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Module 17

MAINTENANCE

OBJECTIVES:

After completing this module you will be able to:

17.1 State the circumstances under which prior approval to do maintenance is required from each of the following:

a) Atomic Energy Control Board (AECB) ⇔ *Page 2*

b) Operations Manager ⇔ *Page 3*

CRO c) Shift Supervisor (SS) ⇔ *Page 3*

CRO d) Control Room Operator (CRO). ⇔ *Page 4*

17.2 Define *pressure boundary work* and state the requirements which apply to: ⇔ *Page 4*

a) Notifying the Ministry of Consumer and Commercial Relations (MCCR) ⇔ *Page 5*

b) Obtaining MCCR approval ⇔ *Page 5*

c) Performing the work ⇔ *Page 5*

d) Inspection/testing of the work. ⇔ *Page 5*

17.3 Describe and give the rationale for each of the following constraints on authorizing safety related system maintenance:

a) Risk versus benefits of doing the maintenance ⇔ *Page 5*

CRO b) System availability requirements for prevailing unit state ⇔ *Page 6*

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Page 6 ⇔ CRO c) Preferred equipment state for maintenance

Page 6 ⇔ d) Use of qualified staff

Page 7 ⇔ CRO e) Working on one channel at a time

Page 7 ⇔ CRO f) Use of different staff on different channels

Page 8 ⇔ CRO g) Testing and inspection requirements

Page 8 ⇔ h) Compliance with design codes and standards

Page 8 ⇔ 17.4 Describe the Supervisor's role in verifying maintenance work.

Page 9 ⇔ 17.5 Explain the need for foreign material exclusion controls when systems are open for maintenance, and list <u>three</u> types of controls.

Page 10 ⇔ 17.6 Explain why maintenance activities must preserve the integrity of equipment *nuclear code classifications, seismic qualification* and *environmental qualification*.

MAINTENANCE AUTHORIZATION

Maintenance is strictly controlled via the work authorization process, to maintain equipment reliability and effectiveness to at least the standards assumed in the safety analysis. The required approvals depend on the nature of the maintenance, and on the importance of the equipment to nuclear safety. The Approver's role is to ensure that the proposed maintenance will comply with the conditions of the Operating License, and that the safety and production risks are acceptable.

Obj. 17.1 a) ⇔

AECB Maintenance Authorization Role

The AECB is not normally involved in maintenance approvals. The AECB issues a Reactor Operating License based on its acceptance of the safety analyses and OP&P, and holds the Utility responsible for day to day operations and maintenance within these prescribed boundaries. However, direct AECB approval <u>is</u> required to do the following types of maintenance:

- Special Safety System non-standard maintenance procedures which do not place component(s) in the safe state, with the reactor in the GSS.

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- Maintenance affecting the operation of *nuclear safeguards* equipment installed by the *International Atomic Energy Agency*.

The Reactor Operating License stipulates that:

> ***Maintenance at the nuclear facility shall be of such a standard that, in the opinion of the Board, the reliability and effectiveness of all equipment and systems as claimed in the Safety Report and the documents listed in the License application are assured.***

The AECB has the right to review the quality of all maintenance as it affects nuclear safety, and to intervene as required.

Operations Manager Maintenance Authorization Role

⇔ *Obj. 17.1 b)*

The Operations Manager is responsible for setting maintenance standards, and directly approves the following:

- Policies governing the preparation of maintenance procedures
- Maintenance procedures for safety related systems, including environmental emissions monitoring equipment, such as the stack monitors
- Non-standard work practices, such as use of non-standard isolating devices for work protection
- Maintenance requiring AECB notification or approval
- Maintenance on non-redundant components of safety related systems, such as the auxiliary boiler feed pump.

Shift Supervisor Maintenance Authorization Role

⇔ *Obj. 17.1 c)*

The Shift Supervisor (SS) monitors and approves shift maintenance activities on behalf of the Operations Manager. The SS authorizes work on safety related systems, because these systems can affect the capability to *control* reactor power, *cool* the fuel, and *contain* radioactivity. The SS's approval entails his review that:

- adequate priority is placed on the maintenance
- the proposed work won't violate the OP&P or the Operating License
- adequate constraints are prescribed to safeguard the capability to *control, cool* and *contain*
- notifications are made and approvals obtained, as required by regulations and procedures
- all other applicable constraints on authorization are addressed (see later)

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SS approval is required to remove even redundant components of safety related systems from service. The SS obtains Operations Manager approval as required. In order to maximize plant safety and reliability, the SS ensures that the duration of maintenance outages on safety related equipment is minimized.

The above are the minimum requirements with respect to SS authorization. The SS may also require that he personally authorize work on non safety related systems, depending on such considerations as:

- Complexity of work procedure
- Degree of safety hazards and required countermeasures
- Inexperience of the personnel requesting or issuing work authorization
- Involvement of external contractors
- Unit or station conditions and potential impact of work on those conditions.

Obj. 17.1 d) ⇔

Control Room Operator Maintenance Authorization Role

The Control Room Operator (CRO) is concerned with the effects of maintenance on his ability to monitor and control unit operation. The CRO approves all maintenance on his unit via the work authorization process. The CRO may defer maintenance which is incompatible with current unit operating conditions. The CRO should notify the SS if he intends to defer maintenance which the SS has already authorized.

Pressure Boundary Maintenance

Obj. 17.2 ⇔

Definition: *Pressure boundary work* is the repair or modification of systems and equipment with design pressure greater than 103 kPa(g). Work on piping, vessels, and associated supports welded thereto is considered pressure boundary work. Direct replacement of gaskets, seals, glands, pump shafts and valve stems, while rigorously controlled to ensure the use of approved materials and work procedures, is not pressure boundary work.

Definition: *Major work* is maintenance involving welding on system equipment which is classified as a pressure boundary. The exception is non radioactive systems containing liquids not more hazardous than water, where welding is *major work* only if the system is a nuclear class 1, 2 or 3 system, or the design pressure exceeds 1720 kPa(g), or operating temperature exceeds 65°C.

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Pressure boundary work is done in compliance with the requirements of the Boilers and Pressure Vessels Act, which is administered by the Ontario Ministry of Consumer and Commercial Relations (MCCR). The AECB has designated the MCCR as its agent in pressure boundary matters, but retains controlling authority. The following requirements apply to pressure boundary work:

- The MCCR (and the AECB) must be Notified whenever a pressure boundary rupture occurs. ⇔ *Obj. 17.2 a)*
- The MCCR must approve the following: ⇔ *Obj. 17.2 b)*
  - starting any proposed *major work*
  - returning a pressure boundary to service after *major work*
  - Welder qualifications
  - Quality Control (QC) Technician qualifications
  - Welding procedures
  - Registration of pressure boundary design
  - Non specification component replacement on nuclear systems
  - Non-standard repairs
  - Hydrostatic or pneumatic testing.
- All pressure boundary repairs, modifications, examination and testing shall be done by properly qualified personnel (certified welders and QC Technicians), according to approved procedures, and using approved materials. ⇔ *Obj. 17.2 c)*
- All pressure boundary repairs and modifications shall be adequately tested and inspected by certified QC Technicians before return to service ⇔ *Obj. 17.2 d)*
- Documentation which is adequate, legible and retrievable shall be maintained as proof of compliance with regulatory requirements for pressure boundary work.

CONSTRAINTS ON MAINTENANCE AUTHORIZATION

The SS should consider the following constraints when deciding whether or not to authorize maintenance, and what conditions to impose on the authorization. ⇔ *Obj. 17.3 a)*

1. Risk versus Benefit of Doing the Maintenance

The first concern is whether the benefits of doing the maintenance justify the risks to safety and production. There is risk associated with completing any maintenance activity, and risk associated with deferring it. In the case of

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discretionary maintenance, the SS should evaluate these risks, and decide whether or not to authorize the work on the basis of minimizing overall risk. This is not to suggest that the SS does a formal risk-benefit analysis before authorizing maintenance, but that he should nevertheless consider such generic questions as: "What are the risks of doing, and not doing, this work? Have we got into trouble doing similar work in the past? If so, have circumstances improved, or can I impose conditions which will reduce the risk this time? Will unit conditions become more conducive to doing this work in the near term?"

Obj. 17.3 b) ⇔

2. *Required System Availability for Prevailing Unit Conditions*

The SS must be careful not to authorize maintenance which will disable equipment which is required to support the prevailing (or future) unit operating state. Conversely, the unit must be placed in a state conducive to doing the maintenance, and safeguards, such as condition guarantees, must be in place to ensure it remains that way. For example, work requiring SDS unavailability would proceed only with the unit in the GSS, and the GSS could not be surrendered while this work was in progress.

The SS would not normally authorize safety related system maintenance with the unit in a transient or unstable condition, or with known process faults which might require safety related system response. For example, work on a SDS would not normally proceed while the unit was experiencing unstable boiler level control. When maintenance is done on the common systems of a multi-unit station, this concern extends to the stability of all affected units.

Finally, certain unit conditions are sometimes preferred due to the capability to monitor the effect of the maintenance. For example, some RRS maintenance is performed at high power, where neutronic signals are large enough to calibrate and test RRS equipment.

Obj. 17.3 c) ⇔

3. *Preferred Component State for Maintenance*

The system or component which is to undergo maintenance must be placed in a safe state, if possible. For example, a special safety system channel might be rejected, a valve placed in its fail safe position, or contacts jumpered to the safe state. Placing a component or system in its safe state may reduce, or even eliminate, an impairment.

Obj. 17.3 d) ⇔

4. *Use of Qualified Staff*

Maintenance to excellent standards requires more than just the correct materials, tools and procedures. The SS must ensure that maintenance, especially on safety related systems, is done only by properly qualified staff—ie, by workers who are

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knowledgeable of the procedures and skilled in the use of pertinent good maintenance practices. Good maintenance practices are taught and their acquisition is verified during trade skills training.

Example: Qualification to work on special safety systems requires successful completion of:

- Classroom training on special safety system maintenance
- Field checkout on special safety system maintenance
- Verification of competence by the Shift Maintenance Supervisor.

5. Work On Channelized Systems

⇔ *Obj. 17.3 e)*

Work on channelized systems is constrained by the following OP&P:

> ***The method of performing maintenance on channelized systems, which shall be used unless Operations Manager approval is given for an alternative method, is to put in a safe state, repair, test, and return one channel to service prior to working on another channel.***

The advantages of this procedure for a channel majority voting arrangement are as follows:

- Placing the channel in the safe state keeps the system fully available, so that on-line maintenance can be done safely.
- Testing each repaired channel prior to rejecting another channel avoids operating with undetected system impairments.
- This procedure limits the consequences of many maintenance errors and procedural deficiencies to the first channel, as such problems will usually be identified and corrected prior to proceeding to the second channel.

6. Use of Different Staff to Maintain Channel Independence

⇔ *Obj. 17.3 f)*

A Maintainer assigned to calibrate all SDS high power trip channels might make the same error on all three channels, such that the unit would trip at a higher power level than intended. Such level 1 impairments can be avoided by assigning a different Maintainer to calibrate each channel, since it is unlikely that three individuals would independently make the same error. Using a different *individual* to work on each safety system channel is thus important to maintaining channel independence. The common cause influence of the *Supervisor* can similarly be eliminated by assigning each channel to a different crew.

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Obj. 17.3 g) ⇔

7. Required Testing and Inspection

The SS must ensure that adequate inspections and testing are specified and completed before returning safety related equipment to service. The specified inspections and tests should verify that the maintenance was performed correctly, and that system performance is at least as good as that credited in the safety analysis.

The SS should remember that some safety system tests cannot be done under unit shutdown conditions, due to negligible neutron flux, HT coolant depressurized, and so on. In such cases, the SS may wish to defer safety system maintenance until unit conditions facilitate testing, rather than leave a channel rejected for the balance of an outage, as a successful test result is a mandatory prerequisite to returning a channel to service.

A poised system is usually tested prior to commencing maintenance. This practice minimizes the assigned unavailability in case faults are introduced during the job. For example, suppose a poised system which is routinely tested once per month fails its test after a 30-minute maintenance outage. If the system passed a pre-maintenance test, the unavailability is reckoned at 30 minutes; otherwise, it must be reckoned at half the monthly test interval, plus the outage duration.

Obj. 17.3 h) ⇔

8. Adherence To Design Codes and Standards

Since the purpose of maintenance is to ensure that systems will operate with the effectiveness and reliability claimed in the safety report, equipment must be maintained to the codes and standards originally specified by the Designers. Otherwise, the safety analysis will be invalidated, and operation will be unsafe.

Compliance with design specifications means the use of the specified materials, maintenance methods, calibration procedures and performance specifications. Such compliance is normally achieved in practice by assigning only qualified personnel to do maintenance, insisting on compliance with approved work plans and maintenance procedures, and by verifying the work. The SS is not qualified to verify independently that plans and procedures properly account for the applicable codes and standards, but he can verify that they have been prepared, reviewed and approved by technically proficient persons, by checking the signatures on the work package.

Obj. 17.4 ⇔

Verification Of Maintenance via Supervision & Testing

As discussed above, maintenance on safety related equipment must be verified through testing before returning the equipment to service. Maintenance on <u>non</u>

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safety related equipment is similarly verified where required by law, or where maintenance errors might cause a conventional safety hazard, or a significant economic penalty. Such verification will establish that the equipment is restored to design specifications, and in the case of a functional test, that the system is operating to specifications, prior to declaring the equipment in service. When practical, testing and inspection should be conducted prior to full re-assembly to allow early detection and correction of faults.

Maintenance is also field verified by supervisors. Direct supervisory surveillance of each and every activity is not required when qualified personnel use approved procedures. However, the Supervisor does spot checks at a frequency sufficient to provide confidence in the quality of the work. The frequency and intensity of supervisory surveillance depends on the worker's qualifications and competence, on the frequency at which the task is completed, and on the potential consequences of errors.

The SS's personal verification activities vary with the importance of the results to nuclear safety. For example, the SS might personally verify a high HT temperature SDS set point adjustment, and that the ECI flow path is clear before unit start-up, but rely on a verbal report on the status of a D_2O collection pump.

Pressure boundary work requires special verifications, as discussed earlier in this module under pressure boundary maintenance authorization.

Foreign Material Exclusion Controls

⇔ *Obj. 17.5*

When systems are opened for maintenance, they become vulnerable to the ingress of foreign material. Depending on the system and the nature of the foreign material, such ingress can be extremely hazardous. For example, in the PHTS, debris driven by high coolant flows can cause erosion, corrosion, mechanical damage, or impaired fuel cooling in one or more fuel channels. In the generator, metallic debris can cause irreparable damage to the core, requiring its replacement. So strict foreign material exclusion controls are established when critical systems are opened for maintenance—eg, **restricted access to the work site, accounting for all materials and tools used, and extensive internal inspections**.

CANDU operating experience indicates that failure to account for and remove all materials used in maintenance on open systems has caused very costly errors. For example, lead shielding left in a Bruce-A boiler caused corrosion, forcing the premature retirement from service of Unit 2, a billion dollar asset. In 1995, a plywood barrier left in the PHT system at Point Lepreau resulted in heat transport pump damage, as well as a lengthy and costly outage to retrieve debris, which otherwise might have caused channel flow blockages. These examples illustrate the possible consequences when foreign material exclusion practices break down. And the consequences could have been much worse.

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Nuclear Code Classification & Special Qualifications

CANDU systems and components are *nuclear code classified* according to their function and service conditions and the effect on nuclear safety if they fail. Nuclear systems piping and equipment are code classified according to CSA Standards in decreasing order of importance to nuclear safety as *nuclear class 1, 2,* or *3 (NC1, NC2,* or *NC3).* For example, systems which directly transport heat from the fuel, and whose failure results in a LOCA, are classified as *NC1. NC2* and *NC3* systems are relatively less critical. It is imperative that *NC1, NC2* or *NC3* material be installed in the corresponding class of system.

As discussed in Module 6, equipment may be specially *qualified* to function under stressful operating conditions. For example, ***seismic qualification*** refers to the ability to function during and after a design basis earthquake, whereas ***environmental qualification*** refers to the ability to function for a specified mission time in the harsh operating environment imposed by certain accidents, such as high temperature, steam, high radiation, or wetting.

Obj. 17.6 ⇔

Seismic and environmental qualifications and nuclear code classifications are credited in the safety analysis as a means of limiting vulnerability to pressure boundary failures, and equipment failures during certain common mode incidents. Therefore, the SS must ensure that identical replacement materials and equipment are used, and that maintenance is done according to approved procedures, so as to maintain the equipment nuclear code classification or special qualification status. When exact replacements are not available, the SS must obtain assistance from Technical Support staff, and approval to install substitutes from the Operations Manager.

Material History Docket

The *material history docket* is the assembly of certified analysis, inspection and test records required for nuclear code classified equipment. The history docket is kept on file to:

- Verify use of the correct materials, and compliance with design standards by the manufacturer (whether the station itself or external supplier)
- Provide a method of tracing various installed applications of similar materials—eg, which pressure tubes or end fittings were manufactured by whom using what alloy and process. In the event of material failures, the consequences of leaving similar materials in service elsewhere can then be assessed, and they can be replaced if necessary. Knowledge of component material type and installation history can help investigators determine the root causes of material failures.

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SUMMARY OF THE KEY CONCEPTS

- The AECB approves non-standard maintenance on special safety systems, where components are not in the safe state, and the reactor is not in the GSS.
- The Operations Manager approves maintenance procedures for safety related systems, non-standard work practices, and maintenance which requires AECB notification or approval.
- The SS authorizes maintenance on safety related systems, because they can affect the capability to control, cool, and contain. Before authorizing maintenance, the SS should review various considerations, as discussed, including the risks versus the benefits of doing the work.
- The CRO reviews all proposed maintenance for potential impact on his capability to monitor and control the unit.
- Pressure boundary work refers to repair or modification of equipment with design pressure greater than 103 kPa(g). MCCR notification and approval requirements were discussed.
- Pressure boundary repairs, examination and testing must be done by qualified personnel. Repairs must be verified by certified QC Technicians using approved QC procedures before returning a pressure boundary to service.
- The unit and equipment must be placed in a state conducive to doing the maintenance, with safeguards in place to keep them that way.
- A different individual, preferably from a different crew, is used to work on each safety system channel. This helps to maintain channel independence, since different Maintainers are unlikely to make the same mistake.
- Testing verifies that safety related equipment performance is equal to or better than that credited in the safety analysis. Pre-maintenance testing minimizes the unavailability assigned as a result of faults introduced during the maintenance. Post-maintenance testing ensures equipment is restored to design and operating specifications.
- Three advantages of rejecting, repairing, testing and returning to service one safety system channel before working on another channel were discussed.
- Qualified staff are those knowledgeable of the applicable procedures, and skilled in the use of good maintenance practices.
- When systems are opened for maintenance, they become vulnerable to the ingress of foreign material, which may be carried throughout the system, causing damage, severe economic penalty, and extreme safety hazards.
- If safety related equipment design specifications, including nuclear code classification, seismic qualification and environmental qualification, are violated as a result of maintenance, the safety analysis will be invalidated and continued operation unsafe.

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ASSIGNMENT

1. Carefully prepare detailed answers to the Module 17 objectives.

2. What regulatory agency controls and monitors pressure boundary work, pursuant to what statute?

3. What requirements with respect to pressure boundary work ensure worker and public safety?

4. Discuss the Operations Manager's role with regard to station maintenance.

5. On what systems must the SS approve maintenance? Why?

6. Why must the CRO approve <u>all</u> maintenance on the unit?

7. Give and explain the rationale for <u>eight</u> constraints considered by the SS prior to authorizing maintenance on safety related systems.

8. Explain why compliance with design codes and standards is necessary, and how this compliance is normally achieved during maintenance.

9. Explain why maintenance which requires opening a system is hazardous to the system. How is this hazard eliminated or controlled?

10. As the duty SS, you are informed that a leak has been detected from a crack in a PHTS pump on a shutdown unit. The pump is to be replaced. State the applicable reports, notifications, approvals, maintenance constraints and concerns with regard to nuclear safety.

11. As the duty SS, you are requested to authorize replacing a pressure transmitter, which is located on the PHTS and provides a signal to a special safety system. You are informed that, because the transmitter type and mounting differs from the original, a short extension of existing tubing is required to connect it. Also, due to the nature of the system, you are unable to reject the associated portion of the safety system logic.

    State the applicable notifications, approvals, maintenance constraints and concerns with regard to nuclear safety and briefly explain why each is applicable.

Prepared by: G. Jager

Revised by: L. Haacke

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