plant, including using equipment to maintain critical safety functions and asking questions to better understand why to take an action. This is a key role of supervisors and managers.

2. Reinforce the proper use of human performance tools when conducting plant operations, but also communicate that use of these tools is a means to an end, not the end in itself. The objective is for operators to properly monitor and control the plant. Human performance tools are a means to support this objective effectively.

3. Use training methods designed to build knowledge of integrated plant operation, design and procedure basis and theory (the applied science and engineering behind plant operations). Drawing systems, asking in-depth questions during walkdowns and using simulator scenarios that assess a crew's decision-making skills are methods that have proven effective.

4. Embed the application and reinforcement of operator fundamentals in processes, procedures, performance indicators and goals.

Include operator fundamentals in ongoing and periodic self-assessments and observations.

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Causes and Contributing Factors

While the industry has applied a significant effort to correct the identified causes and contributors to operator fundamental weaknesses, recent events indicate that these efforts were ineffective or short-lived. Based on an analysis of events, peer review areas for improvement and industry input, the following are some of the more important contributors to these operator fundamental weaknesses:

1. Operator fundamentals were not clearly defined.

2. An overreliance on processes and procedures promoted a compliance-based approach to a task and a "checklist mentality". Operators have been too focused on *how* to perform the task, rather than *why* they are performing the task.

3. In some cases, operators' initial and continuing training insufficiently challenges or reinforces operator fundamentals. Some corrective actions and training were one-time events rather than part of an institutional process. In other situations, the training was too limited in scope.

4. Management and supervisor monitoring, feedback, reinforcement and coaching of fundamentals were insufficient or ineffective. Feedback was focused on the use of human performance tools, without equal consideration for applying conservative decision making and demonstrating a questioning attitude. Consequently, managers and supervisors did not observe or effectively assess the operator's approach to a task, including their concentration and knowledge level.

Because plants are operating more reliably, operators and operations crews have fewer opportunities to experience large plant transients and complex evolutions, such as trips and reactor startups. Such activities have traditionally aided in the development and use of operator fundamentals. Training and coaching methods have not been adequately adjusted to manage this change in experience-based knowledge development.

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SOER 2011-2	Fukushima Daiichi Nuclear Station Fuel Damage Caused by Earthquake and Tsunami and the 2012 Addendum
SOER 2011-1	Large Power Transformer Reliability
SOER 2010-1	Shutdown Safety
SOER 2008-1	Rigging, Lifting and Material Handling
SOER 2007-2	Intake Cooling Water Blockage
SOER 2007-1	Reactivity Management
SOER 2004-1	Managing Core Design Changes
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SOER 2002-2	Emergency Power Reliability
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SER 2012-3	Station Blackout and Loss of Shutdown Cooling Event Resulting from Inadequate Risk Assessment
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SER 2012-1	Personnel Overexposure During In-Core Thimble Withdrawal
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SER 2009-1	Failure of Control Rods to Insert on Demand
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SER 2006-1	Flow-Accelerated Corrosion
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SER 2005-1	Gas Intrusion in Safety Systems
SER 2004-2	Fuel Handling Events
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SER 2003-6	Severe Damage to Fuel External to the Reactor Due to a Loss of Decay Heat Removal
SER 2003-5	Operational Decision-Making
SER 2003-4	Condenser Tube Rupture Resulting in Chemical Excursion and Extended Plant Shutdown
SER 2003-3	Internal Contamination and Exit from Site of Contaminated Workers Due to Deficiencies in Plant Radiation Protection Programme
SER 2003-2	Piping Ruptures Caused by Hydrogen Explosions
SER 2003-1	Lessons Learned from Power Up-Rates
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SER 2001-3	Intake Structure Blockage Results in Multi-Unit Transients and Loss of Heat Sink
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SER 2000-4	Isolation of All Low Pressure Feedwater Heaters Results in Complicated Plant Transient
SER 2000-3	Severe Storm Results in Trip of Three Units and Loss of Safety System Functions Due to Partial Plant Flooding
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SER 2000-1	Reactor Trip and Partial Loss of Essential AC and DC Power During Recovery
SER 1999-4	Criticality Accident at a Uranium Processing Plant
SER 1999-3	Significant Reactor Coolant System Leak Resulting From Residual Heat Removal Piping Failure
SER 1999-2	Spurious Containment Spray Resulting in a Severe Plant Transient
SER 1999-1	Main Steam Safety and Relief Valves Unavailable During a Plant Transient

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