ENGINEERING DESIGN FILE

EDF No.: 4334 EDF Rev. No.: 1 Project File No.:

1. Title: SUMMARY OF RESOLUTION OF ADVANCED TEST REACTOR UNREVIEWED SAFETY QUESTIONS - SE-2003-126, SE-2003-145, SE-2003-146, SE-2003-155, SE-2003-156, and SE-2003-171

2. Index Codes:
Building/Type TRA-670 SSC ID N/A Site Area 531 (TRA)

3. NPH Performance Category: _____ or ☒ N/A

4. EDF Safety Category: SC or ☐ N/A SCC Safety Category: SC or ☐ N/A

5. Summary:

This Engineering Design File (EDF) was prepared to serve as an addendum to the Advanced Test Reactor (ATR) Upgraded Final Safety Analysis Report (UFSAR) (SAR-153) for presentation of the resolutions of six new-information unreviewed safety questions (USQ). In August, the Department of Energy (DOE) Office of Independent Oversight and Performance Assurance (OA) performed an in-depth vertical slice review of selected safety systems at the ATR. During the investigation of an OA team question, Reactor Programs personnel identified a USQ related to an unanalyzed delay time in the ATR emergency firewater injection system (SE-2003-126).

At the time of the OA team's departure from the ATR, several technical questions remained under investigation. These issues and the related issues identified by Reactor Programs personnel were evaluated via the USQ process as applicable. Of the issues investigated related to the OA assessment, two additional new-information USQ determinations were positive. USQ determination SE-2003-145 relates to the way the ATR firewater supply system is modeled in the ATR safety basis and the controls that are derived from that model. USQ determination SE-2003-146 relates to the potential for failures in non-safety-related equipment to adversely impact the function of nearby safety-related equipment.

Recent seismic evaluations were prompted by both OA team questions about the characterization of seismically-induced loss of coolant accidents and by new site-specific seismic design criteria for soil for the Test Reactor Area that were drafted in September 2003. Site-specific seismic criteria for rock and soil have been under development for several years in response to current DOE orders and standards and the open DOE comments in the safety evaluation report from the original approval of the ATR upgraded final safety analysis report. The seismic criteria for rock have been added to the site-wide DOE Idaho Operations Office (ID) architectural engineering standards. The draft seismic soil design criteria are currently under review for inclusion in the DOE-ID architectural engineering standards. As part of an effort to update the existing ATR seismic upgrade plan, Reactor Programs contracted the services of ABS Consulting to review the draft seismic design criteria and to expand previous walkdowns of Seismic Category I safety-related equipment. The ABS Consulting reports identified several areas of concern with the ATR seismic safety basis. Three of these issues have resulted in positive new-information USQ evaluations.

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The six positive new-information USQs addressed in this EDF are:

USQ Evaluation Document Number	Title
SE-2003-126	Emergency firewater injection system time delay
SE-2003-145	ATR firewater supply system modeling issues
SE-2003-146	Potential deficiencies identified during system interaction walkdowns
SE-2003-155	Seismic walkdown of bypass demineralizer cation and anion tanks
SE-2003-171	ATR degassing tank seismic capacity
SE-2003-156	Seismic walkdown of M-11 utility uninterruptible power supply

The OA team also identified a deficiency in that the tubing related to measuring the surge tank level was not on a facility drawing. In addressing this deficiency, Reactor Programs personnel noted that the uncertainty in the position of this tubing was not considered in the determination of the TSR setpoints. Accounting for this uncertainty results in a change to the TSR control limit for surge tank level. Consistent with the USQ procedure, this issue can be accommodated with a TSR change (requiring DOE approval) and does not require a USQ evaluation. This change is included in this submittal package.

Resolution of these USQs required plant modifications and derivation of additional operational controls including revision to the ATR Technical Safety Requirements. These resolution activities are described herein.

Revision 1 makes editorial corrections in Table 2.2.2-1 (firewater pump equipment numbers) and Section 1.1.6 (equipment number 670-E-103), clarifies the commitments derived in Section 2.2.3, and corrects other minor typographical errors.

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6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

	R/A	Typed Name/Organization	Signature	Date
Performer/ Author	N/A	R. T. McCracken	R. T. McCracken	3-15-04
Technical Checker	R	G. L. Sharp	Gregg Sharp	3-15-04
Independent Peer Reviewer (if applicable)	R	N/A		
Approver	A	S. K Penny	Keith Penny	3/15/04
Requestor (if applicable)	Ac	N/A		
Doc. Control	AC	T. McDermott /4R01	Traci McDermott	8/10/04

7. Distribution: (Name and Mail Stop) Reactor Programs Document Control (original + 1), R. T. McCracken, S. K. Penny, D. W. Suthers, J. E. Dwight, D. E. Hale (2 copies), J. C. Chapman

8. Does document contain sensitive unclassified information? ☐ Yes ☒ No
If Yes, what category:

9. Can document be externally distributed? ☐ Yes ☒ No

10. Uniform File Code: 250 Disposition Authority: ENV1-b-4-a
Record Retention Period: Cut off when superseded, obsolete or canceled. Destroy 75 years after cutoff.

11. For QA Records Classification Only: ☐ Lifetime ☒ Nonpermanent ☐ Permanent
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12. NRC related? ☐ Yes ☒ No

13. Registered Professional Engineer's Stamp (if required)

1.0 INTRODUCTION

This Engineering Design File (EDF) was prepared to serve as an addendum to the Advanced Test Reactor (ATR) Upgraded Final Safety Analysis Report (UFSAR) (SAR-153) for presentation of the resolutions of six new-information unreviewed safety questions (USQ). In August, the Department of Energy (DOE) Office of Independent Oversight and Performance Assurance (OA) performed an in-depth vertical slice review of selected safety systems at the Advanced Test Reactor (ATR) (DOE 2003). During the investigation of an OA team question, Reactor Programs personnel identified a USQ related to an unanalyzed delay time in the ATR emergency firewater injection system (EFIS) as documented in SE-2003-126 (BBWI 2003a).

At the time of the OA team's departure from the ATR several technical questions remained under investigation. These issues and the related issues identified by Reactor Programs personnel were evaluated via the USQ process as applicable. Of the issues investigated related to the OA assessment, two additional new-information USQ determinations were positive. USQ determination SE-2003-145 (BBWI 2003b) relates to the way the ATR firewater supply system is modeled in the ATR safety basis and the controls that are derived from that model. USQ determination SE-2003-146 (BBWI 2003c) relates to the potential for failures in non-safety-related equipment to adversely impact the function of nearby safety-related equipment.

Recent seismic evaluations were prompted by both OA team questions about the characterization of seismically-induced loss of coolant accidents (LOCA) and by new site-specific seismic design criteria for soil for the Test Reactor Area drafted in September 2003 (Payne 2003). Site-specific seismic criteria for rock and soil have been under development for several years in response to current DOE orders and standards and the open DOE safety evaluation report comments from the original approval of the ATR upgraded final safety analysis report (DOE 1996). The site-specific seismic criteria for rock have been added to the site-wide DOE-ID architectural engineering standards (DOE-ID 2002). The draft site-specific seismic soil design criteria are currently under review for inclusion in the DOE-ID architectural engineering standards. As part of an effort to update the ATR seismic upgrade plan (Lucoff 1999), Reactor Programs contracted the services of ABS Consulting to review the draft seismic design criteria and to expand previous walkdowns of Seismic Category I safety-related equipment. The ABS reports (ABS 2003a, 2003b) identified several areas of concern with the ATR seismic safety basis. Three of these issues have resulted in positive new-information USQ evaluations SE-2003-155, SE-2003-156, and SE-2003-171 (BBWI 2003d, 2003e, 2003f).

The OA team also identified a deficiency in that the tubing related to measuring the surge tank level was not on a facility drawing. In addressing this deficiency, Reactor Programs personnel noted that the uncertainty in the position of this tubing was not considered in the determination of the TSR setpoints. Accounting for this uncertainty results in a change to the TSR control limit for surge tank level. Consistent with the USQ procedure, this issue can be accommodated with a TSR change (requiring DOE approval) and does not require a USQ evaluation. This change is included in this submittal package.

1.1 Summary of Resolution Efforts

This section provides a summary and the details and references can be found in Section 2.

1.1.1 ATR emergency firewater injection system time delay

The original design of the ATR emergency firewater injection system (EFIS) included drained piping between the EFIS actuation valves and the reactor vessel check valves. The length of drained piping was substantial and would have caused a significant delay in the injection of water into the reactor vessel. The delay could be significant to the performance of the EFIS in mitigating certain loss of coolant accident (LOCA) sequences and was not modeled in the safety basis (SE-2003-126). This USQ was resolved by completing a plant modification to fill the drained piping. With the piping filled with water, water injection into the vessel commences when the actuation valves open, resolving the discrepancy between the plant configuration and the safety basis. Requirements to maintain the piping water filled have been added to the ATR Technical Safety Requirements (TSR) (TSR-186).

1.1.2 ATR firewater supply system modeling issues

The ATR firewater supply system is a multipurpose system. One of the functions of the system is to supply water for the EFIS for LOCA mitigation. The safety basis modeling of the firewater supply system did not account for other usage demands on the system, additional demands created by potential failures outside of the safety-related boundary of the system, or potential failure to start firewater pumps required for LOCA mitigation (SE-2003-145). This USQ was resolved by constructing a more complete model of the firewater supply system, testing the system to validate the model, and using the model to demonstrate that with a firewater pump operating there is ample firewater to meet the EFIS flow rates assumed in the LOCA analyses. The requirement to maintain an operating firewater pump has been added to the ATR TSR. Additional requirements for firewater system operation are derived herein as safety analysis commitments.

Requiring an operating firewater pump is considered an interim resolution. In the long term, system modifications to ensure adequate delivery of water for the EFIS will be investigated.

1.1.3 Deficiencies identified during system interaction walkdowns

The OA team identified a concern with the restraint of compressed gas cylinders in the ATR building. If inadequately restrained, the gas cylinders could become missiles that could damage safety-related equipment.

A walkdown was completed to identify other safety-related system interaction issues. The issues were evaluated for potential USQs, and three issues required correction prior to reactor startup. These issues are the seismic restraint of in-service compressed gas cylinders, constant air monitors, and storage cabinets in proximity to Seismic Category I safety-related equipment (SE-2003-146). These issues were resolved by plant modifications that meet seismic design criteria or by removal of the equipment.

1.1.4 Seismic capacity of bypass demineralizer cation and anion tanks

The ABS consultants concluded the supports for the cation and anion tanks in the ATR bypass demineralizer system would not resist the loads generated by a design basis earthquake. Failure of these supports could result in a more severe seismic LOCA at a higher frequency than addressed in the safety basis (SE-2003-155). A plant modification was completed to adequately support the tanks for a design basis earthquake.

Failure of the bypass demineralizer tanks could result in catastrophic failure of the bypass demineralizer piping. This piping branches off from the primary coolant system (PCS) inlet piping

where it is isolated by a 2.5-in. diameter orifice (flow element FE-37). It returns to the PCS piping at the pump suction header through the CK-B-90 check valve that would provide isolation in the event of a failure in the bypass demineralizer system. The ABS consultants recommended some additional analyses of the bypass demineralizer piping. In lieu of completing that analysis, a catastrophic failure of that piping has been assumed and the resulting 2.5-in. diameter seismic LOCA has been analyzed as a Condition 3 event. The results of that analysis are included herein.

1.1.5 ATR degassing tank seismic capacity

The ABS consultants identified the supports for the PCS degassing tank (670-M-13) needed further evaluation. A previous analysis was reviewed and with the completion of additional analyses, it was concluded that the supports would not resist the loads generated by a design basis earthquake.

Failure of these supports could result in a more severe seismic LOCA at a higher frequency than addressed in the safety basis (SE-2003-171). A plant modification was completed to adequately support the tank for a design basis earthquake.

1.1.6 Seismic walkdown of M-11 utility uninterruptible power supply

The ABS consultants identified that the anchorage for electrical system cabinets (670-E-23, 670-E-105, 670-E-103, 670-E-459, 670-E-28) related to the uninterruptible power supply for the M-11 emergency coolant pump needed further evaluation. A previous analysis was reviewed, and this review coupled with review of the as-built configuration, did not support the conclusion that the cabinets would resist the loads generated by a design basis earthquake.

Seismically-induced failure of electrical power for the M-11 emergency coolant pump could result in a loss of flow that is more severe than addressed in the safety basis (SE-2003-156). A plant modification was completed to adequately support the cabinets.

1.1.7 Surge tank level setpoint change

An error was identified in the engineering design file that described the calculation of the Technical Safety Requirement (TSR) setpoints for the PCS surge tank water level (SAR-153 Section 16.2.2.4). This error was corrected and found to have an insignificant impact on the calculated setpoint. The tubing related to measuring the surge tank level did not appear on a facility drawing. In addressing this deficiency, it was noted that the uncertainty in the position of this tubing was not considered in the determination of the TSR setpoints. The position uncertainty (± 0.25 in.) is significant in this setpoint derivation because the range of the instrument is small (i.e., only 10 in.). Accounting for this uncertainty results in a change to the TSR control limit for surge tank level (Vetter 2003) from > 27% but < 73% to > 28% but < 73%. A TSR change is included in this submittal package.

2.0 DETAILED DISCUSSION OF THE ISSUES

2.1 ATR emergency firewater injection system time delay

The original design of the EFIS left provision for sections of drained piping in the EFIS between the actuation valves and the reactor vessel check valves. This drained piping provided isolation between the reactor PCS and the firewater system. The drained piping also had provisions for detection of leakage through the EFIS actuation valves or the PCS check valves.

When the actuation valves open the air in this drained piping would be pushed into the reactor vessel ahead of the water thus delaying the injection of water. The air injection and delay time have been neglected in the accident analysis modeling since the original design of the facility.

The development of the current safety basis with its more detailed analytical models has placed additional emphasis on the EFIS actuation time. The low reactor vessel pressure actuation system was added as a result of facility safety analysis upgrades and the setpoint has been raised several times to improve injection timing. Thus the discovery condition of the longer than analyzed delay time for water injection resulted in the USQ. The USQ evaluation for this issue was documented in SE-2003-126.

2.1.1 Concerns with drained piping

Julius (2003) determined drained EFIS piping lengths and volumes. The air volumes contained in the drained piping were 20.4 ft^3 in the bottom head EFIS and 7.3 ft^3 in the upper vessel EFIS (Julius 2003). The bottom head EFIS included about 58 ft of drained 8-in. diameter piping and about 4 ft of drained 3-in. diameter piping. Using the initial bottom head EFIS flow rates of about 1,200 gpm from the UFSAR model (Atkinson 1999) resulted in an estimated time delay of about 8 seconds before water is injected via the bottom head EFIS. RELAP5 calculations (Davis 2003) predicted a delay time of 10 seconds for the bottom head system. The RELAP analysis included the effect of the compressibility of the air. The upper vessel EFIS had less drained piping than the bottom head EFIS so the delay time was lower (5 seconds as estimated by RELAP5).

As noted in SE-2003-126, the additional time delay would worsen the consequences of two accidents discussed in the UFSAR. The Condition 3 3-in. diameter LOCA with failure of the LOCA pump shutoff engineered safety feature (ESF) to trip all of the operating primary coolant pumps (PCP) (SAR-153 Section 15.6.5.2) and the Condition 4 3-in. diameter LOCA with failure of one PCP check valve (SAR-153 Section 15.6.5.4) were adversely affected.

An adverse safety impact from air injection (other than the associated time delay) was not expected so a USQ evaluation was not performed for air injection. Air from the upper vessel EFIS is injected into the inlet plenum of the core where it would tend to rise to the top of the reactor vessel. With PCS flow provided by either the PCP or an emergency coolant pump (ECP), air in the upper plenum should be carried out of the vessel through the siphon breakers to the outlet piping thus bypassing the core. The amount of air (approx. 7.3 ft^3) would not adversely impact pump performance and is not much different than air volumes that might exist after normal vessel fill and vent operations. With natural circulation flow, the air would remain in the top of the reactor vessel or exit the top of the vessel if the vessel was open. The air volume is very small relative to the inlet plenum volume (1850 ft^3) and would not pose the risk of uncovering the core or degrading fuel element heat transfer.

Air from the bottom head EFIS is injected into the outlet flow distribution tank via the four 1 7/8-in. lower injection pipes. The air injection rate would be on the order of 2 to 3 ft^3/sec for about 10 seconds (depending on the firewater injection flow). The geometry of four injection pipes and the structure in the lower flow distribution tank would tend to break the air into bubbles. With PCS flow provided by either the PCP or the ECP, the air should be carried out of the vessel via the outlet piping.

As with the upper vessel EFIS, the amount of air (approx. 20 ft^3) would not adversely impact pump performance. With natural circulation flow, the air would rise 10 ft to the bottom of the core then pass through the core to the upper plenum of the reactor vessel. For power operation, natural circulation occurs in accidents that result in complete loss of all AC power, but only after operation of an ECP for a minimum of 30 minutes decay after scram. This amount of air passing through the fuel coolant channels at natural circulation velocities and 30-minute decay heat rates would not compromise fuel cladding temperatures. The air volume is very small relative to the inlet plenum volume (1,850 ft^3) and would not pose the risk of uncovering the core. Natural circulation also occurs during depressurized shutdown operations but for this condition the decay times are much longer than 30 minutes and during depressurized operation which is done with new fuel at very low power levels. The small amount of air passing through the fuel coolant channels at natural circulation velocities and these much lower power levels would not compromise fuel cladding temperatures.

Scoping analyses were performed to support the above qualitative arguments (Davis 2003). The 2-in. diameter seismic LOCA, the 3-in. diameter design-basis LOCA with a stuck open primary coolant pump check valve, and a simulated complete loss of flow accident were analyzed. The scoping analyses showed the air in the EFIS lines did not affect the macroscopic response of the PCS for the transients analyzed. The system pressure, temperature, and flow rates into and out of the vessel were similar with and without air. There were some slight increases in fuel temperatures when air injection was modeled. The analyses showed the qualitative USQ evaluation (SE-2003-126) was conservative for the 3-in. diameter LOCA with a failed primary coolant pump check valve. Thermal-hydraulic margins for this case were not significantly different from those in the UFSAR. The analyses concluded that the air in the EFIS lines should not significantly affect the response of the ATR during any of the transients analyzed. The scoping analyses did not specifically address the 3-in. LOCA with failure of the LOCA pump shutoff ESF. As reported in the USQ SE-2003-126 evaluation, the time delay in water injection could lead to complete draining of the surge tank for this event so the consequences of this event would be worse than presented in the safety basis.

2.1.2 EFIS piping modifications

The EFIS piping was modified to provide for filling and venting the previously drained sections of piping. The fill status of the piping can be verified via sight glasses.

Thus the system configuration will be consistent with the assumptions on system performance in the safety basis. Water injection will commence when the actuation valves open.

The previously open orifice drains were removed, and replaced with double-isolation drain valves. The high points in each of the EFIS piping headers were penetrated, and a double isolation vent was installed (a total of five vents - a vent was installed upstream and downstream of each upper vessel check valve and at a single high point on the lower vessel system). Sight glass level indicators were installed on each of the three EFIS piping headers. Normally accessible, double-isolated low pressure demineralized water (LDW) fill lines were installed to each of the three EFIS piping headers (two upper vessel EFIS headers and one bottom head EFIS header). All of the LDW fill and EFIS vent lines were constructed of 3/8-in. diameter, 0.065-in. wall thickness tubing. The sight glass drains were constructed of 1/2-in. diameter, 0.065-in. wall thickness tubing. The modifications are shown in the Figure 2.1.2-1. As in the past, EFIS flow may be diverted out of the vent and drain lines when EFIS actuates. This diversion flow is estimated to be 15.5 gpm per opening (Hardy 1987). Total diversion flow rates would be 46.5 gpm for the normal configuration (three vents open, two vents closed, and three drains closed) and 124 gpm for the worst case (all eight vents and drains open).

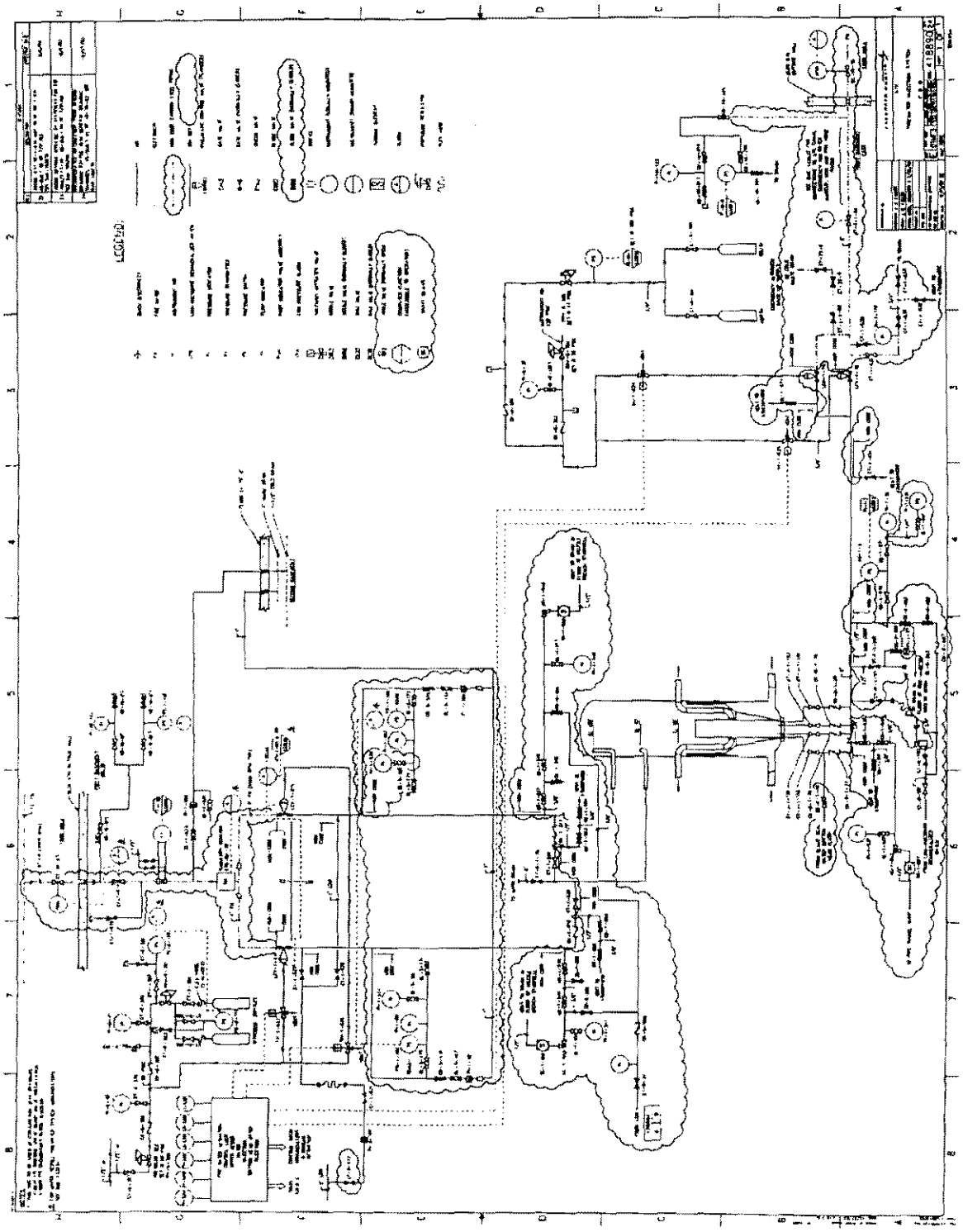

Figure 2.1.2-1: Emergency Firewater Injection System modification (For information only)

2.1.3 Derivation of controls for use of the modified fill and vent system

Filling the previously drained piping with water eliminates the time delay; therefore, the EFIS will perform as modeled in the safety basis. No reanalysis is necessary. Controls for use of the fill and vent system can be derived from existing analyses. A TSR level control is required to ensure the bottom head EFIS piping between check valves (CK-B-1-77, 78, 79, and 80) and level control valves (LCV-1-7A and 7B), upper vessel EFIS piping between check valve (CK-1-618) and level control valve (LCV-1-616), and upper vessel EFIS piping between check valve (CK-1-617) and level control valve (LCV-1-615) are filled with water. This requirement applies in the low power operation mode, the power operation mode, and the pressurized standby mode following power operation until the fuel element cooling time requirement is met. At this point EFIS can be placed in manual. Based on the analysis in Davis (2003), it can be concluded that any small amount of air left in the EFIS piping will not be significant to the results presented in the safety basis.

After the fuel element cooling time is met and EFIS is placed in manual, the EFIS piping will be routinely drained to prevent inadvertent injection of firewater into the PCS. The EFIS piping will be filled during pre-startup checks prior to reactor operation. A routine surveillance is required to ensure the lines stay water filled during operations.

The controls allow the pipe to be drained after EFIS is placed in manual, which is not permitted prior to depressurizing the PCS or prior to decay time meeting the TSR for fuel element cooling time. The fuel element cooling time is met 4 to 10 hours after reactor scram depending on operating power level. EFIS remains in manual during depressurized shutdown operations and during depressurized reactor operation. With the EFIS in manual, the water injection delay time is not significant relative to the time (approximately 9 minutes) required for manual EFIS actuation. Manual EFIS actuation would be necessary in the event of a shutdown or depressurized operation LOCA (SAR-153 Section 15.9). The concern for shutdown or depressurized operation LOCAs is ensuring the fuel elements remain covered with water. Air injection at these low decay or operating power levels would not adversely affect fuel element heat transfer.

All of the necessary controls are included in the TSR revisions. There are no additional safety analysis commitments necessary.

2.1.4 Equipment classification

The vent and fill equipment are classified as safety related Seismic Category I consistent with the guidance in SAR-153 Section 3.2. The vent and fill equipment support operability of the EFIS and maintain the EFIS capability to mitigate the consequences of design basis accidents that result in potential offsite exposures comparable to the 10 CFR 100 guidelines. Seismic analysis for the modification is documented in Nitzel (2003).

2.2 ATR firewater supply system modeling issues

USQ evaluation SE-2003-145 identified deficiencies in the modeling of the firewater supply system delivery of water to the EFIS. The timing of EFIS actuation and the EFIS water flow rate into reactor vessel are important parameters in the LOCA analyses. The previous evaluations of the EFIS flow rate to the reactor vessel were based on firewater system flow data that predates a major upgrade of the firewater supply system that occurred in the late 1970s or early 1980s. The upgrade increased the size of the underground piping supplying the ATR building fire loop. Therefore, the models did not accurately reflect the current system configuration.

The previous evaluations did not consider the normal water usage loads (i.e., the so-called hotel loads) that are fed from the overhead tank, feed water pump and the firewater loop. These hotel loads would compete with the EFIS for firewater when EFIS is fed from the overhead tank thus lowering the flow rate to the reactor vessel. Also the firewater supply system provides backup to utility cooling water (UCW) for the diesel generators when the UCW system pressure drops. These competing demands could exist until a firewater pump starts.

The previous EFIS flow rate evaluations did not consider transient conditions that may occur during the transition from the overhead tank to an operating firewater pump, if the first pump failed to start, or in starting the second firewater pump if fire suppression flow demands were very high. The overhead tank must provide the total flow rate (safety-related EFIS flow plus non-safety-related) until the pump starts and spins up to speed. Since the overhead tank could be empty when the pump start setpoint is reached, there is no water volume to provide the needed flow rate and system pressure, and flow would drop rapidly as the level in the overhead tank standpipe drops. Firewater system pressure and flow rate would continue to drop until a firewater pump starts and provides flow. During this pump start time, the flow rate to the vessel could be less than predicted by the model.

The UFSAR has been ambiguous about the potential to mitigate a LOCA and provide fire suppression. SAR-153 Chapter 9 of the UFSAR states, "The hydraulic demand created by the simultaneous operation of the EFIS and cooling tower deluge systems can be met by the TRA water supply, depending on the number of operating firewater pumps." The TSR bases states, "One firewater pump can supply the minimum requirements for the EFIS. However, in order to provide more reliability and excess capacity to accommodate a simultaneous fire, two operable pumps are required." The previous evaluations have been inconsistent in considering simultaneous demand for LOCA mitigation and fire suppression.

These deficiencies in UFSAR modeling of the firewater system delivery to the EFIS indicate that the firewater system was not adequately controlled to ensure delivery of assumed flow rates to the reactor vessel leading to the declaration of a USQ.

2.2.1 Analysis of firewater supply system

Firewater system testing and analytical modeling were performed to understand the impact of the above deficiencies. The testing provided useful information for validation of the analytical model and provided information on some dynamic effects that are outside the scope of the analytical model. Scenarios were derived consistent with the assumptions in the UFSAR accident analysis. The scenarios were analyzed with the model and the results compared to the minimum flow rate assumed in the UFSAR analysis. Based on the results, operating requirements were established for the firewater supply system.

The simplified models used in the past do not adequately represent the multipurpose usage of the firewater supply system. Therefore, a system model was developed using the commercially available PIPEFLO computer software. While the PIPEFLO code is a fairly simplistic steady-state code, it is adequate for the application of investigating firewater supply system flow rates. The PIPEFLO code was supported by completion of instrumented firewater supply system flow testing. The testing and analysis of the firewater supply system are documented in Rowsell (2003).

The combination of testing and computer modeling showed that the previous models greatly under-predicted firewater supply system flow rates. The piping friction loss in the older models was over estimated relative to the currently installed larger diameter piping. However, the testing and modeling substantiated the basic concern of the USQ evaluation that the system could be over-taxed such that delivery rates to the reactor vessel were less than predicted. The fundamental issue with the firewater supply system is that the firewater pump start setpoints are not derived from performance requirements for either reactor accident mitigation or fire suppression, rather the setpoints have been established based on experience using a criterion that minimizes pump starts during normal facility operation.

The test data show that firewater pumps can start due to dynamic pressures well before the overhead tank is drained when flow demand is high enough. These effects have not been fully evaluated, but are likely due to the flow paths established during the testing. Both the north and south flow paths to the TRA-670 firewater piping loop were open during testing. EFIS flow rates with all actuation valves open appear to be high enough to start a firewater pump, however, EFIS flow rates for the faulted condition (one upper EFIS valve failed) do not appear to be high enough. This dynamic pump start phenomenon is not well enough understood for reliance on it as the primary pump actuation method in the reactor safety analysis.

The firewater supply analysis in Rowsell (2003) considered:

1. A design-basis LOCA with full operation of the EFIS
2. A design-basis LOCA with a faulted EFIS
3. A design-basis LOCA with simultaneous fire suppression demand, and
4. A seismic LOCA with loss of AC power, simultaneous fire suppression demand and UCW demand.

The analyses considered each of the above cases with the EFIS supplied by:

1. The normal firewater system lineup (operating feed water pump and overhead tank at normal level)
2. The 619-12 electric firewater pump, and
3. A TRA-688 firewater pump.

The TRA-688 firewater pumps have the smallest capacity of any TRA firewater pump. Based on the results in Rowsell (2003), the 619-12 electric firewater pump provides the lowest EFIS flow rates of the firewater pumps outside of TRA-688. So modeling these pumps provides enveloping results. Hotel loads up to 1,200 gpm were modeled. A cooling tower deluge flow rate of 3,500 gpm was used to envelop the fire suppression demand. The UCW demand was modeled as 700 gpm. The diversion flow through the EFIS piping vent and fill system was not explicitly modeled, however, the conservatism in the hotel load would account for this diversion. An acceptance criterion was established based on the total EFIS flow rate used in the ATR accident analysis (i.e., 2,085 gpm with the reactor vessel pressure at 17 psia) (Atkinson 1999).

2.2.1.1 Normal system lineup

The analysis shows the normal system lineup will provide adequate total EFIS flow rates for all cases. For the LOCA with simultaneous fire suppression demands, the feed water pump was operating outside of the vendor pump curve, so its reliability and performance are unknown. Additionally, the safety analysis cannot rely on non-safety-related equipment. For the seismic LOCA, the feed water pump was tripped off due to loss of AC power. For this seismic case, the total EFIS flow rate was only slightly above the acceptance criterion. The operation of the feed water pump may adversely delay firewater pump starts since the bailey valve and feed water pump will attempt to maintain normal system pressure.

The safety-related overhead tank alone can supply acceptable flow rates for all cases. However, the inventory of the overhead tank is limited and the previously discussed issues concerning firewater pump start times are not completely resolved when only the overhead tank is modeled.

2.2.1.2 619-12 electric firewater pump

The analyses show the 619-12 electric firewater pump provides adequate flow rates for all cases. The electric firewater pump maintains system pressure high enough to close the check valve that isolates the overhead tank and operating feed water pump for the first two LOCA cases. The 619-12-firewater pump is augmented by flow from the overhead tank and the feed water pump when the simultaneous fire suppression demand is modeled. With a simultaneous fire suppression demand, the 619-12-firewater pump does not maintain system pressure high enough to isolate the overhead tank. For the design-basis LOCA with simultaneous fire suppression demand, the feed water pump is operating outside of the vendor pump curve. For the seismic case, both the 619-12-firewater pump and the feed water pump are assumed failed due to loss of AC power, and the overhead tank alone provides the flow rate.

2.2.1.3 TRA-688 firewater pump

The analyses show a TRA-688 pump provides acceptable flow rates for all cases. However, the TRA-688 pump is augmented by flow from the overhead tank and the feed water pump when the simultaneous fire suppression load is modeled. The TRA-688 pump does not maintain system pressure high enough to isolate the overhead tank. The feed water pump is again operating outside of the vendor pump curve. For the seismic case the feed water pump is assumed failed due to loss of AC power, and the overhead tank alone augments the flow rate from the TRA-688 firewater pump.

2.2.2 Other firewater supply system issues

The firewater supply system safety-related boundaries are defined in Table 9.2-3 of the SAR-153. Some of these boundary valves are normally open to provide operable fire suppression systems for TRA buildings. There have been concerns about the seismic capacity of the underground piping, the penetrations of the underground piping into buildings, and the masonry buildings with fire suppression piping. Reviews by ABS Consulting (ABS 2003a) concluded the underground piping and penetrations into buildings other than TRA-670 should not fail for events up to the design basis earthquake. ABS recommended further review to determine if masonry buildings were reinforced and to determine the type of penetrations of fire suppression system piping into TRA-670. Collapse of masonry buildings could lead to fire suppression system piping failures outside of the safety related boundary. Since TRA-670 is supported to bedrock, differential movement between the building and the underground piping could lead to piping failures. Both issues have been investigated. Drawings and design documents indicate that the masonry buildings at TRA are reinforced (Smith 2003). The fire suppression piping penetrations into TRA-670 are designed to accommodate differential movement (Smith 2003).

The ATR safety basis does not develop an upper limit for EFIS flow rate. There were some concerns with the potential for the bottom head EFIS flow to lift fuel elements out of the core. Testing (Clemons 1992) showed there was no evidence of fuel element lifting at measured bottom head EFIS flow rates of 1,600 gpm. The fuel element T-bars were removed from the test fuel element for this test, the vessel water was lowered to reduce the core pressure, and there was no ECP driving downward flow through the core.

The maximum bottom head EFIS flow rate predicted in Rowsell (2003) was about 2,050 gpm. Normally there would be an ECP running during EFIS injection and there would be a net downward flow through the core. The maximum flow case had the electric firewater pump running. EFIS flow rates during LOCA mitigation are very transient in nature. The LOCA calculations supporting the ATR safety basis show that the EFIS flow rate is initially high, but then decreases rapidly as the EFIS pressurizes the PCS. Within one to two minutes the EFIS flow equilibrates such that EFIS flow rate equals the break flow rate at a constant system pressure. EFIS and break flows are typically less than 1,200 gpm for the current safety basis EFIS model with a source pressure of 63 psig at the firewater pump outlet. With a source pressure about two times higher in pressure than currently assumed, the total EFIS flow rate would be expected to be less than 1,800 gpm (total of both upper vessel and bottom head EFIS) after the flows and pressures stabilize. With the total EFIS flow rate at 1,800 gpm the bottom head EFIS flow rate would be significantly less than the 1,600 gpm test flow rate.

In the event of a shutdown LOCA after the operating firewater pump is secured and with no forced flow in the reactor vessel, the bottom head EFIS would be supplied from the overhead tank and operating feed water pump. For this case the predicted bottom head EFIS flow rate is less than 1,700 gpm (Rowsell 2003). The higher than expected EFIS flow rates are not sufficient to lift a fuel element from its seat because of the fuel element T-Bars.

2.2.3 Derivation of controls for the firewater supply system

The testing and analysis described in Rowsell (2003) indicate that reactor vessel delivery rates will be greater than the values assumed in the safety basis when a firewater pump is running. Thus a TSR level control has been established to maintain an operating firewater pump. This requirement applies in the low power operation mode, the power operation mode, and the pressurized standby mode following power operation until the fuel element cooling time requirement is met. The requirement for maintaining an operating firewater pump is only necessary when the PCS is pressurized and decay heat is high (limited to the operating modes listed above). A TSR surveillance is required to ensure a firewater pump is operating.

Typically, the electric firewater pump (619-12) will be selected for operation. The electric pump is powered from commercial/diesel power. Currently the pump is configured to start either manually or automatically based on the low-pressure setpoint. With the current configuration and the pump in continuous operation it will stop on loss of the power source. It will not start automatically when the alternate power source becomes available unless the system pressure is below the setpoint. However, by isolating the pressure switch and bleeding off the pressure a continuous start signal will be generated and the pump will start automatically, after a 25-second delay, if the primary power source is lost and the alternate power source becomes available.

The seismic LOCA sequence assumes a complete loss of AC power (commercial and diesel); therefore the electric pump would shutdown. The 633-1 diesel firewater pump receives an automatic start signal when its starting battery charger loses AC power. This feature must be operable to provide for an operating firewater pump for the seismic LOCA sequence when the electric pump is selected as the operating pump. The time delay on this feature has the pump started before the EFIS actuation in the design basis seismic events.

This typical lineup with the electric pump operating and the 633-1 diesel firewater pump in standby with an automatic start feature on loss of AC power provides a success path for seismic LOCA mitigation. The four diesel-driven firewater pumps are sufficiently robust that they are expected to survive the design basis earthquake so lineups with a diesel pump operating do not need a pump with a standby auto start feature. The current requirement to maintain at least two operable firewater pumps with irradiated fuel elements in the reactor vessel is not changed (TSR-186).

The SAR currently assumes complete loss of AC power at 2 seconds into the seismic LOCA sequence. EFIS actuation is predicted to occur at 3.5 to 4 minutes into the 2-in. and 2.5-in. seismic LOCAs, and 2.2 to 2.4 minutes into the 3-in. seismic LOCA (Davis and Polkinghorne 1999). EFIS does not contribute substantially to thermal margins until the M-11 emergency pump flow coastdown at 30 minutes. EFIS flow between initial actuation and 30 minutes increases vessel pressure, reduces fuel temperatures, maintains emergency pump net positive suction head, and maintains vessel inventory. The analysis supports a time delay of ≤ 120 seconds for the auto start feature on total loss of AC power on the 633-1 firewater pump.

The Rowsell (2003) analysis predicts the overhead tank will augment the operating firewater pump when there are simultaneous fire suppression and LOCA mitigation demands. If the operating firewater pump fails, the overhead tank alone will supply the demands. In either case, the overhead tank level will decrease fairly rapidly. The low-pressure pump start features would be operable on the other firewater pumps. The analysis in Rowsell (2003) predicts that in either case (overhead tank alone supplying EFIS, fire suppression, UCW, and hotel loads or overhead tank augmenting a pump with these loads) that the high flow rates would reduce pressures such that firewater pump start signals would occur prior to draining the overhead tank or reaching minimum vortex submergence levels in the overhead tank. Air entrainment from a vortex in the overhead tank would not harm the firewater pumps since these pumps take suction from the storage tanks not the overhead tank.

The normal overhead tank level is 32 ft or 110,000 gallons and the overhead tank level is alarmed at 25 ft or 82,000 gallons. Even with the tank alone supplying the all of the above loads at a total flow rate of 7,550 gpm (Rowsell 2003), there would be nearly 11 minutes between the low level alarm and complete draining of the tank. Several pump start signals should have occurred prior to that time.

The requirement for minimum firewater system supply volume (≥ 500,000 gallons) is not changed (TSR-186). However, with the change to require an operating firewater pump, the overhead tank inventory may not be available for LOCA mitigation. The operable firewater pump lineup must be supported by the selection of ground level storage tanks providing the volume.

The water level in the ground level storage tanks (TRA-719A, B, and C) is maintained automatically by automatic start and stop features on the deep well pumps. These features are actuated by calibrated tank level instrumentation. In order to maintain an adequate water inventory, the nominal setpoints are at ≥ 22 ft for the pump start and ≤ 26 ft for the pump shutoff for the deep well pump selected to start first. ABS (2003a, 2003b) recommended additional seismic analysis of the TRA-719C. The tank will be isolated until the analysis is completed.

The TRA-781 tank is filled manually using cooling tower makeup water. The instrumentation used to monitor water level must be calibrated.

The pump-start circuits include time delays that stagger pump starts to avoid severe water hammer effects from simultaneous starting of several pumps. These are shown in Table 2.2.2-1.

Table 2.2.2-1 Firewater pump start pressure setpoints and delay times.

Pump	Start Pressure Setpoint (psig)	Start Time Delay (seconds)
619-10	65 ± 2	5
633-1	60 ± 2	15
619-12	55 ± 2	25
688-M-1	65 ± 2	35
688-M-2	60 ± 2	45

The requirement to have an operating firewater pump will be included in the TSR. The other requirements are safety analysis commitments. These are summarized below:

The following controls are to be invoked whenever an operating firewater pump is required per TSR-186:

- In order for the 619-12 electric firewater pump to qualify as the operating firewater pump (preferred option), the following conditions must be met.
  a. The 619-12 firewater pump pressure switch must be isolated with pressure removed in order to send a continuous start signal.
  b. The 633-1 diesel firewater pump automatic start signal actuated when its starting battery charger loses AC power must be operable.
  c. The time delay on the 633-1 diesel firewater pump must be less than 120 seconds.
- Both the north and south flow paths to the TRA-670 firewater piping loop must be open.

The following controls are to be invoked whenever EFIS is required to be operable as established by TSR-186.

- Consistent with the firewater pump alignment and water supply selected to meet TSR-186 requirements, the instrumentation that controls the automatic start and stop features on the deep well pumps must be calibrated and have nominal setpoints ≥ 22 ft for the pump start and ≤ 26 ft for the pump shutoff for the deep well pump selected to start first, or the level indication instrumentation for the TRA-781 tank must be calibrated.
- The instrumentation that measures water level in the overhead tank must be calibrated and have a nominal low level alarm setpoint of ≥ 24.5 ft.
- Each operable pump selected for TSR compliance must have a minimum supply volume of ≥ 500,000 gallons available.
- The ground level storage tank TRA-719C must be valved out of service until a seismic analysis is completed.

2.2.4 Equipment classification

The TRA-688 firewater pumps, the TRA-781 water tank, and the associated piping for delivery of water from the TRA-781 tank to the TRA-670 firewater piping loop are safety related Seismic Category I. The 633-1 auto start feature on total loss of AC power is safety related Seismic Category I.

2.3 System interaction and seismic issues

2.3.1 Deficiencies identified during system interaction walkdowns

An OA team concern with the restraint of compressed gas cylinders in the ATR building led to an overall concern about the coverage of potential system interactions in the ATR safety basis (DOE 2003). In response to this concern, the system interaction coverage in SAR--153 was reviewed and supplemented by a systematic walkdown to identify other safety-related system interaction issues.

Section 3.6.2 of SAR-153 discusses the determination of rupture locations and dynamic effects associated with the postulated rupture of piping. A recent systems interactions walkdown evaluation (Penny 2003) identified high energy piping in the ATR first and second basement areas that included gland seal water system, N-16 system, and Naval Reactors makeup system piping. No significant vulnerabilities to nearby safety related equipment were identified.

Section 3.7.2.8 of the SAR-153 discusses the interaction of non-Seismic Category I structures with Seismic Category I structures. Evaluations performed to assess the effect of seismic motion of non-Seismic Category I structures on the performance of Seismic Category I structures include seismic walkdowns of the plant completed as part of the ATR probabilistic risk assessment (PRA) (Eide, Khericha, and Thatcher 1989, 1991) and recent systems interactions walkdowns that addressed seismic stability of non-installed items including in-service compressed gas cylinders, CAMs, and storage cabinets (Penny 2003). Storage racks for in-service compressed gas cylinders in proximity to Seismic Category I equipment were installed that would secure the gas cylinders during a Performance Category (PC) 4 seismic event (Hawkes 2003a, 2003b). CAMs and storage cabinets were either relocated or restrained to prevent interaction with Seismic Category I equipment. These corrective actions resolve the conditions noted in SE-2003-146. Surveillance will be conducted to provide assurance that no new seismic interactions are introduced.

2.3.2 Seismic capacity of bypass demineralizer cation and anion tanks and the ATR degassing tank

ABS Consulting was contracted to expand previous walkdowns of Seismic Category I safety-related equipment. Previous walkdown by ABS Consulting were used to evaluate seismic fragility for the ATR PRA and to develop the ATR Seismic Upgrade Plan (Lucoff 1999). The ABS Consulting reports (ABS 2003a, 2003b) identified several areas of concern with the ATR seismic safety basis.

Section 3.9.3.4 of SAR-153 supports the section discussing mechanical systems and components. Seismic walkdowns conducted in 2003 by a team of Seismic Qualification Users Group (SQUG) trained Seismic Capability Engineers (ABS 2003a) led to the modification of the seismic restraints of the degassing tank and bypass demineralizer cation and anion tanks that interface with non-radiographed piping that is connected to the PCS. The systems reviewed were typical of commercial power plants; therefore, SQUG training was applicable. Restraint of the degassing tank was evaluated to meet PC 4 seismic criteria (Lacy 2003). Restraints for the bypass demineralizer tanks were evaluated to meet PC 4 seismic criteria (Winn 2003). These modifications resolve the conditions noted in SE-2003-155 and SE-2003-171.

Entries in Table 3.9-11 that do not correctly reflect the component fragilities include:

Item #20: The ground level storage tank TRA-719C does not necessarily have 2 g capacity following past upgrades

Item #35: The estimated values for the degassing tank were for the unmodified tank and were too optimistic. The fragility of the modified tank is unknown at this time. It can be reassessed during activities that would be part of the Seismic Upgrade Plan.

2.3.2.1 2.5-in. seismic LOCA

One poorly supported run of piping in the bypass demineralizer system was noted in the ABS Consulting report (ABS 2003a). This piping is not expected to catastrophically rupture and thus it is consistent with the seismic LOCA safety basis. In consideration of the other findings of the ABS consultants, a rupture of the bypass demineralizer line (1-42) was analyzed (Polkinghorne 2003). The rupture was assumed to occur downstream of the 2.5-in. diameter orifice (FE-37). The consequences of this 2.5-in. break were evaluated according to the ATR Plant Protection Criteria for Condition 3 events.

The UFSAR RELAP5/MOD2.5 code was used to calculate the thermal-hydraulic response of the core and PCS, and the ATR-SINDA and SINDA-SAMPLE models were used to evaluate protective margins for Plate 19 of the ATR fuel element. The initial conditions and sequence definition for the seismic LOCA analyses were the same as for the seismic LOCA analysis discussed in SAR-153 Section 15.6.4.

Similar to previous seismic LOCA analyses, thermal limits were approached twice during this event. The first approach to limits occurred as the PCPs coasted down (due to loss of AC power), and the second occurred after the DC power supply for the M-11 emergency coolant pump was depleted (30 minutes into the accident), causing ECP M-11 to coast down.

Since the late thermal margins for a 3-inch-diameter seismic LOCA meet the Condition 3 ATR plant protection criteria, only the early margins were evaluated for the 2.5-inch-diameter break. The minimum critical heat flux and flow instability margins were 3.46 and 3.83σ, respectively, which meet the Condition 3 ATR plant protection criteria.

2.3.3 Seismic capacity of utility uninterruptible power supply

Section 3.10.4.2 of SAR-153 supports the section discussing seismic qualification of Seismic Category I instrumentation and electrical equipment. Seismic walkdowns conducted in 2003 by a team of SQUG trained Seismic Capability Engineers (ABS 2003a) led to the modification of the seismic anchorage for electrical cabinets associated with the motor starter and electrical power for operating the M-11 emergency coolant pump. The electrical cabinet restraints were evaluated to meet PC 4 seismic criteria (Richins 2003). These modifications resolve the conditions noted in SE-2003-156.

The information in Table 3.10-1 is correct, except that 670-E-28 and 670-E-459 should be included. The seismic fragility associated with 670-E-28 is provided in entry #11. And the seismic fragility associated with 670-E-459 can be combined with entry #12.

2.3.4 Review of seismic analyses for USQ resolution

SAR-153 Sections 3.7.1 and 2A.2.6.2 describe seismic design parameters for the ATR. DOE-ID 2002 defines the current TRA seismic design parameters for rock. Different seismic design parameters were used in the seismic analyses referenced herein; therefore, Richins (2003), Nitzel (2003), Lacy (2003), Hawkes (2003a, 2003b), and Winn (2003) were reviewed.

The review of the five EDFs resulted in the following observations regarding the seismic loads that were applied:

Richins (2003), Nitzel (2003), and Lacy (2003) all referenced and considered seismic loads based on the current SAR design parameters. Lacy (2003) also considered additional seismic loads based on response spectra scaled from data contained in Appendix S of the DOE A-E Standard (DOE-ID 2001). These spectra are slightly more conservative than the RG-1.60 spectra for frequencies above approximately 14 Hz; thus, seismic loads at least equal to the minimum required by the SAR design parameters were used throughout the analysis documented in Lacy (2003).

The analysis documented in Hawkes (2003a, 2003b) was originally performed using seismic loads based on accelerations found in Table 0111-3 of the previous version of the DOE-ID AE Standard (DOE-ID 2001) for a Performance Category 2 (PC-2) component. The calculations also included evaluation for seismic loads based on the highest performance category, PC-4. The seismic loads used were based on response spectra scaled from data contained in Appendix S of DOE-ID (2001). The acceleration values used are higher than those that would be obtained using RG-1.60. Thus, conservative results for the PC-4 seismic evaluation were obtained.

The analysis documented in Winn (2003) did not use dynamic analyses or the RG-1.60 curves as cited in SAR-153. The analysis used a static analysis with 0.5 g loads in the horizontal direction. A typical dynamic analysis can have horizontal seismic loads for a tank that exceed 1 g. The actual design of the belly bands, anchors, and support structures were very conservative and the original analysis showed adequate margins to failure.

2.3.5 Derivation of controls

The modifications installed passive safety related Seismic Category I supports. Surveillance will be conducted to provide assurance that no new seismic interactions are introduced.

2.3.4 Equipment classification

The new seismic racks for gas bottle storage are safety related Seismic Category I. The new restraints for the bypass demineralizer cation and anion tanks, PCS degassing tank, and utility UPS are safety related Seismic Category I.

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431.02
01/30/2003
Rev. 11

ENGINEERING DESIGN FILE

EDF No.: 5488 EDF Rev. No.: 0 Project File No.: N/A

1. Title: Summary Of Resolution Of Advanced Test Reactor Unreviewed Safety Questions – TRA-USQ-SE-2004-038, TRA-USQ-2004-070, and TRA-USQ-2004-341.

2. Index Codes:
Building/Type TRA-670 SSC ID N/A Site Area 531 (TRA)

3. NPH Performance Category: _____ or ☒ N/A

4. EDF Safety Category: SC or ☐ N/A SCC Safety Category: SC or ☐ N/A

5. Summary:
Advanced Test Reactor Programs personnel have recently undertaken an Advanced Test Reactor (ATR) design reconstitution effort in order to identify and correct safety basis deficiencies that might have developed over the 40 plus years of ATR operations. Some of those deficiencies lead to USQs with interim operating restrictions. This Engineering Design File (EDF) was prepared to serve as an addendum to the ATR Safety Analysis Report (SAR-153) for Unreviewed Safety Question (USQ) resolution and to support changes to the ATR Technical Safety Requirements (TSR-186).

The following table lists the three positive USQs addressed in this EDF including a short description of the issue, imposed restrictions, and resolution to the USQ.

USQ Evaluation Document Number	Description
TRA-USQ-SE-2004-038	Reactor Core Feedback During Loss of Power
Issue:	Calculation models took credit for ATR core negative feedback prior to reactor scram when the regulating rod system would automatically compensate keeping reactor power constant.
Restrictions:	Maintain a minimum of three operable experiment loop commercial power under voltage relays during reactor operation. The under voltage relays cause a reactor scram upon a loss of commercial power.
Resolution:	Loss of commercial power transient was re-evaluated to remove credit for ATR core negative feedback and to correct other deficiencies. Results show that thermal margins remain acceptable and the interim restrictions can be removed.
TRA-USQ-2004-070	Low Reactor Vessel Differential Pressure Safety Limits
Issue:	Accident analyses credited the ATR negative feedback to lower power prior to a scram when the regulating rod system would automatically attempt to keep reactor power constant. These assumptions lead to the conclusion that the reactor vessel differential pressure (low) safety limit may be too low.
Restrictions:	None – An increase in vessel differential pressure (low) safety limit (SL) does not affect the TSR-186 limiting control setting (LCS) 3.1.1, vessel differential pressure (low), since the LCS still protects the SL.
Resolution:	Loss of commercial power was re-evaluated to determine the correct SLs. Results of the updated evaluation show that TSR-186, SL 2.1.2, differential pressure (low) safety limits need to be changed to 30.6 psid and 39.3 psid for 2 and 3 primary cooling pump (PCP) operations, respectively.

431.02
01/30/2003
Rev. 11

ENGINEERING DESIGN FILE

EDF No.: 5488 EDF Rev. No.: 0 Project File No.: N/A

1. Title: Summary Of Resolution Of Advanced Test Reactor Unreviewed Safety Questions – TRA-USQ-SE-2004-038, TRA-USQ-2004-070, and TRA-USQ-2004-341.

2. Index Codes:
Building/Type TRA-670 SSC ID N/A Site Area 531 (TRA)

TRA-USQ-2004-341	Fuel Element Thermal Conditions During Loss of Heat Sink
Issue:	Calculation models assumed Emergency Firewater Injection System (EFIS) actuation 75 seconds after opening the vessel vent valves. TSR-186, LCO 3.3.9 states depressurize the reactor vessel prior to reaching 200°F and open vessel vent valves and actuate EFIS prior to exceeding a reactor shutdown system (RSS) outlet temperature of 228°F. These high temperatures indicate that required fuel cladding thermal margins might not be met for all accident sequences bounded by the calculation.
Restrictions:	None – The ATR was in an extended outage for core internals changeout. Procedure revisions are required prior to resumption of operations.
Resolution:	An updated evaluation was completed to address a complete loss of heat sink and a complete loss of flow accident. Results of the evaluation show that discussions in SAR-153 remain valid and thermal margins are acceptable. TSR-186 limiting condition for operation (LCO), LCO 3.3.9 must be revised to actuate EFIS and open vessel vent valves prior to reaching an RSS outlet temperature of 200°F.

A change to the ATR TSR bases for the loss of coolant accident (LOCA) PCP shutoff system is required to include pertinent physical phenomena that are expected during the event. The TSR-186, LCO 3.2.3.3 allows the system to be bypassed when one PCP is running which brings into question the length of time a pump would operate under cavitation conditions should a LOCA occur at that time. Resolution of this concern involves changing the TSR basis to support bypassing the LOCA PCP shutoff system with one operating pump. The second part of the resolution involves increasing the EFIS (TSR-186, LCO 3.2.3.3) actuation pressure setpoint to ≥ 29.62 psia. This change reduces the length of time a pump would operate under cavitation conditions should a LOCA occur.

Two other issues associated with the emergency coolant pump recirculation system did not result in positive USQs but their correction is discussed. The first issue is evaluated in TRA-USQ-SE-2004-039. This negative USQ describes an error in the selection of the Emergency Coolant Pump Recirculation Flow (EPRF) Setpoint and an assumption involving a start signal to the standby emergency coolant pump (ECP). No interim operating restrictions were invoked because the in-plant setpoint is sufficiently conservative to ensure that accident evaluations remain valid. These discrepancies can be corrected by changing TSR-186, LCO 3.3.3 to ≥ 150 gpm ± 9 gpm.

The last issue associated with the EPRF Comparator RSS Trip LCS did not result in a positive USQ. This issue is evaluated in TRA-USQ-SE-2004-082. This negative USQ describes errors in the calculation of the instrument loop setpoint and uncertainty. No interim operating restrictions were invoked because this system is not relied on for preventing or mitigating any accident sequence. The discrepancy is corrected by changing TSR-186, LCS 3.1.1 Emergency Pump Recirculation Flow to ≥ 95.7 in. wc (water column) or a LCS of ≥ 101.3 gpm.

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Rev. 11

ENGINEERING DESIGN FILE

EDF No.: 5488 EDF Rev. No.: 0 Project File No.: N/A

1. Title: Summary Of Resolution Of Advanced Test Reactor Unreviewed Safety Questions – TRA-USQ-SE-2004-038, TRA-USQ-2004-070, and TRA-USQ-2004-341.

2. Index Codes:
Building/Type TRA-670 SSC ID N/A Site Area 531 (TRA)

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

	R/A	Typed Name/Organization	Signature	Date
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8. Does document contain sensitive unclassified information? ☐ Yes ☒ No
If Yes, what category:

9. Can document be externally distributed? ☐ Yes ☒ No

10. Uniform File Code: 250 Disposition Authority: ENV1-b-4-a
Record Retention Period: Cutoff when superseded, obsolete, or canceled, Destroy 75 years after cutoff.

11. For QA Records Classification Only: ☐ Lifetime ☒ Nonpermanent ☐ Permanent
Item and activity to which the QA Record apply:

12. NRC related? ☐ Yes ☒ No

13. Registered Professional Engineer's Stamp (if required)
N/A

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1.0 INTRODUCTION

The format of this Engineering Design File (EDF) was selected to support an Advanced Test Reactor (ATR) Technical Safety Requirement (TSR) revision and therefore does not follow the guidance in GDE-305 or the format in MCP-2374. Formats listed in these two documents are intended for EDFs that present calculations and results that safety analysis documents reference.

ATR Programs personnel have recently undertaken an ATR design basis reconstitution program (DBRP) in order to identify and correct safety basis deficiencies that might have developed over the years of ATR operations. This EDF was prepared to serve as an addendum to the ATR Safety Analysis Report (SAR-153) for Unreviewed Safety Question (USQ) resolutions and to support changes to the ATR TSRs (TSR-186) that were determined to be required before resuming power operations following the ATR core internals changeout (CIC).

The following sections provide a summary of the positive USQs and any associated issues that require resolution prior to ATR power operations following completion of CIC.

1.1 TRA-USQ-SE-2004-038, Reactor Core Feedback during Loss of Power

The ATR DBRP previously identified a potential issue concerning the loss of commercial power. The detailed analysis is documented in Terry 1994. The analysis includes modeling of the ATR core temperature reactivity feedback. The overall temperature reactivity feedback of the ATR core is negative, which can cause the core power to decrease between the initiation of the loss of commercial power and the plant protection system scram. The resulting flow coast down causes a reactor power–coolant flow mismatch and an increase in the average core temperature. The ATR control system includes a regulating rod system that automatically attempts to maintain a constant reactor power and can overcome the core negative temperature reactivity feedback. This automatic feature was not correctly modeled (INEEL 2004a).

Resolution of the error was accomplished by updating the loss of commercial power analysis (Polkinghorne 2004a). This analysis concluded that even with the regulating rod control system holding core power constant prior to scram, ATR plant protection criteria are met.

The control system for the ATR experiment loop facilities includes under voltage protective relays on the commercial power loop pumps. Operating experience shows these relays function and initiate a reactor scram after any substantial drop in commercial power voltage. The response time of the loop under voltage relays is 0.2 to 0.3 seconds. The power-coolant mismatch at the time of the scram is less severe than during the approximate 1 second delay for the low reactor vessel inlet pressure scram. The experiment loop control system under voltage relays were judged to be reliable enough to support interim operation. Three operable experiment loop under voltage relays established a one out of three scram reliability.

1.2 TRA-USQ-2004-070, Low Reactor Vessel Differential Pressure Safety Limit

The SAR-153 includes results from a loss of commercial power analysis in which both the low vessel inlet pressure and low vessel differential pressure scrams were disabled. The purpose of the analysis was to determine when the minimum margin to the critical heat flux (CHF) in the core decreased to three standard deviations (3σ). The results of the analysis were used to define safety limits (SLs) on reactor vessel low differential pressure. Even though the analysis conservatively modeled effective plate powers greater than the current TSR limits, the analysis incorrectly credited the negative reactivity feedback. The SLs (TSR-186, SL 2.1.2) on reactor vessel differential pressure (low) might be too low (INEEL 2004b). The updated loss of commercial power analysis (Polkinghorne 2004a) revealed that the vessel differential pressure safety limits were incorrect. It should be noted that the setpoints selected for plant operations were conservative with respect to the updated analysis. A new analysis (Polkinghorne 2004b) was completed to determine the SLs. This analysis shows that the low reactor vessel differential pressure SLs are 30.6 and 39.3 psid for 2 and 3 primary coolant pump (PCP) operation, respectively.

The current limiting control settings (LCSs) for vessel differential pressure (low) are conservative and the in-plant settings are conservative relative to the analytical setpoints. The TSR change control process ensures that LCSs are not changed without the approval of the Department of Energy.

1.3 TRA-USQ-2004-341, Fuel Element Thermal Conditions during Loss of Heat Sink

The concern is that TSR-186, LCO 3.3.9 states open the reactor vessel vent valves and actuate Emergency Firewater Injection System (EFIS) prior to exceeding an RSS outlet temperature of 228°F, while the analysis assumed that EFIS was actuated 75 seconds after opening the vessel vent valves (INEEL 2004c). This discrepancy is resolved by updating the analysis for a loss of heat sink and a complete loss of flow accident (Bayless and Polkinghorne 2005). The analysis results indicate that plant protection criteria are met for Condition 2, 3, and 4 faults, when EFIS is actuated and the vessel vent valves are opened prior to reaching an RSS outlet temperature of 200°F.

The actuation of EFIS and opening the reactor vessel vent valves prior to the RSS outlet temperature exceeding 200°F is consistent with the TSR requirement to actuate prior to reaching 228°F. The procedural steps related to delaying EFIS in conjunction with opening the vessel vent valves in response to a loss of heat sink event must be revised prior to ATR power operation.

1.4 Loss of Coolant Accident Primary Coolant Pump Shutoff System

A change to the ATR TSR bases is required to include pertinent physical phenomena that are expected during a loss of coolant accident (LOCA) when the PCP Shutoff System Engineered Safety Feature (ESF) is placed in bypass. The TSR-186, limiting condition for operation (LCO) 3.2.3.3 allows the system to be bypassed when one PCP is running which brings into question the length of time a pump would operate under cavitation conditions should a LOCA occur at that time. Resolution of this concern involves changing the TSR basis to support bypassing the LOCA PCP shutoff system with one operating pump. The second part of the resolution involves increasing the EFIS (TSR-186, LCO 3.2.3.3) actuation pressure setpoint to

≥ 29.62 psia. This change reduces the length of time a pump would operate under cavitation conditions should a LOCA occur during the time the LOCA PCP Shutoff ESF is bypassed.

The function of the PCP Shutoff System ESF is to trip the PCPs on low PCS pressure. The PCP trip time delay is set to assure the thermal margins will be met and the PCS surge tank is not drained before the ESF actuates to trip the PCPs. The analysis indicates that the surge tank will not drain even if one PCP is in operation. Therefore, the applicable plant conditions that require the ESF to be operable are power operation and following power operation until one or no PCP is operating.

Of concern is the time that the PCPs operate following a LOCA. The PCPs require a net positive suction head (NPSH) of 50 ft to operate per manufacturer's recommendations and the ECPs require 20 ft NPSH. An analysis has been completed that considers the break of a 2 in. air line on top the PCS surge tank (Polkinghorne 2003). That analysis predicts that the PCPs would operate for up to 60 seconds with an inadequate NPSH and also indicates that the ECPs would be subject to operations for about 0.5 seconds with inadequate NPSH. Pump operation with inadequate NPSH has been evaluated and indicates that the pumps are expected to operate (Smith 2005a). Another evaluation (Smith 2005b) concludes that the PCPs would not catastrophically fail due to cavitation during these times. A more recent analysis has been completed (Polkinghorne 2004c) that considers a base case 3 in. LOCA followed by partial failure of the LOCA PCP Shutoff ESF (1 PCP continues to run for the duration of the transient). Results of these analyses indicate that even though a PCP operates in a cavitation condition, the length of time in this condition is not expected to fail the PCP, but also assumes that EFIS analytical actuation pressure is increased from 17 to 28 psia.

1.5 TRA-USQ-SE-2004-039 and TRA-USQ-SE-2004-082 Evaluations, Emergency Coolant Pump Recirculation Flow

Emergency coolant pump (ECP) recirculation flow (EPRF) is relied on to determine whether an ECP is operating when required. The DBRP has identified three discrepancies that lead to two negative USQs (INEEL 2004e and INEEL 2004f). The first is a discrepancy between the analysis (Terry 1994) recirculation flow setpoint and its derivation in the TSR-186 bases. The second is the minimum nominal ECP flow used in calculating the EPRF setpoint. The third involves an assumption concerning the calculation of the uncertainty associated with the ECP recirculation setpoint. These items are closely related and Section 2 presents the issues regarding the calculation error and associated uncertainties. Correcting these three discrepancies involves changing the setpoints and incorporating the updated uncertainty analysis. The plant protection system (PPS) reactor shutdown system (RSS) trip LCS should be≥ 95.7 in. wc (water column) or a LCS of ≥ 101.3 gpm. The ECP start signal LCO should also be changed to 150 ± 9 gpm.

2.0 DETAILED DISCUSSION OF THE ISSUES

2.1 TRA-USQ-SE-2004-038, Reactor Core Feedback During Loss of Commercial Power

Loss of commercial power is a Condition 2 fault analyzed in the safety basis. Loss of commercial power causes the operating PCPs to coast down. The resulting reduction in core flow causes an increase in the core average temperature due to the core power–coolant mismatch which results in a gradual lowering of reactor power prior to the scram. The safety analysis models the plant protective system subsystem (low vessel inlet pressure scram) for the scram that reduces core power. The low vessel inlet pressure scram occurs about one second after the loss of commercial power as the primary coolant pumps coast down and their pumping head is lost.

The ATR plant protection criteria require a margin of greater than or equal to 3σ to CHF and flow instability (FI) for Condition 2 faults. The analysis described in the original analysis (Terry 1994) states that calculations showed that the required margin was not met if reactor power was assumed constant during the time before scram. The core feedback model predicted that the feedback would insert –0.05$ during the approximate one second before the low vessel inlet pressure scram actuated. Feedback reduced the core power at the time of the scram by approximately 8%.

2.1.1 Concerns

The analysis described in Section 2.1 assumed that the reactor power was decreasing prior to the reactor scram and thus would meet the applicable margins. However, the analysis neglected to account for the effect of the regulating rod control system, which would automatically attempt to maintain a constant reactor power. The regulating rod control system in the event of the loss of normal power receives power from the diesel electric system so that the regulating rod control system would remain operational after a loss of commercial power. The regulating rod control system includes a nuclear instrument that monitors core power and a control system that moves regulating rod control elements to maintain a constant power. The regulating rod control system can easily overcome the feedback insertion of –0.05$ in one second. Facility Management has imposed a restriction to maintain a minimum of three operable experiment loop commercial power under voltage relays (reactor scrams) during reactor operation to establish a minimum one out of three scram reliability until this issue is resolved (INEEL 2004a).

2.1.2 Analysis of Core Feedback During Loss of Commercial Power

Concerns regarding the power decrease prior to a scram upon a loss of commercial power were re-examined considering that the regulating rod control system would attempt to keep reactor power constant (Polkinghorne 2004a). The RELAP5 code was used to calculate the overall response of the reactor and the SINDA code was used to calculate the response of the limiting fuel plate. Both 2 PCP and 3 PCP operations were modeled. The models are consistent with the other various assumptions presented in SAR-153 Section 15. It should be noted that the margins of safety are greater than previously calculated because reactor scram occurred earlier primarily because the locations of PPS pressure taps in the model were corrected and the core power densities are lowered to the TSR limits.

These calculations result in minimum margins to FI and CHF of 7.30 and 5.14 for 2 PCP operation and 9.12 and 5.81 for 3 PCP operation, respectively. These values meet the Condition 2 ATR plant protection criteria of a margin of safety to FI and CHF of greater than 3σ. Thermal margins of safety are also acceptable for a loss of commercial power in which the inlet pressure PPS subsystem fails (Condition 4 fault) and the vessel differential pressure subsystem scrams the reactor. Because these results are acceptable, the discussions in SAR-153 regarding bounding and bounded sequences remain valid.

2.1.3 Derived Controls

Calculations were performed to determine whether any TSR revisions are required considering that the regulating rod control system would keep reactor power constant upon a loss of commercial power event until reactor scram. The analysis results show that no corrections are required. Further, the analysis confirms that vessel differential pressure and the vessel inlet pressure PPS subsystems are diverse.

Re-evaluating the loss of commercial power shows that thermal margins are met for both Condition 2 and Condition 4 faults of concern. These results establish that discussions in SAR-153 remain valid. Therefore, the facility management restriction of three operable experiment loop under voltage relays (reactor scrams) to establish reactor scram reliability (INEEL 2004a) is no longer necessary and can be removed. The USQ (INEEL 2004a) associated with this issue is resolved.

2.1.4 Equipment Classification

The reanalysis of the loss of commercial power accident corrects previous invalid assumptions along with other errors and confirms that current equipment classifications remain valid. That is, the PPS vessel inlet pressure and vessel differential pressure subsystems are safety related.

2.2 TRA-USQ-2004-070, Low Reactor Vessel Differential Pressure Safety Limits

SAR-153 includes results from a loss of commercial power analysis in which both the low vessel inlet pressure and vessel low differential pressure scrams were disabled. The purpose of the analysis was to determine when the minimum margin to CHF in the core, without scram, decreased to three standard deviations (3σ). The results of the analysis were used to define TSR-186 SLs on reactor vessel low differential pressure. The SLs on reactor vessel low differential pressure were found to be low (INEEL 2004b) because the analysis incorrectly credited negative core reactivity feedback even though the analysis conservatively modeled effective plate powers greater than the current TSR limits.

The SLs on reactor vessel low differential pressure define when 3σ to the CHF is reached if the reactor is not scrammed during a loss of commercial power. The SLs (TSR-186, SL 2.1.2) are currently 21.3 psid for 2 PCP operations and 38.6 psid for 3 PCP operations. An updated analysis (Polkinghorne 2004b) shows that the margins to FI and CHF during a loss of power accident in which the reactor fails to scram on low vessel inlet pressure, but scrams instead on vessel low differential pressure (Condition 4 fault) are greater than 3σ. The reactor vessel low differential pressure trip setpoints used in the safety analysis are 38 psid for 2 PCP operations and 45.8 psid for 3 PCP operations (TSR-186, LCS 3.1.1).

2.2.1 Concerns

A concern involves the loss of commercial power with failure of the low vessel inlet pressure subsystem (INEEL 2004b). This event is considered to be a Condition 4 fault. For this event, the scram is further delayed (vs. low vessel inlet pressure scram) until the vessel low differential pressure scram setpoint is reached. The time delay between loss of commercial power and the reactor scram is up to 1.8 seconds. The previous analysis credited core negative reactivity feedback. The regulating rod control system is powered from the diesel power system in the event of a loss of commercial power. The regulating rod control system would attempt to maintain a constant reactor power up to the point of scram. The concern in this case is whether the selected ATR reactor vessel differential pressure limits are too low.

2.2.2 Reactor Vessel Differential Pressure Safety Limit Analysis

The RELAP5 code was used to calculate the overall response of the reactor and the SINDA code was used to calculate thermal safety margins for the high power fuel plate using the boundary conditions from RELAP5 (Polkinghorne 2004b). The effective plate powers in the SINDA calculation were selected to be 10% higher than those in the ATR TSRs. Ten percent was selected to account for any other uncertainties and to ensure conservative results. The SINDA and SINDA-SAMPLE models used the same input as previous analyses except that new core power histories and hydraulic boundary conditions were obtained from the new RELAP5 model and fuel plate power densities were increased 10%. That is, the effective plate powers were increased to 459.0 MW and 489.7 MW for 2 PCP and 3 PCP operations, respectively. Consistent with the model described in Section 2.1.2 the ATR regulating rod control system was assumed to keep the reactor power constant until scram.

The results of these models show that in all cases, the CHF margin of safety decreased to 3σ before the FI margin and thus the FI margin was not considered further for the selection of SLs. Based on these results, TSR-186 SLs for reactor vessel low differential pressure (SL 2.1.2) are 30.6 psid and 39.3 psid for 2 PCP and 3 PCP operations, respectively.

It should be noted that the associated ATR TSR-186 LCS 3.1.1 is not affected by this change since the LCS low differential pressures are sufficiently larger. That is, the low differential pressure LCSs will be reached well before the SLs.

2.2.3 Derived Controls

The above analysis leads to two controls. The first is the selection of ATR SLs for 2 PCP and 3 PCP operations. Reactor vessel low differential pressure SLs (TSR-186, SL 2.1.2) are 30.6 psid or 39.3 psid for 2 PCP or 3 PCP operations, respectively. Second, LCSs are selected (see LCS 3.1.1) at greater differential pressure than the SLs to ensure that the ATR protection criteria are not approached. For this case, leaving ATR TSR LCS 3.1.1 at their current evaluated values of 38 psid and 45.8 psid for 2 PCP and 3 PCP operations, respectively, is conservative. The reanalysis of vessel low differential pressure shows that the ATR SLs have increased and are closer to the ATR LCSs. The margins of safety in both operating cases remain adequate. The updated uncertainty analysis (Pickar 2005a) shows that the current LCS uncertainty analysis is conservative. Considering instrument uncertainty, calibration procedures, and as left conditions indicate that the current LCSs are conservative.

No interim restrictions were put in place because the SLs were protected by the LCSs and increasing the SL does not affect the results of the safety analysis (SAR-153). The USQ (INEEL 2004b) associated with this issue is resolved by revising TSR-186, SL 2.1.2.

2.2.4 Equipment Classification

The reanalysis of the loss of commercial power accident corrects previous invalid assumptions along with other errors and confirms that current equipment classifications remain valid.

2.3 TRA-USQ-2004-341, Fuel Element Thermal Conditions during Loss of Heat Sink

The TSR-186, LCO 3.3.9 specifies opening the vessel vent valves prior to exceeding 200°F and actuating EFIS prior to exceeding an RSS outlet temperature of 228°F. The analysis for this event actuated EFIS 75 seconds after opening the vessel vent valves instead of at an RSS outlet temperature of 228°F. This indicates a discrepancy between the derivation of the TSR and the supporting analysis and lead to completion of a USQ (INEEL 2004c). Further review of the analysis presented in Pafford (1994) shows that 75 seconds after opening the vent valves, the inlet temperatures are much less than 228°F. Additional modeling is required to resolve this discrepancy. The procedural steps related to delaying EFIS in conjunction with opening the vessel vent valves in response to a loss of heat sink event must be revised prior to ATR power operation.

2.3.1 Concerns

The concern involves the bases for the TSR control for opening of the vent valves. The control establishes that the vessel vent valves are to be opened prior the RSS outlet temperature exceeding 200°F. This is consistent with the analysis. The next statement in the TSR directs actuation of the EFIS prior to the outlet temperature reaching 228°F. The analysis actuates lower EFIS 75 seconds after opening the vessel vent valves. The TSR action is inconsistent with the analysis and lead to a USQ (INEEL 2004c). This concern is resolved by reevaluating two accident sequences and confirming the appropriate actions and their timing.

2.3.2 ATR SAR Accident Analyses

An updated analysis has been completed to address the above concerns (Bayless and Polkinghorne 2005). The following sections describe the updated CLOHS (SAR-153, 15.2.1) and CLOFA (SAR-153, 15.3.3). The presentation method in SAR-153 is used here so that the bounded sequence discussions in SAR-153 remain valid considering the results from the updated analysis presented below.

2.3.2.1 Decrease in Heat Removal by Secondary – SAR-153, Section 15.2

The following sections describe the new analysis (Bayless and Polkinghorne 2005) performed to address the above vessel venting issues. The results of this analysis will be incorporated into SAR-153, Section 15.2.1 since the current discussions in SAR-153 remain applicable.

2.3.2.1.1 Identification of Causes and Accident Description

The evaluation presented here follows the same methodology as those presented in SAR-153, Section 15.2.1. Only that information that is in addition or different than described in SAR-153 is presented here.

2.3.2.1.1.1 Analysis of Effects and Consequences

2.3.2.1.1.2 Method of Analysis

The thermal-hydraulic response for the ATR system as a result of a CLOHS is contained in SAR-153. The previous analysis results showed that thermal-hydraulic margins were met for Condition 2, 3, and 4 faults, but only considered system response over a fairly short period of time. An additional analysis was completed (Bayless and Polkinghorne 2005) using most of the assumptions presented in SAR-153 except that a worst case coolant inlet temperature was calculated and the analysis was performed for an extended period of time. The longer period of time is necessary to assure that minimum thermal margins did in fact occur early in the transient and not at a later time near when EFIS is actuated and the reactor vessel vents are opened.

Calculations were performed with different steady state reactor vessel inlet temperatures to determine which provided the fastest heatup to the vessel vent valve opening. The result of these calculations is that an inlet temperature of 112°F provided the fastest heatup. Another scoping calculation was performed where EFIS was not actuated until the vessel outlet temperature reached 228°F. Depressurization through the vessel vent valve was initiated when the vessel outlet temperature reached 206°F and resulted in boiling in the core. Boiling in the core is not acceptable for a Condition 2 fault. Therefore, the models were changed to actuate EFIS at the setpoint temperature and then open the vent valves as follows.

A vessel vent case was initiated from a reactor power of 250 MW with a vessel inlet temperature of 112°F. The EFIS was manually actuated when the calculated vessel outlet temperature reached 206°F which includes current instrument uncertainty. It should be noted that the updated instrument uncertainty results in about ± 3°F (Falibota 2005b). The reactor trip was from the high vessel inlet temperature subsystem at 150°F, with a 40-sec response time. The PCPs were assumed to be manually tripped 10 minutes after the reactor scram and one ECP (M-10) operates throughout the transient (the second ECP is prevented from starting). One of the two reactor vessel vent valves is available and assumed to require 90 sec to open. Only the bottom head EFIS is actuated and it is assumed that a check valve in one of the four injection lines fails, reducing flow by 25%.

The reactor protection criteria thermal margins were evaluated for this new model using ATR-SINDA and SINDA-SAMPLE with boundary conditions from the RELAP5 results (Bayless and Polkinghorne 2005).

2.3.2.1.1.3 Results

The sequence of major events from the RELAP5 calculations is shown in Table 1 for a reactor power of 250 MW with a core inlet temperature of 112°F. The vessel relief valves lift soon after transient initiation. The peak hot channel temperature which occurs is 293.8°F and a peak outlet temperature of 208°F.

The SINDA models were used to calculate the thermal safety margins for two cases: 1) EFIS was actuated at 206°F (late vent case) and 2) EFIS is actuated at 194°F (early vent case). These were completed to determine which is more limiting. Only the vessel vent phases of these CLOHS transients were simulated because SAR-153 presents the results showing that thermal safety margins near the time of reactor scram are acceptable.

Actuation of the vessel vent system caused the core flow rate to decrease (because coolant was diverted out the open vent valve), which caused fuel and coolant temperatures to increase (~ 5°F). When the calculations were stopped, core temperatures were decreasing because the firewater that is being injected into the flow distribution tank has made its way around the PCS to the top of the core.

Table 1. Sequence of events for the loss of heat sink transient calculations (three-pump operation).

Event	Time (sec)
Transient initiated	0
Safety relief valves first lift	5.8
Reactor scram on high inlet temperature (includes 40.0 second delay)	121.0
Peak hot channel exit temperature reached	121.0
(Peak temperature)	293.8°F
PCPs manually tripped	721.0
Vessel outlet temperature reaches 206°F, EFIS actuated	4208.0
Vent valves manually opened	4508.0
EFIS injection begins	4585.0
Peak vessel outlet temperature reached	4625.0
(Peak temperature)	208.0°F
Transient calculation terminated	6000.0

Following actuation of the vessel vent valves, decreasing pressure and flow caused thermal margins to decrease. For the late venting case, the minimum CHF and FI margins were 8.30 and 13.5σ and occur at about 5180 seconds, respectively. For the early vessel venting case, the minimum CHF and FI margins were 8.34 and 15.0σ at about 2580 seconds, respectively. Thermal margins are slightly lower for the late vent case because the coolant in the reactor vessel had more time to heat up prior to EFIS actuation. These margins are acceptable for Condition 2, 3, and 4 faults and this sequence can be used to bound the other events as described in SAR-153.

2.3.2.1.1.4 Conclusions

The above analysis shows that thermal margins are acceptable and this sequence as described in SAR-153 can be used to bound Condition 2, 3, and 4 faults. Controls (TSR-186, LCO 3.3.9) are required to actuate EFIS and open the vessel vent valves prior to the vessel outlet temperature reaching 200°F.

2.3.2.2 Decrease in Reactor Primary Coolant Flow Rate – SAR-153, Section 15.3

The following sections describe the new analysis (Bayless and Polkinghorne 2005) performed to address the above vessel venting issues. The results of this analysis will be incorporated into SAR-153, Section 15.3.3, Complete Loss of Flow Accident (CLOFA), since the current discussions in SAR-153 remain applicable.

2.3.2.2.1 Identification of Causes and Accident Description

The evaluation presented here follows the same methodology as those presented in SAR-153, Section 15.3.3. Only that information that is in addition or different than described in SAR-153 is presented here.

2.3.2.2.1.1 Analysis of Effects and Consequences

2.3.2.2.1.2 Method of Analysis

The thermal-hydraulic response for the ATR system as a result of a CLOFA (Condition 4) is contained in SAR-153. The previous analysis results showed that thermal-hydraulic margins were met for Condition 3 and 4 faults, but only considered system response over a fairly short period of time. An additional analysis was completed (Bayless and Polkinghorne 2005) using the applicable assumptions presented in SAR-153 and for an extended period of time. The longer period of time is necessary to assure that thermal margins during vessel venting are acceptable.

At transient initiation, a loss of power causes the reactor to scram and the operating coolant pumps to trip. The backup ECP (M-11) starts on low recirculation flow in the M-10 ECP line, then runs for 30 minutes before the battery power is assumed to be depleted and the pump is tripped. The loss of forced flow starts a countdown to actuating EFIS and opening the one available vessel vent valve (assumed that one of two valves is operable), based on the operating power and the reactor vessel outlet temperature at the time forced flow is lost. The base case assumed that only bottom head EFIS is actuated and the flow is reduced by 25%, simulating one injection line check valve failing to open. All transients were initiated from steady-state conditions with a reactor vessel inlet temperature of 125°F.

Two sensitivity cases were completed to determine the effects of EFIS configuration changes. The first case is where only the upper EFIS was actuated and the second case is where both upper and lower EFIS are actuated.

SINDA models were used to calculate thermal safety margins for the CLOFA with bottom head EFIS. Only the vessel vent phase of the transient was simulated because SAR-153 presents the thermal margins near the time of reactor scram and during flow reversal near 1800 seconds.

2.3.2.2.1.3 Results

The sequence of major events from the RELAP5 calculations is shown in Table 2 for the CLOFA. The depressurization associated with vessel vent valve opening removed less than 200 ft^3 of liquid, leaving the surge tank more than 75% full at the end of the calculation. The core temperatures were decreasing at the end of the transient calculation. The calculations show a zero void fraction, indicating that no boiling occurred during the calculation.

When only the upper EFIS was modeled, boiling in the core begins shortly after EFIS flow begins. Calculations indicate boiling is present in each channel, but none of the channels dried out completely.

Maximum fuel and coolant temperatures were calculated with ATR-SINDA. Subcooled boiling began at about 4120 seconds, followed by saturated boiling near 4360 seconds. Maximum fuel temperature was well below the saturation temperature when the calculation was terminated.

Minimum CHF, fuel plate buckling, and AWIT thermal margins were calculated with SINDA-SAMPLE. The minimum CHF was 4.10σ (at 4424 seconds), the minimum buckling margin was 18.8σ (at 4494 seconds), and the minimum AWIT margin was always greater than 40σ. These margins are acceptable for Condition 3 and 4 faults.

Table 2. Sequence of events for the base case CLOFA transient.

Event	Time (sec)
Primary and operating ECP trip	0.0
Reactor Scram	0.75
Backup ECP starts	5.9
Backup ECP tripped	1806
Relief valve cycling starts	2175
EFIS actuated	4176.2
Peak fuel cladding temperature reached	4462
Peak fuel cladding temperature	442.2 °F
Vent Valve opened	4476.2
EFIS injection begins	4560
Transient calculation terminated	8000

2.3.2.2.1.4 Conclusions

Previous analyses (presented in SAR-153) showed acceptable thermal margins early in the CLOHS and CLOFA near the time of reactor scram and the initial flow coastdown. The following present the conclusions following the depressurization of the PCS through the reactor vessel vents.

For the CLOHS transient, all heat transfer to the secondary coolant system is lost at transient initiation. The reactor scrams on high coolant inlet temperature. The PCPs are tripped 10 minutes after scram, and one ECP continues to run throughout transient. Bottom head EFIS is actuated when the vessel outlet temperature reaches 200 ± 6°F and one reactor vessel vent valve was opened 5 minutes later. Scoping calculations identified an initial coolant inlet temperature of 112°F to be the limiting case in that it provides the earliest opening of the vessel vent valves. System thermal hydraulic calculations were performed for the nominal outlet temperature (200°F) and for the bounding cases (194 and 206°F). The core remained highly subcooled throughout the transient. Thermal safety margins were calculated for the two bounding cases. The results show that the higher temperature case (later venting) was more limiting, with minimum CHF and FI margins of 8.30 and 13.5σ, respectively. These margins are acceptable for Condition 2, 3, and 4 faults.

The CLOFA was initiated by a loss of power, which caused the operating coolant pumps to trip and the reactor to scram on low vessel inlet pressure. The remaining ECP starts shortly after the transient begins on low recirculation flow, but is assumed to trip 30 minutes later due to battery depletion. This leads to a flow reversal in the reactor core. EFIS actuation occurs 2370 seconds after the backup ECP trips. EFIS actuation is based on the initial operating power and the coolant outlet temperature when forced flow is lost. One vessel vent valve was opened 5 minutes after EFIS actuation. With only the bottom head EFIS actuated, the RELAP5 calculation did not predict any boiling in the core, while the SINDA calculation predicted some boiling in the hot channel. The minimum buckling and AWIT margins were 18.8 and > 40σ, respectively. These margins are acceptable for Condition 3 and 4 faults.

The analyses shows that thermal limits are met for both transients near depressurization following vessel vent valve opening. For the CLOFA, the bottom head EFIS is more effective than the upper vessel EFIS in providing core cooling.

2.3.3 Derived Controls

The above discussions indicate that TSR-186, LCO 3.3.9 must be changed. The changes are that EFIS is actuated and the vessel vent valves are opened prior to the reactor outlet temperature reaching 200 °F. These actions ensure that the above analysis remains valid and the indicated thermal safety margins are met.

A USQ related to actuation of EFIS before 228°F (INEEL 2004c) is resolved given implementation of the described TSR-186 changes.

2.3.4 Equipment Classification

Equipment classification of the various reactor systems described above does not change from that stated in SAR-153.

2.4 Loss of Coolant Accident Primary Coolant Pump Shutoff System

A change to the ATR TSR-186 bases is required to include pertinent phenomena that are expected during a LOCA when the PCP Shutoff ESF is placed in bypass. The TSR-186, LCO 3.2.3.3 allows the ESF to be bypassed when one PCP is running. This raises a concern about the length of time a pump would operate under a cavitation condition should a LOCA occur while the ESF is in bypass.

The LOCA PCP Shutoff ESF is designed to trip running PCPs following a LOCA. The LOCA ESF is designed to shut off all of the running PCPs on low primary coolant pressure; however, failure of one pump to trip has been analyzed and is tolerated. The bypass switch allows disabling the LOCA PCP Shutoff ESF for system testing and for facilitating PCS startup and shutdown.

The 3-in. small break LOCA event with concurrent partial failure of the LOCA PCP Shutoff ESF (Condition 3) described in SAR-153, Section 15.6.5 establishes the requirements for the LOCA PCP Shutoff ESF. During a LOCA, the rapidly decreasing system pressure, while the core decay heat is still significant, results in rapidly deteriorating thermal margins. To maintain acceptable thermal margins, a significant amount of PCS flow (e.g., greater than emergency flow) is required for approximately 40 seconds following the reactor scram. The decrease in PCS pressure results in PCP cavitation (based on the manufacturer's recommended minimum of 50 ft net pump suction head [NPSH]) but the pump flow is sufficient to maintain adequate thermal margins. The minimum allowable surge tank air volume (alternately maximum liquid level) is an important parameter in determining the PCP suction pressure and thus system flow; the smaller the air volume, the greater the pressure decreases during the LOCA. However, continued operation of the PCPs shows that the pumps are capable of drawing down the surge tank liquid level such that the surge tank blanket air is eventually drawn into the PCS.

The maximum surge tank air volume (or minimum liquid level) is also an important parameter. It will determine at what system pressure surge tank air will commence entering the PCS; the larger the initial air volume, the higher the system pressure will be when air enters the PCS. It has not been demonstrated that this air in the system would not compromise the performance of the ECPs, perhaps resulting in a loss of their ability to pump coolant. As system pressure decays as a result of the LOCA, the PCPs will eventually quit pumping as suction pressure drops. The loss of the ECPs due to air in the PCS would result in a complete loss of flow for the system.

The LOCA PCP Shutoff ESF will shut down the PCPs after a time delay of approximately 65 seconds following a low-pressure trip signal. Thus, the PCPs will be allowed to continue pumping early in the event to provide sufficient flow to maintain thermal margins, then be shut down prior to the point at which the surge tank would be drained and air drawn into the PCS. This approach keeps air from being drawn into the PCS that could degrade the operation of the ECPs. Continued PCS leakage, however, results in the possibility that air from the surge tank may still be drawn into the PCS. To mitigate the problem, the EFIS is actuated on low vessel pressure. EFIS flow sufficiently repressurizes the PCS to prevent surge tank air from entering the system. With the action of the LOCA PCP Shutoff ESF to trip the PCPs on low pressure, EFIS actuation on low vessel pressure and the control of the initial surge tank liquid level, the thermal margins of > 3σ to CHF and FI are maintained during the accident.

2.4.1 Concerns

The concern is that TSR-186, LCO 3.2.3.3 allows the LOCA PCP Shutoff ESF to be disabled following power operations when one PCP is operating. Should a LOCA occur during this time, the possibility exists for cavitation of the operating PCP. Allowing the LOCA PCP Shutoff ESF to be disabled with one PCP operating could lead to the PCP operating much longer in a cavitation mode than has been evaluated should a LOCA occur. The current TSR basis does not address the cavitation issue.

2.4.2 Modeling Issues

An analysis was performed (Polkinghorne 2004c) that modeled a 3 in. base case LOCA with 2 and 3 PCP operations. This analysis contains the models from which calculations were completed to determine the PCP NPSH during the transient. Initial operations with 2 PCPs assuming 1 PCP continues to run results in the PCP running in cavitation for the longest period of time (~420 sec with EFIS actuation at 17 psia or ~140 sec with EFIS actuation at 28 psia).

Evaluation of the PCPs operating in cavitation conditions concludes that there should be no damage for 230 seconds (Smith 2005a). This evaluation is based on the PCP operating below the manufacturer's recommended pump suction head of 50 ft. Further, another evaluation describes potential damage to the pump casing caused by failure of the pump internals (Smith 2005b). This concern addresses the creation of a larger opening in the PCS caused by pump internals failing, causing a break in the pump casing. The results of this evaluation conclude that no evidence could be found that indicate a concern and the fact that a failure of a similar pump at TRA (operating in cavitation for 4 months) did not cause a pump case break. Because of these considerations, PCP damage caused by operation under cavitation conditions is not expected and allowing the LOCA PCP Shutoff ESF to be bypassed when one PCP is running meets current analysis assumptions. EFIS actuation pressure is being increased from 17 to 28 psia to ensure that PCPs are not exposed to cavitation conditions for unnecessary lengths of time. This increase in EFIS actuation pressure reduces the time a PCP operates under cavitation conditions to about 140 seconds and is well within the time frame of the above discussion.

Models have been developed to assess the thermal margins and timing issues associated with various accident sequences. An additional analysis (Polkinghorne 2004c) has been completed to determine the overall effects of increasing the EFIS actuation pressure from 17 to 28 psia. This analysis provides the calculation results for the time a PCP operates under cavitation conditions. Credit for increasing the EFIS actuation pressure is necessary to show that the time PCPs operate under cavitation conditions are limited and do not lead to failure of the PCPs.

2.4.3 Derived Controls

The LOCA PCP Shutoff ESF is required to assure that air is not drawn into the PCS. Partial failure of the ESF has been evaluated (one PCP remains running) and shows that a PCP failure due to operation under cavitation conditions is not expected. However, credit is taken for increasing EFIS actuation pressure from 17 psia to 28 psia to reduce the length of time the PCPs are expected to operate below the manufacturer's recommended NPSH. No change to LCO 3.2.3.3 is necessary. However, changes to the bases for this LCO are necessary to ensure the derivation of the LCO and the analyses are in agreement. In addition, a change to LCO 3.2.1.1 is necessary to ensure EFIS actuation at 28 psia.

An updated uncertainty analysis (Pickar 2005b) has been completed to determine the accuracy of the EFIS actuation pressure instrument loop. This analysis indicates that the EFIS setpoint to ensure actuation at 28 psia should be ≥ 29.62 psia. This increase accounts for total uncertainty in the instrument loop of ± 1.16 psia.

Changes to TSR-186 LCO 3.2.3.3 bases will bring the bases into agreement with the safety analysis (SAR-153). Increasing EFIS actuation pressure helps ensure that the PCPs do not operate under cavitation conditions for an extended length of time, but also compensates for additional uncertainties associated with the surge tank level instrument (see Section 2.3)

2.4.4 Equipment Classification

Classification of equipment different than is currently presented in SAR-153 is not required. The LOCA PCP Shutoff ESF is a safety related system as currently defined in SAR-153.

2.5 TRA-USQ-SE-2004-039 and TRA-USQ-SE-2004-082 Evaluations, Emergency Coolant Pump Recirculation Flow

The following sections describe three aspects of the EPRF system. These items are closely related and will be described individually first and then as needed to develop the appropriate discussion for safety analysis purposes in the following sections. Note that both USQ evaluations were negative because either the in-plant settings were conservative or the system is not relied on to prevent or mitigate an accident sequence.

2.5.1 Emergency Pump Recirculation Flow Discrepancies

2.5.1.1 TRA-USQ-SE-2004-039 Evaluation, Emergency Pump Recirculating Setpoint

SAR-153, Section 15.3.1 describes the loss of commercial power transient and assumes failure of the operating ECP as the limiting single failure. The requirement to start the standby ECP comes from the limiting single failure assumption described in SAR-153, Section 15.0.12. The analysis (Terry 1994) assumes that the operating ECP fails at the beginning of the transient (loss of commercial power) requiring transition to the standby ECP. For this case, the transition to the standby ECP occurs while the PCPs are coasting down. The analysis assumed the standby ECP receives a start signal when the low recirculation flow rate setpoint of 97 gpm is reached. The standby pump is assumed to spin up to full speed in 10 seconds.

The basis for TSR-186, LCO 3.3.3 and the derivation in SAR-153, Section 16.2.2 indicate that the loss of flow from the PCPs concurrent with the failure of the operating ECP would cause the standby ECP to start at a recirculation flow of 90 gpm. A previous analysis of the EPRF established 90 gpm as the nominal setpoint, but this value does not include any uncertainties (Reilly 1977). Uncertainty was stated to be ± 7 gpm. This results in an EPRF setpoint of 97 gpm, which was then used by Terry (1994) to evaluate the loss of commercial power concurrent with the failure of the operating ECP. The TSR-186 bases for the LCO describe 90 gpm as the minimum with an associated uncertainty of ± 9 gpm. This value should be 97 gpm with an uncertainty of ± 9 gpm. This discrepancy is documented via the USQ process in INEEL 2004e and 2004g.

The setpoint methodology for the ATR uses a worst-case setpoint in the analysis. The instrumentation uncertainty and time response are then added to the worst-case setpoint to establish the LCO setting in the TSR. Setting the instrument equal to or more conservatively than the LCO setting is also required by the TSR. The EPRF pump start instrumentation uncertainty, as documented in the TSR-186 is ± 9 gpm. The current TSR setpoint was therefore written ≥ 99 gpm (90 + 9 gpm). The setpoint derived from the analysis (see above) should be ≥ 106 gpm (97 + 9 gpm).

2.5.1.2 TRA-USQ-SE-2004-039 Evaluation, Emergency Pump Recirculation Flow Setpoint Calculation Error

TSR Bases, Section 3.3.3 describes the recirculation flow setpoint. The setpoint is based on a ratio of flows given in Reilly (1977):

$$\text{Setpoint} \geq \frac{(\text{Required minimum emergency flow})}{(\text{Normal emergency flow})} \times (\text{normal recirculation flow})$$

Atkinson (1994) established that a core flow of 2000 gpm provides ample margins to FI immediately following the coast down of the PCPs (adequate flow for decay power). The accident scenario evaluated by Terry (1994) assumed that the operating ECP failed at the initiation of the transient. During PCP coast down, the recirculation loop check valves isolating the ECPs from the PCS open and the standby ECP supplies flow. Normal emergency pump flow is assumed to be about 4690 gpm. The recirculation flow in this configuration (M-11 running and no PCPs running) is about 123 gpm (Reilly 1977) and recirculation flow with 3 PCPs and 1 ECP running is about 210 gpm (Reilly 1977). SAR-153 and TSR-186 are both based on analysis that incorrectly uses a recirculation flow of 210 gpm resulting in a setpoint of 90 gpm.

Flow tests were performed and revealed that the ECP output flows are somewhat different than assumed depending on the flow data that was reviewed. This was resolved by benchmarking the data and RELAP5 models (Davis 1999). Test data reported shows that ECP M-10 has the lowest average flow output of 4460 ± 35 gpm. The M-11 ECP has an average flow output of 4620 ± 190 gpm. This discrepancy is documented via the USQ process in INEEL 2004g and INEEL 2004e.

Further review of the analysis in Terry (1994) indicate that assuming failure of the operating ECP at initiation of the transient may not result in the most limiting power–coolant flow mismatch. Assuming the operating ECP fails immediately results in a start signal being sent to the standby ECP at initiation of the transient. Delaying the start signal to the ECP while the PCPs coast down might result in a low flow situation that does not meet CHF and FI thermal margins. This condition has not been formally evaluated and is further discussed in conjunction the other related issues in Section 2.5.2.

2.5.1.3 TRA-USQ-SE-2004-082, Emergency Pump Recirculation Flow Comparator RSS Trip Limiting Control Setting (GAP-014-04)

Instrument uncertainty associated with the ECP recirculation flow was examined and found to have some issues. Two separate subsystems are associated with ECPs: The recirculation circuitry and the circuitry that issues the start function are separate and should have different uncertainties. Specifically, the instrument uncertainty associated with the recirculation subsystem was found to have a questionable assumption. A more recent analysis of instrument and process uncertainties indicates that the uncertainty should be ± 49.4 in. water column (wc) instead of ± 7 gpm (Falibota 2005a). This discrepancy is documented via the USQ process in INEEL 2004h and INEEL 2004f.

2.5.2 Concerns

Several concerns arise given the existing analysis and basis for ATR TSR controls. First is the discrepancy between the analyzed value and that described in the ATR TSR Basis for ATR LCO 3.3.3. Analysis (Terry 1994) performed for the loss of commercial power transient assumed that the standby ECP would receive a start signal once EPRF reached 97 gpm (not 90 gpm as originally derived). This can be reconciled by re-calculation of the setpoint. The analysis used 97 gpm to which is added the uncertainties associated with the instrument, response time, and pump spin up time (± 9 gpm). This results in a setpoint of ≥ 106 gpm and an uncertainty of ± 9 gpm for ATR LCO 3.3.3.

The loss of commercial power evaluated in Terry (1994) would result in the PCPs and the operating ECP coasting down immediately following initiation of the event. Therefore, the flow produced in the recirculation loop would initially be 210 gpm since the recirculation loop isolation check valves have not yet opened. Further, the ECPs have been found to have a slightly lower output flow than reported in SAR-153. Test data reported in Davis (Davis 1999) shows that ECP M-10 has the lowest average flow output of 4460 ± 35 gpm. The M-11 ECP has an average flow output of 4620 ± 190 gpm. Using the flow scaling approach described in Section 2.5.1.2 and the minimum average flow output from either ECP (minus 2σ) results in a recirculation flow of 4240 gpm.(this value is rounded up to 4300 gpm). Therefore, the following setpoint represents the minimum ECP recirculation flow corresponding to the analysis presented in Terry (1994).

$$98\,\text{gpm} \geq \frac{(2000\ \text{gpm})}{(4300\ \text{gpm})} \times (210\ \text{gpm})$$

The accident analysis for loss of commercial power only takes credit for the start from low EPRF. SAR-153, Section 16.2.1 assumes that action to start the standby ECP would occur when the recirculation flow rate drops to 90 gpm vs. 98 gpm shown above (worst-case setting; non-PPS instruments FT-1-23 and FT-1-24). This assumption demonstrated adequate time to start the second pump. This part of the SAR is referring to the sequence analyzed in Terry (1994). However, the analysis (Terry 1994) used a setpoint of 97 gpm instead of 90 gpm as stated in the SAR-153, Section 16.2.1.

Failure of the operating ECP at the beginning of the loss of commercial power transient may not result in the most limiting power coolant flow mismatch. Assuming that the operating ECP failed at the beginning of the transient would result in a start signal being sent to the standby ECP once the recirculation flow dropped to 97 gpm (as evaluated). This results in the start signal being generated early in the transient. However, if the operating ECP failed at some time after initiation of the transient, flow through the core could be less than required to meet CHF and FI margins. This scenario has not been formally evaluated.

Another issue is the PPS EPRF subsystem that scrams the reactor if there is no ECP running (note that the scram only occurs if the standby ECP does not provide the minimum flow rate within 10 seconds). Requiring an ECP to be running anytime the reactor is operating was designed into the system and therefore there is no accident sequence that relies on this subsystem for transient mitigation. The setpoint for this subsystem is based on depressurized operation and detecting a decrease in the recirculation flow when no PCPs are running. For consistency, this setpoint was chosen to also apply to power and low-power operations. This setpoint is appropriately based on the relation where the recirculation flow rate is the flow rate with no PCP running. The nominal recirculation flow rate with M-11 running (no PCPs are running) is 123 gpm (Reilly 1977).

$$57\,\text{gpm} \geq \frac{(2000\ \text{gpm})}{(4300\ \text{gpm})} \times (123\ \text{gpm})$$

The functional requirement for loss of flow mitigation is to scram the reactor before the core flow drops below 2000 gpm. This functional requirement is met with a setpoint of ≥ 57 gpm for the EPRF subsystem. A revised uncertainty for this subsystem is estimated to be ± 49.4 in. wc (water column) (Falibota 2005a). Using the conversion equations from Falibota (2005a), the LCS would be ≥ 95.7 in. wc after consideration of both measurable and unmeasurable uncertainty. The uncertainties are nonlinear and therefore are not symmetrical.

2.5.3 Emergency Pump Recirculation Flow Setpoint Analysis

The two PPS subsystem EPRF setpoints are not consistent with the analyses. The subsystems are the low EPRF that starts the standby ECP and the low EPRF that shuts down the reactor.

To resolve the above discrepancies in the EPRF low setpoint to start the standby ECP, the ECP recirculation flow is chosen sufficiently high so that a signal to start to the standby ECP is generated as near to the initiation of the transient as possible. The setpoint is selected to be above the minimum required recirculation flow of 98 gpm (as calculated above) but below the normal recirculation flow of 210 gpm. Analysis provided in Terry (1994) has presented cases where the recirculation flow is 97 gpm and 180 gpm, both producing essentially identical results. Both cases result in margins to CHF and FI being acceptable.

The calculation for the reactor shut down setpoint shows that the current TSR-186, LCS 3.1.1 of ≥ 97 gpm is conservative. To remain consistent with the updated uncertainty analysis, TSR-186, LCS 3.1.1 will be ≥ 95.7 in. wc or a LCS of ≥ 101. 3 gpm.

2.5.4 Derived Controls

Loss of commercial power transients have led to two separate controls. The first controls the initial condition that at least one ECP is running during reactor operations and is TSR-186, LCS 3.1.1. This LCS setpoint should be ≥ 95.7 in. wc or a LCS of ≥ 101.3 gpm.

TSR-186, LCO 3.3.3 states the minimum acceptable flow for operations. This control ensures that a start signal to the standby ECP is generated before the flow through the core drops below that required to meet minimum CHF and FI margins. The sequence of concern is a loss of commercial power. For this case, PCPs and one ECP are operating and the recirculation flow is about 210 gpm. The minimum recirculation flow required to ensure that a start signal is sent to the standby ECP is calculated above to be 98 gpm. The loss of commercial power analysis assumes that the operating ECP fails at the beginning of the transient. This failure could lead to a low flow through the core because a start signal on a recirculation flow of 98 gpm would supply the minimum needed flow after the ECP spins up. Therefore, a higher recirculation flow setpoint is required. This setpoint is selected to be between 210 gpm and 98 gpm as follows. (210 – 98)/2 + 98 = 154 gpm. For convenience, this setpoint is rounded to 150 gpm and is assumed to include the instrument uncertainty of 9 gpm. TSR-186, LCO 3.3.3 then becomes ≥ 150 gpm ± 9 gpm (141 + 9). Selecting this setpoint ensures that a start signal occurs early in the transient, allows a higher in-plant setting to protect the LCO (margin), and protects against spurious start signals that might be caused by routine operations (oscillation about a normal recirculation flow of 210 gpm).

The TSR-186 changes described above correct deficiencies and errors associated with the PPS RSS ECP recirculation flow trip set point and the ECP start signal set point. Both USQ evaluations were negative and did not impose any operational restrictions.

2.5.5 Equipment Classification

No change to the subsystems (or components) classification is necessary. Both the PCS ECP subsystems and the PPS RSS EPRF instrumentation are properly classified as safety related systems.

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EDF No.: 5614 EDF Rev. No.: 0 Project File No.: N/A

1. Title: Summary of Interim Safety Basis Supporting Advanced Test Reactor Operation Pending Full Resolution of Unreviewed Safety Questions – TRA-USQ-2004-214 Revision 1, TRA-USQ-2004-396, and TRA-USQ-2004-413

2. Index Codes:
Building/Type TRA-670 SSC ID N/A Site Area 531 (TRA)

3. NPH Performance Category: _____ or ☒ N/A

4. EDF Safety Category: SC or ☐ N/A SCC Safety Category: _____ or ☒ N/A

5. Summary:

Concerns identified in TRA-USQ-2004-214 Revision 1 (ATR Seismic Safety Basis Deterioration), TRA-USQ-2004-396 (ATR Seismic Primary Coolant System Break Size and TRA Support Building Vulnerabilities), and TRA-USQ-2004-413 (ATR Seismic Primary Coolant System Break Size Contribution from Letdown Valves) have been evaluated to support an interim safety basis for ATR power operation. In addition, the impact of the interim safety basis on previous evaluations for USQ evaluation SE-2004-145 (ATR Firewater Supply System Modeling Issues) has been addressed.

This EDF is an evaluation of the safety of the situation (ESS) for the above USQs and revises prior operational restrictions. This EDF is to be included as a temporary addendum to the SAR, supporting reactor operation and TSR revisions, until such time that the above issues are fully resolved and appropriately incorporated into the SAR. Revisions to the ATR Technical Safety Requirements (Sections 3.2.1.2, 3.3.6, and 3.5.5) and additional controls required for ATR operation (e.g., SAR commitments) are summarized in Section 3.1.

The existing EDF-4334 Revision 1 (McCracken 2004) remains applicable as an addendum to the ATR SAR. However, controls defined in Section 2.2.3 of EDF-4334 Revision 1 have been revised and are included in the TSR requirements and SAR Commitments developed herein.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

	R/A	Typed Name/Organization	Signature	Date
Performer/ Author	N/A	G. L. Sharp	JC Chapman For	20 March 2005
Technical Checker	R	T. A. Thatcher	JC Chapman For	20 March 2005
Technical Checker	R	S. R. Wagoner	JC Chapman For	20 March 2005
Independent Peer Reviewer (if applicable)	R			
Approver	A	S. K. Penny	SK Penny For	3/20/05
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Record Retention Period: Cut off when superseded obsolete or canceled. Destroy 75 years after cutoff.

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Not Applicable

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1.0 Introduction

During the Advanced Test Reactor (ATR) extended outage for core internals replacement, some concerns in the facility safety basis were identified that impact reactor operation. Each of these concerns was evaluated through the unreviewed safety question (USQ) process and resulted in operational restrictions that must be addressed before resuming normal ATR power operation and the experiment test program. The concerns include 1) TRA-USQ-2004-214 Revision 1 (ATR Seismic Safety Basis Deterioration), 2) TRA-USQ-2004-396 (ATR Seismic Primary Coolant System Break Size and TRA Support Building Vulnerabilities), and 3) TRA-USQ-2004-413 (ATR Seismic Primary Coolant System Break Size Contribution from Letdown Valves). In addition, some of the concerns identified above, and the respective resolutions, impact the interim resolution for USQ evaluation SE-2004-145 (ATR Firewater Supply System Modeling Issues), documented in McCracken (2004). The concerns are summarized below.

1.1. TRA-USQ-2004-214, Revision 1, ATR Seismic Safety Basis Deterioration

This USQ determination (INEEL 2004) challenges the basis for reliable long-term water inventory from the emergency firewater injection supply system (EFIS Supply). Prior Department of Energy (DOE) review and approval of the ATR safety basis concluded that outstanding seismic comments did not pose an unanalyzed condition for the facility because the seismic probabilistic risk assessment (PRA) was considered to accurately describe the seismic risk for the facility and showed that the risk was acceptable. The PRA model assumes that long-term EFIS supply will be provided through post-seismic event restoration of commercial electrical power. On-site raw water supplies, however, are not sufficient to last until commercial power can be reasonably assumed to be restored. Therefore, uninterrupted EFIS delivery to the ATR vessel is not ensured following a seismically induced loss of coolant accident (LOCA).

1.2. TRA-USQ-2004-396, ATR Seismic Primary Coolant System Break Size and TRA Support Building Vulnerabilities

Seismic impact walk-downs were conducted at TRA by ARES Corporation consultants. The ARES report (ARES 2004) identified several structures, systems and components (SSC) that could be vulnerable to failure during Performance Category 3 (PC-3) and/or Performance Category 4 (PC-4) seismic events. These include:

- Several small primary coolant system (PCS) lines (1 in. or less),
- The bypass demineralizer shielding block partition wall, and
- Several older masonry block buildings (e.g., TRA-619) that have not been shown to have adequate reinforcement.

These potential failures could contribute to an increase in the LOCA leakage currently analyzed in the safety basis and unexpected firewater system losses (pumps and/or pipe breaks) that could challenge the ability of the EFIS Supply to deliver the minimum required EFIS flow rate to the ATR vessel assumed in the safety basis (INEEL 2005a).

1.3. TRA-USQ-2004-413, ATR Seismic Primary Coolant Break Size Contribution from Letdown Valves

The PCV-1-1 and LCV-1-3C letdown valves are automatically controlled by the distributed control system (DCS), which was not previously seismically qualified. Additional inventory loss due to continued PCS letdown was not modeled in the safety basis analyses and would result in the equivalent break area being greater than that analyzed for a seismically-induced LOCA (INEEL 2005b).

1.4. TRA-USQ-SE-2003-145, ATR Firewater Supply System Modeling Issues

Deficiencies in the Upgraded Final Safety Analysis Report (SAR) modeling of firewater delivery to the EFIS indicated that the firewater system was not adequately controlled to ensure delivery of the assumed flow rate to the reactor vessel (INEEL 2003). McCracken (2004) documents evaluation of an EFIS operational configuration that ensured a success path for providing the assumed EFIS flow rate to the ATR following postulated LOCAs. The EFIS configuration discussed in McCracken (2004) is impacted by the postulated SSC seismic failures discussed above. This includes additional evaluation of available EFIS water inventories and non-safety related firewater demands and a basis for improved firewater pump reliability and firewater pump start delays. An acceptable configuration of the EFIS supply, that ensures firewater delivery to the EFIS, is reestablished herein. The controls established in Section 2.2.3 of McCracken (2004) are revised herein.

1.5. Purpose

The purpose of this Engineering Design File (EDF) is to address the aforementioned concerns and support power operation of the ATR and the experiment test program. This EDF, which will be submitted to the DOE for review as an evaluation of safety of the situation (ESS) for the above USQs, revises existing operational restrictions in support of reactor operation. This EDF is to be included as an addendum to the SAR, supporting reactor operation and the revised Technical Safety Requirements (TSR), until such time that the above issues are fully resolved and appropriately incorporated into the SAR. Revisions to the ATR TSR and additional controls required for ATR operation (e.g., SAR commitments) are summarized in Section 3.0 (Conclusions). This EDF supersedes portions of the SAR Addendum EDF-4334, Revision 1 (McCracken 2004).

A separate EDF has been prepared to address selected concerns (USQs) resulting from gaps identified through the in-progress Design Basis Reconstitution Program (Harwood 2005).

Revised TSR controls are established herein for the following TSR sections:

- Section 3.2.1.2, Emergency Firewater Injection Supply System
- Section 3.3.6, Primary Coolant Leakage
- Section 3.5.5, Cask Handling and Irradiated Fuel Element Storage

The format of this EDF was selected to support SAR and TSR revisions and therefore does not follow the guidance in GDE-305 or the format in MCP-2374. Format and content listed in these documents are intended for EDFs that present analysis and calculations.

2.0 Detailed Discussion and Evaluation

2.1. TRA-USQ-2004-214 Revision 1, ATR Seismic Safety Basis Deterioration

2.1.1. Concern

Review of the long-term EFIS water supply, as part of developing a final resolution to the firewater modeling USQ (INEEL 2003), included review of the available raw water inventory following a seismic event. The review resulted in TRA-USQ-2004-214, Revision 1 (INEEL 2004) which identified discrepant conditions between assumptions in the ATR seismic PRA and the ability of the EFIS Supply to provide long-term injection to the reactor vessel. Long-term EFIS injection has historically been dependant on commercial electrical power being restored and operation of at least one deep-well pump. The deep-well pumps are driven by electric motors and were not originally designed with an emergency power source. The aboveground raw water storage inventory was found to be insufficient to provide continuous fire protection and EFIS demands until such time that offsite commercial power could be assumed to be restored (Thatcher 2005).

USQ determination TRA-USQ-2004-214 (INEEL 2004) challenges the availability of reliable long-term water from the EFIS Supply. Prior DOE review and approval (Lange 1998) of the ATR safety basis concluded that outstanding seismic comments did not pose an unanalyzed condition for the facility because the seismic probabilistic risk assessment was considered to accurately describe the seismic risk for the facility. The seismic PRA model assumes that long-term EFIS water inventory will be provided via restoring commercial electrical power following the seismic event.

The potential for reduced or interrupted EFIS injection to the vessel also impacts the assumptions in the LOCA analyses presented in the SAR. The LOCA analyses generally quantify the consequences from accident initiation until a time at which long-term post-accident conditions are stable and can be maintained. Continuous EFIS injection is key to maintaining the reactor core in a stable and coolable condition following a LOCA; therefore, long-term EFIS Supply is inherently assumed in the SAR Chapter 15 LOCA analyses. Failure of the EFIS or EFIS Supply to continuously provide the minimum required flow rate to the reactor vessel would ultimately lead to worse consequences than currently presented in the SAR.

2.1.2. Evaluation of Seismic PRA Basis and EFIS Long-Term Water Supply

Aboveground EFIS Supply water storage is maintained in the overhead storage tank (TRA-718) and four ground-level storage tanks (TRA-781 and TRA-719A, TRA-719B & TRA-719C). The ATR TSR currently requires a supply volume ≥ 500,000 gallons. The SAR (McCracken 2004) specifies that this supply volume must be available to each operable firewater pump that is selected for TSR compliance. The SAR (McCracken 2004) further requires an alarm to alert operators, if the indicated water level in the overhead tank (TRA-718) drops below 24.5 ft. This corresponds to maintaining a water volume in the overhead tank (TRA-718) of approximately 80,000 gallons (Sharp 2005a).

Following a LOCA the total volume of all firewater supply tanks was not sufficient to provide long-term core cooling for 24 hours or 72 hours. (Note that these inventories are also revised as part of evaluating TRA-USQ-2004-396 in Section 3.2). The aboveground water inventory must ultimately be replenished by operation of at least one deep-well. The deep-well pumps, however, have been dependent on commercial power to operate. In order to address this condition, an emergency diesel power supply has been installed on deep-well pump Number 3.

The diesel power design requires an immediate fuel tank capable of fueling the diesel for at least 20 hours, and a second readily-available fuel supply which provides an additional 52 hour fuel supply. Hence, an onsite deep-well pump emergency power supply, lasting 72 hours without offsite support, is now available. The basic design requirements for the emergency power source and the deep-well pump are documented in Sharp (2005b). A 72-hour readily-available fuel supply is consistent with the PRA guidance in ANSI/ANS-28.51-2003 for assuming recovery of offsite commercial power following a seismic event. A 72-hour commercial power recovery time is also assumed in an interim seismic PRA for the ATR (Thatcher 2005). The interim seismic PRA concludes that the risk is 4.8E-05/yr for all seismic risk contributors. Seventy-two hours also provides sufficient time, with high confidence, to be able to obtain additional fuel for continued operation of the diesel generator, if required.

Note that the evaluation in Thatcher (2005) is an interim seismic PRA that is intended to update the previous PRA models with the best available information in order to provide an estimate of risk. The complete seismic qualification of SSCs, as outlined in PLN-588 (2004), has not yet been performed. Some of the fragilities used are also preliminary. Thatcher (2005) evaluates the risk of ATR fuel damage due to seismic events during full power operation, reactor shutdown with fuel in the reactor vessel, and irradiated fuel storage in the canal.

The above evaluation is also supported by revised firewater supply inventory requirements and usage rate analysis discussed in Section 2.2. The available (required) inventory and usage rate supports the time required for operator action to start the emergency deep-well pump diesel and establish flow from at least one deep-well pump (see Section 2.2.2.2).

The newly installed emergency diesel generator and the Number 3 deep-well pump and required components to ensure the safety function are required to be seismically qualified. Novascone (2005b) documents the seismic evaluation of the diesel generator and the deep-well pump. This and other recent seismic analyses have used the seismic spectra for rock documented in Payne (2002) and for soil documented in Payne (2004). The deep-well pump mounting and piping were also evaluated in Johnson (2005). The deep-well pump houses are not seismically-qualified. However, the ARES (2004) report provided a preliminary fragility estimate and an estimate of the high-confidence-of-a-low-probability-of-failure (HCLPF) slightly below the design basis earthquake. The interim seismic PRA used the fragility estimate in the estimation of seismic risk.

Overall reliability and defense-in-depth considerations require the availability of the commercially-powered deep-well pumps and deep-wells. Hence, TSR controls are also established for operability of commercially-powered deep-wells.

2.1.3. Derived Controls

An operable emergency diesel power source supplying a deep-well pump is required in order to reestablish an acceptable risk level. A TSR control (TSR-186, Section 3.2.1.2) is implemented requiring an operable deep-well pump with an emergency power source. A seismic survivability evaluation of the diesel generator, all supporting SSCs transferring power to the pump, the deep-well pump, and the deep-wells (except the buildings as noted above) has been performed. A seismically robust flow path for providing EFIS to the reactor vessel is also required.

Two operable deep-wells (total) are required in TSR-186 (Section 3.2.1.2) in order to establish a minimum level of deep-well reliability. (One emergency-powered deep-well is required to be operable, hence one commercially-powered deep-well is also required to be operable.)

An acceptable allowed outage time is included in the TSR, and discussed in the TSR bases. The allowed outage time is based on the analysis and assumptions in Thatcher (2005). Surveillance and functional testing requirements are also established in the TSR.

2.1.4. Equipment Classification

The deep-well pump emergency-power diesel generator, the deep-well pumps, and the deep-wells are safety related Seismic Category 1 equipment. A seismically robust flow path providing EFIS to the reactor vessel is also required.

The commercially-powered deep-wells are safety related.

2.2. TRA-USQ-2004-396, ATR Seismic Primary Coolant System Break Size and TRA Support Building Vulnerabilities

2.2.1. Concern

Seismic impact walk-downs were conducted at TRA by ARES Corporation consultants and ATR support personnel. The ARES (2004) report identified several SSC that could be vulnerable to failure during PC-3 and/or PC-4 seismic events. These include:

- Several small PCS lines (1 in. or less),
- The bypass demineralizer shielding block partition wall, and
- Several older masonry block buildings (e.g., TRA-619) that have not been shown to have adequate reinforcement.

These potential failures would contribute to both an increase in the net LOCA break size currently analyzed in the safety basis and unexpected firewater system losses (pumps and/or pipe breaks) that could challenge the ability of the EFIS Supply to deliver the assumed EFIS flow rate to the ATR vessel (INEEL 2005a).

2.2.2. Evaluation of Seismic Primary Coolant System and Support Building Vulnerabilities

2.2.2.1 Seismic Primary Coolant System Break Size Evaluation

Wagoner (2005) develops revised break scenarios for postulated Condition 3 and Condition 4 seismic LOCAs, considering the potential PCS failures identified in the ARES report (ARES 2004). The revised break sizes were analyzed in Polkinghorne (2005a). This analysis also modeled PCS leakage of 50 gpm (at system pressure) to account for normal system leakage during reactor operation. The analysis demonstrated that core safety margins meet ATR plant protection criteria. The fuel buckling margin was greater than two standard deviations ($>2\sigma$) for the Condition 3 fault, and the margin to the aluminum-water ignition threshold (AWIT) temperature was $>3\sigma$ for the Condition 4 fault.

In addition to the above analysis, several deficiencies in the PCS piping and in piping attached to the PCS have been repaired (Wagoner 2005). Piping structural supports for seismic restraint of piping outside of the radiograph boundary play an important role in limiting postulated LOCA break sizes. An analysis of the shielding wall in the bypass demineralizer area within TRA-670 has also been completed (Novascone 2005a). The analysis concludes that the seismic capacity of the wall exceeds the load demand; hence this wall is not expected to fail during a PC-4 seismic event.

2.2.2.2 Seismic Support Building (Firewater System) Vulnerabilities Evaluation

The firewater system provides the water supply and injection for the ATR EFIS and for fire suppression throughout the RTC site area. Many of the older buildings at RTC are built of masonry block and are susceptible to failure during a PC-3 or PC-4 seismic event. The firewater water system piping in buildings that fail is also expected to experience at least partial failure. The resulting breaks in the firewater system piping reduce both the flow rate and the total water inventory available for accident mitigation.

Rowsell (2005a) documents an analysis of the firewater supply system assuming severe failures in the firewater piping. The analysis assumes > 70% of the total susceptible break area is exposed. Revised upper vessel and bottom head EFIS flow rates were developed and modeled in the revised seismic LOCA analyses (Polkinghorne 2005a). The model demonstrates that with two running firewater pumps (688-M-1 and 688-M-2 or 633-1 and one 688 pump) that the minimum required EFIS flow is provided to the reactor vessel.

Engineering has been working to solve the Seismic PRA USQ and new seismic concerns identified from a recent walkdown (ARES 2004). Because of this work, a recent walkdown and review by seismic engineers of the firewater piping in the TRA-671 cooling tower pump house revealed that the firewater supply piping in the building is not well supported. Isolation of the building, using existing valves, would isolate a portion of the ATR firewater loop. This is a 12-in. diameter firewater pipe that supplies water for the cooling tower deluge system and fire suppression systems in the TRA-671 building.

Based on the Rowsell (2005a) analysis, an additional large leak in the firewater system piping in TRA-671 would be outside of the analysis. This issue must be addressed prior to reactor operation. The firewater piping in the TRA-671 building must be isolated from the firewater supply system during reactor operation until the piping can be seismically supported and qualified.

The Rowsell (2005a) firewater system model was also used to calculate the maximum firewater demand and drain rates (pump output) from the ground-level storage tanks (TRA-781, TRA-719A, TRA-719B, and TRA-719C). The available volume and usage rates were used to establish the supply inventory requirements and the minimum time available for operator action to establish long-term firewater supply and delivery (Sharp 2005a). Long-term flow is obtained by starting a deep-well pump and its emergency diesel generator (if applicable) and must be established before the ground-level storage inventory is depleted. No credit was taken during a postulated seismic event for the inventory in the overhead tank (TRA-718) since potential failures in the raw water system could deplete this source. The calculations also assume that the TRA-619 firewater pumps (619-10 and 619-12) do not operate during the event (auto start feature defeated). The inventory and drain rate calculations (Sharp 2005a) demonstrated that a TSR required inventory of 900,000 gal in TRA-781 and combined inventory of 725,000 gal in the TRA-719A, B, & C tanks provides 50 minutes for operator isolation of the ATR firewater loop, and an additional 1 hour and 15 minutes to establish deep-well flow and to realign the firewater

piping, including break isolation where possible, for delivery to the ATR core. Isolation of the ATR firewater loop requires closing the firewater loop cross-connect valves (BF-10-12 & BF-10-13). Closure of these valves, while under flow, has been successfully tested (Rowsell 2005d). Finally, Rowsell (2005a) demonstrates that a deep-well pump will develop enough pump head and flow to provide the minimum required flow to the ATR core under post-seismic conditions with the southern portion of the RTC firewater loop isolated.

2.2.2.3 Safety Basis Evaluation of the Revised Emergency Firewater Injection Supply System Operational Configuration

In the process of addressing seismic vulnerabilities, a revised basis for pump start and operation of the firewater supply system has been developed. This includes requiring that the 688-M-1, 688-M-2 and 633-1 firewater pumps be operable, the 619-10 and 619-12 pumps be placed in manual start, and increased ground-level tank required inventories. Operation of the 619 pumps could result in depleting the inventory of the TRA-719 tanks too quickly (Sharp 2005a). The revised operational configuration is also evaluated against the existing ATR safety basis and conditions where the firewater system is required to provide core protection.

Firewater Pump Start Setpoints:

An updated basis, including an uncertainty analysis, for the firewater pump start pressure setpoints has been established. Rowsell (2005a) documents the analytical limit for the pump start pressure setpoint (50 psig). Kirkpatrick (2005a) and (2005b) document an uncertainty analysis, and the resulting TSR setpoints (Limiting Conditions Operation) for the pump pressure starts. Automatic start of the firewater pumps is credited to mitigate LOCA consequences. Firewater pumps are assumed to operate following a seismic event. The TSR pressure setpoint for the firewater pumps is ≥ 55 psig, based on the analytical limit of 50 psig (Rowsell 2005a) and an uncertainty (accuracy) of ± 5 psi (Kirkpatrick 2005a, 2005b). (Note that the uncertainty from Kirkpatrick (2005a, 2005b) has been rounded up to the nearest whole number.)

The pump start setpoints are established such that if firewater system pressure drops below the pressure required to provide the minimum required EFIS flow, then a pump start signal will be generated. This ensures that if a first or second firewater pump is required in order to meet demands, a pump start signal will be generated. Analysis (Rowsell 2005a) has shown that two operating pumps will provide sufficient EFIS flow under worse case postulated (post-seismic) conditions. A third firewater pump is required to be operable in order to improve firewater supply system reliability and to allow for an assumed single failure in the accident analyses. Accident analyses discussed herein also model or have evaluated up to a 2-minute delay from the time that firewater system pressure drops below the pump start setpoint until pump start occurs and injection begins. For any condition where firewater system pressure remains greater than the pump start setpoint, the EFIS flow rate will be greater than the minimum required EFIS flow rate.

Revised Non-Seismic LOCA Analysis with EFIS Injection Provided by Gravity-Feed:

The ability of the firewater system to reliably mitigate a Condition 2 LOCA is sensitive to the reliability of diesel-driven firewater pumps. The reliability is further challenged by the new requirement to place the electric firewater pump (pump 619-12) in manual start mode. This condition has been addressed by a revised analysis which demonstrates that gravity feed from the TRA-781 tank provides sufficient flow for this LOCA event. The revised analysis (Polkinghorne 2005b) demonstrates that the minimum critical heat flux and flow instability margins are acceptable for Condition 2 faults with EFIS provided by gravity feed. Gravity feed was shown to provide adequate EFIS flow for several hours. This analysis does not credit a

running firewater pump, the overhead tank (TRA-718), or rapid/automatic startup of a diesel firewater pump. Rowsell (2005b) also demonstrates that adequate flow can be provided by gravity-feed from the TRA-719 tanks.

Revised Seismic LOCA Analysis with Increased Leakage, Reduced EFIS Flow Rate, and 2-Minute Delay for Firewater Pump Start:

Calculations were performed to investigate ATR thermal safety margins during two new and potentially more limiting seismically-induced LOCA scenarios. For the first LOCA, a Condition 3 fault, an earthquake is assumed to cause a 1-in. reactor inlet break and valves PCV-1-1 and LCV-1-3C are assumed to fail open. The second case, a Condition 4 fault, an earthquake is assumed to cause a 1-in. reactor inlet break, a rupture of the bypass demineralizer inlet line, and valve PCV-1-1 to fail full open. Although assumed to fail, seismic upgrades to the DCS are being pursued to reduce the likelihood that PCV-1-1 and LCV-1-3C fail open. In each case, numerous breaks in the firewater supply system piping are assumed to occur, resulting in a reduction in the EFIS injection flow rate. In addition, no credit for injection or inventory supplied from the overhead storage tank (TRA-718) is assumed. In the analysis emergency firewater injection is initiated > 2 minutes from the time of EFIS actuation in order to allow time for the firewater pumps to sense low pressure in the firewater piping and to supply EFIS injection. The analyses concluded that core safety margins were acceptable for each postulated seismic LOCA (Polkinghorne 2005a).

Non-Seismic LOCA (3-inch) with Concurrent Failures:

As discussed above, a revised LOCA analysis was prepared for the non-seismic (base case) 3-in. break presented in the SAR (Polkinghorne 2005b). The existing analyses for the non-seismic LOCA events with concurrent failures, presented in Section 15.6.5, have not been reanalyzed modeling the reduced EFIS flow rates or 2-minute pump start delay.

The SAR Section 15.6.5 LOCA evaluations below rely on a minimum water volume of ≥ 40,000 gal in the overhead storage tank (TRA-718). This corresponds to a tank level of approximately 15 ft (Sharp 2005a). The tank level is maintained much greater than 15 ft by a nominal low level alarm at ≥ 24.5 ft (McCracken 2004), which corresponds to approximately 80,000 gal (Sharp 2005a). The maximum drain rate from the overhead tank (TRA-718) is less than 5000 gpm (without seismic firewater system failures), which results in a minimum submergence level for potential vortex formation of 6.8 ft (Erickson 2003). A water level of 6.8 ft in the hemispherical bottom of the overhead tank (TRA-718) corresponds to less than 11,664 gal of unusable volume.

$$\begin{aligned} \text{Vol. (partial sphere)} &= (1/6)(\pi)(6.8\text{ ft})\{(3)[(13\text{ ft})^2 - (13 - 6.8)^2] + (6.8\text{ ft})^2\} \\ &= 1559\text{ ft}^3 \\ &= 11{,}664\text{ gal} \end{aligned}$$

Therefore, the available volume of 28,336 gal (40,000 gal – 11,664 gal) draining at 5000 gpm will provide ~5.7 minutes (28,336 gal / 5000 gpm) of EFIS injection during a non-seismic event. Assuming 7 ft for uncertainty in the level indication (expected to be very conservative) results in a minimum required water level of 22 ft and a corresponding water volume of 70,147 gal (Sharp 2005a). The available water volume at 22 ft is 58,483 gal (70,147 gal – 11,664). The TSR required water volume is 58,000 gal (rounded), corresponding to a level of ≥ 22 ft.

The existing LOCA with concurrent failure event analyses are evaluated below in order to demonstrate that the conclusions presented in the SAR remain valid.

Section 15.6.5.1 (Upper Vessel or Bottom Head EFIS Out-of-Service): The current SAR analysis for this event is documented in Polkinghorne (1999). The analysis concludes that the minimum margins occur prior to EFIS actuation, and therefore, are bounded by the base case 3-inch LOCA discussed in SAR Section 15.6.4. Reduced EFIS flow and a potential pump start delay in EFIS injection does not affect the results prior to the time of EFIS actuation. Therefore, the calculated minimum margin will not be reduced provided the accident conditions following EFIS actuation are mitigated such that they do not become more limiting. Initial EFIS injection (flow rate and time of initiation) is not affected due to availability of the overhead storage tank (TRA-718) to provide more than 5 minutes of flow in response to a non-seismic LOCA. Once the overhead tank (TRA-718) inventory is exhausted, a reduced EFIS flow (gravity-feed from TRA-781) would be provided during firewater pump start ($\leq$ 2 min), following which full EFIS flow would be restored. During the 2-minute time period of reduced EFIS injection, the postulated accident conditions may not be bounded by the SAR analysis. Polkinghorne (2005b) showed that gravity-feed flow was sufficient for a 3-inch LOCA with one upper EFIS injection path failed closed (3-in base case). The worst case condition for the 3-inch break with one EFIS path unavailable would be with the upper vessel EFIS out-of-service and only the bottom head EFIS path operable. Bottom head injection includes four 2-inch injection lines of schedule 40 pipe. This piping has an inside diameter of 2.067 in., hence the total area of four lines is $4(\pi)[(1/2)(2.067\text{ in})]^2 = 13.4\text{ in}^2$. The area of the 3-inch postulated break is 7.1 in^2. Since the injection area is nearly twice the break area in this inflow-outflow system, gravity-feed will be sufficient during the brief 2-minute period of reduced flow to maintain emergency coolant pump NPSH. Therefore, margins will remain greater than the minimum calculated margins earlier in the transient.

Section 15.6.5.2 (Failure to Shut Off One PCP): The current SAR analysis for this event is documented in Polkinghorne (1999). This event is analyzed to demonstrate that air from the surge tank does not enter the primary coolant system and degrade emergency pump performance. By doing so, this postulated accident is shown to be bounded by the base case 3-inch LOCA analysis (SAR Section 15.6.4). The analysis shows that the minimum surge tank water level occurs at the time of EFIS injection. Once EFIS injection is initiated, the surge tank water level begins to increase. The overhead tank (TRA-718) is available to provide EFIS injection for more than 5 minutes following EFIS actuation; therefore, initial EFIS injection (flow rate and time of initiation) modeled in the analysis is not affected and surge tank draining will be initially reversed as predicted. Once the overhead tank (TRA-718) inventory is exhausted, a reduced EFIS flow (gravity-feed from TRA-781 or TRA-719) would be provided during firewater pump startup ($\leq$ 2 min), following which full EFIS flow will be restored. During the period of reduced EFIS flow (beginning after 5 min) the surge tank would start draining again, but at a lower rate than predicted prior to EFIS actuation. From Polkinghorne (2004), the surge tank level would have recovered to approximately 100 in. Based on the drain rate calculated in Polkinghorne (2004), a 2-minute surge tank draining period late in the transient would not result in completely draining the surge tank. Note that Polkinghorne (2004) assumes a revised EFIS actuation setpoint of 28 psia. The revised analytical setpoint (28 psia) is being implemented simultaneously with this EDF through Harwood (2005).

Interim controls for USQ TRA-USQ-2004-385 (INEEL 2005c) may be affected by the above evaluation. The interim controls developed for TRA-USQ-2004-385 must be reevaluated prior to loading the core with irradiated fuel.

Section 15.6.2.3 (Failure of PPS Low-Vessel-Inlet Pressure Subsystem) and Section 15.6.5.4 (One PCP Check Valve Fails to Close): The current SAR analyses for these events are documented in Polkinghorne (1999). The analyses conclude that the minimum margins occur near the time of EFIS actuation. The overhead tank (TRA-718) is available to provide EFIS injection for more than 5 minutes following EFIS actuation; therefore, initial EFIS injection (flow rate and time of initiation) modeled in the analysis is not affected and the minimum margins presented in the SAR will not be reduced. Once the overhead tank (TRA-718) inventory is exhausted, a reduced EFIS flow (gravity-feed from TRA-781) would be provided during firewater pump start (≤ 2 min), following which full EFIS flow will be restored. Minimum calculated margins would not be reduced during the 2-minute period of degraded EFIS flow because the period of reduced flow follows the limiting conditions of the accident and gravity-feed from the TRA-781 tank is sufficient to maintain net positive suction head for the running emergency coolant pump that maintains forced core flow.

Canal Make-up and Inventory:

TSR-186, 3.5.5 currently requires a canal make-up inventory of ≥ 50,000 gal. This inventory is based on providing canal make-up for 24 hours. This requirement is revised to be more consistent with the basis for tank inventory requirements for reactor operation and the firewater supply system requirements.

Following a seismic event, canal make-up flow requires a single firewater pump (overhead tank [TRA-718] not available). Due to the very slow canal drain rate (< 38 gpm), neither automatic pump start nor continuous operation are required. Hence, an operable firewater pump with automatic or manual start capability will provide the required flow. The firewater pump will require a supply inventory (TRA-781 or TRA-719 tanks). For convenience in monitoring inventory levels, the inventory requirements are assigned to be the same as those developed for reactor operation. Therefore, with irradiated fuel in the canal, TRA-781 must contain ≥ 900,000 gal or the TRA-719 tanks must contain ≥ 725,000 gal. Deep-well operability is not required without irradiated fuel in the reactor vessel. Therefore, normal water usage loads must be managed (or isolated if needed), in response to a canal drain event. The reactor operation inventory levels provide sufficient water to supply normal water usage loads, until isolated.

2.2.3. Derived Controls

Reactor primary coolant system total leakage at system pressure (identified and unidentified) may not exceed 50 gpm (TSR-186, 3.3.6).

In order to ensure at least 2 firewater pumps start and run, allowing for an assumed single failure, 3 firewater pumps must be operable during power operation, low power operation, and pressurized standby following power operation until the fuel cooling time is met. The operable firewater pumps must be 688-M-1, 688-M-2, and 633-1, with a TSR pump start setpoint of ≥ 55 psig (accuracy ± 5 psi) and start time of ≤ 2 min (TSR-186, 3.2.1.2). These firewater pumps must be seismically qualified and not rely on commercial power.

The fuel damage risk is much lower following reactor operation and after having met the fuel cooling time limit. Therefore, the requirement for firewater pump operability is relaxed to 2 pumps (both 688 pumps or one 688 pump and 633-1) when irradiated fuel is in the reactor vessel. For this condition, the ground-level storage tank inventory requirements must be met for the tanks supplying the operable firewater pumps. (TSR-186, 3.2.1.2)

The 619-10 and 619-12 firewater pumps must have the auto start function disabled whenever the minimum ground-level tank inventories are required. This will be ensured by placing these pumps in manual start mode (SAR commitment).

The ability for operators to isolate the ATR firewater loop within 50 minutes of the seismic scram followed by starting a deep-well pump and establishing long-term firewater supply within an additional 75 minutes must be shown and these actions initiated from the emergency procedure network (EPNs). (SAR commitment)

The compliment of operators must support the ability of the operations staff to perform the operator actions discussed above. (TSR-186 AC 5.3.2)

Minimum required water inventories of 900,000 gal in the TRA-781 tank and 725,000 gal in the TRA-719 tanks must be maintained with irradiated fuel in the reactor vessel (TSR-186, 3.2.1.2).

The overhead raw water storage tank (TRA-718) must have a TSR required inventory of ≥ 58,000 gal (TSR-186, 3.2.1.2). In addition, the instrumentation that measures water level in the overhead tank (TRA-718) must be calibrated (SAR Commitment).

TRA-671 firewater piping must be isolated in order to prevent unacceptable firewater supply losses (SAR Commitment).

A minimum required water inventory of 900,000 gal in the TRA-781 tank <u>or</u> 725,000 gal in the TRA-719 tanks must be maintained with irradiated fuel in the ATR canal (TSR-186, 3.5.5). (For this condition, the ground-level storage tank inventory requirements must be met for the tanks supplying the operable firewater pumps.)

A single firewater pump (688-M-1, 688-M-2 or 633-1) must be operable in manual or automatic start mode with irradiated fuel in the ATR canal (TSR-186, 3.5.5).

2.2.4. Equipment Classification

The 688-M-1, 688-M-2, and 633-1 firewater pumps and pump start controls are safety related Seismic Category 1 equipment, including assurance that the buildings that house the pumps (TRA-633 and TRA-688) will not fail and cause the pumps to fail.

The TRA-781 and TRA-719A, B, & C ground-level storage tanks are safety related and Seismic Category 1 structures.

The overhead tank (TRA-718) is a safety related and Seismic Category 1 structure. (EFIS flow from the overhead tank (TRA-718) is not credited in response to seismic events; however, collapse of the tank could cause damage to other SSCs beyond that modeled in safety basis analyses.)

2.3. TRA-USQ-2004-413, ATR Seismic Primary Coolant Break Size Contribution from Letdown Valves

2.3.1. Concerns

The PCV-1-1 and LCV-1-3C letdown valves are automatically controlled by the DCS, which is not seismically qualified. The current seismic LOCA scenarios analyzed and presented in the SAR do not include additional inventory loss due to continued PCS letdown. Therefore, failure of the letdown valves could result in a more limiting seismically initiated LOCA (increased overall inventory loss) than was analyzed in the safety basis (INEEL 2005b).

2.3.2. Evaluation of Potential PCV-1-1 and LCV-1-3C Failure

Revised analyses of the Condition 3 and Condition 4 seismic LOCA events have been performed (Polkinghorne 2005a). The analyses model PCV-1-1 and LCV-1-3C in the failed open position. The analyses demonstrate that core safety margins are acceptable for each event. The fuel buckling margin is greater than two standard deviations ($>2\sigma$) for the Condition 3 fault, and the margin to the aluminum-water ignition threshold (AWIT) temperature is $>3\sigma$ for the Condition 4 fault.

2.3.3. Derived Controls

No new controls are required.

2.3.4. Equipment Classification

No new safety related SSC are required.

2.4. TRA-USQ-SE-2004-145, ATR Firewater Supply System Modeling Issues

2.4.1. Impact on Interim Safety Basis and Controls

McCracken (2004) documents an interim safety basis addressing concerns identified in USQ SE-2003-145. The interim basis implemented the requirement for a running firewater pump during reactor power operation, low power operation, and during pressurized standby following power operation until fuel element cooling time is met. Additional supporting controls were also defined in McCracken (2004) and that were applied when an operating firewater pump was required:

- In order for the 619-12 electric firewater pump to qualify as the operating firewater pump (preferred option), the following conditions must be met:
    a. The 619-12 firewater pump pressure switch must be isolated with pressure removed in order to send a continuous start signal.
    b. The 633-1 diesel firewater pump automatic start signal actuated when its starting battery charger loses AC power must be operable.
    c. The time delay on the 633-1 diesel firewater pump must be less than 120 seconds.
- Both the north and south flow paths to the TRA-670 firewater piping loop must be open.

Also, the following controls were to be invoked when EFIS was required to be operable as established by TSR-186 (McCracken 2004):

- Consistent with the firewater pump alignment and water supply selected to meet TSR-186 requirements, the instrumentation that controls the automatic start and stop features on the deep-well pumps must be calibrated and have nominal setpoints ≥ 22 ft for pump start and ≤ 26 ft for the pump shutoff for the deep well pump selected to start first, or the level indication instrumentation for the TRA-781 tank must be calibrated.

- The instrumentation that measures water level in the overhead tank (TRA-718) must be calibrated and have a nominal low level alarm setpoint of ≥ 24.5 ft.

- Each operable pump selected for TSR compliance must have a minimum supply volume of ≥ 500,000 gal available.

- The ground level storage tank TRA-719C must be valved out of service until a seismic analysis is completed. (This analysis was completed in Lacy (2004).)

The McCracken (2004) controls are impacted by the interim safety basis developed herein. Hence, these controls are revised as follows.

2.4.2. Evaluation of EFIS Supply System Modeling and Required Performance

2.4.2.1 Running Firewater Pump during Reactor Operation

A running firewater pump during reactor operation addressed the concerns that firewater system pressure start setpoints for pump start might not be timely and reliable and that the delay for a pump(s) to start was not bounded by safety basis analysis models. The concern with pump reliability and start delay included conditions where the overhead tank (TRA-718) could provide initial EFIS flow, but once depleted a firewater pump would be required for continued flow.

Revised LOCA analyses and evaluation of existing analyses are discussed in Section 2.2.2.3. These analyses and evaluations rely on gravity-feed from the ground-level storage tanks, flow from the overhead storage tank (TRA-718), and allow for greater than 2 minutes for firewater pumps to start and provide flow. The revised analyses support deleting the TSR requirement for a continuously running firewater pump.

2.4.2.2 North and South Firewater Flow Paths Open

This control is unchanged at this time. However, analysis in Rowsell (2005c) has shown that the required minimum EFIS flow rate can be provided through a single open flow path. This control may be further investigated and relaxed at a future date. Note, the Critical Firewater Path, required by the TSR, includes the firewater loop piping north of loop isolation valves L-2 and L-7 that is aligned from the TRA-781 and TRA-719 tanks and the operable deep-well pumps to the reactor. The firewater flow path south of isolation valves L-2 and L-7 will normally be open, but may be required to be isolated following a seismic event.

2.4.2.3 Ground-Level Storage Tank Inventory Requirements

The ground-level storage tank inventory requirements are revised based on Sharp (2005a), as previously discussed in Section 2.2. A minimum inventory of 900,000 gal in TRA-781 and a combined minimum inventory of 725,000 gal in the TRA-719A, B, & C tanks is required.

2.4.2.4 Overhead Tank (TRA-718) Inventory Requirements

McCracken 2004 establish a requirement for the overhead tank (TRA-718) level instrumentation to be calibrated and to alarm if the water level drop below 24.5 ft. This requirement is also required by this EDF. The overhead tank (TRA-718) is assumed to provide initial EFIS injection for the postulated Condition 3 and Condition 4 non-seismic LOCA scenarios discussed in SAR Sections 15.6.5 (3-inch breaks with concurrent failures). A TSR control is established that ≥ 58,000 gal be maintained in the overhead tank (TRA-718).

2.4.2.5 Operable Pump TSR Compliance and Corresponding Inventory Supply

This requirement is fundamentally unchanged, although the revised inventory basis requires both the TRA-781 and TRA-719 tanks be in-service with irradiated fuel in the core. Hence, pump and supply volume alignment is ensured.

2.4.3. Derived Controls

The revised firewater supply system controls, which supersede those identified in Section 2.2.3 of EDF-4334 Revision 1 (McCracken 2004) are summarized below. These controls (SAR Commitments) are applicable when EFIS is required to be operable as established by TSR-186.

- Both the north and south flow paths to the TRA-670 firewater piping loop (cross-connect lines) must be open. (The Critical Firewater Path open is required by TSR-186, 3.2.1.2)
- The instrumentation that controls the automatic start and stop features on the deep-well pumps must be calibrated and have nominal setpoints ≥ 22 ft for pump start and ≤ 26 ft for the pump shutoff for deep-well pump selected to start first. (A minimum inventory in TRA-719A, B, & C tanks of ≥ 725,000 gal is required by TSR-186, 3.2.1.2.)
- The level indications instrumentation for the TRA-781 tank must be calibrated and level surveillances must ensure a minimum volume of ≥ 900,000 gal. (A minimum combined inventory in TRA-781 of ≥ 900,000 gal is required by TSR-186, 3.2.1.2.)
- The instrumentation that measures water level in the overhead tank (TRA-718) must be calibrated. (A minimum inventory in the overhead tank [TRA-718] of ≥ 58,000 gal is required by TSR-186, 3.2.1.2.)
- The TRA 619-10 and 619-12 firewater pumps must be placed in manual start mode.

2.4.4. Equipment Qualification

No additional equipment qualifications are required.

3.0 Conclusions

Concerns identified in TRA-USQ-2004-214 Revision 1 (ATR Seismic Safety Basis Deterioration), TRA-USQ-2004-396 (ATR Seismic Primary Coolant System Break Size and TRA Support Building Vulnerabilities), and TRA-USQ-2004-413 (ATR Seismic Primary Coolant System Break Size Contribution from Letdown Valves) have been evaluated to support an interim safety basis for ATR power operation. In addition, the impact of the interim safety basis on previous evaluations for USQ evaluation SE-2004-145 (ATR Firewater Supply System Modeling Issues) has been addressed.

This EDF is an ESS for the above USQs and revises prior operational restrictions. This EDF is to be included as a temporary addendum to the SAR, supporting reactor operation and TSR revisions, until such time that the above issues are fully resolved and appropriately incorporated into the SAR. Revisions to the ATR Technical Safety Requirements (Sections 3.2.1.2, 3.3.6, and 3.5.5) and additional controls required for ATR operation (e.g., SAR commitments) are summarized below.

The existing EDF-4334 Revision 1 (McCracken 2004) remains applicable as an addendum to the ATR SAR. However, controls defined in Section 2.2.3 of EDF-4334 Revision 1 have been revised and are included in the TSR requirements and SAR Commitments developed herein.

TSR action statement completion times were developed with consideration of seismic and non-seismic fuel damage frequency and expected equipment reliabilities. With the limited flexibility in equipment operability requirements, and considering the condition of current plant equipment, there may be an increase in the frequency for entering into action statements. Therefore, a program to track safety related equipment failure experience, particularly TSR equipment, and to track the duration of time spent in action statements will be developed and implemented.

3.1. Summary of TSR Controls and SAR Commitments

TSR-186, Section 3.2.1.2:

- The 688-M-1, 688-M-2, and 633-1 firewater pumps with automatic start setpoint ≥ 55 psig, based on an accuracy of ± 5 psi, and start time of ≤ 2 min must be operable during power operation, low power operation, and pressurized standby following power operation until the fuel cooling time is met. These firewater pumps must be seismically qualified and not rely on commercial power.

- Minimum water inventories of ≥ 900,000 gal in the TRA-781 tank and ≥ 725,000 gal in the TRA-719 tanks must be maintained during power operation, low power operation, and pressurized standby following power operation until the fuel cooling time is met.

- Two firewater pumps (both 688 pumps or one 688 pump and 633-1) must be operable when irradiated fuel is in the reactor vessel. (For this condition, the ground-level storage tank inventory requirements must be met for the tanks supplying the operable firewater pumps.)

- Minimum water inventories of ≥ 900,000 gal in the TRA-781 tank and ≥ 725,000 gal in the TRA-719 tanks must be maintained with irradiated fuel in the reactor vessel. (For this condition, the ground-level storage tank inventory requirements must be met for the tanks supplying the operable firewater pumps.)

- The overhead raw water storage tank (TRA-718) must have an inventory of ≥ 58,000 gal during power operation, low power operation, and pressurized standby following power operation until the fuel cooling time is met.

- One seismically-qualified deep-well pump with diesel emergency-power source must be operable with irradiated fuel in the reactor vessel.

- Two deep-wells must be operable with irradiated fuel in the reactor vessel. The operable emergency-powered deep-well required above qualifies as one of the two required operable deep-wells.

TSR-186, Section 3.3.6:

- Reactor primary coolant system total leakage at system pressure (identified and unidentified) may not exceed 50 gpm.

TSR-186, Section 3.5.5:

- A required water inventory of ≥ 900,000 gal in the TRA-781 tank or ≥ 725,000 gal in the TRA-719 tanks must be maintained with irradiated fuel in the ATR canal. (For this condition, the ground-level storage tank inventory requirements must be met for the tanks supplying the operable firewater pumps.)

- A single firewater pump (688-M-1, 688-M-2 or 633-1) must be operable in manual or automatic start mode with irradiated fuel in the ATR canal.

TSR-186, Section 5.3.2:

- The ATR required shift compliment must support the ability of the operations staff to complete operator actions to isolate the ATR firewater loop and establish long-term firewater supply as discussed in the SAR Commitment below.

SAR Commitments:

- Both the north and south flow paths to the TRA-670 firewater piping loop (cross-connect lines) must be open when EFIS is required to be operable as established by TSR-186.

- The instrumentation that controls the automatic start and stop features on the deep-well pumps must be calibrated and have nominal setpoints ≥ 22 ft for pump start and ≤ 26 ft for the pump shutoff for the deep-well pump selected to start first.

- The level instrumentation for the TRA-781 tank must be calibrated and level surveillances must ensure a minimum volume of ≥ 900,000 gal.

- The instrumentation that measures water level in the overhead tank (TRA-718) must be calibrated and have a nominal low level alarm setpoint of ≥ 24.5 ft.

- The 619-10 and 619-12 firewater pumps must have the auto start function disabled (e.g., pump in manual start mode) whenever the TRA-719 tank inventory requirements are applicable.

- The ability for operators to isolate the ATR firewater loop from the RTC firewater loop, within 50 minutes of the seismic scram followed by aligning and starting a deep-well pump in order to establish long-term firewater supply within an additional 75 minutes must be supported by facility procedures and initiated from the EPNs. A seismically robust flow path providing EFIS to the reactor vessel is also required.

- TRA-671 firewater piping must be isolated or seismic issues remedied in order to prevent unacceptable firewater supply losses prior to loading the core with irradiated fuel.

- The interim controls developed for TRA-USQ-2004-385 must be reevaluated prior to loading the core with irradiated fuel.

- A program to track safety related equipment failure experience, particularly TSR equipment, and to track the duration of time spent in action statements will be developed and implemented..

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CHAPTER 17

QUALITY ASSURANCE

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ACRONYMS/ABBREVIATIONS

ASME	American Society of Mechanical Engineers
ATR	Advanced Test Reactor
CFR	Code of Federal Regulations
DAR	Document Action Request
DOE	U.S. Department of Energy
ES&H	Environmental, Safety, and Health
M&TE	Measuring and Test Equipment
NBS	National Bureau of Standards
NCR	Nonconformance Report
NDE	Nondestructive Examination
NIST	National Institute of Standards and Technology
QA	Quality Assurance
QA&O	Quality Assurance and Oversight
QAPD	Quality Assurance Program Description
QCE	Quality Control Engineering
RP	Reactor Programs
SSC	structures, systems, and components
TRA	Test Reactor Area

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17. QUALITY ASSURANCE

17.1 Policy Statement

Reactor Programs (RP) management has the responsibility to meet the requirements of the Contractor's *Quality and Requirements Management* Quality Assurance Program Description (QAPD). The Contractor's QAPD defines the Contractor's Quality Assurance Program and is based on the requirements of the American Society of Mechanical Engineers (ASME) NQA-1. The QAPD also implements requirements from 10 CFR 830, Subpart A, and Department of Energy (DOE) Order O 414.1A (DOE 2001). The QAPD is annually reviewed and updated. The quality requirements and responsibilities for design, procurement, fabrication, installation, testing, and operation (including planning and scheduling) of structures, systems, and components are well-defined and are implemented by Contractor's Quality Assurance and Oversight Organization (QA&O) as part of the overall Contractor's Quality Assurance Program. RP management is responsible for achieving quality, and all individuals are responsible for the quality of their work.

17.2 Quality Assurance Program

The Advanced Test Reactor (ATR) Quality Assurance Program is defined by the QAPD. The QAPD establishes the requirements to control all phases of quality activity associated with the ATR. The QAPD is implemented by various Contractor procedures and RP-controlled documents. The QAPD is a risk-based, graded-approach program. The rigor of quality requirements is commensurate with the risk associated with failure of the system, structure, or component.

17.2.1 Organization

The QAPD describes and refers to the Quality Assurance (QA) organizational structure, functional responsibilities, levels of authority, and interfaces. The descriptions include the onsite organizational elements that function within the scope of the Contractor's Quality Assurance Program.

17.2.2 Quality Assurance Outline

Specifically, the Contractor's Quality Assurance Program outlines the following quality aspects:

- Defines the applicable quality requirements for the Program
- Identifies the types of personnel and management levels with quality performance responsibilities and their organizational relationships
- Identifies the procedures to be followed in performing quality-related tasks.

The QAPD controls:

- Structures, systems, and components
  - Design
  - Procurement
  - Fabrication and construction
  - Inspection
  - Surveillance and testing
  - Handling, storage, and shipping
- Controlled documents
  - Preparation
  - Review and approval
  - Issuance and change
  - Record storage and retention requirements
- Measuring and test equipment
- Nonconforming materials

- Personnel training
- Work processes.

The QAPD specifies:

- Corrective actions for conditions adverse to quality
- QA personnel qualifications
- Quality improvement program
- Independent quality audits.

Work assigned to parties outside the RP organization is identified. For assigned work, management controls are established, responsibilities are assigned, and lines of communication are identified. Initial planning estimates are based on sound data and assumptions about RP personnel, material and service costs, availabilities, and productivity.

Reviews are performed in accordance with the QAPD before any major scheduled or planned work to verify, at a minimum, the following:

- Work prerequisites have been satisfied.
- Detailed technical and QA procedures have been reviewed for adequacy and appropriateness.
- Personnel have been suitably trained and qualified.
- Proper equipment, material, and resources are available.

Responsibility and authority to stop unsatisfactory work are assigned so that planning and schedule considerations do not override safety considerations. After any stop-work action, work is restarted in accordance with the Contractor's *Safety and Health* stop work procedure.

17.3 Design Control

The RP Management ensures that the design of structures, systems, or components is defined, controlled, and verified consistent with requirements in the QAPD.

17.3.1 Design Requirements

Design inputs, processes, analyses, verification requirements, and output documents are identified in a RP-controlled document and in Contractor procedures. Each design planning tabulation includes assigning a quality level to the system, structure, or component impacted by the design. Problem prevention and quality improvement processes are integrated into the design process, which includes peer reviews, design reviews, value engineering, and reliability/availability/maintainability reviews. RP personnel review the design to ensure acceptance of the design process and that the appropriate level of design detail is being applied according to the requirements set forth in the QAPD. Essential design records are assembled and placed in a project file or engineering design file, and are controlled according to the QAPD.

17.3.2 Design Verification

The adequacy of a design is verified through design reviews, alternate calculations, or qualification testing. The QAPD and Contractor procedures contain considerations to be addressed with these methods.

17.3.3 Design Changes

Changes to approved designs are reviewed and approved at the same level as the original design. Documents used to implement design changes (such as design drawings, specifications, facility change forms, code requirements, and work releases) are controlled commensurate with that of the original design.

17.3.4 Fabrication

Fabrication of structures, systems, and components (SSC) are controlled by (a) controlling the instruction, procedures, and drawings that describe or define SSC or work to be performed, (b) controlling special processes, (c) controlling procurement, or (d) requiring inspection. These quality activities are defined in the QAPD and are discussed in this chapter.

17.4 Procurement Control

Procurement of materials and services is controlled by controlling the purchase requisition documentation, supplier selection, and acceptance of material or service. General plant project and capital equipment items are procured by Contractor's Procurement organization and are controlled under a separate system.

17.4.1 Purchase Requisition Documentation

The preparation, review, approval, and control of procurement documents are done by following the QAPD and applicable Contractor procedures. Procurement documents include or reference applicable design bases and other requirements necessary to ensure the adequate quality of the item or services. Changes to procurement documents are subject to controls commensurate with those applied to the processing of the original documents. Requisitions for materials and services are consistent with the QAPD and applicable Contractor procedures. The end use application will determine the appropriate Quality Level assignment for the procurement activity and as applicable, may include the following:

- The performance, interface, acceptance, and other requirements as appropriate
- Approved, released drawings or specifications that are required to describe technical requirements for items to be used in configuration controlled systems
- A detailed statement of work for requisitions where services are to be performed
- Identification of any documentation that must be submitted by the supplier
- Requirement that suppliers and their own suppliers have a QA program consistent with the technical requirements of the item or service being procured
- Identification of data from the supplier concerning quality and technical information for ordering spare and replacement parts as appropriate.

17.4.2 Purchase Requisition Review

Review and approval of requisitions for materials and services are conducted according to Contractor procedures.

17.4.3 Procurement Document Changes

Revisions to procurement documents, excluding editorial clarifications, receive the same level of review and approval as the original document.

Procurement coordinates any contract changes at the direction of the requester. Supplier data accompanying requisitions are maintained with Procurement; however, copies of supplier data can be obtained on request.

17.4.4 Supplier Selection

Suppliers who furnish items and services are evaluated and selected using a graded approach in accordance with the QAPD.

17.4.5 Acceptance of Items or Services

An inspection instruction sufficiently detailed to ensure that source or receiving inspection accurately verifies product conformance to specified requirements is prepared in accordance with the QAPD.

Reporting and controlling items that do not satisfy specified acceptance criteria is performed as required by the QAPD. Control of nonconforming materials, components, and fabrication and construction features is discussed in Section 17.11.

17.5 Instructions, Procedures, and Drawings

RP personnel perform work processes under controlled conditions using work controlling documents such as approved instructions, procedures, or drawings consistent with requirements of the QAPD. The instructions, procedures, and drawings contain or reference appropriate acceptance criteria necessary to perform the work. Instructions, procedures, and drawings are developed, issued or released, reviewed, approved, and controlled under Contractor and RP-controlled procedures.

Work instructions are used to provide sufficient technical information to ensure successful completion of quality-related activities. As required, work instructions are reviewed by certified quality engineers to ensure inclusion of appropriate acceptance criteria. Work directions provide a level of detail commensurate with the risk, complexity, and importance of the work.

In accordance with the QAPD revisions to documents receive the same or commensurate level of review and approval as the document's original review, unless changes do not affect the expertise by the organization(s). A Document Action Request (DAR) system is used to document and authorize changes to RP-controlled documents with the exception of work instructions. Changes to work instructions are completed in accordance with Contractor procedures.

Minor changes (such as punctuation, spelling, grammar, and other editorial corrections that do not alter the technical content) are not required to return through the review and approval cycle.

17.6 Document Control

17.6.1 General Requirements

The preparation, review, approval, issuance, and changes to documents that specify quality requirements or prescribe activities affecting quality are controlled in a manner consistent with the QAPD, Contractor Procedures, and RP-controlled procedures. RP personnel are responsible for ensuring that RP-controlled documents are properly reviewed, maintained, distributed, stored, and archived or discarded.

The document preparer, reviewers, and approvers are responsible for ensuring that the document is adequate and complete. Document review and approval requirements are in accordance with the QAPD, Contractor Procedures, and RP-controlled procedures. Preparation, review, approval, issuance, and any changes in instructions, procedures, and drawings are performed in accordance with the QAPD, Contractor procedures, and RP-controlled procedures.

17.6.2 Change

The DAR System is used to document and authorize changes to all RP-controlled documents with the exception of work instructions. Changes to work instructions are completed in accordance with RP procedures. The requirements and responsibilities of the DAR System are specified in the Contractor procedures and RP-controlled documents. Revisions to controlled documents require the same level of review and approval as the original documents unless the changes are not applicable to the reviewing organization. Documents not under RP control, such as engineering drawings, are controlled by Contractor procedures.

Minor changes (such as spelling, grammar, punctuation, and other editorial corrections that do not alter the technical content) are not required to return through the review and approval cycle.

17.6.3 Interval Reviews

All controlled documents are reviewed periodically by authorized personnel and are updated to ensure that documents remain current. The authorities and time intervals for review and approval are specified in Contractor and RP-controlled documents.

17.7 Control of Processes

17.7.1 General Requirements

Processes are controlled according to the Contractor's QAPD. RP provides control for any facility process that controls or verifies quality. These processes include, but are not limited to, welding, brazing, heat treating, and nondestructive evaluation.

ATR operations and maintenance activities routinely involve the control of processes where quality cannot be verified by final inspection alone. These processes follow written procedures and depend instead on the operator's skill, equipment capability, and defined process parameters to ensure quality. They generally fall into the categories of special inspection processes and special manufacturing processes.

17.7.2 Special Processes

Special processes are performed by qualified personnel using proper equipment and following approved written procedures. All nondestructive evaluation procedures are reviewed and approved by a Contractor's Certified Level III Inspector in his or her respective discipline according to applicable code requirements. The qualifications of personnel and approved procedures are available.

Qualification of special processes, equipment, and personnel is the responsibility of the RP manager for activities under his or her purview. Procedures delineate the requirements of special processes. These procedures ensure that evidence is recorded to verify acceptable accomplishment of special processes using qualified procedures, personnel, and properly controlled equipment.

17.8 Inspection, Surveillance, and Test Controls

17.8.1 Inspection

Inspections for acceptance of items and activities are performed in accordance with the QAPD by qualified personnel independent from those performing the activity being inspected. Inspection activities are performed to ensure work activities and conditions comply with specified requirements. For required inspections, inspection plans are prepared and followed; they also specify characteristics to be inspected, personnel authorized to perform inspections, inspection sequence if important, methods to be employed, acceptance criteria, and documentation of inspection results. When sampling methods are used, they are based on recognized sampling practices.

Personnel, who are qualified and/or certified, perform or verify acceptance of inspection and tests to satisfy code, standard, or other technical requirements. These personnel are independent of the activity that they are inspecting.

Personnel need not be certified to perform information or self-check type inspections unless the inspections involve hardware or software acceptance.

Inspection planning instructions, procedures for in-process and final inspection, or other documents describe inspections planned for work activities. These documents contain criteria for when inspections are to be performed and requirements for documenting inspections. Hold points are placed on associated work documents, when required, to ensure work does not proceed beyond the hold point without the inspector's approval. Unsatisfactory conditions encountered during inspection are either resolved before proceeding or documented to permit evaluation and resolution.

Quality inspection records comply with the QAPD.

Procedures and work instructions are reviewed by qualified personnel before work is performed to ensure that inspection criteria are established. This review ensures that inspection requirements, methods, and acceptance criteria have been clearly identified.

17.8.2 Surveillance

Periodic surveillances by knowledgeable and experienced personnel ensure that required standards of performance, procedural compliance, and equipment safety are maintained. The requirements for conducting and documenting surveillance activities, including the documentation for resolution of any nonconforming conditions, are found in the QAPD.

17.8.3 Test Control

Testing of TRA facility items, structures, systems, and components is conducted consistent with the requirements given in the QAPD. ATR Facility personnel conduct the testing as necessary to ensure that structures, systems, and components will perform satisfactorily in service. The testing requirements are specified in RP-controlled procedures.

Test procedures include:

- Instructions for performing the test

- Test prerequisites such as calibrated instruments, adequate equipment, trained or certified personnel, preparation conditions, and completeness of item to be tested
- Required controlled environment
- Provisions for data collections
- Required hold points
- Acceptance criteria.

The status of test-related activities is documented using approved written procedures including test objectives and prerequisites, identification of test items, pretest conditions, calibration status of measurement equipment, test setup, environment, test methods, test calculations, test data, and acceptance criteria.

Test records identify the following, as a minimum:

- Item tested
- Date of test
- Inspector, tester, or data recorder
- Type of observation
- Measuring and test equipment used
- Results and acceptability
- Traceability to nonconformance reports generated, if any
- Final test approval and person evaluating test results.

Review of test procedures is conducted to ensure that quality issues are addressed adequately and that acceptance criteria are specified in the test requirements documents. Reworked or repaired items require retesting in accordance with Company level documents.

17.9 Control of Measuring and Test Equipment

17.9.1 General Requirements

The control of measuring and test equipment associated with the ATR Facility is conducted in accordance with the requirements of the QAPD.

17.9.2 Calibration Control

All calibration control activities meet the requirements of the established Calibration Program. Calibration intervals are established and maintained to ensure acceptable accuracy and reliability of the measurement devices. The RP has defined the reliability target for measurement devices and established a system for adjusting the calibration interval when the reliability target is not met. Calibration requirements for instruments are to be traceable to the National Institute of Standards and Technology (NIST), formally National Bureau of Standards (NBS). If this relationship does not exist, the basis of calibration is documented and approved by responsible managers. The calibration requirements are based on the use, accuracy requirement, stability, and amount of usage of the measuring and test equipment (M&TE).

RP assigns personnel to be responsible for ensuring that M&TE is uniquely identified and available for calibration. The user managers ensure that selected equipment is calibrated at sufficient range, accuracy, stability, and resolution to satisfy specific requirements. The ATR Operations Manager ensures that the equipment is used under environmentally safe conditions and the inspection or test results obtained with equipment that is later found to be out-of-tolerance are evaluated and documented to determine the validity of measurements and tests involving this equipment since the last calibration.

RP-controlled documents define the requirements and responsibilities for calibration of M&TE at TRA. RP supervision ensures that all M&TE used for gathering of test data, and for activities affecting quality, are controlled and calibrated at specified intervals and adjusted to maintain required accuracy. RP-controlled documents give guidance for handling, transporting, storing, and using M&TE.

17.9.3 Measuring and Test Equipment Records

Records include an individual record of calibration for each item of M&TE and provide a description of the item, calibration interval, date calibrated, identification of the calibration source, calibration procedure used, calibration results, and actions taken.

17.10 Handling, Storage, and Shipping Control

17.10.1 General Requirements

ATR Facility personnel control the handling, storage, cleaning, preservation, and shipping of materials consistent the Contractor's QAPD.

17.10.2 Requirements and Instructions

RP-controlled documents provide additional requirements and instructions not included in the previously referenced QAPD section for handling, storage, and shipping of quality-related items, hazardous materials, radioactive materials, etc. The RP documents also identify Contractor or higher level documents that require radioactive shipment control, which apply to the ATR Facility.

17.10.3 Records

The control system for quality records is in accordance with the Contractor's QAPD.

17.11 Control of Nonconforming Materials, Components, and Fabrication/Construction Features

It is the responsibility of all RP personnel to ensure that ATR Facility items that are unacceptable or that cannot be verified to meet requirements are controlled to prevent their inadvertent use or installation consistent with requirements for control of nonconforming items.

17.11.1 Identification of Nonconformances

All RP personnel are responsible for ensuring that nonconforming items are identified and documented. If practical, identification and segregation of these items occur at the time the nonconformance is documented. If items are found to be unacceptable or unverifiable, a Nonconformance Report (NCR) is issued as required by the QAPD. The cognizant quality engineer or inspector is responsible for maintaining the NCR file.

17.11.2 Disposition and Closure of Nonconformances

The responsibility for dispositioning of the NCR is assigned by TRA QA&O to an individual or group. The responsible individual or group then determines the best solution for the nonconforming condition. This disposition is reviewed and approved.

Requirements for the disposition, documentation, and subsequent reinspection of reworked or repaired items are set forth in Contractor procedures.

Items that require rework, repair, or replacement are inspected and tested to the same standards as the original item unless alternative methods are approved by the same level of review as the original acceptance criteria.

17.11.3 Stop Work Order

Work may be stopped because of either an unsafe condition, the performance of unsatisfactory work, or a breakdown in the quality system. The line organization has the responsibility for issuing formal stop work and for assuring reviews by other required organizations such as quality, safety, and environmental of restart actions prior to the release from a stop work condition.

Every knowledgeable employee has the ability and authority to issue a stop work order for safety purposes.

17.12 Corrective Actions for Identified Conditions Adverse to Quality

ATR Facility personnel correct any ATR conditions adverse to quality as soon as practical. Documentation of corrective actions for hardware is contained within the procedures for control of nonconforming items, as described previously.

ATR Facility personnel are responsible for promptly reporting to management any identified conditions that are adverse to quality. Conditions adverse to quality are identified by methods which include inspections, surveillances, audits/assessments, and routine and special operations. Once identified, these conditions are documented in inspections reports, NCRs, self-assessment and appraisal forms, and surveillance and audit reports. The ATR Operations Manager is responsible for ensuring that corrective action or follow-up is initiated for items identified or reported to be adverse to quality, including assessment of root cause and documentation of corrective action taken to prevent recurrence. The ATR Operations Manager ensures that the condition is identified and reported to appropriate management.

17.13 Control of Personnel Training and Qualifications

17.13.1 ATR Facility Personnel

Achieving a quality product or service within the ATR Facility is the responsibility of the ATR Operations Manager and employees consistent with their level of responsibility. Employees receive indoctrination and training appropriate with their assigned activities and level of responsibility. The requirements for indoctrination and training of ATR Facility personnel are set forth in the QAPD.

ATR Facility management is responsible for providing training to operations personnel on new or significantly revised quality procedures to ensure acceptable proficiency, knowledge, and understanding of QA principles.

17.13.2 Quality Assurance Personnel

Professional qualifications for QA&O personnel are defined by the QAPD.

17.14 Quality Improvement

Items and processes that do not meet established quality requirements are identified, controlled, and corrected. Processes are established and implemented to promote continuous improvement in accordance with the QAPD.

17.14.1 Problem Detection

Conditions adverse to quality are identified by personnel awareness and judgement, inspections, reviews, testing, surveillances, self-assessments, and internal and external audits. Contractor and RP-controlled procedures are in place in accordance with the QAPD.

17.14.2 Problem Prevention

Quality improvement reduces the variability of processes that influence the product's quality. Performance data, internal and external failure costs, prevention costs, and other quality-related information are analyzed to identify trends that adversely impact quality, and to identify opportunities to improve items and processes.

The ATR Facility quality improvement process is implemented in the QAPD in four steps: (a) Plan, (b) Do, (c) Check, and (d) Act.

17.14.2.1 Plan. Planning occurs at all levels within the organization, supporting and promoting accomplishment of the strategic plan and mission. Each work process is planned to ensure that it adds value to the operation, contributes to strategic goals, and produces outcomes that meet customer requirements and expectations.

17.14.2.2 Do. Plans are implemented by employees equipped with proper knowledge, tools, and equipment. During implementation, adjustments are made to improve the process. Data is collected to monitor the activity.

17.14.2.3 Check. Processes are monitored by identifying performance indicators and developing measurements for each indicator to gauge progress, plot trends, and reflect success. Inspections and assessments are tools for measuring effectiveness in meeting customer requirements and expectations and identifying opportunities for process improvement. Nonconforming items are identified, reported, and dispositioned to ensure that they do not result in failures in the process. Assessment deficiencies are identified and prioritized, and corrective actions are monitored using the issue management process. Issues are resolved using the issue management process, which focuses on identifying root cause(s) and implementing corrective action(s) that not only prevent recurrence but also improve the process. Performance measures are monitored to determine process effectiveness, and the results feed the planning and acting phases.

17.14.2.4 Act. The process is improved, based on data from performance measures and assessment results. Assessments may occur throughout the work process and focus on pertinent work process activities. Areas of performance that most directly affect the process's ability to meet customer requirements receive the most attention. Corrective actions identified in the Check phase are aimed at refining systems rather than addressing a current event. Employees are recognized and rewarded for their contribution toward process success and improvement.

17.14.3 Process Improvement

ATR personnel are encouraged by management to identify problems and suggest improvements. Procedures currently in place allow individuals to provide recommendations for improvement and to identify problems with existing processes. Process improvement is defined in Contractor and RP controlled documents.

17.14.4 Trend Analysis

The ATR Operations Manager is responsible for a timely analysis of item reliability and quality information such as audit/assessments reports, inspection reports, surveillance reports, and corrective action reports. Cost-related information (such as internal and external failure costs, prevention costs, and the price of nonconformance) is also analyzed by the manager to identify trends that adversely impact quality and to identify opportunities to improve items and processes.

17.15 Quality Assurance Documents and Records

ATR Facility personnel maintain quality records consistent with requirements of the QAPD to ensure the maintenance and retrievability of objective evidence of quality for the ATR Facility. A document is considered a quality record when it is completed. Documents do not require the control elements of quality records. Quality records are legible, accurate, traceable, complete, and validated by authorized personnel.

Corrections to quality records are made by authorized personnel according to controlled procedures. If a quality record has been lost or damaged, the ATR Operation Manager uses the appropriate and necessary resources commensurate with the importance of the record to reconstruct information contained in the record.

For quality record protection, the access to quality record storage areas is limited and controlled. The RP managers identify personnel authorized to have access to quality record storage areas. The RP records coordinator maintains a list of personnel, designated by line managers, who have unescorted access to quality records. Records are not removed from the storage areas except by the RP records coordinator or an alternate.

Records are filed and stored in a temporary storage facility in a manner that will ensure their protection from damage or loss during the normal course of business. This temporary storage facility is adequate storage for meeting the requirements of NQA-1. Issue record sheets in front of documents or other appropriate methods are used as a ready indicator of whether the document has been maintained properly.

If designated by management, quality records are submitted to the Contractor's Records Management for permanent storage at the end of their retention in temporary storage.

17.16 Independent Quality Audits

17.16.1 Independent Management Assessment

ATR Facility management, implementing the whole or parts of the Contractor's Quality Assurance Program, regularly assesses the adequacy of the facility management part of the program to ensure its effective implementation.

17.16.2 Audits

In accordance with the QAPD the ATR Facility is periodically evaluated or assessed. The QA&O is used to satisfy these requirements.

17.16.3 Surveillances

Periodic surveillances by qualified personnel ensure that required standards of performance, procedural compliance, and equipment safety are maintained. RP-controlled procedures provide instructions for conducting self-assessment surveillances.

The ATR Operations Manager is responsible for

- Developing, tracking, and updating the surveillance plan.
- Providing training to personnel as necessary to conduct effective surveillances.
- Ensuring that (a) root causes are identified for all significant conditions adverse to quality, (b) lessons learned are disseminated, and (c) priorities are established.
- Ensuring appropriate managers are apprised of major findings, strengths, weaknesses, proposed corrective actions, and their completion.

17.17 References

ASME, 1997, *Quality Assurance Program Requirements for Nuclear Facilities*, NQA-1, American Society of Mechanical Engineers, December 31, 1997.

CFR, 2002, *Quality Assurance Requirements*, 10 CFR 830, Subpart A, *Code of Federal Regulations*, Office of the Federal Register, February 4, 2002.

Companywide Manual, *Quality and Requirements Management*.

DOE, 2001, *Quality Assurance*, Order 414.1A, U.S. Department of Energy, Washington, D.C., Change 1, July 12, 2001.

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CHAPTER 18

HUMAN FACTORS ENGINEERING

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ACRONYMS/ABBREVIATIONS

ANSI	American National Standards Institute
ATR	Advanced Test Reactor
CFR	Code of Federal Regulations
DCS	distributed control system
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EDF	engineering design file
EFIS	emergency firewater injection system
ESF	engineered safety features
HFE	human factors engineering
IEEE	Institute of Electrical and Electronics Engineers
LOCA	loss of coolant accident
MIL-STD	Military Standard
NRC	U.S. Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Commission Report
ORPS	Occurrence Reporting and Processing System
OSHA	Occupational Safety and Health Administration
PRA	probabilistic risk assessment
RDAS	reactor data acquisition system
TRA	Test Reactor Area
UCI	user-computer interface
UCRL	University of California Research Laboratory
UFSAR	Upgraded Final Safety Analysis Report
VVS	Vessel Vent System

18. HUMAN FACTORS ENGINEERING

This chapter describes a systematic inquiry into the importance to safety of reliable, correct, and effective human-machine interactions for the operation of the Advanced Test Reactor (ATR) (DOE 1994).

18.1 Human Factors at the ATR and Identification of Safety Significant Human Actions

18.1.1 Human Factors at the ATR

Between 1980 and 1985, the first formal Human Factors Engineering (HFE) review of the ATR reactor control room was conducted (Boone and Banks 1980). Initial function and task analyses were conducted on the reactor, process, and experimental loop control functions, and the analyses were used to allocate staffing and operating responsibilities. In addition, upgrades to the ATR Process Distributed Control System (DCS) and the Reactor Data Acquisition System (RDAS) were pursued, in part, to respond to operator information needs during all phases of reactor facility operation.

Between 1985 and 1989, a number of HFE design reviews and evaluations were conducted, again focusing collectively on the reactor, process, and experimental loop control functions (Ward and Warburton 1985; Chapman 1993; Byers 1990; Haney 1989).

Since 1990, a series of interrelated HFE studies have been conducted as part of the design of upgrades to the experimental loop, reactor, and process control functions, and for locating process control and reactor control in a single room (Byers 1991; Richards 1990a, b, and 1992).

In lieu of published DOE standards and guidelines, post-1990 ATR HFE design, review, and evaluation initiatives rely primarily on standards and guidelines developed for commercial nuclear power and for the military. Among these are 29 CFR 1910.132, 1910.133, and 1910.134, DOE Handbook Design Consideration, DOE-HDBK-1132-99, MIL-STD-1472D, ANSI Standard Z88.2-1992, and U.S. Nuclear Regulatory Commission (NRC) reports NUREG-0700 and NUREG/CR-4227 (DOE 1999; DOD 1989; ANSI 1992; NRC 1981, 1985).

In summary, HFE has been an explicit design and operational consideration at ATR dating back at least to the early 1980s. Current instrumentation, work station layouts, and communications used by ATR personnel during normal operations, consider human-machine requirements established by the above HFE standards and guidance documents, as appropriate for a test reactor facility. Likewise, HFE criteria established by these standards and guidelines are considered for the design of the general working environment involving such factors as heat, light, noise, and protective clothing as they may impact performance, especially under abnormal operating conditions.

18.1.2 Identification of Safety-Significant Human Actions

In order to assess the adequacy of HFE for supporting ATR responses to potential accident situations, the events in Chapter 15 (Accident Analysis) and the ATR probabilistic risk assessment (PRA) (Eide, Khericha, and Thatcher 1991) were used to identify safety-significant human actions. For most of the design basis accidents analyzed in Chapter 15, the Plant Protective System automatically provides the required protective action. However, there are events that require operator action. These events are bounded in Chapter 15 by four limiting accidents: the Complete Loss of Secondary, the Complete Loss of Flow, the Large Crack or other Failure of the Storage Canal, and the Shutdown Loss of Coolant Accident (LOCA) with Irradiated Fuel in the Core. A review was made of the sequences in the PRA Human Reliability Analysis and no additional events were identified from the dominant accident scenarios that require a human factors evaluation.

Table 18.1-1. DOE Requirements and Human Factors Engineering standards matrix.

HFE Area	DOE Orders	HFE Standards
Operational aids	Order 5480.23, Attachment 1: 14a	NUREG-0700: 6.3.1; DOE-STD-1062-93[a]
Control/display integration	Order 5480.23, Attachment 1: 14b	NUREG-0700: 6.5, 6.7.1; DOE-STD-1062-93; MIL-STD-1472D: 5.1, 5.2, 5.15.3
Controls - general	Order 5480.23, Attachment 1: 14b	NUREG-0700: 6.4; DOE-STD-1062-93
Hand-operated controls	Order 5480.23, Attachment 1: 14b	NUREG-0700: 6.4; DOE-STD-1062-93
Controls for user-computer interface (UCI)	Order 5480.23, Attachment 1: 14b	NUREG-0700: 6.4; DOE-STD-1062-93
Visual displays	Order 5480.23, Attachment 1: 14b	NUREG-0700: 6.5, 6.7; DOE-STD-1062-93MIL-STD-1472D: 5.1, 5.2
Scale indicators	Order 5480.23, Attachment 1: 14b	NUREG-0700: 6.5, 6.7; DOE-STD-1062-93MIL-STD-1472D: 5.1, 5.2
Displays	Order 5480.23, Attachment 1: 14b	NUREG-0700: 6.5, 6.7; DOE-STD-1062-93MIL-STD-1472D: 5.1, 5.2
Environment	Order 5840.23, Attachment 1: 14c	MIL-STD-1472D: 5.8.1, 5.8.2, 5.8.3; DOE-STD-1062-93
Hazards & safety	Order 5840.23, Attachment 1: 14c	MIL-STD-1472D: 5.8.1, 5.8.2, 5.8.3; DOE-STD-1062-93
Protective clothing	Order 5840.23, Attachment 1: 14c	OSHA 29 CFR 1910.132, 1910.133, 1910.134;DOE-STD-1062-93; ANSI-STD-Z88.2-1992: 6.15, 7.2
Communications	Order 5840.23, Attachment 1: 14c	NUREG-0700: 6.2.1; DOE-STD-1062-93
Labeling	Order 5480.23, Attachment 1: 14b	NUREG-0700: 6.6; DOE-STD-1062-93
User-computer interface	Order 5480.23, Attachment 1: 14b	DOE-STD-1062-93; *User-Computer Interface in Process Control: A Human Factors Handbook* (Gilmore, Gertman, & Blackman 1989)

a. Draft standard.

18.2 Task Analysis

Both the Complete Loss of Secondary and the Complete Loss of Flow Events are mitigated by actuation of the Vessel Vent System (VVS) and the Emergency Firewater Injection System (EFIS). Actuation of these two engineered safety features (ESFs) establishes feed and bleed cooling in the reactor vessel. The Distributed Control System (DCS) and upright panels in the control room are used to provide system status during normal and off normal operations. The VVS and the EFIS are actuated from the upright panels in the control room.

In the case of a canal drainage event resulting in leakage from the canal that is not maintained by normal makeup, the canal level annunciator in the control room will alarm. Makeup water is provided by automatic actuation of the canal firewater makeup system or by manually opening the Canal Emergency Makeup valve BL-8-442.

In the case of the Shutdown LOCA, the system status is provided by the DCS. Mitigating the shutdown LOCA requires manually opening EFIS isolation valves GT-1-84 or GT-1-614, or alternatively, GT-10-35, or GT-10-63.

Successful termination of the four accident sequences (Complete Loss of Secondary, Complete Loss of Flow, Large Crack or other Failure of the Storage Canals, and the Shutdown LOCA with Irradiated Fuel in the Core) requires that the plant status is correctly identified and that the necessary mitigating actions are successfully performed. The mitigating systems are the two engineered safety features (the VVS and the EFIS), and the safety-related portion of the Low Pressure Demineralized Water System that provides canal emergency makeup capability.

18.3 ATR Human Factors Engineering Analysis

18.3.1 Human Factors Engineering Analysis

As required by DOE Order 5480.23 (DOE 1994), an HFE analysis was done of the ATR human-machine interactions (primarily instrumentation and controls) within the context of the limiting accidents requiring operator action.

18.3.1.1 Human Factors Engineering Checklists. Checklists employed in the HFE analysis were developed using DOE and non-DOE HFE standards. These included MIL-STD 1472D (DOD 1989); NUREG-0700 (NRC 1981); DOE-HDBK-1132-99 (DOE 1999); OSHA 29 CFR 1910.132, 1910.133, 1910.134; ANSI Z88.1992 (ANSI 1992); and UCRL 15673 (UCRL 1985).

The resulting series of HFE checklists addresses the human-machine interface requirements established by DOE 5480.23, Attachment 1, Sections 14a through 14c (DOE 1994):

- 14a Instrumentation, communication, and operational aids
  - Instrumentation
  - Communications
  - Operational Aids.
- 14b Layout and design of controls and instrumentation and labeling
  - Control/Display Integration
  - Controls/General
  - Hand-Operated Controls
  - Visual Displays
  - Scale Indicators
  - Displays
  - Labeling
  - User-Computer Interface.[a]
- 14c Work environment factors such as heat, light, noise, physical access, protective clothing, and breathing apparatus.
  - General Environment
  - Protective Clothing and Breathing Apparatus.

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[a] The User-Computer Interface checklist contains numerous criteria designed to evaluate a software/hardware system and its interface with the human operator. Some of these criteria are not applicable to analyzing the safety of a facility or system. These criteria are strictly concerned with the user-friendliness of the system. Therefore, these criteria were not evaluated during the walkdown and are reflected in the Not Applicable observations.

ATR HFE checklists, used in the HFE analysis, are contained in Appendix B to the HFE analysis report (Overlin and Ryan 1997). Table 18.1-1 contains a complete listing of HFE sources used to develop the ATR HFE checklists.[a] The checklists were used in the HFE evaluation of the ATR human-machine interfaces for the four limiting accidents requiring operator action.

18.3.1.2 Human Actions and Equipment Interfaces. The systems evaluated were the distributed control system (DCS), the Canal low level alarm and the EFIS and VVS controls in the control room, the two EFIS isolation valves: GT-1-84 and GT-1-614, the two firewater isolation valves: GT-10-35 and GT-10-63, and the Canal Emergency Makeup Valve: BL-8-442. These are the systems identified in the limiting accident scenarios. The DCS is used to provide information on system status during normal and off-normal operations. The EFIS and VVS controls allow the operator to open the vent valves and control water flow through the firewater injection system from the control room. The EFIS and the firewater isolation valves and the canal makeup valve are manually operated. The EFIS isolation valves are in the first basement, but are operated from the main floor. The firewater isolation valves are outside of the ATR building; GT-10-35 is approximately 50 meters east of the ATR building and GT-10-63 is approximately 20 meters south of the main ATR building and 10 meters east of the truck door airlock. The canal makeup valve is on the south canal parapet in the fuel storage area.

[a] In many cases, the DOE orders used to complete the list of HFE standards are not specifically applicable to the ATR. The HFE checklists provides HFE guidance that can be generally applied to any facility.

18.4 Human Factors Engineering Analysis Results

This section summarizes HFE analysis results of the ATR review against the checklists developed from the DOE orders and standards listed in Table 18.1-1. Section 18.4.1 presents the HFE checklist review results. Section 18.4.2 presents an analysis of judged deviations from full HFE checklist compliance, and their resolutions. Responding to the requirements of DOE Order 5480.23, Attachment 1 Topic 14d, Section 18.5.1 discusses the effects of the limiting accidents on the operators' environment. Section 18.5.2 presents a trending and comparative analysis of human error rates as a percentage of ATR ORPS reports, and compares them with the mean percentages of a group of similar DOE facilities (DOE 1994).

18.4.1 Human Factors Engineering Review Results

A summary of judged deviations from full HFE compliance with the checklists is provided in Table 18.4-1. The detailed results can be found in the HFE analysis report (Overlin and Ryan 1997). Table 18.4-1 combines all the information tabulated for human-machine interactions involving the applicable systems and equipment into the 14 HFE review categories. The observations are separated into three categories: Not Applicable, Compliance, and Deviation from Full Checklist Compliance. The total number of observations performed, both with and without the Not Applicable observations, are included. The percent judged compliance and deviation from full HFE Checklist Compliance are calculated by dividing the number of compliances or deviations from Full Checklist Compliance by the total number of observations, not including the Not Applicable.

The instrumentation and controls, and other workstation and environmental factors, were found to be in compliance with relevant HFE standards in 96 % of applicable observations. Of the 3,375 observations, 1,549 were determined to be not applicable to some of the instrumentation and controls and other workstation and environmental factors; 1,826 observations were determined to be applicable. There were 79 judged deviations from full HFE Checklist Compliance. A detailed analysis of judged deviations from full HFE Checklist Compliance is presented in Section 2 of the HFE Analysis report (Overlin and Ryan 1997).

The following is a summary of the judged deviations from full HFE checklist compliance.

- Distributed Control System
  - There is a lack of direct means for interpreting some alarms and lack of specific error messages.
  - Display formatting is inconsistent, as is spacing of contents, and non-primary colors are used.
  - There are conflicting abbreviations and names of control and displays, and upper- and lower-case alphas are not used.

- Valves
  - Valves lack flow indications and labeling as to function and direction of movement between open and closed.
  - Outside valve labels are obscured.
  - Distributed Control System and Valve Operating Environments
  - Respirators for emergency use are not thoroughly inspected at least once per month.

The total ATR compliance and judged deviations from full HFE checklist compliance percentage tallies presented in Table 18.4-1 are positive results considering

- ATR's use of off-the-shelf equipment from a variety of vendors
- The age of some of the equipment.

18.4.2 ATR Human Factors Engineering Deviations Disposition

Operating experience over the last several years suggests that none of these deviations poses an immediate threat to the safety of the public or ATR workers. In addition, accident sequences involving human-machine interactions have been treated in the ATR PRA Human Reliability Analysis. The PRA results indicate that the impact of HFE on human actions is not a leading contributor to core damage under the current ATR operating configuration. The HFE evaluation shows that while HFE may be a factor in the operation of the ATR, HFE has been adequately addressed for the mitigation of design-basis events requiring human intervention.

HFE deviations are tracked in the ATR Self-Assessment Program for disposition by one or more of the following: administrative controls, minor changes to equipment operating configurations, changes to equipment, or retaining the current configuration.

Table 18.4-1. Summary of Human Factors Engineering analysis results.

HFE Analysis Results						Percentages (excluding N/A's)	
HFE Compliance category	N/A	Deviations from Full Checklist Compliance	Compliance	Total observations	Total observations minus N/A's	Compliance	Non compliance
Control/display integration	280	24	236	540	260	91%	9%
Visual displays	0	1	47	48	48	98%	2%
Scale indicators	37	0	0	37	0	Not applicable	Not applicable
Displays	20	0	79	99	79	100%	0%
Controls-General	234	12	127	373	139	91%	9%
Hand-operated controls	399	0	30	429	30	100%	0%
User-computer interface	203	12	586	801	598	98%	2%
Controls for UCI	58	0	49	107	49	100%	0%
Labeling	261	25	439	725	464	95%	5%
Communications	5	1	30	36	31	97%	3%
Environment	28	1	16	45	17	94%	6%
Hazards and safety	21	0	32	53	32	100%	0%
Protective clothing	2	2	60	64	62	97%	3%
Operational aids	1	1	16	18	17	94%	6%
ATR Totals	**1,549**	**79**	**1,747**	**3,375**	**1,826**	**96%**	**4%**

18.5 Human Performance in Potential Accident Environments

This section describes a systematic inquiry into the ability of the staff to accomplish its tasks in potential accident environments. The results of the accident analysis in Chapter 15 (Accident Analyses) are used to identify the environment expected during design basis accidents requiring human intervention. Historical data from ATR's participation in the DOE Occurrence Reporting and Processing System (ORPS) have been used to investigate the involvement of human-machine interactions as causal factors in human errors experienced in operating the ATR.

18.5.1 Accident Environment

The Complete Loss of Secondary and the Complete Loss of Flow events result in a relatively slow heatup of the water in the reactor vessel. No fuel damage occurs in these events when they are successfully terminated. High levels of radioactivity requiring control room evacuation prior to operator response are not predicted.

The Shutdown LOCA and the Failure of the Storage Canal accidents require manual opening of valves from the first floor or outside of the ATR building. No fuel damage and release of fission products is predicted for either of these two events when successfully terminated. These events do not involve high temperatures, pressures, or steam; radiation fields in excess of those expected during normal and anticipated operating conditions are not predicted.

18.5.2 ATR Operating Experience

This section describes the results of the analysis of ATR's participation in the DOE ORPS. These results provide a framework for identifying the involvement of human-machine interactions as a causal factor in the ATR human-error experience and for comparing ATR human-error rates to rates in other similar facilities.

ATR implements a process for identifying abnormal or undesirable conditions and events, including those involving human error. This process consists of documenting each occurrence in a structured manner; prioritizing; doing causal reviews; determining proper corrective action; tracking resolution; applying lessons learned; officially closing out each abnormal or undesirable condition; and informing the originator.

Table 18.5-1 shows the absolute and relative progress being made at ATR in human-error reduction from March 1990 through May 1996, the period for which ORPS reports are currently available. The comparison group mentioned in this table consisted of nine DOE reactor facilities similar to ATR (specifically, the C, K, L, N, and P reactors; Experimental Breeder Reactor-II; Fast Flux Test Facility; High Flux Beam Reactor; and High Flux Isotope Reactor).

The total-reports rows show total ORPS reports for ATR and the comparison group. The human-error reports rows show the total numbers and percentages of ORPS reports involving human error. The human-machine interface rows give the numbers and percentages of reports that cited human-machine interface as a causal factor of the human error.

A study of Table 18.5-1 shows that within the comparison group, the percentage of total reports involving human error decreased from 57% to 17%, then increases to 43% ending in 1996. The comparison group's percentage of reports citing human-machine interface as a casual factor for the period of 1990 to 1994 decreased from 9% to 1%, increased in 1994 to 13% then reduced to 0% by 1996.

In contrast, the percentage of ATR's total reports involving human error increased since 1991 from 32% to 53% as of 1995. This percentage is higher than the comparison group's; however, it is consistent with data collected from other complex, high-reliability settings, whose data suggest that about 65% of events involve human error (Trager 1985). Table 18.5-1 also shows that the contribution of human-machine interface as a cited casual factor in ATR's human errors decreased from 14% for 1990 to 8% for 1995. The assessment of the information in Table 18.5-1 shows that while human error is a factor in the operation of the ATR, the contribution of the human-machine interface as a causal factor poses no significant radiological or chemical safety risk.

Table 18.5-1. ATR Operational-experience trending and comparison with other reactor facilities.[a]

	Numbers and percentages of reports, by year						
Source of reports, and causes cited	1990 (partial year)	1991	1992	1993	1994	1995	1996 (through May)
Total reports							
ATR	13	44	39	44	50	45	10
Comparison group	76	611	504	397	239	187	51
Total reports citing human error							
ATR[b]	7 (54%)	14 (32%)	16 (41%)	21 (48%)	19 (38%)	24 (53%)	4 (40%)
Comparison group[c]	43 (57%)	222 (36%)	167 (33%)	91 (23%)	40 (17%)	50 (27%)	22 (43%)
Reports citing human-machine interface							
ATR[d]	1 (14%)	1 (7%)	1 (6%)	0 (0%)	1 (5%)	2 (8%)	0 (0%)
Comparison group[e]	4 (9%)	23 (10%)	4 (2%)	1 (1%)	5 (13%)	6 (12%)	0 (0%)

a. Based upon ORPS reports.

b. Percentages based upon total ATR reports.

c. Percentages based upon total comparison-group reports.

d. Percentages based upon total ATR reports that cite human error.

e. Percentages based upon comparison group's total reports that cite human error.

18.6 References

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CHAPTER 19

APPLICABLE STATUTES, RULES, REGULATIONS AND DEPARTMENTAL ORDERS

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ACRONYMS/ABBREVIATIONS

ATR	Advanced Test Reactor
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy, Idaho Operations Office
EPA	U.S. Environmental Protection Agency
I.C.	Idaho Code
IDAPA	Idaho Administrative Procedures Act
INEL	Idaho National Engineering Laboratory
INEEL	Idaho National Engineering and Environmental Laboratory
UCNI	Unclassified Controlled Nuclear Information
UFSAR	Upgraded Final Safety Analysis Report

19. APPLICABLE STATUTES, RULES, REGULATIONS, AND DEPARTMENTAL ORDERS

Contractors responsible for the design, construction, operation, or decommissioning of U.S. Department of Energy (DOE) nuclear facilities and selected DOE nonfacility nuclear operations are required to perform safety analyses. These safety analyses develop and demonstrate the adequacy of the safety basis for the nuclear facility or nonfacility nuclear operation.

This chapter of the Upgraded Final Safety Analysis Report (UFSAR) identifies the applicable statutes, rules, regulations, and DOE orders that are currently binding upon the safety basis and operation of the facility. These include any state or local statutes, ordinances, and other requirements that would establish safety constraints on facility operation.

The statutes, rules, regulations, and DOE orders that form the current criteria for the safety and the operational bases are identified in the following two sections.

19.1 Safety Basis

Most of the ATR facility was installed as part of the original construction and was designed to meet the statutes, rules, regulations, and DOE orders applicable at the time. Since the initial construction, modifications have been made to the facility. In some cases, these were done to upgrade the facility to requirements given in new or updated statutes, rules, regulations, and departmental orders. In other cases, modifications were made because of changing programmatic requirements or aging equipment. At the time the modifications were made, they met the statutes, rules, regulations, and departmental orders in effect at that time.

Listed in Table 19.1-1 are the statutes, rules, regulations, and DOE orders that form the current criteria for the safety basis for the design and construction supporting the ATR facility operations, maintenance, and modifications. The current criteria apply only to the design, analysis, fabrication, and installation of new plant modification and construction. In addition, Table 19.1-1 lists the chapters to which the criteria apply.

Table 19.1-1. Binding statutes, rules, regulations, and department orders.

Statutes, rules, regulations, and department orders	Associated UFSAR Subject	UFSAR Chapter
DOE Guide 421.1-2	*Implementation Guide for Use in Developing Safety Analyses to Meet Subpart B 10 CFR 830*, October 24, 2001.	ES
DOE-ID 420.D	*Requirements and Guidance for Safety Analysis*, July 17, 2000.	9
DOE Order 151.1A	*Comprehensive Emergency Management System*, U.S. Department of Energy, Washington, D.C., November 1, 2000.	13
DOE Order 232.1A	*Occurrence Reporting and Processing of Operations Information*, U.S. Department of Energy, Washington, D.C., July 21, 1997.	13
DOE Order 414.1A	*Quality Assurance*, U.S. Department of Energy, Washington, D.C., Change 1, July 12, 2001.	3, 17, 21
DOE Order 420.1	*Facility Safety*, U.S. Department of Energy, Washington, D.C., October 24, 1996 (Order canceled).	9
DOE Order 420.1A	*Facility Safety*, U.S. Department of Energy, Washington, D.C., May 20, 2002.	4, 9, 13
DOE Order 430.1A	*Life Cycle Asset Management*, U.S. Department of Energy, Washington, D.C., October 14, 1998.	22
DOE Order 433.1	*Maintenance Management Program for Nuclear Facilities*, U.S. Department of Energy, Washington, D.C., June 1, 2001.	14
DOE Order 435.1	*Radioactive Waste Management*, July 9, 1999, Change 1, August 28, 2001, U.S. Department of Energy, Washington, D.C. (Not specifically discussed in Chapter 11)	11
DOE Order 440.1A	*Worker Protection Management for DOE Federal and Contractor Employees*, U.S. Department of Energy, Washington, D.C., March 27, 1998.	9, 21
DOE Order 450.1	*Environmental Protection Program, U.S. Department of Energy, Washington, D.C., January 15, 2003. (Not specifically discussed in Chapter 11)*	11, 21
DOE Order 473.1	*Physical Protection Program, U.S. Department of Energy, Washington, D.C., December 23, 2002.*	2
DOE Order 5400.5	*Radiation Protection of the Public and the Environment*, Change 2, U.S. Department of Energy, Washington, D.C., January 7, 1993.	11, 12, 15.0

Table 19.1-1. (continued).

Statutes, rules, regulations, and department orders	Associated UFSAR Subject	UFSAR Chapter
DOE Order 5480.1A	*Environmental Protection, Safety, and Health Protection Program for DOE Operations*, U.S. Department of Energy, Washington, D.C., August 13, 1981. (historical)	16
DOE Order 5480.4	*Environmental Protection, Safety, and Health Protection Standards*, Change 4, U.S. Department of Energy, Washington, D.C., January 7, 1993. (Not specifically discussed in Chapter 11)	3, 11
DOE Order 5480.6	*Safety of Department of Energy-Owned Nuclear Reactors*, U.S. Department of Energy, Washington, D.C., September 23, 1986. (Order cancelled)	1, 3, 20
DOE Order 5480.19	*Conduct of Operations Requirements for DOE Facilities*, Change 2, U.S. Department of Energy, Washington, D.C., October 23, 2001.	13
DOE Order 5480.20A	*Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities*, U.S. Department of Energy, Washington, D.C., July 12, 2001.	13, 14
DOE Order 5480.21	*Unreviewed Safety Questions*, U.S. Department of Energy, Washington, D.C., December 24, 1991. (historical)	ES
DOE Order n 5480.22	*Technical Safety Requirements*, Change 2, U.S. Department of Energy, Washington, D.C., January 23, 1996. (historical)	16
DOE Order 5480.23	*Nuclear Safety Analysis Reports*, Change 1, U.S. Department of Energy, Washington D.C., March 10, 1994. (historical)	ES, 1, 2, 3, 12, 14, 15.0, 18, 20, 21
DOE Order 5480.30	*Nuclear Reactor Safety Design Criteria*, U.S. Department of Energy, Washington, D.C., Change 1, March 14, 2001. (historical)	3
DOE Order 5481.1B	*Safety Analysis and Review System*, Change 1, U.S. Department of Energy, Washington, D.C., May 19, 1987. (Order cancelled)	1
DOE SEN-35-91	*Nuclear Safety Policy*, SEN-35-91, Secretary of Energy Notice, U.S. Department of Energy, Washington, D.C., September 9, 1991.	ES, 1
DOE STD-1020-94	*Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*, Change 1, U.S. Department of Energy, Washington, D.C., January 1996. (historical)	3

Table 19.1-1. (continued).

Statutes, rules, regulations, and department orders	Associated UFSAR Subject	UFSAR Chapter
DOE-STD-1020-2002	*Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*, U.S. Department of Energy, Washington, D.C., January 2002.	2, 2A, 3
DOE STD-1021-93	Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems, and Components, Change 1, U.S. Department of Energy, Washington, D.C., April 2002.	2, 2A, 3
DOE STD-1027-92	*Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, Change 1, U.S. Department of Energy, Washington, D.C., September 1997.	ES, 9, 15.12, 20
DOE HDBK-1132-99	*DOE Handbook Design Considerations*, U.S. Department of Energy, Washington, D.C., April 1999.	18
DOE ATR SER	*Advanced Test Reactor Safety Evaluation Report*, U.S. Department of Energy, February 1996.	3
DOE-ID Order 440.C	*Hoisting and Rigging Program, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho, Rev. 1, August 1, 2002.*	9, 20
DOE-ID Order 5480.1A	*Environmental, Safety, and Health Protection Program*, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho, April 5, 1989. (Order cancelled)	16
DOE-ID AE Standards	*DOE-ID Architectural Engineering Standards*, Revision 19, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho, July 1995. (historical)	2, 2a, 3
DOE-ID AE Standards	*DOE-ID Architectural Engineering Standards*, Revision 29, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho, September 2002.	2, 2a, 3
10 CFR 50, Appendix A	*General Design Criteria for Nuclear Power Plants, Code of Federal Regulations*, Office of the Federal Register, December 23, 1999.	3
10 CFR 50.49	*Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants, Code of Federal Regulations*, Office of the Federal Register, December 14, 2001.	3
10 CFR 50.55a	*Codes and Standards, Code of Federal Regulations*, Office of the Federal Register, June 12, 1971.	5, 14

Table 19.1-1. (continued).

Statutes, rules, regulations, and department orders	Associated UFSAR Subject	UFSAR Chapter
10 CFR 61.55	*Waste Classification, Code of Federal Regulations*, Office of the Federal Register, November 2, 2001.	12
10 CFR 100.11	*Determination of Exclusion Area, Low Population Zone, and Population Center Distance, Code of Federal Regulations*, Office of the Federal Register, November 4, 2002.	ES, 6, 16, 15.0, 15.12
10 CFR 100, Appendix A	*Seismic and Geologic Siting Criteria for Nuclear Power Plants, Code of Federal Regulations*, Office of the Federal Register, January 10, 1977.	3
10 CFR 830	*Nuclear Safety Management, Code of Federal Regulations*, Office of the Federal Register, February 4, 2002.	13
10 CFR 830, Subpart A	Quality Assurance Requirements, *Code of Federal Regulations*, Office of the Federal Register, February 4, 2002.	3, 17
10 CFR 830, Subpart B	*Safety Basis Requirements, Code of Federal Regulations*, Office of the Federal Register, January 1, 2002.	ES, 1, 3, 14, 15.0
10 CFR 835	*Occupational Radiation Protection, Code of Federal Regulations*, Office of the Federal Register, November 4, 1998.	ES, 12, 15.0
29 CFR 1910	*Occupational Safety and Health Standards, Code of Federal Regulations*, Office of the Federal Register, July 21, 2003.	13
29 CFR 1910, Subpart H	*Hazardous Materials, Code of Federal Regulations*, Office of the Federal Register, November 7, 2002.	21
29 CFR 1910, Subpart Z	*Toxic and Hazardous Substances, Code of Federal Regulations*, Office of the Federal Register, November 7, 2002.	21
29 CFR 1910.119	*Process Safety Management of Highly Hazardous Chemicals, Code of Federal Regulations*, Office of the Federal Register, November 7, 2002.	20
29 CFR 1910.132	*General Requirements, Code of Federal Regulations*, Office of the Federal Register, July 1, 1994.	18
29 CFR 1910.133	*Eye and Face Protection, Code of Federal Regulations*, Office of the Federal Register, May 2, 1996.	18

Table 19.1-1. (continued).

Statutes, rules, regulations, and department orders	Associated UFSAR Subject	UFSAR Chapter
29 CFR 1910.134	*Respiratory Protection, Code of Federal Regulations*, Office of the Federal Register, April 23, 1998.	18
29 CFR 1910.1020	*Access to Employee Exposure and Medical Records, Code of Federal Regulations*, Office of the Federal Register, June 20, 1996.	21
29 CFR 1910.1200	*Hazard Communications, Code of Federal Regulations*, Office of the Federal Register, March 7, 1996.	21
29 CFR 1926	*Safety & Health Regulations for Construction, Code of Federal Regulations*, Office of the Federal Register, September 12, 2002. (CFR not referenced in chapters because this is for construction work)	11
40 CFR 61, Subpart M	*National Emission Standard for Asbestos, Code of Federal Regulations*, Office of the Federal Register, September 18, 2003. (Not specifically discussed in Chapter 11)	11
40 CFR 61, Subpart H	*National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities, Code of Federal Regulations*, Office of the Federal Register, September 9, 2002. (Not specifically discussed in Chapter 11)	11
40 CFR 191	*Environmental Radiation Protection Standards for Managing and Disposing of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes, Code of Federal Regulations*, Office of the Federal Register, August 2, 2000. (Not specifically discussed in Chapter 11)	11
40 CFR 260	*Hazardous Waste Management System: General, Code of Federal Regulations*, Office of the Federal Register, June 28, 2001. (Not specifically discussed in Chapter 11)	11
40 CFR 261	*Identification and Listing of Hazardous Waste, Code of Federal Regulations*, Office of the Federal Register, July 30, 2003. (Not specifically discussed in Chapter 11)	11
40 CFR 262	*Standards Applicable to Generators of Hazardous Waste, Code of Federal Regulations*, Office of the Federal Register, March 8, 2000. (Not specifically discussed in Chapter 11)	11
40 CFR 263	*Standards Applicable to Transporters of Hazardous Waste, Code of Federal Regulations*, Office of the Federal Register, February 12, 1997. (Not specifically discussed in Chapter 11)	11

Table 19.1-1. (continued).

Statutes, rules, regulations, and department orders	Associated UFSAR Subject	UFSAR Chapter
40 CFR 355	*Emergency Planning and Notification, Code of Federal Regulations*, Office of the Federal Register, September 8, 2003.	20
40 CFR 370	*Hazardous Chemical Reporting: Community Right-to-Know, Code of Federal Regulations*, Office of the Federal Register, February 11, 1999.	20
40 CFR 761	*Polychlorinated Biphenyls (PCBS) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions, Code of Federal Regulations*, Office of the Federal Register, April 18, 2003. (Not specifically discussed in Chapter 11)	11
49 CFR 171	*Hazardous Material Regulations, Code of Federal Regulations*, Office of the Federal Register, October 6, 2003. (Not specifically discussed in Chapter 11)	11
49 CFR 173	*Shippers—General Requirements for Shipments and Packaging, Code of Federal Regulations*, Office of the Federal Register, October 30, 2003. (Not specifically discussed in Chapter 11)	11
49 CFR 173.435	*Table A_1 and A_2 Values for Radionuclides, Code of Federal Regulations*, Office of the Federal Register, August 28, 2001.	12
EPA 56 FR 194	Support Document for the Designation of the Eastern Snake River Plain Aquifer as a Sole Source Aquifer, EPA 910.9-90-020, U.S. Environmental Protection Agency, Region 10, Office of Ground Water, Seattle, Washington, August 1990.	2
State of Idaho, IDAPA 58.01.01	Idaho Department of Environmental Quality Rules and Regulations, Title 1, Chapter 1, *Rules for the Control of Air Pollution in Idaho*, Boise, ID.	11
State of Idaho, IDAPA 58.01.05	Idaho Department of Environmental Quality Rules and Regulations, Title 1, Chapter 5, *Rules and Standards for Hazardous Waste*, Boise, ID.	11
State of Idaho, IDAPA 58.01.06	Idaho Department of Environmental Quality Rules and Regulations, Title 1, Chapter 6, *Solid Waste Management Rules*, Boise, Idaho.	11
State of Idaho, IDAPA 58.01.17	Idaho Department of Environmental Quality Rules and Regulations, Title 1, Chapter 17, *Wastewater-Land Application Permit Rules*, Boise, ID.	11
State of Idaho, Idaho Code Section 39-100	State of Idaho, I.C. 39-100, Idaho Code Section 39, Health and Safety, Chapter 1, *The Idaho Environmental Protection and Health Act*, Idaho Code Sections 39-101 through 39-130, Boise, ID.	11

Table 19.1-1. (continued).

Statutes, rules, regulations, and department orders	Associated UFSAR Subject	UFSAR Chapter
State of Idaho, Idaho Code Section 39-3600	State of Idaho, I.C. 39-3600, Idaho Code Section 39, Health and Safety, Chapter 36, *Water Quality*, Boise, ID.	11
State of Idaho, Idaho Code Section 39-4400	State of Idaho, I.C. 39-4400, Idaho Code Section 39, Health and Safety, Chapter 44, *Hazardous Waster Management Act of 1983*, Boise, ID.	11

19.2 Operational Basis

Listed in Table 19.1-1 are the binding statutes, rules, regulations, and DOE orders that form the current criteria for the operational basis for ATR. Table 19.1-1 also lists the chapters to which the criteria apply. Table 19.2-1 lists the construction and operating permits.

Table 19.2-1. Construction and operating permits.

Permit	Permit number	Project
State of Idaho permit to construct an air pollution emitting source (State of Idaho 2002)	023-00001	TRA Evaporation Pond
Application for a Title V Operating Permit for the Idaho National Engineering and Environmental Laboratory	INEEL/EXT-2000-01610	
Volume I—Sitewide Standards and Information and Operating Permit Application Guide		
Volume VIII—Test Reactor Area		

CHAPTER 20

HAZARD ANALYSIS AND CLASSIFICATION OF THE FACILITY

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ACRONYMS/ABBREVIATIONS

ACT	actinides
AP	activation product
ATR	Advanced Test Reactor
CASN	Chemical Abstract Service Number
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
EG&G Idaho	EG&G Idaho, Inc.
EDF	engineering design file
FP	fission product
ICRP	International Commission on Radiological Protection
INEEL	Idaho National Engineering and Environmental Laboratory
IPT	inpile tube
LMITCO	Lockheed Martin Idaho Technologies Company, Inc.
MW_t	megawatts thermal
PCS	primary coolant system
PRA	probabilistic risk assessment
SAR	Safety Analysis Report
SARA	Superfund Amendments and Reauthorization Act
TPQ	Threshold Planning Quantity
TQ	Threshold Quantity
TRA	Test Reactor Area
UFSAR	Upgraded Final Safety Analysis Report

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20. HAZARD ANALYSIS AND CLASSIFICATION OF THE FACILITY

20.1 Introduction

This chapter contains a description of the hazard classification process, presents the inventories of hazardous materials (radioactive materials and hazardous chemicals), and evaluates the hazards associated with the facility.

Hazard analysis and classification are the processes used to identify hazards within a facility and to categorize the hazards and the facility. The Department of Energy (DOE 1994) requires hazard analysis and classification for nuclear facilities and provides definitions of three graded classification categories applicable to nuclear facilities. The classification categories are graded based on the potential consequences of radioactive and/or hazardous material releases. Further guidance in nuclear facility hazard classification is provided in DOE standards (DOE 1992). By definition, a Hazard Category 1 facility is one for which the hazard analysis shows the potential for significant offsite consequences. This category has been interpreted to include Category A reactors (i.e., steady state power level >20 MW_t) (DOE 1986) and facilities designated by the Program Secretarial Officer (DOE 1992). Figure 20.1-1 contains a flowchart of the hazard-classification decision process. The Advanced Test Reactor (ATR) at the Idaho National Engineering and Environmental Laboratory's (INEEL's) Test Reactor Area (TRA) has an approved operating power level of up to 250 MW_t and therefore is a Category A reactor and a Hazard Category 1 nuclear facility.

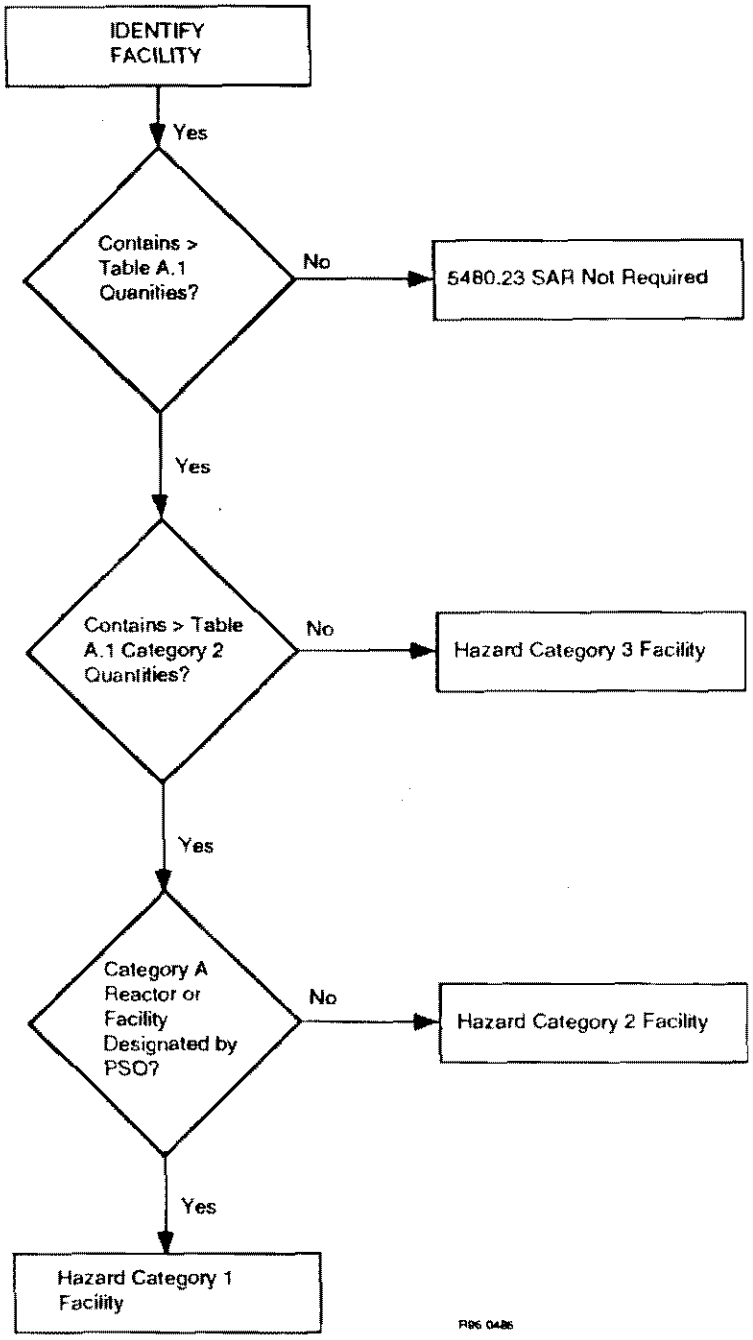

Figure 20.1-1. Hazard-classification decision process. **(For Information Only)**

20.2 Hazardous Material Inventories

DOE Order 5480.23 requires that an inventory of hazardous materials (type and amount) be prepared (DOE 1994). This inventory is to include radioactive and nonradioactive hazardous materials that could lead to a potential release that threatens or challenges the health and safety of individuals onsite or offsite. The inventory provides the basis for the facility hazards analysis and for determining the hazard level classification for the facility.

20.2.1 Radioactive Materials

There are four potential sources of radionuclides at ATR. The sources include the core, the canal, isotope production, and the in-pile tube (IPT) with fueled tests.

Table 20.2-1 contains the radionuclide inventory for the ATR fuel at scram and at various decay times out to 365 days after scram. These inventories were calculated based on an irradiation history of 250 MW_t for 60 days and represent an upper bound on what would be expected at ATR. The derivation of this inventory is documented in Carboneau (1993).

Table 20.2-2 contains the maximum expected fuel inventory in the ATR canals. The inventory is based on a worst-case operation sequence in which a number of irradiated cores are present in the canal (McCracken 1986). Only the noble gases and volatile radionuclides are listed in Table 20.2-2.

The ATR canals contain a variety of irradiated core internal components and hardware with multiple activation products. The core and internal structural materials consist primarily of the following: aluminum, beryllium, various stainless steel and inconel alloys, stellite, and hafnium. The significant radionuclides in discharged core internals include Tritium (H-3) in the discharged beryllium reflectors, which is less than 2 MCi, and the cobalt in discharge equipment such as inpile tubes and gear box support beams, which is well below the cobalt quantities produced in the isotope production program. The hafnium absorber material contains mainly Hf-181, which is relatively short-lived. The activity in this hardware is fixed and is small compared to the activity of the irradiated fuel stored in the canals. The canal inventory also includes experiments and capsules containing radionuclides produced in the isotope production program.

Table 20.2-3 contains the maximum expected radionuclides inventories in the canal from both activation products and isotope production. While substantial quantities of activation products and isotope production are generated in ATR, they are not significant to the total activity from the fuel in the core, and therefore are not considered in the consequences of fuel damage events considered in this section. The total quantities are bounded by the total activity present either in the core or canal.

The consequences of the release to the environment of the entire inventory of the radionuclides contained in a fueled test were considered in Chapter 15 (Accident Analyses). The test fission power is significantly lower than the core power of 250 MW and therefore the consequences from an accident involving a loop test would be bounded by the total core melt sequences discussed in this chapter.

20.2.2 Explosive Materials

There are no explosives stored at ATR. However, it is possible that hydrogen gas could be produced in explosive concentrations during severe accidents. It is further possible that a hydrogen explosion could cause damage to the confinement. The radiological consequences of confinement failure during severe accidents is covered in the ATR Probabilistic Risk Assessment (PRA) (Eide, Khericha, and Thatcher 1991;Thatcher et al. 1994). As for personnel concerned, evacuation would have taken place before any detonation.

20.2.3 Hazardous Chemicals

A SARA report is prepared for the INEEL annually in compliance with the hazardous chemicals reporting as defined under the Superfund and Reauthorization Act (SARA) Title III, Section 312. The regulations specific to Section 312 of SARA are given in 40 CFR 370. An inventory of SARA reportable materials present in the ATR facility at the end of each calendar year is prepared for the INEEL SARA 312 report.

In the initial UFSAR submittal, the 1993 SARA inventory of reportable chemicals present in the ATR facility was used as the basis for the hazardous chemical analysis and classification. The chemicals in the SARA inventory were screened to identify hazardous materials in quantities that would require consideration in the facility hazard analysis. The chemicals were screened against the Threshold Quantities (TQ) in the list of highly hazardous chemicals, toxins, and reactives from Appendix A of 29 CFR 1910.119; and the Threshold Planning Quantities (TPQ) in 40 CFR 355 as described in McCracken (1997).

An updated inventory of hazardous chemicals has been prepared using the SARA reportable materials for the year beginning inventory 1997 (Buescher 1997).

Table 20.2-4 contains the inventory of hazardous chemicals in the ATR Facility to be used in the hazard analysis and classification. The table provides the hazardous chemical, building number, the American Chemical Society's Chemical Abstract Service Number (CASN), physical state, storage code, average quantity, Threshold Quantity (TQ) (29 CFR 1910.119, "Process Safety Management"), and Threshold Planning Quantity (TPQ) (From 40 CFR 355, "Emergency Planning and Notification"). The inventory in Table 20.2-4 was developed using the TQ, and TPQ as screening criteria as described in McCracken (1997) and reviewed in Buescher (1997) and Wagoner (1998).

The physical state is denoted with L for a liquid, G for a gas, or S for a solid. The storage code provides information regarding the type of storage and storage conditions. Table 20.2-5 provides storage code explanations. The hazard code provides the type of hazard associated with the chemical and is denoted as follows:

- A - acute health hazard, including highly toxic, toxic, irritant, sensitizer, corrosive, and other chemicals that can cause an adverse effect to a target organ. The effect usually occurs rapidly as a result of a short-term exposure and is of short duration.
- C - chronic or delayed health hazard, including carcinogens and other chemicals that can cause an adverse effect to a target organ. The effect usually occurs as a result of a long-term exposure and is of long duration.

- F - fire hazard, including flammable, combustible liquid, pyrophoric, and oxidizing hazardous chemicals.
- S - sudden release of pressure, including explosives and compressed gases.
- R - reactive, including unstable reactive, organic peroxides, and water reactive hazardous chemicals.

Sulfuric acid is the only hazardous chemical in the ATR area that exceeds any one of the two screening thresholds. Sulfuric acid storage location in TRA-671 involves quantities that exceed the TPQ.

The chemical hazard evaluation of the facility shows that except for the sulfuric acid used in processing the demineralized water and the secondary cooling system water, the quantities of hazardous chemicals are all within the two screening thresholds.

Hazardous chemicals may be used in the facility without modifying the Upgraded Final Safety Analysis Report (UFSAR) if the quantity of each hazardous chemical is less than the TQ specified in 29 CFR 1910.119, and the TPQ specified in 40 CFR 355. If the inventory of a hazardous chemical is projected to exceed these screening quantities, then hazard analyses must be performed and any potential threat or challenge to the health and safety of individuals on site and off site must be incorporated into the UFSAR.

Table 20.2-1. ATR fuel inventory for irradiation history of 250 MW for 60 days.

ACTIVITY IN CURIES FOR ACTINIDES+DAUGHTERS

RADIONUCLIDE	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
TL206	4.545E-24	4.545E-24	4.545E-24	4.545E-24	4.545E-24	4.545E-24	4.545E-24	4.545E-24	4.545E-24	4.545E-24	4.545E-24
TL207	1.340E-10	1.350E-10	1.361E-10	1.403E-10	1.605E-10	4.002E-10	8.665E-10	1.569E-09	2.514E-09	3.703E-09	2.356E-08
TL208	1.645E-07	1.668E-07	1.651E-07	1.752E-07	1.994E-07	6.090E-07	1.241E-06	2.035E-06	2.981E-06	4.071E-06	1.583E-05
TL209	2.614E-12	2.570E-12	2.625E-12	2.816E-12	3.268E-12	3.252E-12	2.668E-12	3.024E-12	3.771E-12	4.638E-12	1.251E-11
PB209	1.211E-10	1.219E-10	1.220E-10	1.207E-10	1.513E-10	1.506E-10	1.235E-10	1.400E-10	1.746E-10	2.147E-10	5.790E-10
PB210	1.258E-12	1.266E-12	1.289E-12	1.349E-12	1.604E-12	3.005E-12	3.642E-12	3.872E-12	3.952E-12	3.979E-12	4.035E-12
PB211	1.344E-10	1.345E-10	1.365E-10	1.407E-10	1.610E-10	4.013E-10	8.689E-10	1.573E-09	2.521E-09	3.713E-09	2.363E-08
PB212	4.578E-07	4.578E-07	4.595E-07	4.705E-07	5.544E-07	1.695E-06	3.455E-06	5.663E-06	8.296E-06	1.133E-05	4.407E-05
PB214	6.498E-14	6.307E-14	6.612E-14	6.838E-14	7.929E-14	2.256E-13	5.121E-13	9.263E-13	1.469E-12	2.143E-12	1.122E-11
BI208	6.546E-24	6.546E-24	6.546E-24	6.546E-24	6.546E-24	6.546E-24	6.546E-24	6.546E-24	6.546E-24	6.546E-24	6.546E-24
BI210M	4.563E-24	4.563E-24	4.563E-24	4.563E-24	4.563E-24	4.563E-24	4.563E-24	4.563E-24	4.563E-24	4.563E-24	4.563E-24
BI210	8.013E-13	8.066E-13	8.227E-13	8.666E-13	1.078E-12	2.690E-12	3.525E-12	3.830E-12	3.938E-12	3.974E-12	4.038E-12
BI211	1.344E-10	1.353E-10	1.365E-10	1.407E-10	1.610E-10	4.013E-10	8.689E-10	1.573E-09	2.521E-09	3.713E-09	2.363E-08
BI212	4.578E-07	4.580E-07	4.591E-07	4.875E-07	5.549E-07	1.695E-06	3.455E-06	5.663E-06	8.296E-06	1.133E-05	4.407E-05
BI213	1.210E-10	1.179E-10	1.215E-10	1.303E-10	1.513E-10	1.506E-10	1.235E-10	1.400E-10	1.746E-10	2.147E-10	5.790E-10
BI214	6.498E-14	6.340E-14	6.614E-14	6.838E-14	7.929E-14	2.256E-13	5.121E-13	9.263E-13	1.469E-12	2.143E-12	1.122E-11
PO210	3.994E-14	4.026E-14	4.123E-14	4.390E-14	5.773E-14	2.918E-13	6.955E-13	1.116E-12	1.503E-12	1.846E-12	3.234E-12
PO211M	8.452E-20	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PO211	3.763E-13	3.789E-13	3.822E-13	3.939E-13	4.507E-13	1.124E-12	2.433E-12	4.405E-12	7.059E-12	1.040E-11	6.616E-11
PO212	2.933E-07	2.934E-07	2.942E-07	3.124E-07	3.555E-07	1.086E-06	2.214E-06	3.628E-06	5.315E-06	7.260E-06	2.823E-05
PO213	1.184E-10	1.153E-10	1.189E-10	1.275E-10	1.480E-10	1.473E-10	1.208E-10	1.370E-10	1.708E-10	2.101E-10	5.665E-10
PO214	1.085E-09	1.084E-09	1.074E-09	1.050E-09	9.504E-10	3.998E-10	1.475E-10	5.503E-11	2.138E-11	9.468E-12	1.122E-11
PO215	1.342E-10	1.348E-10	1.364E-10	1.407E-10	1.610E-10	4.013E-10	8.689E-10	1.573E-09	2.521E-09	3.713E-09	2.363E-08
PO216	4.576E-07	4.598E-07	4.664E-07	4.844E-07	5.747E-07	1.695E-06	3.455E-06	5.663E-06	8.296E-06	1.133E-05	4.407E-05
PO218	6.499E-14	6.529E-14	6.612E-14	6.839E-14	7.930E-14	2.256E-13	5.122E-13	9.265E-13	1.470E-12	2.143E-12	1.122E-11
AT217	1.210E-10	1.219E-10	1.243E-10	1.303E-10	1.513E-10	1.506E-10	1.235E-10	1.400E-10	1.746E-10	2.147E-10	5.790E-10
RN218	1.085E-09	1.084E-09	1.074E-09	1.050E-09	9.503E-10	3.995E-10	1.470E-10	5.410E-11	1.991E-11	7.326E-12	5.628E-15
RN219	1.342E-10	1.348E-10	1.364E-10	1.407E-10	1.610E-10	4.013E-10	8.689E-10	1.573E-09	2.521E-09	3.713E-09	2.363E-08

Table 20.2-1. (continued).

RADIONUCLIDE	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
RN220	4.576E-07	4.598E-07	4.664E-07	4.844E-07	5.747E-07	1.695E-06	3.455E-06	5.663E-06	8.296E-06	1.133E-05	4.407E-05
RN222	6.498E-14	6.525E-14	6.609E-14	6.836E-14	7.928E-14	2.256E-13	5.122E-13	9.265E-13	1.470E-12	2.143E-12	1.122E-11
FR221	1.210E-10	1.219E-10	1.243E-10	1.303E-10	1.513E-10	1.506E-10	1.235E-10	1.400E-10	1.746E-10	2.147E-10	5.790E-10
FR223	6.190E-12	6.202E-12	6.256E-12	6.391E-12	7.018E-12	1.395E-11	2.513E-11	3.968E-11	5.761E-11	7.891E-11	3.258E-10
RA222	1.085E-09	1.084E-09	1.074E-09	1.050E-09	9.503E-10	3.995E-10	1.470E-10	5.410E-11	1.991E-11	7.326E-12	5.628E-15
RA223	1.342E-10	1.348E-10	1.364E-10	1.407E-10	1.610E-10	4.013E-10	8.689E-10	1.573E-09	2.521E-09	3.713E-09	2.363E-08
RA224	4.576E-07	4.598E-07	4.663E-07	4.843E-07	5.746E-07	1.695E-06	3.455E-06	5.663E-06	8.296E-06	1.133E-05	4.407E-05
RA225	2.650E-10	2.642E-10	2.618E-10	2.555E-10	2.297E-10	1.260E-10	1.231E-10	1.539E-10	1.930E-10	2.346E-10	5.790E-10
RA226	8.327E-14	8.361E-14	8.462E-14	8.736E-14	1.005E-13	2.667E-13	5.766E-13	1.014E-12	1.581E-12	2.279E-12	1.122E-11
RA228	4.957E-15	4.977E-15	5.039E-15	5.207E-15	6.006E-15	1.596E-14	3.417E-14	5.951E-14	9.192E-14	1.314E-13	6.146E-13
AC225	1.210E-10	1.218E-10	1.242E-10	1.303E-10	1.512E-10	1.506E-10	1.235E-10	1.400E-10	1.746E-10	2.147E-10	5.790E-10
AC227	4.485E-10	4.497E-10	4.533E-10	4.631E-10	5.085E-10	1.011E-09	1.821E-09	2.876E-09	4.175E-09	5.718E-09	2.361E-08
AC228	5.633E-08	4.493E-08	2.280E-08	3.735E-09	1.094E-12	1.596E-14	3.417E-14	5.951E-14	9.193E-14	1.314E-13	6.146E-13
TH226	1.085E-09	1.083E-09	1.074E-09	1.050E-09	9.503E-10	3.995E-10	1.470E-10	5.410E-11	1.991E-11	7.326E-12	5.628E-15
TH227	2.329E-10	2.336E-10	2.359E-10	2.419E-10	2.693E-10	5.833E-10	1.165E-09	1.988E-09	3.052E-09	4.357E-09	2.330E-08
TH228	5.937E-07	5.967E-07	6.057E-07	6.301E-07	7.455E-07	1.964E-06	3.805E-06	6.090E-06	8.796E-06	1.190E-05	4.402E-05
TH229	5.550E-11	5.562E-11	5.596E-11	5.688E-11	6.100E-11	9.678E-11	1.383E-10	1.800E-10	2.221E-10	2.645E-10	5.790E-10
TH230	3.388E-09	3.398E-09	3.427E-09	3.505E-09	3.858E-09	6.927E-09	1.050E-08	1.411E-08	1.776E-08	2.145E-08	4.895E-08
TH231	5.357E-02	5.347E-02	5.323E-02	5.273E-02	5.195E-02	5.182E-02	5.182E-02	5.182E-02	5.182E-02	5.182E-02	5.182E-02
TH232	8.744E-13	8.768E-13	8.840E-13	9.031E-13	9.893E-13	1.736E-12	2.597E-12	3.459E-12	4.321E-12	5.182E-12	1.136E-11
TH233	4.547E-03	1.055E-04	1.317E-09	1.104E-22	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TH234	8.575E-04	8.579E-04	8.590E-04	8.619E-04	8.745E-04	9.476E-04	9.856E-04	1.002E-03	1.008E-03	1.011E-03	1.013E-03
PA231	1.667E-07	1.669E-07	1.677E-07	1.697E-07	1.788E-07	2.615E-07	3.561E-07	4.508E-07	5.454E-07	6.400E-07	1.291E-06
PA232	4.178E-02	3.997E-02	3.502E-02	2.461E-02	5.034E-03	5.347E-09	6.843E-16	8.758E-23	1.121E-29	1.435E-36	0.000E+00
PA233	2.816E-02	2.829E-02	2.866E-02	2.967E-02	3.448E-02	7.515E-02	1.023E-01	1.151E-01	1.211E-01	1.238E-01	1.262E-01
PA234M	3.976E-03	8.579E-04	8.590E-04	8.620E-04	8.745E-04	9.476E-04	9.856E-04	1.002E-03	1.008E-03	1.011E-03	1.013E-03
PA234	3.020E-03	2.456E-03	1.321E-03	2.532E-04	1.284E-06	1.232E-06	1.281E-06	1.302E-06	1.311E-06	1.315E-06	1.317E-06
PA235	2.364E-08	7.495E-10	2.388E-14	2.437E-26	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
U230	1.085E-09	1.082E-09	1.073E-09	1.049E-09	9.493E-10	3.991E-10	1.469E-10	5.405E-11	1.989E-11	7.318E-12	5.622E-15
U231	6.243E-07	6.158E-07	5.909E-07	5.293E-07	3.226E-07	4.419E-09	3.127E-11	2.214E-13	1.568E-15	1.332E-17	5.026E-33

Table 20.2-1. (continued).

RADIONUCLIDE	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
U232	3.658E-05	3.671E-05	3.710E-05	3.799E-05	4.070E-05	5.611E-05	7.326E-05	9.007E-05	1.065E-04	1.226E-04	2.289E-04
U233	5.313E-06	5.313E-06	5.313E-06	5.313E-06	5.314E-06	5.332E-06	5.364E-06	5.403E-06	5.446E-06	5.490E-06	5.814E-06
U234	4.762E-03	4.763E-03	4.763E-03	4.764E-03	4.768E-03	4.811E-03	4.861E-03	4.910E-03	4.959E-03	5.008E-03	5.361E-03
U235	5.182E-02	5.182E-02	5.182E-02	5.182E-02	5.182E-02	5.182E-02	5.182E-02	5.182E-02	5.182E-02	5.182E-02	5.182E-02
U236	2.126E-01	2.126E-01	2.126E-01	2.126E-01	2.126E-01	2.126E-01	2.126E-01	2.126E-01	2.126E-01	2.126E-01	2.126E-01
U237	4.720E+06	4.680E+06	4.561E+06	4.259E+06	3.130E+06	2.168E+05	9.957E+03	4.573E+02	2.100E+01	9.651E-01	3.590E-04
U238	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03
U239	3.834E+06	1.119E+05	2.778E+00	1.458E-12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
U240	7.723E+01	7.000E+01	5.212E+01	2.374E+01	6.890E-01	2.565E-09	2.565E-09	2.565E-09	2.565E-09	2.565E-09	2.565E-09
U241	8.214E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NP235	2.052E-03	2.052E-03	2.051E-03	2.049E-03	2.038E-03	1.947E-03	1.848E-03	1.753E-03	1.663E-03	1.578E-03	1.083E-03
NP236M	4.753E+00	4.469E+00	3.714E+00	2.269E+00	2.469E-01	1.107E-09	2.576E-19	5.999E-29	1.397E-38	3.252E-48	0.000E+00
NP236	8.100E-07	8.100E-07	8.100E-07	8.100E-07	8.100E-07	8.100E-07	8.100E-07	8.100E-07	8.100E-07	8.100E-07	8.100E-07
NP237	8.544E-02	8.579E-02	8.682E-02	8.942E-02	9.918E-02	1.243E-01	1.261E-01	1.262E-01	1.262E-01	1.262E-01	1.262E-01
NP238	5.979E+05	5.818E+05	5.361E+05	4.310E+05	1.614E+05	3.240E+01	1.768E-03	1.280E-05	1.270E-05	1.270E-05	1.266E-05
NP239	3.742E+06	3.677E+06	3.417E+06	2.808E+06	1.161E+06	5.521E+02	1.104E-01	2.954E-02	2.953E-02	2.953E-02	2.952E-02
NP240M	8.432E+03	7.073E+01	5.258E+01	2.395E+01	6.951E-01	2.565E-09	2.565E-09	2.565E-09	2.565E-09	2.565E-09	2.565E-09
NP240	3.336E+04	9.278E+03	1.996E+02	7.149E-03	2.963E-15	1.018E-23	1.018E-23	1.018E-23	1.018E-23	1.018E-23	1.018E-23
NP241	8.214E-03	4.542E-05	7.657E-12	6.642E-30	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PU236	2.037E-02	2.049E-02	2.081E-02	2.142E-02	2.225E-02	2.198E-02	2.154E-02	2.112E-02	2.070E-02	2.029E-02	1.758E-02
PU237	2.921E-01	2.917E-01	2.906E-01	2.877E-01	2.749E-01	1.851E-01	1.173E-01	7.437E-02	4.713E-02	2.987E-02	1.134E-03
PU238	1.727E+02	1.738E+02	1.768E+02	1.838E+02	2.016E+02	2.121E+02	2.120E+02	2.119E+02	2.117E+02	2.116E+02	2.106E+02
PU239	6.522E+00	6.546E+00	6.616E+00	6.779E+00	7.220E+00	7.531E+00	7.531E+00	7.531E+00	7.531E+00	7.531E+00	7.531E+00
PU240	4.086E+00	4.087E+00	4.087E+00	4.087E+00	4.087E+00	4.087E+00	4.087E+00	4.087E+00	4.087E+00	4.087E+00	4.087E+00
PU241	1.535E+03	1.535E+03	1.535E+03	1.535E+03	1.535E+03	1.529E+03	1.523E+03	1.517E+03	1.511E+03	1.505E+03	1.463E+03
PU242	6.745E-03	6.745E-03	6.745E-03	6.745E-03	6.745E-03	6.745E-03	6.745E-03	6.745E-03	6.745E-03	6.745E-03	6.745E-03
PU243	1.150E+04	8.697E+03	3.758E+03	4.008E+02	1.695E-02	5.341E-12	5.341E-12	5.341E-12	5.341E-12	5.341E-12	5.341E-12
PU244	2.568E-09	2.568E-09	2.568E-09	2.568E-09	2.568E-09	2.568E-09	2.568E-09	2.568E-09	2.568E-09	2.568E-09	2.568E-09
PU245	7.202E-02	6.319E-02	4.268E-02	1.499E-02	1.353E-04	2.571E-22	9.179E-43	3.277E-63	1.170E-83	4.177-104	0.000E+00
PU246	6.019E-05	5.987E-05	5.892E-05	5.647E-05	4.662E-05	8.855E-06	1.303E-06	1.916E-07	2.819E-08	4.148E-09	4.438E-15

Table 20.2-1. (continued).

RADIONUCLIDE	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
AM239	7.140E-06	6.355E-06	4.480E-06	1.764E-06	2.662E-08	4.366E-24	2.670E-42	1.633E-60	9.985E-79	6.106E-97	0.000E+00
AM240	1.521E-03	1.480E-03	1.363E-03	1.096E-03	4.104E-04	8.240E-08	4.465E-12	2.419E-16	1.311E-20	7.104E-25	0.000E+00
AM241	8.779E-02	8.835E-02	9.003E-02	9.453E-02	1.147E-01	2.896E-01	4.906E-01	6.908E-01	8.902E-01	1.089E+00	2.489E+00
AM242M	2.544E-03	2.544E-03	2.544E-03	2.544E-03	2.544E-03	2.543E-03	2.542E-03	2.541E-03	2.540E-03	2.539E-03	2.533E-03
AM242	3.689E+02	3.383E+02	2.609E+02	1.306E+02	5.795E+00	2.531E-03	2.530E-03	2.529E-03	2.528E-03	2.527E-03	2.520E-03
AM243	2.864E-02	2.886E-02	2.924E-02	2.949E-02	2.952E-02	2.952E-02	2.952E-02	2.952E-02	2.952E-02	2.952E-02	2.952E-02
AM244M	1.389E+03	5.666E+01	3.847E-03	2.953E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AM244	7.137E+01	6.222E+01	4.122E+01	1.375E+01	9.823E-02	2.568E-13	2.568E-13	2.568E-13	2.568E-13	2.568E-13	2.568E-13
AM245	7.202E-02	6.958E-02	5.184E-02	1.863E-02	1.681E-04	1.641E-13	1.538E-13	1.441E-13	1.351E-13	1.266E-13	7.941E-14
AM246	6.023E-05	5.997E-05	5.902E-05	5.656E-05	4.669E-05	8.869E-06	1.305E-06	1.920E-07	2.824E-08	4.155E-09	4.445E-15
CM241	7.161E-06	7.150E-06	7.116E-06	7.025E-06	6.631E-06	4.019E-06	2.256E-06	1.266E-06	7.105E-07	3.988E-07	6.327E-09
CM242	1.477E+01	1.487E+01	1.512E+01	1.551E+01	1.573E+01	1.411E+01	1.242E+01	1.093E+01	9.626E+00	8.475E+00	3.399E+00
CM243	2.297E-03	2.297E-03	2.296E-03	2.296E-03	2.296E-03	2.292E-03	2.287E-03	2.283E-03	2.278E-03	2.274E-03	2.241E-03
CM244	1.310E+00	1.314E+00	1.315E+00	1.317E+00	1.317E+00	1.314E+00	1.310E+00	1.306E+00	1.301E+00	1.297E+00	1.268E+00
CM245	6.717E-05	6.717E-05	6.717E-05	6.717E-05	6.718E-05	6.718E-05	6.718E-05	6.718E-05	6.718E-05	6.718E-05	6.717E-05
CM246	4.858E-06	4.858E-06	4.858E-06	4.858E-06	4.859E-06	4.859E-06	4.859E-06	4.859E-06	4.859E-06	4.859E-06	4.858E-06
CM247	5.341E-12	5.341E-12	5.341E-12	5.341E-12	5.341E-12	5.341E-12	5.341E-12	5.341E-12	5.341E-12	5.341E-12	5.341E-12
CM248	5.118E-12	5.118E-12	5.118E-12	5.118E-12	5.118E-12	5.118E-12	5.118E-12	5.118E-12	5.118E-12	5.118E-12	5.118E-12
CM249	1.536E-06	4.199E-07	8.587E-09	2.768E-13	7.348E-15	2.671E-15	8.313E-16	2.587E-16	8.049E-17	2.505E-17	5.780E-21
CM250	1.557E-18	1.557E-18	1.557E-18	1.557E-18	1.557E-18	1.557E-18	1.557E-18	1.557E-18	1.557E-18	1.557E-18	1.557E-18
CM251	6.046E-16	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BK249	1.186E-08	1.202E-08	1.207E-08	1.205E-08	1.197E-08	1.132E-08	1.060E-08	9.937E-09	9.312E-09	8.726E-09	5.475E-09
BK250	2.850E-07	1.853E-07	5.099E-08	1.632E-09	1.484E-15	1.103E-15	1.023E-15	9.485E-16	8.796E-16	8.157E-16	4.750E-16
BK251	1.123E-09	2.609E-10	3.276E-12	2.788E-17	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CF249	2.220E-13	2.274E-13	2.437E-13	2.872E-13	4.823E-13	2.121E-12	3.900E-12	5.567E-12	7.129E-12	8.593E-12	1.671E-11
CF250	1.176E-10	1.204E-10	1.242E-10	1.256E-10	1.256E-10	1.251E-10	1.246E-10	1.240E-10	1.235E-10	1.229E-10	1.192E-10
CF251	4.300E-13	4.301E-13	4.301E-13	4.301E-13	4.301E-13	4.301E-13	4.300E-13	4.300E-13	4.300E-13	4.300E-13	4.298E-13
CF252	2.981E-11	2.981E-11	2.980E-11	2.979E-11	2.972E-11	2.917E-11	2.855E-11	2.794E-11	2.734E-11	2.676E-11	2.292E-11
CF253	2.762E-12	2.753E-12	2.727E-12	2.657E-12	2.364E-12	8.596E-13	2.675E-13	8.323E-14	2.590E-14	8.060E-15	1.860E-18
CF254	2.295E-14	2.293E-14	2.286E-14	2.269E-14	2.192E-14	1.627E-14	1.154E-14	8.184E-15	5.803E-15	4.115E-15	3.497E-16

Table 20.2-1. (continued).

RADIONUCLIDE	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
CF255	4.247E-15	1.577E-15	5.228E-18	3.216E-21	1.143E-35	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ES253	2.363E-13	2.434E-13	2.643E-13	3.183E-13	5.288E-13	1.025E-12	6.638E-13	3.314E-13	1.483E-13	6.252E-14	6.721E-17
ES254M	7.094E-14	6.848E-14	6.160E-14	4.646E-14	1.304E-14	2.166E-19	6.616E-25	2.021E-30	6.172E-36	1.885E-41	0.000E+00
ES254	1.189E-15	1.188E-15	1.188E-15	1.186E-15	1.177E-15	1.102E-15	1.022E-15	9.478E-16	8.790E-16	8.151E-16	4.745E-16
ES255	2.243E-16	2.282E-16	2.297E-16	2.270E-16	2.149E-16	1.354E-16	7.949E-17	4.640E-17	2.708E-17	1.581E-17	9.606E-20
TOTAL	1.295E+07	9.071E+06	8.520E+06	7.501E+06	4.455E+06	2.191E+05	1.172E+04	2.212E+03	1.768E+03	1.741E+03	1.693E+03
ACTIVITY IN CURIES FOR ACTINIDES+DAUGHTERS (BY ELEMENT)											
TL	1.646E-07	1.669E-07	1.652E-07	1.753E-07	1.995E-07	6.094E-07	1.242E-06	2.036E-06	2.983E-06	4.075E-06	1.586E-05
PB	4.580E-07	4.581E-07	4.597E-07	4.708E-07	5.547E-07	1.695E-06	3.456E-06	5.665E-06	8.299E-06	1.134E-05	4.409E-05
BI	4.580E-07	4.582E-07	4.594E-07	4.878E-07	5.552E-07	1.695E-06	3.456E-06	5.665E-06	8.299E-06	1.134E-05	4.409E-05
PO	7.523E-07	7.546E-07	7.619E-07	7.981E-07	9.314E-07	2.782E-06	5.670E-06	9.294E-06	1.361E-05	1.860E-05	7.232E-05
AT	1.210E-10	1.219E-10	1.243E-10	1.303E-10	1.513E-10	1.506E-10	1.235E-10	1.400E-10	1.746E-10	2.147E-10	5.790E-10
RN	4.588E-07	4.611E-07	4.676E-07	4.856E-07	5.758E-07	1.696E-06	3.456E-06	5.665E-06	8.299E-06	1.133E-05	4.409E-05
FR	1.272E-10	1.281E-10	1.305E-10	1.367E-10	1.583E-10	1.645E-10	1.486E-10	1.797E-10	2.322E-10	2.936E-10	9.048E-10
RA	4.591E-07	4.612E-07	4.678E-07	4.858E-07	5.759E-07	1.696E-06	3.456E-06	5.665E-06	8.299E-06	1.134E-05	4.409E-05
AC	5.690E-08	4.550E-08	2.338E-08	4.328E-09	6.609E-10	1.162E-09	1.944E-09	3.016E-09	4.349E-09	5.933E-09	2.419E-08
TH	5.897E-02	5.444E-02	5.409E-02	5.359E-02	5.282E-02	5.277E-02	5.281E-02	5.283E-02	5.284E-02	5.284E-02	5.288E-02
PA	7.694E-02	7.158E-02	6.586E-02	5.540E-02	4.039E-02	7.610E-02	1.033E-01	1.161E-01	1.221E-01	1.248E-01	1.272E-01
U	8.555E+06	4.792E+06	4.561E+06	4.259E+06	3.130E+06	2.168E+05	9.957E+03	4.576E+02	2.128E+01	1.236E+00	2.714E-01
NP	4.382E+06	4.268E+06	3.953E+06	3.239E+06	1.323E+06	5.846E+02	2.401E-01	1.575E-01	1.574E-01	1.573E-01	1.568E-01
PU	1.322E+04	1.042E+04	5.481E+03	2.131E+03	1.748E+03	1.753E+03	1.747E+03	1.741E+03	1.735E+03	1.729E+03	1.686E+03
AM	1.829E+03	4.574E+02	3.023E+02	1.445E+02	6.041E+00	3.242E-01	5.252E-01	7.254E-01	9.248E-01	1.123E+00	2.524E+00
CM	1.608E+01	1.619E+01	1.643E+01	1.683E+01	1.705E+01	1.542E+01	1.373E+01	1.224E+01	1.093E+01	9.775E+00	4.670E+00
BK	2.980E-07	1.976E-07	6.306E-08	1.368E-08	1.197E-08	1.132E-08	1.060E-08	9.937E-09	9.312E-09	8.726E-09	5.475E-09
CF	1.509E-10	1.537E-10	1.574E-10	1.588E-10	1.586E-10	1.577E-10	1.577E-10	1.580E-10	1.584E-10	1.587E-10	1.592E-10
ES	3.086E-13	3.133E-13	3.274E-13	3.662E-13	5.433E-13	1.027E-12	6.649E-13	3.324E-13	1.492E-13	6.335E-14	5.418E-16
TOTAL	1.295E+07	9.071E+06	8.520E+06	7.501E+06	4.455E+06	2.191E+05	1.172E+04	2.212E+03	1.768E+03	1.741E+03	1.693E+03

Table 20.2-1. (continued).

CUMULATIVE TABLE TOTALS											
AP+FP	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ACT+FP	1.295E+07	9.071E+06	8.520E+06	7.501E+06	4.455E+06	2.191E+05	1.172E+04	2.212E+03	1.768E+03	1.741E+03	1.693E+03
AP+ACT+FP	1.295E+07	9.071E+06	8.520E+06	7.501E+06	4.455E+06	2.191E+05	1.172E+04	2.212E+03	1.768E+03	1.741E+03	1.693E+03

ACTIVITY IN CURIES FOR FISSION PRODUCTS

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
H 3	2.120E+02	2.120E+02	2.120E+02	2.120E+02	2.119E+02	2.111E+02	2.101E+02	2.091E+02	2.082E+02	2.072E+02	2.005E+02
BE 10	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06
C 14	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.400E-05
CU 66	1.021E-03	8.433E-11	4.751E-32	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 67	1.500E-08	1.467E-08	1.371E-08	1.146E-08	5.116E-09	4.703E-12	1.475E-15	4.624E-19	1.450E-22	4.546E-26	0.000E+00
ZN 69	6.948E-10	1.941E-10	3.437E-11	1.451E-11	3.861E-13	8.638E-27	1.535E-42	2.728E-58	4.847E-74	8.614E-90	0.000E+00
ZN 69M	4.526E-11	4.093E-11	3.025E-11	1.351E-11	3.595E-13	8.044E-27	1.429E-42	2.540E-58	4.514E-74	8.022E-90	0.000E+00
GA 70	1.326E-12	2.644E-14	1.933E-19	3.891E-33	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CO 72	1.819E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NI 72	5.994E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 72	1.294E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 72	1.473E+02	1.430E+02	1.308E+02	1.030E+02	3.522E+01	3.215E-03	7.015E-08	1.531E-12	3.340E-17	7.289E-22	0.000E+00
GA 72	1.482E+02	1.479E+02	1.450E+02	1.284E+02	4.998E+01	4.614E-03	1.007E-07	2.197E-12	4.794E-17	1.046E-21	0.000E+00
CO 73	1.955E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NI 73	3.072E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 73	2.301E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 73	4.909E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 73	5.057E+02	3.812E+02	1.626E+02	1.676E+01	6.071E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 73M	5.057E+02	3.812E+02	1.626E+02	1.676E+01	6.071E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CO 74	1.490E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NI 74	4.897E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 74	5.146E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 74	1.250E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 74	1.296E+03	5.554E-02	2.320E-15	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
CO 75	1.958E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NI 75	2.006E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 75	5.654E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 75	2.768E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 75	3.136E+03	3.282E-16	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 75	3.146E+03	1.182E+03	5.803E+01	1.877E-02	3.694E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 75M	1.302E+02	2.299E-17	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 75	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NI 76	6.561E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 76	5.488E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 76	6.483E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 76	9.078E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 76	9.679E+01	9.183E+01	7.841E+01	5.145E+01	7.724E+00	5.634E-07	3.279E-15	1.909E-23	1.111E-31	6.466E-40	0.000E+00
NI 77	9.087E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 77	2.358E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 77	7.510E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 77	1.824E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 77	7.195E+03	6.370E+03	4.409E+03	1.652E+03	1.995E+01	4.751E-16	3.134E-35	2.067E-54	1.364E-73	8.996E-93	0.000E+00
GE 77M	1.704E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 77	2.053E+04	2.005E+04	1.855E+04	1.462E+04	4.220E+03	6.103E-02	1.586E-07	4.120E-13	1.071E-18	2.781E-24	0.000E+00
SE 77M	5.170E+01	4.973E+01	4.601E+01	3.627E+01	1.047E+01	1.514E-04	3.933E-10	1.022E-15	2.655E-21	6.899E-27	0.000E+00
NI 78	1.020E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 78	8.942E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 78	8.615E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 78	3.718E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 78	4.152E+04	1.597E+04	9.073E+02	4.326E-01	4.879E-16	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 78	4.198E+04	3.172E+04	4.673E+03	6.768E+00	6.633E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 79	1.045E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 79	3.325E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 79	3.389E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
GE 79	8.815E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 79	1.071E+05	1.114E+01	1.013E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 79	1.939E-01	1.939E-01	1.939E-01	1.939E-01	1.939E-01	1.939E-01	1.939E-01	1.939E-01	1.939E-01	1.939E-01	1.939E-01
SE 79M	1.072E+05	1.962E+01	1.784E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 79M	5.675E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 80	1.416E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 80	1.516E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 80	4.425E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 80	2.229E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 80	2.535E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 80	1.457E+00	5.205E-01	2.006E-01	1.631E-02	2.034E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 80M	6.574E-01	4.804E-01	1.875E-01	1.524E-02	1.900E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CU 81	7.412E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 81	2.651E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 81	2.353E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 81	2.908E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 81	4.124E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 81	4.313E+05	9.540E+03	6.155E+01	5.568E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 81M	1.385E+04	3.244E+03	4.167E+01	3.770E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 81	1.660E-08	1.660E-08	1.660E-08	1.660E-08	1.660E-08	1.660E-08	1.660E-08	1.660E-08	1.660E-08	1.660E-08	1.660E-08
KR 81M	1.705E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 82	2.674E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 82	7.728E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 82	2.705E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 82	4.356E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 82M	1.642E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 82	1.054E+04	1.015E+04	9.022E+03	6.590E+03	1.603E+03	7.665E-03	5.565E-09	4.041E-15	2.934E-21	2.130E-27	0.000E+00
BR 82M	4.742E+03	6.068E-03	1.271E-20	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZN 83	2.053E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 83	1.916E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
GE 83	1.972E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 83	8.471E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 83	4.045E+05	1.011E+04	1.543E-01	2.210E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 83M	6.722E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 83	1.084E+06	6.513E+05	1.146E+05	1.107E+03	9.449E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 83M	1.084E+06	9.529E+05	3.001E+05	4.281E+03	4.031E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GA 84	1.106E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 84	3.847E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 84	6.369E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 84	1.999E+06	2.284E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 84	2.036E+06	1.660E+05	6.489E+01	5.302E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 84M	3.884E+04	3.704E-02	3.213E-20	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 85	1.291E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 85	4.159E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 85	1.266E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 85M	9.243E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 85	2.532E+06	7.572E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 85	5.947E+03	5.954E+03	5.965E+03	5.971E+03	5.969E+03	5.941E+03	5.910E+03	5.878E+03	5.847E+03	5.816E+03	5.599E+03
KR 85M	2.561E+06	1.903E+06	7.521E+05	6.328E+04	9.202E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 86	2.286E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 86	2.287E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 86	2.648E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 86	1.916E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 86M	1.932E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 86	3.851E+03	3.839E+03	3.803E+03	3.710E+03	3.319E+03	1.263E+03	4.144E+02	1.360E+02	4.461E+01	1.463E+01	4.934E-03
RB 86M	7.264E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 87	3.667E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 87	1.293E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 87	1.965E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 87	4.357E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
KR 87	5.172E+06	1.757E+06	6.676E+04	1.089E+01	9.842E-17	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 87	1.300E-05	1.301E-05	1.301E-05	1.301E-05	1.301E-05	1.301E-05	1.301E-05	1.301E-05	1.301E-05	1.301E-05	1.301E-05
SR 87M	4.347E+00	2.652E+00	6.022E-01	1.156E-02	2.175E-10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GE 88	4.195E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 88	5.282E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 88	7.173E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 88	5.018E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 88	7.319E+06	4.496E+06	1.039E+06	2.089E+04	4.845E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 88	7.390E+06	5.013E+06	1.160E+06	2.333E+04	5.410E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AS 89	4.159E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 89	1.863E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 89	3.785E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 89	9.274E+06	3.766E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 89	9.620E+06	5.079E+04	3.768E-03	3.662E-22	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 89	5.594E+06	5.590E+06	5.571E+06	5.520E+06	5.297E+06	3.707E+06	2.456E+06	1.627E+06	1.078E+06	7.140E+05	3.723E+04
Y 89M	6.446E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 90	6.451E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 90	2.548E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 90	9.229E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 90	9.549E+06	9.041E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 90M	1.990E+06	8.557E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 90	4.657E+04	4.657E+04	4.657E+04	4.657E+04	4.656E+04	4.648E+04	4.639E+04	4.630E+04	4.621E+04	4.612E+04	4.548E+04
Y 90	4.897E+04	4.892E+04	4.878E+04	4.843E+04	4.742E+04	4.650E+04	4.642E+04	4.633E+04	4.624E+04	4.615E+04	4.549E+04
Y 90M	3.111E+01	1.989E+01	5.201E+00	1.453E-01	1.482E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR 90M	2.720E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 91	6.458E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 91	7.897E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 91	6.807E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 91	1.130E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 91	1.178E+07	1.020E+07	6.585E+06	2.049E+06	1.072E+04	1.808E-16	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
Y 91	6.155E+06	6.160E+06	6.167E+06	6.151E+06	5.951E+06	4.373E+06	3.065E+06	2.148E+06	1.506E+06	1.055E+06	8.244E+04
Y 91M	6.836E+06	6.358E+06	4.184E+06	1.302E+06	6.810E+03	1.149E-16	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE 92	9.665E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 92	3.812E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 92	2.980E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 92	9.567E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 92	1.207E+07	7.240E+06	1.561E+06	2.606E+04	2.619E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 92	1.211E+07	1.120E+07	5.665E+06	3.837E+05	3.511E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 93	9.452E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 93	1.013E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 93	7.092E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 93	1.283E+07	1.972E+02	7.006E-13	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 93	1.303E+07	1.150E+07	7.620E+06	2.541E+06	1.816E+04	4.579E-15	1.589E-36	5.517E-58	1.915E-79	6.646-101	0.000E+00
ZR 93	9.872E-01	9.885E-01	9.914E-01	9.953E-01	9.972E-01	9.972E-01	9.972E-01	9.972E-01	9.972E-01	9.972E-01	9.972E-01
NB 93M	4.107E-03	4.118E-03	4.151E-03	4.238E-03	4.633E-03	8.046E-03	1.197E-02	1.588E-02	1.977E-02	2.364E-02	5.097E-02
BR 94	6.568E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 94	4.556E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 94	3.553E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 94	1.186E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 94	1.258E+07	1.724E+05	3.654E-01	2.707E-16	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 94	1.081E-05	1.081E-05	1.081E-05	1.081E-05	1.081E-05	1.081E-05	1.081E-05	1.081E-05	1.081E-05	1.081E-05	1.081E-05
NB 94M	1.050E+00	1.781E-06	8.689E-24	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BR 95	1.490E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 95	2.058E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 95	1.819E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 95	1.095E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 95	1.289E+07	4.846E+03	2.314E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR 95	6.391E+06	6.386E+06	6.369E+06	6.323E+06	6.121E+06	4.619E+06	3.337E+06	2.411E+06	1.742E+06	1.259E+06	1.223E+05
NB 95	2.869E+06	2.874E+06	2.892E+06	2.937E+06	3.125E+06	3.987E+06	3.940E+06	3.433E+06	2.805E+06	2.206E+06	2.630E+05
NB 95M	4.214E+04	4.218E+04	4.229E+04	4.255E+04	4.296E+04	3.425E+04	2.476E+04	1.789E+04	1.292E+04	9.337E+03	9.072E+02

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
BR 96	6.797E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KR 96	3.363E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 96	4.055E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 96	7.579E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 96	1.212E+07	2.430E-09	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB96	2.840E+04	2.676E+04	2.240E+04	1.393E+04	1.643E+03	1.483E-05	7.740E-15	4.040E-24	2.109E-33	1.101E-42	0.000E+00
KR 97	8.268E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 97	7.327E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 97	3.885E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 97	1.020E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR 97	1.203E+07	1.108E+07	8.667E+06	4.496E+06	2.346E+05	1.801E-06	2.694E-19	4.032E-32	6.033E-45	9.029E-58	0.000E+00
NB 97	1.208E+07	1.162E+07	9.295E+06	4.520E+06	2.358E+05	1.940E-06	2.903E-19	4.345E-32	6.501E-45	9.729E-58	0.000E+00
NB 97M	1.140E+07	1.050E+07	8.209E+06	4.259E+06	2.222E+05	1.706E-06	2.552E-19	3.819E-32	5.715E-45	8.552E-58	0.000E+00
KR 98	8.622E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 98	1.060E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 98	1.412E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 98	7.298E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR 98	1.169E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 98	9.337E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 98M	1.175E+07	2.360E+06	1.856E+04	4.541E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 99	8.188E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 99	3.104E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 99	4.060E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR 99	1.155E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 99	1.183E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 99M	3.061E+05	3.910E-09	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO 99	1.247E+07	1.222E+07	1.147E+07	9.695E+06	4.552E+06	6.487E+03	3.374E+00	1.754E-03	9.124E-07	4.745E-10	0.000E+00
TC 99	6.010E+00	6.019E+00	6.047E+00	6.114E+00	6.312E+00	6.487E+00	6.487E+00	6.487E+00	6.487E+00	6.487E+00	6.487E+00
TC 99M	1.123E+07	1.114E+07	1.074E+07	9.290E+06	4.387E+06	6.250E+03	3.250E+00	1.690E-03	8.790E-07	4.571E-10	0.000E+00
RB100	3.455E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
SR100	4.798E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y100	1.774E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR100	1.078E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB100	6.350E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB100M	6.350E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC100	1.787E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR101	5.963E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y101	5.473E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR101	7.011E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB101	1.008E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO101	1.034E+07	3.533E+04	1.367E-03	2.339E-23	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC101	1.034E+07	2.200E+05	2.400E-02	7.091E-22	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR102	3.980E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y102	1.086E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR102	3.604E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB102	7.761E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO102	8.623E+06	4.910E+03	8.472E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC102	8.626E+06	4.950E+03	8.540E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC102M	2.851E+03	1.415E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR103	9.745E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y103	1.081E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR103	1.076E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB103	4.505E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO103	6.428E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC103	6.467E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU103	4.286E+06	4.280E+06	4.261E+06	4.211E+06	3.994E+06	2.525E+06	1.487E+06	8.758E+05	5.158E+05	3.038E+05	6.815E+03
RH103M	3.864E+06	3.858E+06	3.841E+06	3.797E+06	3.601E+06	2.276E+06	1.340E+06	7.895E+05	4.650E+05	2.739E+05	6.144E+03
SR104	1.711E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y104	5.195E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR104	1.637E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
NB104	1.663E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO104	3.797E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC104	3.925E+06	4.446E+04	4.937E-02	6.531E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH104	1.196E+06	4.904E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH104M	8.661E+04	4.113E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y105	4.554E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR105	2.103E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB105	4.395E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO105	1.967E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC105	2.189E+06	7.447E+01	2.117E-12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU105	2.210E+06	1.672E+06	6.550E+05	5.385E+04	7.053E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH105	1.478E+06	1.496E+06	1.450E+06	1.120E+06	2.751E+05	1.341E+00	9.952E-07	7.388E-13	5.485E-19	4.072E-25	0.000E+00
RH105M	6.187E+05	4.694E+05	1.839E+05	1.512E+04	1.980E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR106	4.996E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB106	1.479E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO106	7.839E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC106	9.234E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU106	9.771E+04	9.770E+04	9.765E+04	9.753E+04	9.698E+04	9.235E+04	8.728E+04	8.248E+04	7.795E+04	7.367E+04	4.913E+04
RH106	5.505E+05	9.770E+04	9.765E+04	9.753E+04	9.698E+04	9.235E+04	8.728E+04	8.248E+04	7.795E+04	7.367E+04	4.913E+04
RH106M	2.209E+05	1.176E+05	1.776E+04	1.149E+02	1.615E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y107	7.500E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR107	2.395E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB107	2.345E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO107	2.876E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC107	4.261E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU107	4.678E+05	1.333E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH107	4.683E+05	1.287E+04	1.304E-01	6.279E-15	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD107	7.544E-03	7.548E-03	7.548E-03	7.548E-03	7.548E-03	7.548E-03	7.548E-03	7.548E-03	7.548E-03	7.548E-03	7.548E-03
PD107M	5.992E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR108	5.527E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
NB108	1.749E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO108	7.129E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC108	1.885E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU108	2.389E+05	2.281E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH108	2.396E+05	2.433E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH108M	7.005E+02	5.282E-04	2.264E-22	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG108	5.201E-01	1.762E-08	1.762E-08	1.762E-08	1.762E-08	1.761E-08	1.760E-08	1.760E-08	1.759E-08	1.758E-08	1.752E-08
AG108M	1.980E-07	1.980E-07	1.980E-07	1.980E-07	1.980E-07	1.979E-07	1.978E-07	1.977E-07	1.976E-07	1.975E-07	1.969E-07
ZR109	4.517E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB109	5.844E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO109	9.442E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC109	6.361E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU109	1.227E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH109	1.254E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH109M	6.271E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD109	1.462E+05	1.326E+05	9.735E+04	4.271E+04	1.048E+03	1.164E-11	9.217E-28	7.300E-44	5.781E-60	4.578E-76	0.000E+00
PD109M	6.306E+04	2.577E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG109M	1.461E+05	1.326E+05	9.738E+04	4.272E+04	1.048E+03	1.164E-11	9.220E-28	7.302E-44	5.783E-60	4.579E-76	0.000E+00
CD109	1.511E-05	1.511E-05	1.510E-05	1.509E-05	1.502E-05	1.445E-05	1.381E-05	1.321E-05	1.263E-05	1.208E-05	8.756E-06
NB110	2.858E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO110	1.287E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC110	2.122E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU110	7.515E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH110	7.838E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH110M	3.234E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG110	5.610E+04	2.502E+00	2.500E+00	2.496E+00	2.475E+00	2.303E+00	2.119E+00	1.950E+00	1.794E+00	1.651E+00	9.087E-01
AG110M	1.882E+02	1.881E+02	1.880E+02	1.876E+02	1.861E+02	1.731E+02	1.593E+02	1.466E+02	1.349E+02	1.241E+02	6.832E+01
NB111	8.869E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO111	8.651E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC111	5.560E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
RU111	4.632E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH111	5.985E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD111	6.061E+04	1.806E+03	1.656E+02	2.204E+01	2.526E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD111M	6.218E+02	4.840E+02	2.272E+02	3.025E+01	3.467E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG111	6.013E+04	5.980E+04	5.844E+04	5.493E+04	4.155E+04	3.699E+03	2.269E+02	1.392E+01	8.542E-01	5.241E-02	1.057E-10
AG111M	6.031E+04	1.916E+03	1.876E+02	2.497E+01	2.870E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD111M	5.162E+00	9.356E-01	5.569E-03	6.482E-09	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO112	1.001E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC112	1.155E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU112	2.242E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH112	3.903E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD112	4.164E+04	3.887E+04	3.160E+04	1.820E+04	1.520E+03	6.861E-07	1.130E-17	1.862E-28	3.068E-39	5.055E-50	0.000E+00
AG112	4.263E+04	4.174E+04	3.629E+04	2.153E+04	1.800E+03	8.127E-07	1.339E-17	2.206E-28	3.634E-39	5.988E-50	0.000E+00
MO113	6.576E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC113	2.508E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU113	1.185E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH113	3.260E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD113	3.929E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG113	3.540E+04	2.738E+04	1.249E+04	1.541E+03	1.255E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG113M	3.966E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD113M	6.346E+00	6.351E+00	6.358E+00	6.364E+00	6.362E+00	6.341E+00	6.316E+00	6.291E+00	6.267E+00	6.242E+00	6.070E+00
IN113M	7.723E-06	3.347E-06	2.725E-07	3.392E-10	2.874E-23	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO114	4.603E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC114	3.543E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU114	4.302E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH114	2.222E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD114	3.572E+04	3.210E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG114	3.609E+04	3.314E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN114	2.052E-01	2.577E-02	2.568E-02	2.544E-02	2.440E-02	1.695E-02	1.114E-02	7.320E-03	4.809E-03	3.160E-03	1.554E-04
IN114M	2.696E-02	2.693E-02	2.684E-02	2.659E-02	2.549E-02	1.772E-02	1.164E-02	7.648E-03	5.025E-03	3.302E-03	1.623E-04

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
MO115	1.970E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC115	3.437E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU115	1.020E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH115	1.184E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD115	3.149E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG115	2.397E+04	3.870E+02	1.476E-03	5.244E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG115M	9.256E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD115	3.160E+04	3.094E+04	2.863E+04	2.327E+04	9.149E+03	2.808E+00	2.484E-04	2.197E-08	1.943E-12	1.718E-16	0.000E+00
CD115M	1.795E+03	1.793E+03	1.786E+03	1.767E+03	1.687E+03	1.126E+03	7.063E+02	4.431E+02	2.780E+02	1.744E+02	6.149E+00
IN115	4.032E-12	4.042E-12	4.072E-12	4.145E-12	4.345E-12	4.599E-12	4.701E-12	4.766E-12	4.806E-12	4.831E-12	4.873E-12
IN115M	3.219E+04	3.194E+04	3.048E+04	2.525E+04	9.949E+03	3.133E+00	4.991E-02	3.114E-02	1.954E-02	1.226E-02	4.322E-04
TC116	1.990E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU116	1.808E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH116	5.517E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD116	3.003E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG116	1.733E+04	6.234E-10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG116M	1.733E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN116	1.449E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN116M	1.144E+04	2.462E+03	2.455E+01	1.130E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC117	2.433E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU117	9.717E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH117	1.219E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD117	3.224E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG117	1.697E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG117M	1.697E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD117	2.213E+04	1.306E+04	2.638E+03	3.705E+01	1.708E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD117M	1.191E+04	7.940E+03	2.337E+03	8.953E+01	3.778E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN117	2.035E+04	1.805E+04	6.741E+03	1.761E+02	5.059E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN117M	2.582E+04	2.272E+04	8.160E+03	2.146E+02	3.933E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN117M	1.377E+01	1.371E+01	1.355E+01	1.311E+01	1.130E+01	3.120E+00	7.068E-01	1.601E-01	3.627E-02	8.217E-03	1.945E-07

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
RU118	1.569E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH118	5.366E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD118	1.364E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG118	2.602E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG118M	1.421E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD118	3.733E+04	7.154E+03	5.013E+01	9.011E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN118	3.734E+04	7.166E+03	5.021E+01	9.026E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN118M	9.700E+00	7.398E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH119	1.070E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD119	7.415E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG119	2.640E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD119	1.770E+04	2.563E+00	7.586E-12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD119M	1.770E+04	9.344E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN119	1.026E+04	2.733E+01	2.622E-05	2.310E-21	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN119M	2.663E+04	4.707E+02	4.515E-04	3.979E-20	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN119M	8.551E+01	8.550E+01	8.544E+01	8.528E+01	8.456E+01	7.856E+01	7.217E+01	6.630E+01	6.090E+01	5.595E+01	3.044E+01
RU120	7.765E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH120	1.163E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD120	2.387E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG120	1.808E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD120	3.606E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN120	1.842E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN120M	1.842E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH121	1.195E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD121	6.195E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG121	1.048E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD121	3.540E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN121	3.034E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN121M	8.346E+03	9.972E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN121	3.938E+04	3.742E+04	3.205E+04	2.119E+04	3.291E+03	3.223E-04	2.636E-12	2.155E-20	1.762E-28	1.441E-36	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
SN121M	4.276E-02	4.276E-02	4.276E-02	4.275E-02	4.275E-02	4.271E-02	4.266E-02	4.261E-02	4.256E-02	4.251E-02	4.217E-02
RH122	1.229E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD122	1.478E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG122	5.419E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD122	3.395E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN122	3.718E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN122M	3.233E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB122	2.625E+03	2.569E+03	2.410E+03	2.031E+03	9.401E+02	1.188E+00	5.372E-04	2.430E-07	1.099E-10	4.974E-14	0.000E+00
SB122M	2.500E+01	6.268E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH123	1.146E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD123	3.302E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG123	2.670E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD123	3.119E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN123	3.068E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN123M	1.367E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN123	3.292E+03	3.291E+03	3.286E+03	3.274E+03	3.222E+03	2.803E+03	2.386E+03	2.031E+03	1.729E+03	1.472E+03	4.638E+02
SN123M	3.660E+04	4.633E+03	9.169E+00	5.657E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE123	5.009E-14	5.010E-14	5.014E-14	5.023E-14	5.065E-14	5.397E-14	5.724E-14	5.998E-14	6.229E-14	6.422E-14	7.150E-14
TE123M	7.431E-01	7.427E-01	7.416E-01	7.388E-01	7.260E-01	6.245E-01	5.249E-01	4.412E-01	3.708E-01	3.117E-01	8.962E-02
PD124	6.500E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG124	1.213E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD124	3.006E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN124	5.782E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB124	6.410E+02	6.404E+02	6.386E+02	6.337E+02	6.122E+02	4.538E+02	3.212E+02	2.274E+02	1.610E+02	1.140E+02	9.563E+00
SB124M	2.193E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG125	2.905E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD125	1.639E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN125	2.809E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN125M	2.153E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN125	3.256E+04	3.236E+04	3.179E+04	3.030E+04	2.442E+04	3.766E+03	4.355E+02	5.038E+01	5.827E+00	6.739E-01	1.284E-07

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
SN125M	5.028E+04	8.157E+00	3.373E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB125	3.079E+03	3.081E+03	3.086E+03	3.099E+03	3.149E+03	3.288E+03	3.252E+03	3.190E+03	3.125E+03	3.062E+03	2.642E+03
TE125M	1.941E+02	1.946E+02	1.962E+02	2.003E+02	2.185E+02	3.599E+02	4.783E+02	5.573E+02	6.080E+02	6.391E+02	6.363E+02
PD126	8.325E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AG126	1.104E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD126	1.680E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN126	9.859E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN126	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01
SB126	2.497E+03	2.486E+03	2.452E+03	2.362E+03	1.997E+03	4.667E+02	8.721E+01	1.631E+01	3.068E+00	5.929E-01	2.433E-02
SB126M	1.133E+03	1.440E+01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01	1.738E-01
CD127	8.439E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN127	5.540E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN127M	5.560E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN127	2.105E+05	1.088E+05	1.502E+04	7.638E+01	3.647E-09	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN127M	1.045E+05	1.904E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB127	3.369E+05	3.342E+05	3.216E+05	2.855E+05	1.664E+05	1.541E+03	6.949E+00	3.133E-02	1.412E-04	6.368E-07	9.453E-24
TE127	3.170E+05	3.150E+05	3.080E+05	2.827E+05	1.731E+05	1.390E+04	1.028E+04	8.488E+03	7.014E+03	5.796E+03	1.475E+03
TE127M	1.362E+04	1.364E+04	1.369E+04	1.381E+04	1.413E+04	1.268E+04	1.049E+04	8.666E+03	7.161E+03	5.917E+03	1.506E+03
AG128	2.947E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD128	3.726E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN128	1.298E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN128	7.564E+05	1.847E+05	2.690E+03	3.402E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB128	3.418E+04	2.930E+04	1.847E+04	5.395E+03	2.122E+01	3.027E-20	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB128M	7.825E+05	2.245E+05	3.266E+03	4.129E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I128	1.817E+04	6.508E+02	2.990E-02	8.100E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD129	6.399E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN129	8.109E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN129	4.602E+05	7.023E+00	2.495E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN129M	7.103E+05	2.524E-09	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB129	1.411E+06	1.038E+06	3.965E+05	3.042E+04	2.920E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
TE129	1.356E+06	1.198E+06	5.658E+05	1.334E+05	9.143E+04	5.347E+04	2.880E+04	1.551E+04	8.352E+03	4.498E+03	5.308E+01
TE129M	1.515E+05	1.515E+05	1.512E+05	1.494E+05	1.405E+05	8.215E+04	4.424E+04	2.383E+04	1.283E+04	6.910E+03	8.155E+01
I129	9.884E-03	9.898E-03	9.925E-03	9.951E-03	1.000E-02	1.035E-02	1.057E-02	1.069E-02	1.075E-02	1.079E-02	1.083E-02
XE129M	3.091E+01	3.069E+01	3.003E+01	2.834E+01	2.186E+01	2.297E+00	1.707E-01	1.269E-02	9.432E-04	7.011E-05	5.598E-13
CD130	1.639E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN130	1.500E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN130	1.921E+06	3.740E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB130	4.479E+05	5.599E+04	1.094E+02	6.519E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB130M	2.537E+06	9.792E+00	6.154E-17	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I130	5.396E+04	4.844E+04	3.460E+04	1.411E+04	2.489E+02	1.584E-13	4.630E-31	1.353E-48	3.956E-66	1.156E-83	0.000E+00
I130M	2.267E+04	2.197E+00	1.998E-12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD131	1.566E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN131	4.941E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN131	1.985E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB131	5.213E+06	1.427E+05	2.770E+00	7.547E-13	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE131	5.275E+06	8.597E+05	1.425E+05	9.843E+04	1.865E+04	1.021E-02	6.088E-10	3.629E-17	2.163E-24	1.289E-31	0.000E+00
TE131M	7.565E+05	7.267E+05	6.328E+05	4.372E+05	8.283E+04	4.537E-02	2.704E-09	1.612E-16	9.608E-24	5.727E-31	0.000E+00
I131	5.983E+06	5.965E+06	5.854E+06	5.556E+06	4.337E+06	4.627E+05	3.484E+04	2.624E+03	1.976E+02	1.488E+01	1.305E-07
XE131M	6.148E+04	6.150E+04	6.156E+04	6.163E+04	6.048E+04	2.473E+04	5.367E+03	1.014E+03	1.827E+02	3.227E+01	1.171E-04
CD132	1.249E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN132	1.333E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN132	1.194E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB132	3.381E+06	4.712E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB132M	2.166E+06	5.431E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE132	8.914E+06	8.761E+06	8.308E+06	7.209E+06	3.808E+06	1.508E+04	2.550E+01	4.313E-02	7.293E-05	1.233E-07	1.614E-27
I132	9.057E+06	8.955E+06	8.548E+06	7.427E+06	3.923E+06	1.554E+04	2.628E+01	4.444E-02	7.514E-05	1.271E-07	1.662E-27
CS132	7.624E+01	7.556E+01	7.357E+01	6.850E+01	4.968E+01	3.071E+00	1.237E-01	4.985E-03	2.008E-04	8.091E-06	7.987E-16
IN133	7.981E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN133	3.408E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB133	4.533E+06	4.029E-09	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
TE133	7.896E+06	2.313E+05	2.448E+03	1.487E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE133M	5.918E+06	1.320E+06	1.460E+04	8.870E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I133	1.377E+07	1.316E+07	1.083E+07	6.355E+06	5.768E+05	5.372E-04	2.041E-14	7.756E-25	2.947E-35	1.120E-45	0.000E+00
I133M	2.652E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE133	1.355E+07	1.355E+07	1.350E+07	1.308E+07	9.598E+06	3.169E+05	6.017E+03	1.142E+02	2.168E+00	4.114E-02	1.837E-14
XE133M	4.109E+05	4.103E+05	4.053E+05	3.738E+05	1.802E+05	5.093E+01	3.827E-03	2.876E-07	2.162E-11	1.625E-15	0.000E+00
IN134	1.436E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN134	2.407E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB134	5.455E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB134M	5.215E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE134	1.356E+07	1.855E+06	4.739E+03	5.782E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I134	1.543E+07	6.811E+06	1.034E+05	3.881E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I134M	9.285E+05	1.602E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE134M	4.953E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS134	3.763E+04	3.764E+04	3.765E+04	3.763E+04	3.752E+04	3.664E+04	3.564E+04	3.467E+04	3.372E+04	3.281E+04	2.691E+04
CS134M	1.751E+05	1.085E+05	2.587E+04	5.648E+02	1.897E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN135	2.503E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB135	3.967E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE135	6.639E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I135	1.275E+07	1.034E+07	5.513E+06	1.030E+06	5.425E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE135	4.706E+05	2.044E+06	4.056E+06	2.796E+06	2.148E+04	4.934E-17	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE135M	2.317E+06	1.658E+06	8.830E+05	1.650E+05	8.689E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS135	3.330E-02	3.339E-02	3.408E-02	3.612E-02	3.846E-02	3.847E-02	3.847E-02	3.847E-02	3.847E-02	3.847E-02	3.847E-02
CS135M	4.279E+04	8.909E+03	8.037E+01	2.834E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA135M	8.026E+00	7.648E+00	6.616E+00	4.495E+00	7.896E-01	2.244E-07	6.275E-15	1.755E-22	4.907E-30	1.372E-37	0.000E+00
SN136	1.104E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB136	6.029E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE136	3.785E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I136	6.191E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I136M	3.941E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
CS136	2.707E+04	2.695E+04	2.660E+04	2.568E+04	2.191E+04	5.536E+03	1.132E+03	2.315E+02	4.735E+01	9.684E+00	1.101E-04
BA136M	4.461E+03	4.442E+03	4.383E+03	4.231E+03	3.610E+03	9.124E+02	1.866E+02	3.816E+01	7.804E+00	1.596E+00	1.814E-05
SB137	4.308E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE137	8.507E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I137	6.579E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE137	1.214E+07	4.774E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS137	4.848E+04	4.849E+04	4.849E+04	4.848E+04	4.847E+04	4.839E+04	4.830E+04	4.821E+04	4.812E+04	4.803E+04	4.738E+04
BA137M	4.641E+04	4.587E+04	4.587E+04	4.587E+04	4.586E+04	4.578E+04	4.569E+04	4.561E+04	4.552E+04	4.544E+04	4.482E+04
SB138	2.692E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE138	1.759E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I138	3.340E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE138	1.262E+07	3.571E+04	8.032E-04	3.239E-24	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS138	1.362E+07	1.754E+06	7.682E+02	8.141E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS138M	5.049E+05	1.765E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA138	8.863E-11	8.863E-11	8.863E-11	8.863E-11	8.863E-11	8.863E-11	8.863E-11	8.863E-11	8.863E-11	8.863E-11	8.863E-11
SB139	1.211E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE139	2.622E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I139	1.482E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE139	1.025E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS139	1.292E+07	1.966E+03	5.818E-09	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA139	1.306E+07	5.418E+06	2.651E+05	8.492E+01	1.600E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE140	2.442E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I140	4.345E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE140	7.153E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS140	1.168E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA140	1.243E+07	1.238E+07	1.221E+07	1.178E+07	1.001E+07	2.446E+06	4.813E+05	9.468E+04	1.863E+04	3.665E+03	3.153E-02
LA140	1.255E+07	1.255E+07	1.252E+07	1.239E+07	1.119E+07	2.816E+06	5.539E+05	1.090E+05	2.144E+04	4.217E+03	3.629E-02
TE141	8.471E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I141	6.197E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE141	2.370E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
CS141	8.921E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA141	1.192E+07	1.277E+05	1.491E-01	2.255E-17	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA141	1.197E+07	9.121E+06	3.170E+06	1.886E+05	5.772E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE141	8.762E+06	8.766E+06	8.749E+06	8.641E+06	8.106E+06	4.657E+06	2.456E+06	1.296E+06	6.835E+05	3.606E+05	3.668E+03
TE142	1.700E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I142	4.499E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE142	7.687E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS142	5.726E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA142	1.168E+07	4.922E+03	3.664E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA142	1.189E+07	5.467E+06	3.705E+05	2.827E+02	2.647E-12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE142	1.345E-05	1.346E-05	1.347E-05	1.347E-05	1.347E-05	1.347E-05	1.347E-05	1.347E-05	1.347E-05	1.347E-05	1.347E-05
PR142	1.015E+05	9.464E+04	7.615E+04	4.265E+04	3.140E+03	4.764E-07	2.230E-18	1.044E-29	4.888E-41	2.288E-52	0.000E+00
PR142M	2.242E+04	7.522E+01	2.842E-06	4.570E-26	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I143	1.841E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE143	1.049E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS143	3.062E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA143	1.067E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA143	1.189E+07	3.173E+04	5.764E-04	1.314E-24	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE143	1.216E+07	1.174E+07	1.035E+07	7.399E+06	1.631E+06	3.312E+00	8.958E-07	2.423E-13	6.552E-20	1.772E-26	0.000E+00
PR143	1.125E+07	1.125E+07	1.125E+07	1.117E+07	1.011E+07	2.727E+06	5.887E+05	1.271E+05	2.744E+04	5.924E+03	9.929E-02
I144	7.023E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE144	1.325E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS144	6.407E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA144	8.561E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA144	1.081E+07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE144	1.539E+06	1.539E+06	1.538E+06	1.535E+06	1.524E+06	1.430E+06	1.329E+06	1.236E+06	1.149E+06	1.068E+06	6.316E+05
PR144	2.151E+06	1.542E+06	1.538E+06	1.535E+06	1.524E+06	1.430E+06	1.330E+06	1.236E+06	1.149E+06	1.068E+06	6.317E+05
PR144M	1.854E+04	1.846E+04	1.845E+04	1.842E+04	1.829E+04	1.716E+04	1.595E+04	1.483E+04	1.378E+04	1.281E+04	7.580E+03
ND144	1.111E-10	1.113E-10	1.116E-10	1.125E-10	1.167E-10	1.514E-10	1.888E-10	2.236E-10	2.559E-10	2.860E-10	4.476E-10
XE145	3.074E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
CS145	1.452E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA145	4.013E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA145	7.427E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE145	7.915E+06	8.652E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR145	7.917E+06	6.341E+06	3.163E+06	4.952E+05	1.177E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE146	2.821E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS146	1.639E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA146	1.363E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA146	4.636E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE146	6.000E+06	1.729E+04	4.037E-04	1.798E-24	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR146	6.018E+06	4.452E+05	1.562E+01	1.787E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE147	5.128E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS147	1.200E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA147	2.635E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA147	2.156E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE147	4.505E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR147	4.614E+06	5.013E+03	4.669E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND147	4.375E+06	4.356E+06	4.288E+06	4.113E+06	3.408E+06	6.681E+05	1.019E+05	1.555E+04	2.373E+03	3.620E+02	5.030E-04
PM147	1.014E+05	1.016E+05	1.024E+05	1.044E+05	1.123E+05	1.414E+05	1.448E+05	1.427E+05	1.398E+05	1.368E+05	1.171E+05
SM147	4.672E-08	4.687E-08	4.732E-08	4.854E-08	5.431E-08	1.147E-07	1.914E-07	2.680E-07	3.431E-07	4.167E-07	9.003E-07
CS148	3.730E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA148	3.079E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA148	7.220E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE148	3.091E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR148	3.418E+06	9.506E-10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM148	5.255E+05	5.199E+05	5.034E+05	4.620E+05	3.141E+05	1.182E+04	7.761E+02	3.366E+02	2.007E+02	1.212E+02	3.272E+00
PM148M	2.669E+04	2.665E+04	2.654E+04	2.624E+04	2.495E+04	1.613E+04	9.749E+03	5.892E+03	3.561E+03	2.152E+03	5.810E+01
SM148	3.306E-12	3.317E-12	3.349E-12	3.429E-12	3.719E-12	4.399E-12	4.510E-12	4.565E-12	4.598E-12	4.618E-12	4.648E-12
BA149	1.887E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA149	1.440E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
CE149	1.583E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR149	2.171E+06	4.302E-10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND149	2.252E+06	1.033E+06	9.331E+04	1.534E+02	4.544E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM149	3.705E+06	3.650E+06	3.404E+06	2.765E+06	1.080E+06	3.124E+02	2.580E-02	2.131E-06	1.760E-10	1.454E-14	0.000E+00
SM149	5.099E-13	5.682E-13	7.358E-13	1.125E-12	2.146E-12	2.800E-12	2.800E-12	2.800E-12	2.800E-12	2.800E-12	2.800E-12
CS150	9.524E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA150	8.863E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA150	2.060E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE150	6.040E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR150	1.216E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM150	3.430E+05	2.044E+05	4.332E+04	6.909E+02	5.650E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA151	1.824E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE151	1.562E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR151	6.137E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND151	8.706E+05	1.068E+03	1.945E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM151	8.521E+05	8.176E+05	7.062E+05	4.778E+05	8.237E+04	1.991E-02	4.616E-10	1.070E-17	2.482E-25	5.755E-33	0.000E+00
SM151	1.544E+02	1.559E+02	1.599E+02	1.681E+02	1.823E+02	1.852E+02	1.851E+02	1.850E+02	1.849E+02	1.847E+02	1.839E+02
BA152	4.248E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA152	1.025E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE152	2.781E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR152	2.486E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND152	5.474E+05	3.981E+02	1.501E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM152	5.900E+05	6.187E+02	2.333E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM152M	7.672E+03	1.171E-01	4.159E-16	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU152	5.573E-01	5.573E-01	5.573E-01	5.572E-01	5.570E-01	5.550E-01	5.526E-01	5.503E-01	5.480E-01	5.457E-01	5.296E-01
EU152M	8.084E+01	6.967E+01	4.459E+01	1.356E+01	6.408E-02	4.474E-22	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD152	2.358E-14	2.366E-14	2.384E-14	2.406E-14	2.417E-14	2.424E-14	2.432E-14	2.440E-14	2.448E-14	2.456E-14	2.513E-14
LA153	3.154E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE153	2.691E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR153	6.677E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
ND153	3.073E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM153	3.417E+05	8.680E-02	7.411E-22	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM153	1.500E+06	1.457E+06	1.333E+06	1.051E+06	3.609E+05	3.424E+01	7.814E-04	1.783E-08	4.069E-13	9.285E-18	0.000E+00
GD153	3.585E+00	3.584E+00	3.582E+00	3.575E+00	3.544E+00	3.290E+00	3.019E+00	2.771E+00	2.543E+00	2.333E+00	1.260E+00
LA154	6.889E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE154	1.687E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR154	1.159E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND154	1.177E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM154	1.396E+05	2.261E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM154M	1.992E+04	1.701E-16	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU154	1.821E+03	1.821E+03	1.821E+03	1.820E+03	1.819E+03	1.809E+03	1.797E+03	1.785E+03	1.773E+03	1.761E+03	1.680E+03
CE155	7.283E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR155	1.439E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND155	3.747E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM155	7.095E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM155	8.078E+04	1.971E+03	2.589E-02	2.487E-15	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU155	1.197E+03	1.197E+03	1.197E+03	1.197E+03	1.196E+03	1.184E+03	1.170E+03	1.157E+03	1.144E+03	1.131E+03	1.041E+03
GD155M	4.939E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE156	2.220E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR156	1.130E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND156	7.715E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM156	2.535E+04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM156	3.294E+04	2.844E+04	1.827E+04	5.616E+03	2.778E+01	2.887E-19	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU156	1.390E+05	1.386E+05	1.373E+05	1.335E+05	1.165E+05	3.557E+04	9.044E+03	2.300E+03	5.847E+02	1.487E+02	8.055E-03
CE157	7.258E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR157	7.537E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND157	1.352E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM157	9.162E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM157	1.719E+04	5.711E-01	1.623E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU157	6.237E+04	5.708E+04	4.342E+04	2.093E+04	7.850E+02	3.442E-10	1.895E-24	1.043E-38	5.739E-53	3.159E-67	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
PR158	3.179E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND158	1.559E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM158	2.545E+03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM158	8.462E+03	1.278E+03	4.390E+00	1.181E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU158	9.580E+03	3.974E+03	4.424E+01	4.624E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR159	6.101E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ND159	8.078E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM159	3.651E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM159	2.610E+03	1.137E-10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU159	3.251E+03	3.747E+01	3.858E-05	4.170E-21	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD159	4.614E+03	4.339E+03	3.470E+03	1.912E+03	1.306E+02	1.040E-08	2.313E-20	5.146E-32	1.145E-43	2.546E-55	0.000E+00
ND160	2.053E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM160	1.123E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM160	9.960E+02	6.163E-04	1.459E-22	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU160	1.325E+03	7.218E-04	1.709E-22	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB160	1.009E+02	1.008E+02	1.006E+02	9.992E+01	9.709E+01	7.567E+01	5.676E+01	4.257E+01	3.193E+01	2.395E+01	3.043E+00
ND161	9.358E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM161	2.801E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM161	1.313E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU161	3.571E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD161	4.374E+02	9.158E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB161	5.178E+02	5.137E+02	5.010E+02	4.686E+02	3.470E+02	2.566E+01	1.271E+00	6.299E-02	3.121E-03	1.546E-04	6.729E-14
PM162	1.240E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM162	1.858E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU162	1.132E+02	1.061E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD162	2.041E+02	7.268E-02	1.058E-12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB162	2.018E+02	2.656E-01	4.097E-12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB162M	5.870E+00	3.376E+00	5.229E-01	3.619E-03	6.906E-13	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM163	1.258E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU163	1.937E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
GD163	6.581E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB163	7.112E+01	1.082E+00	2.998E-06	4.539E-21	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM164	7.016E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU164	2.990E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD164	2.321E+01	5.009E-01	5.034E-06	2.367E-19	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB164	2.953E+01	5.814E-01	5.842E-06	2.747E-19	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM165	3.154E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
EU165	3.781E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD165	7.312E+00	1.713E-21	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB165	1.294E+01	2.545E-21	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
DY165	7.970E+01	4.443E+01	7.570E+00	6.754E-02	4.041E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
DY165M	3.588E+01	5.132E-21	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
DY166	9.279E+00	9.123E+00	8.669E+00	7.566E+00	4.101E+00	2.033E-02	4.453E-05	9.756E-08	2.137E-10	4.682E-13	3.923E-32
HO166	1.923E+01	1.873E+01	1.731E+01	1.418E+01	6.562E+00	3.029E-02	6.635E-05	1.454E-07	3.184E-10	6.976E-13	5.845E-32
HO166M	1.514E-05	1.514E-05	1.514E-05	1.514E-05	1.514E-05	1.513E-05	1.513E-05	1.513E-05	1.513E-05	1.513E-05	1.513E-05
ER167M	1.983E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ER169	1.822E-02	1.811E-02	1.778E-02	1.692E-02	1.356E-02	1.994E-03	2.183E-04	2.390E-05	2.616E-06	2.863E-07	3.674E-14
TM170	1.667E-04	1.666E-04	1.664E-04	1.658E-04	1.632E-04	1.418E-04	1.206E-04	1.026E-04	8.731E-05	7.427E-05	2.328E-05
TM170M	1.978E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ER171	5.256E-10	4.371E-10	2.514E-10	5.752E-11	7.539E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TM171	1.203E-06	1.203E-06	1.202E-06	1.202E-06	1.198E-06	1.168E-06	1.133E-06	1.100E-06	1.068E-06	1.037E-06	8.383E-07
ER172	9.947E-13	9.669E-13	8.882E-13	7.083E-13	2.558E-13	3.753E-17	1.416E-21	5.343E-26	2.016E-30	7.607E-35	0.000E+00
TM172	6.304E-07	6.168E-07	5.777E-07	4.853E-07	2.214E-07	2.465E-10	9.635E-14	3.767E-17	1.473E-20	5.757E-24	0.000E+00
TOTAL	1.129E+09	3.369E+08	2.466E+08	1.795E+08	1.115E+08	3.937E+07	2.323E+07	1.604E+07	1.176E+07	8.887E+06	2.235E+06
ACTIVITY IN CURIES FOR FISSION PRODUCTS (BY ELEMENT)											
H	2.120E+02	2.120E+02	2.120E+02	2.120E+02	2.119E+02	2.111E+02	2.101E+02	2.091E+02	2.082E+02	2.072E+02	2.005E+02
BE	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06	1.339E-06
C	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.401E-05	5.400E-05
CO	2.183E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NI	1.673E+02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
CU	2.325E+03	1.475E-08	1.371E-08	1.146E-08	5.116E-09	4.703E-12	1.475E-15	4.624E-19	1.450E-22	4.546E-26	0.000E+00
ZN	3.240E+04	1.430E+02	1.308E+02	1.030E+02	3.522E+01	3.215E-03	7.015E-08	1.531E-12	3.340E-17	7.289E-22	0.000E+00
GA	1.810E+05	5.291E+02	3.075E+02	1.451E+02	4.998E+01	4.614E-03	1.007E-07	2.197E-12	4.794E-17	1.046E-21	0.000E+00
GE	1.193E+06	2.391E+04	5.537E+03	1.669E+03	1.995E+01	4.751E-16	3.134E-35	2.067E-54	1.364E-73	8.996E-93	0.000E+00
AS	3.699E+06	5.187E+04	2.330E+04	1.468E+04	4.228E+03	6.103E-02	1.586E-07	4.120E-13	1.071E-18	2.781E-24	0.000E+00
SE	1.141E+07	2.296E+04	1.496E+02	3.646E+01	1.066E+01	1.941E-01	1.939E-01	1.939E-01	1.939E-01	1.939E-01	1.939E-01
BR	2.610E+07	8.275E+05	1.237E+05	7.697E+03	1.603E+03	7.665E-03	5.565E-09	4.041E-15	2.934E-21	2.130E-27	0.000E+00
KR	4.592E+07	9.115E+06	2.164E+06	9.444E+04	5.969E+03	5.941E+03	5.910E+03	5.878E+03	5.847E+03	5.816E+03	5.599E+03
RB	6.237E+07	5.068E+06	1.164E+06	2.704E+04	3.319E+03	1.263E+03	4.144E+02	1.360E+02	4.461E+01	1.463E+01	4.947E-03
SR	7.838E+07	2.308E+07	1.376E+07	7.642E+06	5.355E+06	3.754E+06	2.502E+06	1.673E+06	1.124E+06	7.602E+05	8.271E+04
Y	9.976E+07	3.544E+07	2.368E+07	1.043E+07	6.023E+06	4.420E+06	3.111E+06	2.195E+06	1.552E+06	1.101E+06	1.279E+05
ZR	6.432E+07	1.747E+07	1.504E+07	1.082E+07	6.356E+06	4.619E+06	3.337E+06	2.411E+06	1.742E+06	1.259E+06	1.223E+05
NB	8.771E+07	2.743E+07	2.048E+07	1.177E+07	3.628E+06	4.021E+06	3.965E+06	3.451E+06	2.818E+06	2.216E+06	2.639E+05
MO	4.478E+07	1.226E+07	1.147E+07	9.695E+06	4.552E+06	6.487E+03	3.374E+00	1.754E-03	9.124E-07	4.745E-10	0.000E+00
TC	4.620E+07	1.141E+07	1.074E+07	9.290E+06	4.387E+06	6.256E+03	9.737E+00	6.489E+00	6.487E+00	6.487E+00	6.487E+00
RU	7.584E+06	6.049E+06	5.014E+06	4.363E+06	4.091E+06	2.617E+06	1.574E+06	9.583E+05	5.938E+05	3.775E+05	5.595E+04
RH	9.176E+06	6.052E+06	5.590E+06	5.030E+06	3.973E+06	2.368E+06	1.428E+06	8.720E+05	5.430E+05	3.476E+05	5.527E+04
PD	5.052E+05	1.737E+05	1.293E+05	6.096E+04	2.568E+03	7.548E-03	7.548E-03	7.548E-03	7.548E-03	7.548E-03	7.548E-03
AG	6.476E+05	2.640E+05	2.050E+05	1.209E+05	4.459E+04	3.874E+03	3.883E+02	1.625E+02	1.375E+02	1.258E+02	6.923E+01
CD	3.546E+05	6.090E+04	3.544E+04	2.517E+04	1.084E+04	1.135E+03	7.127E+02	4.494E+02	2.842E+02	1.806E+02	1.222E+01
IN	1.080E+06	8.284E+04	4.546E+04	2.564E+04	9.949E+03	3.168E+00	7.269E-02	4.611E-02	2.937E-02	1.872E-02	7.499E-04
SN	7.871E+06	3.714E+05	8.493E+04	5.493E+04	3.103E+04	6.650E+03	2.894E+03	2.148E+03	1.796E+03	1.529E+03	4.945E+02
SB	2.238E+07	1.834E+06	7.485E+05	3.295E+05	1.731E+05	5.751E+03	3.668E+03	3.433E+03	3.289E+03	3.176E+03	2.652E+03
TE	5.564E+07	1.543E+07	1.014E+07	8.324E+06	4.329E+06	1.776E+05	9.431E+04	5.704E+04	3.597E+04	2.376E+04	3.752E+03
I	8.032E+07	4.528E+07	3.088E+07	2.038E+07	8.838E+06	4.783E+05	3.487E+04	2.624E+03	1.976E+02	1.489E+01	1.083E-02
XE	6.229E+07	1.776E+07	1.891E+07	1.648E+07	9.861E+06	3.417E+05	1.138E+04	1.129E+03	1.849E+02	3.231E+01	1.171E-04
CS	5.756E+07	1.987E+06	1.395E+05	1.124E+05	1.080E+05	9.057E+04	8.507E+04	8.311E+04	8.189E+04	8.084E+04	7.429E+04
BA	7.406E+07	1.798E+07	1.253E+07	1.183E+07	1.006E+07	2.493E+06	5.272E+05	1.403E+05	6.416E+04	4.910E+04	4.482E+04
LA	7.422E+07	2.717E+07	1.606E+07	1.258E+07	1.119E+07	2.816E+06	5.539E+05	1.090E+05	2.144E+04	4.217E+03	3.629E-02
CE	4.635E+07	2.207E+07	2.064E+07	1.757E+07	1.126E+07	6.087E+06	3.786E+06	2.531E+06	1.832E+06	1.428E+06	6.353E+05

Table 20.2-1. (continued).

	SCRAM	2.0HR	8.0HR	1.0D	4.0D	30.0D	60.0D	90.0D	120.0D	150.0D	365.2D
PR	3.984E+07	1.970E+07	1.604E+07	1.326E+07	1.166E+07	4.174E+06	1.934E+06	1.378E+06	1.190E+06	1.086E+06	6.392E+05
ND	8.517E+06	5.390E+06	4.382E+06	4.113E+06	3.408E+06	6.681E+05	1.019E+05	1.555E+04	2.373E+03	3.620E+02	5.030E-04
PM	6.761E+06	5.321E+06	4.786E+06	3.836E+06	1.613E+06	1.697E+05	1.554E+05	1.490E+05	1.436E+05	1.391E+05	1.172E+05
SM	1.643E+06	1.489E+06	1.351E+06	1.057E+06	3.611E+05	2.195E+02	1.851E+02	1.850E+02	1.849E+02	1.847E+02	1.839E+02
EU	2.191E+05	2.028E+05	1.838E+05	1.575E+05	1.203E+05	3.856E+04	1.201E+04	5.242E+03	3.502E+03	3.041E+03	2.722E+03
GD	5.356E+03	4.343E+03	3.474E+03	1.915E+03	1.342E+02	3.290E+00	3.019E+00	2.771E+00	2.543E+00	2.333E+00	1.260E+00
TB	9.400E+02	6.198E+02	6.021E+02	5.686E+02	4.441E+02	1.013E+02	5.803E+01	4.263E+01	3.193E+01	2.395E+01	3.043E+00
DY	1.249E+02	5.355E+01	1.624E+01	7.633E+00	4.101E+00	2.033E-02	4.453E-05	9.756E-08	2.137E-10	4.682E-13	3.923E-32
HO	1.923E+01	1.873E+01	1.731E+01	1.418E+01	6.562E+00	3.030E-02	8.149E-05	1.528E-05	1.513E-05	1.513E-05	1.513E-05
ER	2.165E-01	1.811E-02	1.778E-02	1.692E-02	1.356E-02	1.994E-03	2.183E-04	2.390E-05	2.616E-06	2.863E-07	3.674E-14
TM	3.664E-04	1.685E-04	1.682E-04	1.675E-04	1.646E-04	1.430E-04	1.218E-04	1.037E-04	8.838E-05	7.531E-05	2.412E-05
TOTAL	1.129E+09	3.369E+08	2.466E+08	1.795E+08	1.115E+08	3.937E+07	2.323E+07	1.604E+07	1.176E+07	8.887E+06	2.235E+06
CUMULATIVE TABLE TOTALS											
AP+FP	1.129E+09	3.369E+08	2.466E+08	1.795E+08	1.115E+08	3.937E+07	2.323E+07	1.604E+07	1.176E+07	8.887E+06	2.235E+06
ACT+FP	1.142E+09	3.459E+08	2.551E+08	1.870E+08	1.159E+08	3.959E+07	2.324E+07	1.605E+07	1.176E+07	8.889E+06	2.236E+06
AP+ACT+FP	1.142E+09	3.459E+08	2.551E+08	1.870E+08	1.159E+08	3.959E+07	2.324E+07	1.605E+07	1.176E+07	8.889E+06	2.236E+06

Table 20.2-2. ATR canal irradiated fuel radionuclides inventories.

Radionuclide	Activity[a] (Ci)
Kr-85	2.057E+4
Kr-85m	4.046E+5
Kr-88	3.910E+5
All Kr	9.354E+5
Rb-88	4.367E+5
All Rb	4.443E+5
Te-127m	4.383E+4
Te-129m	3.449E+5
Te-132	8.164E+6
All Te	1.006E+7
I-131	7.275E+6
I-132	8.408E+6
I-133	9.426E+6
I-134	4.789E+3
All I	2.876E+7
Xe-131m	1.222E+5
Xe-133	1.500E+7
Xe-133m	4.002E+5
All Xe	2.021E+7
Cs-134	1.143E+5
Cs-137	1.669E+5
All Cs	3.320E+5
Ba-140	1.858E+7
All Ba	1.878E+7
All fission products	3.184E+8

a. McCracken (1986).

Table 20.2-3. ATR canal maximum expected radionuclide inventories from activation products and isotope production.

Part I.	
Isotope	Curies per Year
C-14	100
Ce-141	50
Co-58	< 150
Co-60	6.0E6
Cr-51	< 150
Cu-64	< 150
Cu-67	1.0E3
Dy-165	100
Fe-55	1,000
Fe-59	175
Gd-153	6.0E4
H-3	9.0E7
Ho-166	< 150
Ir-192	3.5M
I-125	1.0E3
Mo-99	1.0E6
Ni-63	1.0E4
Os-194	20
P-32	< 150
Pd-103	10
Re-186	5.0E5
Se-75	< 150
Sm-145	100
Sm-153	10
Sn-119	5.0E5
Sr-85	25
Sr-89	5.0E5
S-35	330
Ta-182	100
Te-123m	50
Tm-170	1,000
Xe-133	600
Yb-169	< 150

Table 20.2-3. (continued).

Part I.			
Isotope		Curies per Year	
Y-90		500	
Other		See Part II.	
Part II. Small-quantity radioisotopes (< 1,000 curies per year) to be produced as requested.			
Ac-227	Cs-131	Na-22	Sc-47
Ar-37	Cu-67	Nb-95	Sm-151
Am-241	Es-254	Np-237	Sn-113
Ca-41	Eu-155	Os-191	Sn-117m
Cl-36	Ho-167	Pm-145	Ti-204
Cd-115m	I-123	Pm-147	Tm-171
Cf-252	I-131	Pt-195m	U-232
Cm-244	In-111	Pu-242	Xe-127
Co-57	Kr-85	Ru-103	

Table 20.2-4. ATR hazardous chemical inventory for hazards analysis and classification.

Chemical or substance	Location	CASN	State	Storage code	Hazard code	Average quantity	Maximum quantity	TQ[a] (lb)		TPQ[b] (lb)
Sulfuric acid solution	TRA-671	7664-93-9	L	C24	AR	125,000 lb	125,000 lb	NA		1,000

a. TQ - Threshold quantity from 29 CFR 1910.119 Appendix A, List of highly hazardous chemicals, toxics, and reactives.

b. TPQ - Threshold planning quantity from 40 CFR 355 Appendix A, List of extremely hazardous substances.

Table 20.2-5. Storage, temperature, and pressure codes.

Storage code	Type of storage
A	Above ground tank
B	Below ground tank
C	Tank inside building
D	Steel drum
E	Plastic or nonmetallic drum
F	Can
G	Carboy
H	Silo
I	Fiber drum
J	Bag
K	Box
L	Cylinder
M	Glass bottles or jugs
N	Plastic bottles or jugs
O	Tote bin
P	Tank wagon
Q	Rail car
R	Other
Temperature and pressure code	Storage conditions
Pressure	
1	Ambient pressure
2	Greater than ambient pressure
3	Less than ambient pressure
Temperature	
4	Ambient temperature
5	Greater than ambient temperature
6	Less than ambient temperature
7	Cryogenic conditions

20.3 Operational Hazards

The ATR is a Category A nuclear reactor; therefore, radioactive and fissile material is received, handled, irradiated, and stored at the facility. As a result, the major hazard of this facility is from these radioactive materials. The following subsections discuss this hazard and other hazards associated with operating the facility. The non-radioactive hazards considered are hazards from corrosive materials; explosive or pyrophoric materials; thermal and thermal radiation; flammable materials; toxic or pathogenic materials, electrical systems; ionizing and nonionizing radiation; asphyxiation or drowning; mass, gravity, or height; pressure-volume; kinetic-rotational and kinetic-linear energy; high noise levels; and lifting of heavy objects; chemical storage; slip, trips, and falls; batteries lead/acid; and carcinogenics.

ATR has numerous support buildings and structures which include a variety of these same hazards. The support buildings and structures are identified in the UFSAR Executive Summary and Chapter 1. The hazards associated with each of these support buildings and structures are listed in Table ES-1.

20.3.1 Nuclear Hazards

Potential severe ATR fuel-damage and radiological-release accidents were identified and analyzed for the ATR PRA (Eide, Khericha, and Thatcher 1991; Thatcher et al. 1994). All of the non-seismic severe fuel-damage accident sequences (i.e., sequences of protective action failures following or coincident with fuel-threatening initiating events) were estimated to have a mean frequency (estimated probability per year) of less than 1×10^{-6}/yr. Thus, these severe fuel-damage accident sequences are categorized as beyond-design-basis events. Fuel-damaging seismic events also require the occurrence of a beyond-design-basis earthquake (greater than the Safe Shutdown Earthquake).

Several fuel damage events are discussed in Chapter 15. Since ATR is Hazard Category 1 nuclear facility based on the power level and the calculations discussed in Chapter 15, no additional accident analysis calculations are presented in Chapter 20.

20.3.2 Corrosive

Significant quantities of acids and caustics are stored at TRA in support of ATR (see Table 20.2-4). TRA-671 contains 120,000 lbs of sulfuric acid. Other small quantities of acids and bases are stored and used throughout TRA. Personnel exposure, handling, and storage of these materials conform to the Contractor's *Safety and Health* manual.

20.3.3 Explosive or Pyrophoric

There are no explosive materials stored at TRA. Section 3.10.8 of Eide, Khericha, and Thatcher (1991) addresses explosions resulting from accidental chemical releases. No significant sequences were found due to chemicals stored at ATR.

Hydrogen storage bottles and hydrogen generated from lead/acid batteries may be considered an explosive hazard. The hazard is controlled by the requirements of the fire protection codes and meets DOE requirements.

Some potentially pyrophoric material is machined in TRA-670. The hazards associated with this work are covered by the Contractor's procedures and manuals.

20.3.4 Thermal and Thermal Radiation

ATR and several of the support buildings contain exposed pipes, components, laboratory equipment, electric heaters, space heaters, electrical wiring and equipment, and furnaces that are thermally hot. These hazards are standard industrial hazards.

20.3.5 Flammable Gas/Materials

The detailed internal-fire analysis in Section 3.10.3 of Eide, Khericha, and Thatcher (1991) addresses the presence of combustible materials such as diesel fuel and lubricating oil. This analysis summarizes the internal-fire accident sequences and includes descriptions of fire areas, fire suppression systems, locations of combustibles, fire-induced initiating events, and event trees. Several of the accident sequences listed in Eide, Khericha, and Thatcher (1991) result in fuel damage. The consequences of all credible events that went to fuel damage were compared to the consequences of events discussed in Section 15.12.10. The credible events discussed in Eide, Khericha, and Thatcher (1991), meet the applicable Plant Protection Criteria discussed in Chapter 15.0.14.

ATR and identified support buildings have storage cabinets that meet the requirements for handling and storage of small quantities of flammable and combustible materials. This hazard is a standard industrial hazard.

20.3.6 Toxic/Pathogenic

No pathogens are used at ATR. Table 20.2-4 contains a list of hazardous chemicals used at ATR, and Chapter 21 (Hazardous Material Protection) contains a description of the hazardous materials program at ATR. Most of the toxic materials are stored in small quantities. Toxic materials are discussed in Section 3.10.8 of Eide, Khericha, and Thatcher (1991) and are not considered a risk to control room operators.

The Primary/Pathogenic Hazard at TRA is potential Hantavirus infection. Entry into areas where observed mouse droppings are present is controlled to minimize the potential for Hantavirus infection.

20.3.7 Electrical

The electrical power distribution system at ATR is described in Section 3.4.11 of Eide, Khericha, and Thatcher. (1991) and in Chapter 8 (Electric Power) of this UFSAR. Failure of some components of the electrical components of the electrical system can result in accident sequences that lead to core damage. Electrical component failure was an initiator for several of the accident sequences listed in Eide, Khericha, and Thatcher (1991) that resulted in fuel damage. The consequences of all credible events that went to fuel damage were compared to the consequences of events discussed in Section 15.12.10. The credible events discussed in Eide, Khericha, and Thatcher (1991), meet the applicable Plant Protection Criteria discussed in Chapter 15.0.14.

Safety precautions are in place for greater than 600 V. Anything below the minimum threshold of 600 V does not require analysis. Company procedures are in place and Lockout/Tagout shall be followed to protect the workers from the electrical hazards. Operating at greater than 600 V is governed by electrical industry codes and standards which are implemented by the company procedures. The electrical industry accepts this method of addressing the electrical hazards and no further analysis is required other than the Electrical Job Safety Analysis required prior to the initiation of work on electrical systems. A restriction on the distance that must be maintained by the general public during normal operations is also provided in the procedures.

20.3.8 Ionizing and Nonionizing Electromagnetic Radiation

There are numerous places at ATR where ionizing and nonionizing electromagnetic radiation is present. For example, ultraviolet light is used to treat canal water, and electric arc welding is used. Direct radiation sources are present at the reactor, piping, tanks, ion exchange units, the canal area, laboratories, and in the experimental cubicles. Radioactive sources are also associated with nuclear instrumentation and radiography equipment.

Radiation doses to personnel at ATR and support buildings are controlled using the "as low as reasonably achievable" philosophy and sound radiation-control practices. Specific provisions of the ATR radiation protection program are discussed in Chapter 12 (Radiation Protection).

20.3.9 Asphyxiation or Drowning

The potential for asphyxiation or drowning exists in the reactor vessel (during refueling and CIC), in the canal area, in raw water storage tanks TRA-719, and in confined spaces such as tanks that contain an inert gas or low-oxygen atmosphere. Other potential asphyxiation sources include the fire suppression systems and the bulk helium system in TRA-670. These are standard industrial hazards covered by the Contractor's procedures and manuals.

20.3.10 Mass/Gravity/Height

The potential for accidents involving mass, gravity, and height exists at ATR. Ladders, stairs, and scaffolds are potentially present in all areas of ATR and support buildings, as are numerous cranes, lifts, and hoists. These types of hazards are common to both nuclear and nonnuclear industries, regardless of the type of material handled, and are standard industrial hazards covered by the Contractor's procedures and manuals.

20.3.11 Pressure-Volume

Numerous systems or components at ATR and support buildings are pressurized, such as the Primary Coolant System (PCS), the test loops, the reactor vessel, and compressed air systems. In addition, the ATR confinement is maintained at slight negative pressure. Several of the accident sequences discussed in Eide, Khericha, and Thatcher (1991) involve breaks in the PCS. The credible events discussed are bounded by the consequences of the event compared to Section 15.12.10. In all cases, the consequences of the credible events meet the applicable Plant Protection Criteria discussed in Chapter 15.0.14.

20.3.12 Kinetic-Rotational and Kinetic-Linear Energy

Numerous systems at ATR and the support buildings contain pumps, motors, or fans that have rotating components. The fork lifts, cranes, and dollies are sources of linear kinetic energy. Finally, pressurized piping at ATR is a source of liquid linear kinetic energy. Regardless of the type of material handled, these types of hazards are common to nuclear and nonnuclear industries and are standard industrial hazards covered by the Contractor's procedures and manuals. Rotational and linear missile hazards are discussed in Chapter 3 (Design of Structures, Components, Equipment, and Systems).

20.3.13 High Noise Levels

Noise levels at ATR are monitored by Industrial Hygiene personnel. Areas that exceed 85 dBA require hearing protection. Personnel access and exposure to high noise levels conform to the requirements of the Contractor's *Safety and Health* manual. These hazards are standard industrial hazards.

20.3.14 Lifting of Heavy Objects

Numerous cranes are used throughout TRA-670 for lifting heavy objects such as casks. Due to the consequences of dropping heavy objects, limitations can be placed on lifts; when necessary, the limitations will limit the reactor operating condition, the location of lift, and the height of lift. These limitations are noted in the ATR Lift Book in the ATR reactor control room. The lifts at ATR and the support buildings are conducted in accordance with DOE-ID Order 440.C (DOE-ID 2002), which is met by PDD-600, "*Site Maintenance Management Program*," (INEEL 2003).

Dropping heavy loads within the ATR building can initiate several reactor and canal accidents which are discussed in Chapter 15 (Accident Analysis).

20.3.15 Radiological

Radiation and contamination hazards exist in ATR and several of the support buildings. These hazards are controlled in accordance with the Radiological Control Manual to mitigate the hazards associated with the contamination and the potential release to the environment. Some of the items that reduce the risk includes Radiological Worker Training, PPE, ALARA reviews, and RWPs.

20.3.16 Chemical Storage

Bulk Chemical Storage is a hazard in TRA-671. Small inventories are maintained in approved storage locations in ATR and the support buildings. These hazards are standard industrial hazards.

20.3.17 Slip, Trips, and Falls

Some of the hazards identified are from elevated platforms, low overhead piping and shafts, pits, grates, slick floors, manholes, and working at heights. These are considered a standard industrial hazard.

20.3.18 Batteries Lead/Acid

The hazard identified is a potential leak or explosion of the battery that would spread acid and debris in the surrounding area. This hazard is considered to be a Standard Industrial Hazard.

20.3.19 Carcinogenics

There are several carcinogens located in TRA-670. The major carcinogen is Asbestos. This material resides in ATR and several of the support buildings. All asbestos materials must be identified and posted. Any work to be performed in areas containing asbestos must be surveyed to identify the extent of the hazard and mitigative measures incorporated into the work, which meets requirements. Since the asbestos is fixed, no release is anticipated unless disturbed by work on the material containing asbestos. The other carcinogens are standard industrial hazards and are covered by the Contractor's procedures and manuals.

20.4 Hazard Level Classification Accidents

20.4.1 Radiological Accidents

Several fuel damage events are discussed in Chapter 15. Since ATR is Hazard Category 1 facility based on the power level and the calculations discussed in Chapter 15, no additional accident analysis calculations are presented in Chapter 20.

20.4.2 Nonradiological Accidents

Another facility containing a quantity of sulfuric acid that is above the screening threshold is TRA-671. Located on the east end of TRA-671 is an addition which contains the Secondary Coolant Chemical Addition System. The addition, which contains all of the chemicals used in the secondary coolant system, is an insulated metal building with a divided concrete sump below grating to contain spillage from the bulk tanks. Located in the northwest portion of this addition is an 8,000-gallon (120,000 lb) sulfuric acid tank which normally operates at a pressure between 5 and 14 psig. A hazard analysis was completed which shows this addition as a low hazard (Abbott 1993; Bonney 1995).

20.5 Classification of Individual Hazards

The hazards outlined in Section 20.3 were generally standard industrial ones. However, several of them (e.g., electrical) could also serve as the initiators for nuclear accidents involving ATR. Based on the doses calculated for a total core melt discussed in Section 15.12.10, ATR exhibited the potential for significant offsite consequences and was classified as a Hazard Category 1 facility.

20.6 Classification of the Facility

Although no numerical criterion for significant offsite consequences has been established, doses in the range of 100 to 1,000 rem are typically considered significant. Therefore, ATR exhibited the potential for significant offsite consequences (based on an assessment for a total core melt event presented in Section 15.12.10) and was classified as a Hazard Category 1 facility.

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CHAPTER 21

HAZARDOUS MATERIAL PROTECTION

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ACRONYMS/ABBREVIATIONS

ALARA	as low as reasonably achievable
ATR	Advanced Test Reactor
CFR	Code of Federal Regulations
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy, Idaho Operations Office
EG&G Idaho	EG&G Idaho, Inc.
IDCP	Internal Dosimetry Control Program
IH	Industrial Hygienist
INEEL	Idaho National Engineering and Environmental Laboratory
JHA	Job Hazard Analysis
MIL-STD	Military Standard
MSDS	Material Safety Data Sheet
NIOSH	National Institute for Occupational Safety and Health
OMP	Occupational Medical Program
OSHA	Occupational Safety and Health Administration
PEL	Personnel Exposure Limit
PPS	plant protective system
RP	Reactor Programs
QA	Quality Assurance
QC	Quality Control
TRA	Test Reactor Area
UFSAR	Upgraded Final Safety Analysis Report

21. HAZARDOUS MATERIALS PROTECTION PROGRAM

The Advanced Test Reactor (ATR) complex maintains a hazardous-material protection program that complies with Occupational Safety and Health Administration (OSHA) laws, U.S. Department of Energy (DOE) and DOE Idaho Operations Office (DOE-ID) orders, and the Contractor's procedures. As specified by DOE Order 5480.23, "Nuclear Safety Analysis Reports," hazardous material is defined as any solid, liquid, or gaseous material that is toxic, explosive, flammable, corrosive, or otherwise physically or biologically threatening to health (DOE 1994). Oil is excluded from this definition.

21.1 As Low As Reasonably Achievable Program

The INEEL general policy outlined in the Contractor's *Safety and Health* Manual under the Industrial Hygiene section is to keep individual chemical exposures below personnel exposure limit (PELs). The As Low as Reasonably Achievable (ALARA) Program is conducted qualitatively relative to hazardous materials protection by maintaining exposures below the industrial workplace PELs.

21.2 Toxic and Chemical Sources

Hazardous materials used and stored at the ATR complex fall into four classifications: corrosive, flammable, toxic/pathogenic, and pressure-volume materials. These sources are summarized in this chapter. Specific volumes, locations, and storage/usage information are included in Chapter 20 (Hazard Analysis and Classification of Facility) of this Upgraded Final Safety Analysis Report (UFSAR). Hazardous materials are stored and handled in accordance with 29 CFR 1910, Subpart H, "Hazardous Materials," and 29 CFR 1910, Subpart Z, "Toxic and Hazardous Substances."

21.2.1 Corrosives

Sulfuric acid, nitric acid, and lead-acid batteries are used at ATR or supporting facilities. Sodium hydroxide is the most frequently used caustic material used at ATR supporting facilities. There are also small quantities of other acids and caustics in use in the laboratories and at temporary job sites.

21.2.2 Flammables

Small quantities of paint solvent are in temporary use at job sites. Small quantities of flammable gases and vapors are released during welding operations using oxy/acetylene tanks on temporary job sites and in reactor maintenance operations. Hydrogen is generated during charging of battery banks, and may build up in battery rooms. Propane is used to power vehicles such as fork lifts. Diesel fuel is used in diesel generators, and gasoline and diesel fuel occasionally enter the reactor building in fuel tanks of trucks that carry casks and equipment.

21.2.3 Toxics/Pathogenics

In the reactor building (TRA-670), heavy metals are present in the form of lead-containing surface coatings, lead shielding, lead-acid battery banks, cadmium neutron absorbers, lead calcium lighting, carbon and stainless steel building components, and mercury switches. Also located in the reactor vessel and storage canal are beryllium reflector blocks and beryllium outer shim control cylinders. Halogenated compounds (e.g., bromine) are used for water treatment. Materials containing asbestos are used for insulation as system components, and as part of structural materials in several buildings within the complex. An Asbestos inspection is periodically conducted for the entire Test Reactor Area (TRA). Solvents are used at job locations within the complex. There is a potential accumulation of carbon monoxide in diesel generator areas and in areas where equipment powered by propane is used. Pesticides, herbicides, and insecticides are used occasionally on TRA grounds. Small quantities of miscellaneous chemicals detailed in Chapter 20 (Hazard Analysis and Classification of Facility) are used in specialized applications and as laboratory chemicals.

21.2.4 Pressure-Volume Materials

Pressure-volume materials are usually associated with steam systems or stressed systems. A listing of such systems at ATR includes:

- Primary coolant surge tank
- ATR experiment loops
- Reactor vessel
- Primary coolant system and pipe supports, including piping, pumps, and heat exchangers
- Compressed-air systems.

Tanks under pressure are also used at ATR. These include numerous gas bottles (argon, halon, neon, hydrogen, helium, P-10 argon-methane gas, and nitrogen), high-pressure air tanks, compressed-air storage tanks, and compressed air breathing systems.

21.3 Bioassay and Medical Monitoring Program

Bioassay and other medical monitoring methods and frequencies at the TRA Site are based upon the applicable source terms present at the various site areas, the worker potential for intake of hazardous material and/or radionuclides, and the ability to detect minimum exposures to the material, as required and implied by DOE Orders and DOE Guidance. Specific implementation programs include the Idaho National Engineering and Environmental Laboratory (INEEL) Occupational Medical Program (OMP) and the TRA facility Internal Dosimetry Control Program (IDCP). This section specifies INEEL and Reactor Programs (RP) specific bioassay and medical monitoring requirements and general guidance for implementing these programs.

21.3.1 INEEL Occupational Medical Program

The DOE Contractor OMP is prescribed in DOE Order O 440.1A (DOE 1998). Its objectives are to

- Protect DOE contractor employees against health hazards in their work environments.
- Assist management in ensuring the placement of DOE contractor employees in work that can be performed in a reliable and safe manner consistent with the requirements of the Americans with Disabilities Act of 1990.
- Provide support to contractor management in the medical, mental, and substance-abuse aspects of personnel reliability and fitness for duty.
- Ensure the early detection, treatment, and rehabilitation of employees who are ill, injured, or otherwise impaired.
- Apply preventive medical measures toward the maintenance of the optimum physical and mental health of employees through health promotion and education.
- Provide professional guidance and consultation to contractor management on all health-related issues.
- Provide employees, as appropriate, with professional medical evaluation, guidance, counseling, and referrals to specialists in support of optimum physical and mental health.
- Protect the privacy of employees and the confidentiality of their medical records.
- Provide support to DOE and contractor management and the Office of Epidemiology and Health Surveillance/Office of Health by the collection and analysis (when requested) of employee health data for the purpose of early detection and prevention of occupational and nonoccupational illness and injuries.

The OMP organization is administratively and procedurally organized to provide guidance for the overall occupational medical program and to establish minimum requirements for the protection and evaluation of human health in the work environment and during emergency situations.

21.3.2 RP-Specific Bioassay and Medical Monitoring

Medical monitoring requirements for some specific chemicals are described in the Contractor's *Safety and Health*. While medical monitoring may be based solely on the chemical, in some cases duration of exposure will determine whether medical monitoring is required.

Hazard sampling is based on the availability of protocols developed by the National Institute of Occupational Safety and Health (NIOSH) (Eller 1984). The IH is responsible for developing guidelines for evaluation and control of health hazards having no mandatory standards.

21.3.3 Industrial Hygiene Sample Analysis

Three distinct steps are involved in industrial hygiene sample analysis: (a) sampling and shipping, (b) laboratory analysis, and (c) sample result notification. The Industrial Hygienist (IH) is responsible for ensuring that representative samples are collected, that chain-of-custody is maintained to provide sample integrity, and that notification of sample results is made to management as appropriate.

Sample analysis is performed by the Contractor's Environmental Hygiene Laboratory, or an approved outside laboratory. Where the IH determines that employee notification is required, the employee is notified within the DOE and OSHA time limit requirement. The notification procedures are contained in the Contractor's *Safety and Health*.

21.4 Air and Workplace Monitoring

21.4.1 Workplace Monitoring Program

Workplace monitoring is prescribed by DOE Order O 440.1A, "Worker Protection Management for DOE Federal and Contractor Employees," and is implemented through the Contractor's *Safety and Health* (DOE 1998). The IH routinely performs walk-through surveys of work areas for hazards.

21.4.2 Permanent Monitoring Instrumentation

Several area hydrogen detectors are located in Building TRA-670. The locations of these detectors are as follows:

- Inside Plant Protective System (PPS) Battery Rooms
- Inside the Utility/Instrument Battery Room.

21.4.3 Portable Monitoring Instrumentation

The IH maintains and uses a variety of portable hazardous material monitoring instrumentation. These instruments are inventoried, calibrated, and maintained in accordance with the manufacturer's instructions Manufacturers' operating and maintenance procedures for all industrial hygiene instrumentation are kept in the IH's office with the equipment. The industrial hygiene equipment typically used for monitoring hazardous materials at the ATR includes:

- Combination combustible gas/carbon dioxide/and oxygen meters
- Direct reading instruments for colormetric tubes
- Flow meters and pump calibrators
- Personal air sampling pumps.

21.5 Instrument Calibration

Industrial hygiene instrument calibration is required by the National Institute for Occupational Safety and Health (NIOSH) to ensure representative exposure measurements. The standard for all calibrations performed is ANSI/NCSL Z540-1, "Calibration Laboratories and Measuring and Test Equipment, General Requirements (ANSI 1994)." DOE Order 414.1A recommends this standard and requires its use in all DOE operations (DOE 2001). Industrial hygiene instrument calibration is performed by one or more of the following organizations, as appropriate:

- The Contractor's Standards and Calibration Laboratory
- Approved manufacturer or authorized vendor
- Industrial Hygienists (IHs) or qualified technicians
- TRA Maintenance Operations.

21.5.1 Calibration Requirements

Procedures for accomplishing manufacturers' calibration requirements are outlined in the manufacturers' technical manuals, or Company developed procedures.

21.5.2 Calibration Equipment

Primary calibration of instrumentation is performed at the Contractor's Standards and Calibration Laboratory or at an approved manufacturer or authorized manufacturer or authorized vendor. All equipment used for secondary calibration is calibrated in accordance with the requirements presented in ANSI/NCSL Z540-1 (ANSI 1994)."

21.6 Recordkeeping and Hazardous Material Exposures

Recordkeeping is required for all aspects of hazardous material protection, including hazard communication, calibration and maintenance of equipment and instrumentation, workplace monitoring and sampling, and employee exposure. The IH maintains all of these records. The Contractor's *Quality and Requirements Management* manual requires establishing and implementing a records management program within each organization. Exposure records shall be legible; identifiable; retrievable; protected against damage, deterioration, or loss; and retained for a prescribed period as described in the Contractor's *Safety and Health*.

The Contractor's *Safety and Health*, implements the requirements of DOE Order O 440.1A and 29 CFR 1910.1020, which state employee exposures to hazardous chemical, physical, and biological agents are required to be evaluated and documented in a record that is easily retrievable by the employee (DOE 1998). Requests for exposure records information are conducted by completing a Hazardous Agent Exposure Records Release Authorization Form.

21.7 Hazard Communication Programs

Hazard Communication for Reactor Programs is maintained in accordance with Company Hazard Communications procedures as outlined in the Contractor's *Safety and Health* Manual.

21.8 Hazard Evaluation and Elimination

21.8.1 Hazard Evaluation

A hazard evaluation is performed as required by DOE Order 440.1A (DOE 1998). The hazard evaluation is prepared by an IH in accordance with Company Industrial Hygiene procedures as outline in the Contractor's *Safety and Health* Manual.

The IH will determine the type and frequency of monitoring activities, monitor and document personnel exposures to hazards according to guidelines (see Section 21.3.2), evaluate exposures that may exhibit additive effects and monitor results for risk assessment for personnel, and conduct periodic hazard control monitoring. When a hazard has been identified, the IH will recommend hazard control measures to management.

21.8.2 Hazard Elimination

Hazard elimination through the implementation of sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources is a requirement of DOE Order 450.1 "Environmental Protection Program" (DOE 2003). The objective of this order is to promote increased protection of public health and the environment by eliminating or minimizing releases from all aspects of DOE-ID operations to all environmental media.

Reactor Programs prepares annual waste minimization plans for their facilities and operations. These plans contain a description of the operation, process characterization, and pollution prevention strategy. In the process characterization section, waste streams and waste minimization procedures are presented.

21.9 References

ANSI, 1994, ANSI/NCSL Z540-1, *Calibration Laboratories and Measuring and Test Equipment, General Requirements*, January 1994.

CFR, 1996a, *Access to Employee Exposure and Medical Records*, 29 CFR 1910.1020, *Code of Federal Regulations*, Office of the Federal Register, June 20, 1996.

CFR, 1996b, *Hazard Communications*, 29 CFR 1910.1200, *Code of Federal Regulations*, Office of the Federal Register, March 7, 1996.

CFR, 2002a, *Hazardous Materials*, 29 CFR 1910, Subpart H, *Code of Federal Regulations*, Office of the Federal Register, November 7, 2002.

CFR, 2002b, *Toxic and Hazardous Substances*, 29 CFR 1910, Subpart Z, *Code of Federal Regulations*, Office of the Federal Register, November 7, 2002.

Companywide Manual, *Quality and Requirements Management*.

Companywide Manual, *Radiation Protection*.

Companywide Manual, *Safety and Health*.

DOE, 1994, *Nuclear Safety Analysis Reports*, Order 5480.23, Change 1, U.S. Department of Energy, Washington, D.C., March 10, 1994. (historical)

DOE, 1998, *Worker Protection Management for DOE Federal and Contractor Employees*, Order 440.1A, U.S. Department of Energy, Washington, D.C., March 27, 1998.

DOE, 2001, *Quality Assurance*, Order 414.1A, U.S. Department of Energy, Washington, D.C., Change 1, July 12, 2001.

DOE, 2003, *Environmental Protection Program*, Order 450.1, U.S. Department of Energy, Washington, D.C., January 15, 2003.

Eller, Peter M. (ed.), 1984, *NIOSH Manual of Analytical Methods*, 3rd ed., U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, Cincinnati, OH, February 1984.

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CHAPTER 22

PROVISIONS FOR DECONTAMINATION AND DECOMMISSIONING

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ACRONYMS/ABBREVIATIONS

ATR	Advanced Test Reactor
D&D	Decontamination and Decommissioning
DOE	U.S. Department of Energy
NEPA	National Environmental Policy Act of 1969
NRC	U.S. Nuclear Regulatory Commission
UFSAR	Upgraded Final Safety Analysis Report

22. PROVISIONS FOR DECONTAMINATION AND DECOMMISSIONING

This chapter presents conceptual and existing plans for decontaminating and decommissioning (D&D) the Advanced Test Reactor (ATR) following the guidelines in U.S. Department of Energy (DOE) Order 430.1A, "Life Cycle Asset Management" (DOE 1998). This chapter also presents considerations of the facility D&D design features, D&D plans (including design planning requirements for future major modifications and generic D&D plans), and environmental/public health and safety issues.

22.1 Facility Design Features

Because the ATR was designed and built before D&D design requirements were issued, design considerations to simplify and promote D&D and/or increase the potential for reuse were not specifically included in the design documentation (DOE 1998). The existing Aging Program has demonstrated that ATR could be operated until 2014. Additional work and upgrades could extend the life even further (Durney et al. 1987). Therefore, D&D activities will not occur immediately and may be governed by requirements of future regulations and guidance. At that time, features built into the initial design that would promote D&D activities (see Section 22.2.1), reduce waste generation, and reduce future potential impacts will be documented during the characterization phase of D&D efforts. Any future modifications of radioactively contaminated access areas at ATR will follow the DOE requirements for D&D in place at that time (see Section 22.2.1 for more details).

22.2 Decontamination and Decommissioning Plans

At the end of the plant mission, DOE will be responsible for D&D of the reactor plant and the appropriate support facilities. A D&D plan will be adopted and subject to regulatory and public review before implementation. The following subsections discuss general D&D plans (including D&D planning requirements for future major modifications), generic D&D plans, and plans for mitigating environmental, and health and safety concerns.

22.2.1 Decontamination and Decommissioning Planning Requirements for Future Major Modifications

Major modifications of the ATR use Technical Design Requirements to document required design features of the modifications. These requirements include promotion of the D&D process and minimization of radioactive, hazardous, and mixed waste generation as required by ATR facility-specific General Design Criteria in Chapter 3 (Design of Structures, Components, Equipment, and Systems). For example, the Technical Design Requirements will require the designers to submit a plan that addresses eventual decommissioning and presents an evaluation of D&D options as they would apply to ATR. The evaluation will include a comparison of (a) potential environmental impacts from accidents in normal operations and impact mitigation measures, (b) regulatory compliance considerations and future requirements that may be more restrictive, (c) estimated quantities of wastes and mitigative measures, (d) estimated occupational and public exposures and mitigative measures, and (e) estimated costs and schedules. The plan will not require a detailed level of description, but it will provide a sufficient basis for determining that the proposed design has incorporated the latest technology for promoting eventual D&D while minimizing waste generation, site and environmental contamination, exposure to workers and the public, and preventing an increase in residual risks both during and after decommissioning.

At a minimum, the Technical Design Requirements for the modifications will consider

- Architectural/structural requirements that promote dismantling and handling reactor system components with features like modular components, preplaced lifting attachments, and passageway and compartment sizes
- Architectural/structural requirements that promote demolition and removal of plant structures such as preplaced blast holes, and nonembedment of pipe
- Techniques for the eventual disassembly, shielding, and handling of the core, reflector, and shielding components
- Requirements that prevent or reduce concentrations of radioactive contaminants or increase efficiency of decontamination by use of coatings, liners, sacrificial surfaces, enclosed cable trays, etc.
- Requirements to reduce or prevent the activation of structural and component materials by material selection, purification, preparation, shielding, and location
- Requirements that promote minimization, segregation, and handling of radioactive and hazardous waste.

22.2.2 Description of Generic Decontamination and Decommissioning Options

For nuclear facilities, three basic decommissioning options have been defined in a U.S. Nuclear Regulatory Commission (NRC) Program Status Paper (Calkins 1980) and the *Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities* (NRC 1981). These options are DECON, ENTOMB, and SAFSTOR. The most appropriate option will be selected at the time of decommissioning based on National Environmental Policy Act (NEPA) regulations in place at that time, and on DOE's mission. The Decommissioning Plan will specify the option to be used and how it will be implemented at ATR.

DECON is the immediate removal of all radioactive materials to acceptable levels to permit the property to be released for unrestricted use by the public. Decontamination is followed by dismantlement, transportation, and burial of radioactive waste. In a final step, the outer structure is demolished, and the site is restored by grading and revegetation.

ENTOMB is the encasement of the facility in a material possessing long-lived structural integrity until a time when the dose level allows unrestricted use. This option is intended for sites where the radioactivity will decrease to acceptable limits within approximately 100 years.

SAFSTOR involves placing a facility in temporary storage for subsequent decontamination and unrestricted facility use. This temporary storage must provide acceptable risk levels to the public. The SAFSTOR option is divided into four major phases:

1. Chemical and mechanical decontamination

2. Deactivation of equipment not needed during the interim care phase

3. Interim care (surveillance and maintenance)

4. Final dismantlement.

Surveillance, maintenance, and certain operations (such as ventilation and security activities) are conducted during the interim care phase to ensure safe confinement of the radioactivity and hazardous materials. Scheduled programs of periodic inspections and monitoring continue.

Final dismantlement begins with a planning phase. The equipment that is necessary for dismantlement but was previously made inoperable is activated and refurbished as necessary. Dismantlement then follows the same process as the DECON option.

Projections of D&D impacts specific to the ATR have not been made; however, estimates have been made for the D&D of typical pressurized water reactor commercial power reactors using the DECON option. The estimated population dose was 3.0×10^{-5} mrem/yr (lung) during the period of D&D operations. The ENTOMB and the SAFSTOR options were projected to result in an even lower dose.

In summary, there is a range of D&D options. Specific decisions concerning D&D will be deferred until near the end of the operating life of the plant. By then, there may be significant changes in D&D technology and practices, energy use and generation needs, and regulatory requirements.

22.2.3 Environmental Issues

Environmental issues associated with D&D are discussed in the following subsections. The subsections discuss disposition of support facilities; disposal of radioactive, hazardous, mixed, and nonhazardous wastes; and permitting.

22.2.3.1 Disposition of Support Facilities. Facilities no longer needed will be removed and disposed of in accordance with the regulatory requirements for demolition, removal, and disposal in place at that time. Because demolition and removal operations are, in general, well established and are routinely practiced, they are not expected to result in significant environmental impacts. If there is projected to be significant landscape disturbance as a result of D&D activities, appropriate erosion control and revegetation plans will be developed.

22.2.3.2 Disposal of Radioactive, Hazardous, Mixed, and Other Wastes. Federal, State, and local regulations and guidelines exist to control the handling, storage, and disposal of all categories of waste. DOE has internal procedures and training to ensure compliance with those regulations. Current regulations require that after a regulated material is declared excess, it must be disposed of expeditiously following all regulatory requirements. Additional regulations are expected to be developed in the future.

Based on an analysis of the potential consequences associated with the D&D of similar facilities at the INEEL (DOE 1995), the following generalizations are likely to apply to the ATR. Decontamination activities at the end of operations will result in a significant increase in the volume of waste generated. This increase is likely to last from 10 to 15 years. However, most waste management operations would not differ significantly from those employed during construction and normal operations of the plant complex; nor would the operations raise significant waste management issues requiring abnormal approaches or resolution. Therefore, the waste management plans presented in Chapter 11 (Radioactive and Hazardous Material Waste Management) of this Upgraded Final Safety Analysis Report, which were developed for normal operations of the reactor complex, should only require minor modifications to meet the needs of the D&D phase.

22.2.3.3 Permitting. Depending on the D&D option and implementation plans specified in the decommissioning plan, DOE may be required to obtain permits from appropriate State and Federal agencies to dismantle the facility and dispose of its component parts. An active and cooperative program of working with permit-issuing agencies will be maintained to ensure a timely and satisfactory closeout of permits. As part of this permit process, detailed plans will be developed and provided to the appropriate agencies on the proposed procedures for D&D of the facilities and for the disposal of regulated materials. The plans will provide sufficient detail to provide reasonable assurance that the D&D and waste disposal activities will be performed in accordance with all applicable regulations, and will be accomplished with no significant impacts to the environment nor any adverse effects to the health and safety of workers or the public.

22.3 References

Calkins, G. D., 1980, *Thoughts on Regulation Changes for Decommissioning*, Rev. 2, NUREG-0590, U.S. Nuclear Regulatory Commission, Washington, D.C., August 1980.

DOE, 1995, *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement*, DOE/EIS-0203-F, U.S. Department of Energy, Washington, D.C., April 1995.

DOE, 1998, *Life Cycle Asset Management*, Order 430.1A, U.S. Department of Energy, Washington, D.C., October 14, 1998.

Durney, J. L., et al., 1987, *ATR Vessel Lifetime and Primary Coolant System IGCSS Assessment*, PG-T-87-009, EG&G Idaho, Inc., December 1987.

NRC, 1981, *Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, NUREG-0586, U.S. Nuclear Regulatory Commission*, Washington, D.C., January 1981.

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22.2.4 Public Health and Safety Issues

Public health and safety issues, including radiological considerations, controls, and security requirements, are presented in the following subsections.

22.2.4.1 Radiological Considerations and Controls. All control practices common during operations will be maintained during the decommissioning phases to ensure the continuing safe operation of the complex. These practices will include, but will not be limited to, (a) restricted access to controlled areas, (b) monitoring, controlling, and/or capturing airborne or liquid effluents, (c) monitoring and controlling worker exposures to radioactive and hazardous sources, and (d) appropriately monitoring for the level of hazard in the area, either periodically, continuously, remotely, or by inspection.

22.2.4.2 Security Requirements. Fences, controlled access, and security protection similar to programs in place during normal operations will be used during the decommissioning phases for portions of the facility that remain secure. For other portions of the complex, fences, locked buildings, and periodic patrols will be maintained at an appropriate level of security.

22.2.4.3 Data Files. Pertinent data, calculations, decision bases, and reports generated during the decommissioning project will be permanently maintained and archived to meet DOE D&D Program requirements. The data file will provide the documentation required to support release of the ATR facility/area by providing a complete documented history of the decommissioning project. The level of detail and type of documents included in the data file will be commensurate with the technical complexity of the decommissioning project.

22.2.4.4 Final Report. The ATR final D&D report will document an overview of the project activities, accomplishments, final facility or site status, and lessons learned. Specific content requirements for the report include the following:

- An abstract
- Summary
- Introduction
- Facility description before decommissioning
- Physical condition
- Radiological conditions
- Hazardous chemical conditions
- Objectives and work scope
- Work performed

- Project management/project engineering
- Decision analysis
- Site preparation
- Decommissioning operations and waste disposal
- Postdecommissioning radiological surveys
- Postdecommissioning hazardous chemical surveys
- Cost and schedule
- Volume of waste generated
- Personnel exposure
- Postdecommissioning condition
- Lessons learned
- References.