U.S. Nuclear Regulatory Commission

U.S. RESEARCH REACTORS

PREPARATION OF SAFETY EVALUATION REPORT

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Overview of License Renewal

- Facility Operating License usually issued for a period of 20 years, but not longer than 40 years
- License renewal is required to continue to operate the facility
- Renewed license usually issued for a period of 20 years
- Renewed licenses may be renewed

Overview of License Renewal

- License renewal may include changes to the facility design or operation that would normally require a license amendment
  - Change in the licensed maximum power
  - Change in the maximum fuel burnup
  - Change in the facility administrative controls
  - Change in the cooling system design

License Renewal Process

- U.S. Nuclear Regulatory Commission (NRC) informs the licensee 1 year beforehand that the license is due to expire
- Licensee files application for license renewal 30 days before the license expires

License Renewal Process

- Licensee operates the facility in accordance with the current Facility Operating License until the NRC makes a final determination on the renewal application (timely renewal)
- NRC accepts or rejects the application
- NRC informs the public of the application

License Renewal Process

- NRC reviews the application
- Opportunity for public involvement
- NRC issues a renewed license
- Licensee conducts activities in accordance with the renewed license

License Renewal Application

- Final Safety Analysis Report (FSAR)
- Technical Specifications
- Emergency Plan
- Security Plan
- Operator Training and Requalification Plan

License Renewal Application

- Quality Assurance Plan
- Startup Plan
  - Required only if the application requests a major change in facility operations, e.g., an increase in licensed maximum power that requires extensive system or instrumentation upgrades
- Environmental Report

NRC Application Review

- Initial review for completeness and acceptability
- NRC officially files the application on the facility docket
- Inform the public of the application and offer the public an opportunity to request a hearing

NRC Application Review

- Technical review of the Final Safety Analysis Report
  - Verify safety-related conclusions
  - Use technical guidance documents
  - Use inspection reports
  - Use operating experience
  - Use prior NRC approval

NRC Application Review

- Review of the Technical Specifications to verify compliance with the regulations
  - Technical Specifications often require updates to meet the current regulations
- Review of Emergency Plan, Security Plan, Operator Training and Requalification Plan, and Quality Assurance Plan against current guidance

NRC Application Review

- If required, review of startup plan to ensure the licensee can safely bring the reactor into routine operation in accordance with the renewed license
- Review of the environmental report to verify compliance with the National Environmental Policy Act

NRC Application Review

- Request for Additional Information
  - A question asked to provide missing information
  - A question asked to clarify an inconsistency
  - A question asked to resolve a misunderstanding
  - Used for supplementing the application with information that must be part of the official NRC file or “docket” for the facility

NRC Application Review

- An application for renewal of a Facility Operating License for a testing facility <u>shall</u> be reviewed by the Advisory Committee on Reactor Safeguards
- An application for renewal of a Facility Operating License for a research reactor <u>may</u> be reviewed by the Advisory Committee on Reactor Safeguards

NRC Renewal Documentation

- Final Environmental Impact Statement required for a testing facility
- Environmental Assessment required for a research reactor
- Notice informing the public of the Final Environmental Impact Statement or Environmental Assessment

NRC Renewal Documentation

- License Renewal Package
  - Renewed Facility License
  - Technical Specifications
  - Final Safety Evaluation Report
  - Notice informing the public of the license renewal

License Renewal Goals

- Provide reasonable assurance that the facility will continue to operate without undue risk to public health and safety or the environment
- Establish a current licensing basis
- Promote minimum regulation in accordance with the Atomic Energy Act

Safety Evaluation Report

- The reviewer should evaluate and conclude:
  - The design, testing, and performance of the structures, systems, and components (SSCs) important to safety during normal operation are acceptable. Safe operation of the facility can reasonably be expected to continue.
  - The licensee’s management organization is adequate to maintain and operate the reactor. Security measures, training programs, and research activities are adequate to ensure safe operation of the facility and protection of its special nuclear material (SNM).
  - The expected consequences of postulated accidents are not likely to exceed the guidelines specified in 10 CFR Part 20 for doses in restricted as well as unrestricted areas.
  - Releases of radioactive materials and wastes from the facility are not expected to result in concentrations beyond the limits specified by the Commission’s regulations and are consistent with the as low as reasonably achievable (ALARA) principle.
  - The TS, which state limits for controlling the operation of the facility, provide a high degree of assurance that the facility will be operated in accordance with the assumptions and analyses in the SAR. The licensee’s historical data also show no significant degradation of equipment. The TS will continue to ensure that no significant degradation of SSCs will occur.

Safety Evaluation Report

- The reviewer should evaluate and conclude:
  - The financial data submitted with the application show that the licensee has reasonable access to sufficient revenues to cover operating costs and to eventually decommission the reactor facility.
  - The licensee's program for providing for the physical protection of the facility and its SNM complies with the requirements of 10 CFR 73.67, "Licensee Fixed Site and In-Transit Requirements for the Physical Protection of Special Nuclear Material of Moderate and Low Strategic Significance."
  - The procedures for training its reactor operators and the plans for operator requalification are adequate and provide reasonable assurance that the reactor will be operated in a competent manner.
  - The licensee maintains an Emergency Plan in compliance with 10 CFR 50.54(q) and 10 CFR Part 50 which provides reasonable assurance that the licensee is prepared to assess and respond to emergency events.

Safety Evaluation Report

- Written report in each section should include:
  - Relevant SAR section (or quote from the SAR section)
  - Regulations requirements
  - Other related sources (for example: NUREG-1537, ANSI-15.1)
  - Conclusion (basis of your own findings to include the Regulations, NUREG, Web sources, calculations, inspections, history of the facility)

Safety Evaluation Report

- **<u>Example 1: Geography</u>**
- The MST Reactor is located in the City of Rolla in Phelps County, MO. It is about 100 miles (mi) southwest of St. Louis and 180 mi southeast of Kansas City. The MSTR building lies approximately 1 mi east of the main campus.

- Rolla has a total area of 11.3 square miles (mi2), of which 99 percent is land and less than 0.1 percent is water. The surrounding terrain is hilly and rolling. While the land is generally too rocky and sloped to support large-scale agriculture, there is some beef, dairy cattle, hog, and chicken farming in the area.
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- TSs 5.1.1 and 5.1.2 contain features applicable to the MST site, as described below:
  - TS 5.1.1. The Nuclear Reactor Building is located on the east side of the Missouri University of Science and Technology campus near 14th Street and Pine Street in Rolla, MO.

  - 5.1.2. The reactor is housed in a steel-framed, double-walled building designed to restrict leakage. Air and other gases may be exhausted through vents in the reactor bay ceiling 9.1 m (30 ft) above grade. The Reactor Building's free volume is approximately 1700 m3.

- Design feature TSs are defined in 10 CFR 50.36(d)(4) as those features of the facility such as materials of construction and geometric arrangements, which, if altered or modified, would have a significant effect on safety. TS design features need prior review and approval from the NRC to change. The location, design materials, and geometry defined above are used in calculations that could affect safety such as public doses from radiation. Because the site is clearly defined, TS 5.1.1 and 5.1.2 are acceptable to the staff

Safety Evaluation Report

- **Example 2: Meteorology**

- The licensee describes the general climate in the Rolla area as "a continental midwestern type and is not influenced by any local mountains or large bodies of water." According to data provided in the SAR, temperatures in this region ranged from a maximum of 110 degrees Fahrenheit (F) (43.3 degrees Celsius (C)) to a minimum of -27 degrees F (-32.8 degrees C), with a mean annual temperature of 54.5 degrees F (12.5 degrees C) over the past 30 years.

- The licensee provided the following metrological data in the SAR and responses to the staff's RAIs. Average annual precipitation from 1961 to 1990 ranged from 28.03 inches (in.) (71 centimeters (cm)) to 41.4 in. (105.1 cm). The highest annual precipitation was 63.06 in. (160.1 cm). Average monthly precipitation ranged from 1.67 in. (4.24 cm) to 5.0 in. (12.70 cm). The average annual snowfall for the region was 18.3 in. (46.5 cm). The maximum monthly snowfall was 25.1 in. (63.8 cm). The highest annual snowfall was 38.1 in. (96.8 cm). Mean annual windspeed in this area is 9.9 miles per hour (mph). The maximum windspeed was 60 mph (97 kilometers per hour (km/hr)), with wind gusts of 85 mph (137 km/hr). From January 1993 to March 2007, seven tornadoes were observed in Phelps County. Three of these were rated as F0 (Gale Tornado) (windspeed between 40–72 mph (64–116 km/hr)) on the Fujita Scale, two were an F1 (Moderate Tornado) (windspeed 73–112 mph (117–180 km/hr)), one was an F2 (Significant Tornado) (windspeed 113–157 mph (182–253 km/hr)), and one was an F3 (Severe Tornado) (158–206 mph (254–331 km/hr)). The licensee states that the reactor building walls and ceiling consist of an I-beam structure with additional angular bracing bars. The building can withstand the live wind loads up to 49.21 pounds per square foot (lb/ft2). According to the licensee, the building and reactor pool are constructed of a reinforced steel frame and a poured concrete floor. Therefore, a direct hit by a tornado is not expected to result in damage to the pool integrity or core structure. The SAR also states that no damages resulting from high winds or tornadoes have occurred on the MSTR site since its construction.

Safety Evaluation Report

- **<u>Example 2 (cont.)</u>**

- The staff concludes that the licensee has provided sufficient historical meteorological data in the SAR and in its response to RAIs to characterize the reactor site. These metrological data will enable the licensee to predict the meteorological impacts on reactor safety and operation. They also provide the licensee sufficient information to analyze the conservative dispersion estimate for postulated airborne release in the unlikely event of a radiological accident. Based on the above information and its independent review of meteorological data maintained by the National Oceanic and Atmospheric Administration, the staff concludes that no weather-related events of credible frequency or consequences will render the MSTR unsuitable for use during the extended period of operation. Chapters 3 and 13 of this SER discuss the destruction of the pool integrity causing a massive loss of pool water and provide an evaluation demonstrating that an instantaneous loss of pool water would not result in core damage.

Safety Evaluation Report

- **EXAMPLE 3: Fuel Design Considerations**

- The design features of the fuel elements are given in TS 5.3.2 as follows:
- TS 5.3.2 Fuel Elements

- 1) Plate fuel elements of the MTR type are used. The overall dimensions of each element are approximately 7.6 × 7.6 × 91.4 centimeters (cm) (3 × 3 × 36 inches (in.)). The active length of fuel is approximately 24 in. and the fuel is clad in aluminum alloy. The fuel elements have 18 fuel plates joined to two side plates. The whole assembly is joined at the bottom to a cylindrical nose piece that fits into the core grid plate. The fuel meat is U3Si2 dispersed in an aluminum matrix and is enriched to approximately 20 percent U-235.

- 2) Control rod fuel elements are similar to the elements described in (1) with the exception that the center eight plates have been removed and have been replaced with guide plates so that the control rod cannot come in contact with the fuel plates.

- 3) Half-fueled elements have nine plates fueled with low-enriched uranium (LEU) (either the front ones or the rear ones, as appropriately marked) and nine dummy (or unfueled) plates.
- 4) An irradiation fuel element has six fuel plate positions left unoccupied (plate positions 11 through 16), plates 10 and 17 are unfueled, and all the others (1 through 9 and 18) are fueled.

- TS 5.3.2 controls the important aspects of the design of fuel used in the MSTR SAR, and therefore, TS 5.3.2 is acceptable to the staff.

Safety Evaluation Report

- **Example 3 (cont.)**
- TSs 2.1, 2.2, 3.2.2, 3.3(1) and 3.3(2) help to protect the fuel integrity and are given as follows:
  - TS 2.1. The safety limit shall be on the temperature of fuel element cladding, which shall be 510°C (950°F)
  - TS 2.2. The LSSS shall be on reactor thermal power, P, which shall be no greater than 300 kW, or 150% of full power.
  - TS 3.2.2. The reactor shall not be operated unless the safety system channels presented in Table 3.2 are operable. Values listed in the table are the limiting setpoints. For operational convenience, the actual setpoints may be on more restrictive values.
  - TS 3.3(1). The reactor shall not be operated unless the water level is at least 4.88 meters (m) (16 feet (ft)) above the core.
  - TS 3.3 (2) The resistivity of the pool water shall be greater than 0.2 megohm-cm as long as there are fuel elements in the pool. This requirement may be waived for a period of up to 3 weeks once every 3 years

Safety Evaluation Report

- **Example 3 (cont.)**

- TS 2.1, "Safety Limits," specifies that the temperature of fuel element cladding must not exceed 510 degrees C (950 degrees F) to maintain the integrity of fuel cladding, which is conservatively set 17 degrees C lower than the blister limit of 527 degrees C to provide additional margin, and as such is acceptable to the staff.

- TS 2.2, "Limiting Safety System Settings," ensures that the maximum cladding temperature of fuel elements is well below 221 degrees F (105 degrees C), or equivalent to the reactor power limit setting of 300 kW. NUREG-1313 finds that the initial releases of fission products will not occur at cladding temperatures less than the blister temperature of 981 degrees F (527 degrees C). The LSSS specified in the MSTR is much lower than the blister cladding limit in NUREG-1313. The large safety margin between the blister cladding temperature and the LSSSs gives reasonable assurance that the fuel cladding is well protected and that the reactor will continue to operate safely during the period of this license. Therefore, TS 2.2 is acceptable to the staff.

- TS 3.2.2, "Reactor Safety Systems," specifies the high-power safety system channels to automatically scram the reactor if its power level were to exceed 300 kW, and therefore, TS 3.2.2 is acceptable to the staff.

- TS 3.3, "Coolant System," will ensure that adequate cooling is provided for the reactor core at all times and that corrosion of the fuel element cladding will be minimized to ensure adequate heat transfer and as such is acceptable to the staff.

Safety Evaluation Report

- **Example 3(Cont.)**

- The staff also reviewed the MTR fuel design in NUREG-1313, “Evaluations of Low-Enriched Uranium Silicide-Aluminum Dispersion Fuel for Use in Non-Power Reactors,” issued July 1988, and concludes that this type of fuel element will be safely performed in nonpower reactors. The Ohio State University research reactor, the Rhode Island Nuclear Science Center, and the University of Massachusetts at Lowell have used this type of fuel element and acknowledged that this type of fuel element has demonstrated many years of safe operation.

- The staff finds that the licensee has described the various types of fuel elements used in the MSTR, including appropriate design limits, and the technological and safety-related bases. The staff concludes that the licensee has sufficiently provided information on the constituents, materials, components, and fabrication specifications on the fuel design. The staff notes that this type of fuel element has accumulated safe operating experience at the MSTR and similar research reactor facilities. Furthermore, the staff reviews this type of fuel in NUREG-1313 and concludes it is safe operation for nonpower reactor. The staff reviews the related TSs and finds that the licensee has included appropriate design limits, SL, LSSS, and LCOs for the fuel elements. Based on above consideration, the staff concludes that there is reasonable assurance that the fuel will continue to operate safely during the period of the renewed license.

Safety Evaluation Report

- **Example 4: Maximum Hypothetical Accident (MHA)**

- The licensee presents the MHA, the accident with the greatest potential impact on the health and safety of the public, in Section 13.1.1 of the SAR. This accident assumes that an irradiated experiment containing fissile material fails and releases all gaseous fission products in the reactor building. The MSTR license allows for two different types of fueled experiments, one of which generates less than 1 W of power and the other generates between 1 W and 25 W of power. The second type of fuel experiment has an added restriction requiring it to be located beneath at least 4.88 m (16 ft) of water.

- For the first experiment failure, the licensee calculates a maximum dose (TEDE) to a member of the public of 7 mrem, and to MSTR personnel of 64 mrem, respectively. For the second experiment failure, the licensee calculates a maximum dose (TEDE) to a member of the public of 46 mrem, and to MSTR personnel of 410 mrem. Because the potential impact of a failed 25-W experiment is the greatest of all reviewed accidents, the license declares that the failure of a 25-W fuel experiment is the MHA for the MSTR.

- The values presented are well within the regulatory requirements of 10 CFR Part 20. In addition, while performing the calculations the licensee applied the following conservative assumptions, resulting in highly conservative or noncredible consequence estimates. The NRC staff evaluates each of these assumptions as follows:

Safety Evaluation Report

- **Example 4 (cont.)**
- (1) Experiments running for an infinite amount of time and all fission products, including long-lived ones, are saturated.
- This is a conservative assumption, since less than one-half of the fission products would be at saturation after a 1-day (8-hour) irradiation, and as such is acceptable to the NRC staff.
- (2) All (100 percent) noble gases and 50 percent of the halogens would be released from the experiment on total failure.
- This consumption is consistent with NUREG-0772, and as such is acceptable to the NRC staff.
- (3) Pool water does not provide any scrubbing of the noble gases.
- This assumption does not account for any physical size or form of the material in the fueled experiment. Noble gases can be trapped in the material matrices, but this assumption does not provide any credit for trapping. Because this assumption is conservative, it is acceptable to the NRC staff.
- (4) Pool water removes 90 percent of the iodine isotopes.
- The licensee states that this assumption is also conservative, since 95 percent of iodine isotopes are removed by the pool water, and as such it is acceptable to the NRC staff.
- (5) Isotopes are instantaneously released to and uniformly distributed in the reactor room air.
- There will be a delay between the time of capsule failure and fission product release under 4.88 m (16 ft) of water to the building environment. The evacuation time is assumed to be 5 minutes, so any evacuation would be started before the activity in the air would saturate. In addition, this assumption ignores radioactive decay during the finite mixing time. Because it is a conservative assumption, it is acceptable to the NRC staff

Safety Evaluation Report

- **Example 4 (cont.)**

- In addition, the licensee also assumes that the exhaust fans are not in operation. The free air volume of the reactor bay is 1,700 m3. An average breathing rate of the reactor personnel is 1.25x106 cubic centimeters per hour, and that person would stay in the reactor room full of airborne radioactive gases and particulates for 5 minutes. Those assumptions are consistent with NUREG-0772 and the facility description. In addition, the licensee states that an evacuation time of 5 minutes is conservative based on the licensee's experience in previous emergencies of 3 minutes evacuation time. Therefore, those assumptions are acceptable to the NRC staff.

- In its results, the licensee calculates a maximum thyroid dose of 28.3 millisieverts (mSv) (2.83 rem) and a maximum dose (TEDE) of 4.10 mSv (0.410 rem) to MSTR personnel. The thyroid dose value is more than a factor of 10 below the regulatory limit for an individual organ of 500 mSv (50 rem) specified in 10 CFR 20.1201, and the TEDE value is a factor of 10 below the regulatory limit of 50 mSv (5 rem) specified in 10 CFR 20.1201.

- For calculation of a maximum dose to an individual outside the reactor building, the licensee assumes that the exhaust fans are operating and that the most exposed individual remains in place throughout the time required to remove essentially all of the contaminated air from the reactor room. It also assumes that there is additional dispersion of the exhausted air before the dose recipient is immersed in it, with an equivalent of 2.0×10-2 seconds per cubic meter. The licensee also assumed that all radioisotopes released in the reactor building leak out within 24 hours. There was no radioactive decay and, hence, no decrease in the source strength. Because those assumptions are conservative in that they do not account for the removal of any radioisotope as the result of radioactive decay and/or from plating out of the air, or they do not allow for any sealing of the building. Because these assumptions are conservative, they are acceptable to the NRC staff.

Safety Evaluation Report

- **<u>Example 4 (Cont.)</u>**

- The licensee calculates the TEDE for an individual located just outside of the reactor building as 0.46 mSv (0.046 rem), which is below the regulatory limit of 1 mSV (0.1 rem) specified in 10 CFR 20.1301, "Radiation Dose Limits for Individual Members of the Public."

- The NRC staff verified the licensee's analysis and assumptions and concludes that the MHA has been adequately analyzed.

- TS 3.7.2(3) provides limits to the fueled experiment as follows:
  - Fueled experiments shall not be allowed in or near the reactor unless specifically approved by the Radiation Safety Committee. Fueled experiments in the amount which would generate a power greater than 25 W shall not be irradiated at the MSTR facility. Fueled experiments which generate more than 1 W power shall be irradiated in the reactor pool at least 4.88 m (16 ft) deep under the pool water surface. Fueled experiments which generate less than 1 W power may be irradiated anywhere in the facility. Fueled experiments shall be encapsulated to contain all fission products during irradiation. The encapsulation device shall be designed to prevent degrading of the device due to pressure and temperature of the fueled experiment.

Safety Evaluation Report

- **Example 4 (Cont.)**

- The licensee proposed two changes to TS 3.7.2(3), one of which is to reduce power from 100 W to 25 W and the other is to ensure the integrity of the fueled container (encapsulation). Those changes ensure that a fueled experiment will not result in undue radioactivity release to the environment and ensure compliance with 10 CFR Part 20. Therefore, TS 3.7.2(3) is acceptable to the NRC staff.

- The licensee states that fueled experiments have not been used for the past 15 years. Their future use is unlikely. In addition, the licensee states that the MSTR SOPs require a review by the Radiation Safety Committee and also include administrative steps to prevent a failure of a fueled experiment.

Safety Evaluation Report

- **Example 4 (cont.)**

- Base on the above considerations, the NRC staff concludes that the licensee's assumptions and calculational methods are consistent with guidance contained in regulatory guides, NUREG series documents, and previous NRC licensing actions. The NRC staff reviewed the licensee's assumptions and calculation method and concludes that the licensee is capable of calculating conservative doses for the limiting MHA. The NRC staff reviewed the associated TS and frequency of an experiment and concludes that a fueled experiment failure is unlikely, and the resulting doses from the limiting MHA would be below the applicable regulatory limits.

- Questions?

- Thank you for your attention.