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Attn.: Document Control Desk

Subject: Response to Request for Additional Information for Battery Upgrade License Amendment Request (EPID: L-2021-NFA-0000)

The Massachusetts Institute of Technology (MIT) hereby submits a response to the Request for Additional Information (RAI) dated March 18, 2021, on the License Amendment Request (LAR) to upgrade the Emergency Electrical Power System batteries at the MIT Reactor.

Accordingly, MIT provides responses in the following format: the NRC RAI question in italics, followed by the MIT answer in normal font. Wherever necessary, MIT's responses will reference supporting documents in various Enclosures.

RAI #1. The LAR states: "They [the batteries] are designed for a performance life of 20 years (7 years full warranty, with 20 years prorated warranty)."

a. What is the expected service life of the batteries at MIT?

b. What is technical basis for the service life and criteria for replacement of the batteries? IEEE Standard Std. 1188, Section 8, discusses battery replacement criteria.

c. Provide reliability information on the absorbent glass mat batteries (e.g., test data, including the test conditions and quality assurance) to justify the expected life of the batteries (i.e., a warranty is not a guarantee of performance, it is a financial agreement).

Response to **RAI #1**:

a. The expected service life of the Valve-Regulated Lead-Acid (VRLA) batteries at MIT is 20 years, during which time the batteries should deliver their expected performance in their application at the MIT reactor.

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b. The expected service life being equal to the designed performance life is derived from the following technical basis:

(1) Maintenance and surveillance on the new battery will follow the manufacturer's recommendations. Where the manufacturer's recommendations do not indicate otherwise, IEEE Std. 1188-2005 recommendations will also be followed.

(2) The new batteries are sized with plenty of capacity, and will be capable of providing emergency power for the types and frequencies of power outages at the MIT Reactor.

(3) Supporting equipment for the new batteries, including the battery charger, will be modernized with the upgrade. The new charging unit is a model recommended by the manufacturer, and is sized to complement the new battery bank. Under normal circumstances, there will also be a monitoring system that continuously provides performance tracking data and alarms for early indication of aging effects and anomalies. Adequate battery charging and monitoring prevent thermal runaway and premature aging in the batteries.

(4) The new batteries will continue to operate in the reactor's Utility Room, which is an indoor, temperature-controlled area outside the containment. In Section 8.3 of the "Installation and Operating Manual", the manufacturer recommends an operating temperature of 77 F ± 10 F (25 C ± 5.5 C). The Utility Room temperature is maintained well within this range, being fed with conditioned building air in the summer and provided with steam heat in the winter. The room has good ventilation air flow by means of a continuous exhaust fan in a ceiling vent above the battery location. These environmental factors help prevent thermal runaway and premature aging in the batteries.

(5) For extended electrical power outages (longer than an hour), reactor procedures provide instructions to reduce battery load by securing emergency lighting and unnecessary instrumentation, decreasing the current drawn by more than 30%.

(6) The use of emergency power supply in the last 20 years of operating experience at the MIT reactor has been moderate. The electrical supply to the MIT Reactor is "industrial quality", per the local power company. For the period from 2011 and 2020, off-site electrical power has been momentarily lost an average of twice a year. For the period from 2000 to 2010, the average was about four times a year. These numbers show improvement in their hardware and reliability of steady power supplies, fulfilling their commitment to reduce power fluctuations. Additionally, in the last 20 years, there have been four electrical power outages of more than momentary duration, with the most recent one being on 2 December 2015 for about 20 minutes, and the longest one being on 13 August 2003, when the emergency batteries were used for about three hours. Other major use of the emergency batteries was for one-hour discharge tests, which in the past decade were performed once every two years, and prior to that, annually.

c. A bank of the proposed type of batteries (C&D AT-15P, 120 cells) has been in operation at the MIT Cogeneration Plant since 2016. There they have provided reliable, failure-free performance since the time they were installed, supported by a similar type of charging unit and the same type of monitoring unit that the MIT Reactor will use. The AT-15P batteries delivered to the MIT Reactor passed the manufacturer's IEEE Std. 1188-2005 testing. – See Enclosure 1, test conditions and results for tests performed for Order Number 2516069 at the Reynosa Facility of C&D Technologies.

RAI #2. *The acceptance criteria outlined in NUREG-1537, Part 2 states that the source of electrical power (i.e., batteries) should be capable of supplying power for the duration required by the SAR analysis. The licensee provides a discussion in the LAR regarding sizing of the batteries, and states that the manufacturer estimates that the proposed battery system exceeds the capacity of the existing battery by 133.88 percent, by incorporating aging and design growth factors.*

a. Indicate the sizing methodology used by the manufacturer and clarify whether the methodology outlined in IEEE Std. 485, was used.

b. Page 6 of the LAR Safety Review #2020-32 provides a table on the total battery current output and states that the equipment on emergency power is not limited to the items listed in TS Table 3.6-1. Provide all the expected loads on the battery and differentiate between continuous or momentary loads. One option is to provide a duty cycle diagram (if non-continuous loads are involved), depicting the sequence of loads the battery system is expected to supply for the specified time periods, as shown in IEEE Std. 485, Figure 2. If the batteries will only be subject to continuous loads, provide a statement as such.

Response to **RAI #2**:

a. The manufacturer's Sizing Program adheres to IEEE Std. 485-2020 "IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications" and IEEE Std. 1184 "Guides for Batteries for Uninterruptible Power Supply Systems". See the third page of Enclosure 2, C&D Technologies battery calculation report (total of five pages, including the previously submitted Rating Table).

b. The equipment on reactor emergency power consists entirely of continuous loads, feeding the equipment listed in TS Table 3.6-1. Other equipment besides these items includes extra facility lighting, redundant neutron flux level channels, redundant core tank coolant level indicators, redundant primary coolant outlet temperature indicators, and redundant radiation monitors. These extra loads on the emergency battery bank are meant to ensure compliance with TS 3.6 Emergency Power requirements.

RAI #3. The licensee refers to the C&D Technologies msEndur II "Installation and Operating Manual" in the LAR but does not provide specifics on installation. IEEE Std. 1187, addresses installation design criteria and procedures.

a. What is the basis for the installation design and actual installation of these batteries (e.g., IEEE Std. 1187)?

b. If not conforming to IEEE Std. 1187, discuss how ventilation for temperature and hydrogen control have been addressed (e.g., adequate air flow for proper cooling (for both aging and capacity) and adequate ventilation to prevent the accumulation of hydrogen above combustible limits (i.e., 4 percent concentration). Information on ventilation is discussed in IEEE Std. 1187 Section 5.4. In addition, discuss the types of battery protection being applied (i.e., fuses, circuit breakers, etc.). IEEE Std. 1187, Section 5.8 outlines battery protection. Lastly, discuss any instrumentation, controls, and alarms that will be available for the battery system to ensure the battery remains capable during its service life. IEEE Std. 1187, Section 5.5, includes information on instrumentations, controls, and alarms.

Response to **RAI #3**:

a. The manufacturer's installation design and actual installation of these batteries follow IEEE Std. 1187-2013 guidelines. Enclosure 3a contains a complete copy of the manufacturer's "Installation and Operating Manual". (Previously only an excerpt was sent, showing Part 9 – Maintenance.)

b. **For ventilation for temperature and hydrogen control**, as discussed previously, the batteries will be installed in the Utility Room, which is heated and vented to maintain a relatively constant ambient temperature, uniform throughout the large, undivided room. The ceiling is equipped with a vent and continuous exhaust fan above the battery location. Upon loss of off-site power, the fan stops but the louvres in the vent stay open. The Utility Room's main entrance doors from the indoor hallway are fitted with large vents that admit conditioned air into the room and direct it up towards the height of the battery bank. The battery bank will occupy less than 1% of the room's volume.

   For battery protection, as per IEEE Std. 1187 Section 5.8.1, the battery bank is connected to the emergency power system through a 2-pole, 200-amp fused disconnect switch. Immediately downstream from the fused switch, it connects to a 2-pole, 100-amp switch at the motor-generator set, and to a 2-pole, 100-amp circuit breaker at the emergency lighting panel. The system is normally aligned so that power from the batteries will be available to start the motor-generator set when needed. The batteries also supply direct-current lighting in the Utility Room. When normal power fails, the motor-generator set starts after a 12-second delay. The delay is to prevent it from starting during short-duration power outages. See Enclosure 3b, MIT Reactor Safety Analysis Report (SAR) Figure 8-1, which is a schematic of the MIT Reactor's normal and emergency electrical power distribution.

For instrumentation, controls, and alarms for the new battery system, a Phoenix Broadband Technologies SC4 battery monitoring unit (see brochure, Enclosure 3c) will be installed, capable of monitoring battery voltages, internal resistance, and operating temperatures, and capable of providing data storage and alarms. This monitoring unit provides convenience in the measurement, recording, and tracking of many important battery parameters, including overall voltage, individual cell voltages, internal resistances, etc. However, if it is not operable, all required parameters will be measured using handheld instruments. The monitoring unit will not be connected to the public internet.

RAI #4. *VRLA batteries are more sensitive to temperature variations than the VLA batteries. VRLA batteries are more sensitive to the conditions that lead to thermal runaway, which could potentially shorten battery life. Additional information on thermal runaway is discussed in Annex B of IEEE Std. 1187 and Annex C of IEEE Std. 1188. The possibility of thermal runaway may be minimized by use of appropriate ventilation between and around the cells and by limiting the charger output current and voltage by using temperature-compensated chargers. The likelihood of thermal runaway can be minimized through periodic inspections and the use of temperature-compensated charging (or other charge-current-limiting methods). Address how thermal runaway is minimized; for example, is there routine temperature monitoring and monitoring of float current with the intent to minimize this concern?*

Response to **RAI #4**:

The batteries will operate in the Utility Room, as provided in the answer to RAI #3b. The battery bank will occupy less than 1% of the room's volume. The room is well-ventilated and temperature-controlled, minimizing the possibility of thermal runaway.

Battery charging will be performed based on manufacturer recommendations per Parts 7 & 8 of the "Installation and Operating Manual" (Enclosure 3a). Use of the charger's float-current monitoring and temperature-compensated charging will minimize the likelihood of thermal runaway. The charging device will be a HindlePower model AT30, floor mount, 480-volt 3-phase, 30-amp, temperature-compensated charger (see brochure, Enclosure 4). Charger size calculation is included in the first page of Enclosure 2.

Periodic inspections of the batteries will be performed according to the manufacturer's recommendations in Part 9 of the manufacturer's manual, along with more frequent visual inspections and review of battery monitor data.

RAI #5. The licensee references IEEE Std. 1188 in the LAR and states that the discharge test will continue to be performed consistent with IEEE Std. 1188, Section 6.3.

a. If the licensee is conforming in full with IEEE Std. 1188 for maintenance, testing, and replacement, state as such.

b. If the licensee is not fully conforming to IEEE Std. 1188, discuss why the monthly and quarterly, maintenance activities per IEEE Std. 1188, Section 5.2, are not addressed to ensure capability and consideration for determining battery replacement. Specifically, certain monthly (e.g., overall float voltage, charger output & current, ambient temperature), quarterly (e.g., cell/unit internal ohmic values, voltage of each cell/unit), and yearly (e.g., AC ripple current and/or voltage applied) are not addressed in the LAR. IEEE Std. 1188 recommends measuring voltage of each cell/unit quarterly and the LAR indicates the licensee will be measuring it semi-annually. In addition, if test results are not within the acceptance limits, what corrective actions are taken? For example, IEEE Std. 1188, Section 5.3 addresses immediate and routine corrective actions.

Response to **RAI #5**:

Where surveillance and performance test recommendations are in the manufacturer's "Installation and Operating Manual", we intend to follow those recommendations according to the manual. Specifically, the manufacturer recommends that individual cell voltage be measured and recorded semi-annually, so this takes priority over the IEEE Std. 1188 Section 5.2.2 recommendation for this to be quarterly. Under normal circumstances, we expect to measure and record individual cell voltages quarterly. However, we aligned the Technical Specification to the manufacturer's recommendation of semi-annually. The manufacturer has commented that, in their experience with their VRLA products, measuring the negative terminal temperatures is more important than checking individual cell voltages. This is why, they recommend a higher surveillance frequency for negative terminal temperature measurements, matching the IEEE Standard.

Other than the above, we will follow the IEEE Std. 1188-2005 recommendations. For instance, according to IEEE Std. 1188 Section 5.2, all inspections should be made under normal float conditions if possible, with all measurements and observations recorded for future comparison. – The manufacturer's instructions do not address this, so we will therefore follow the recommendation of the IEEE Standard. For monthly inspections, the total system [overall] float voltage, charger output current and voltage, ambient temperature, condition of ventilation and monitoring equipment, etc., will be checked and recorded. (The manufacturer's manual mentions only the float voltage, so this list is taken from the IEEE Standard.) Likewise, for quarterly inspections, the internal resistance and the temperature of the negative terminal of each cell will be checked and recorded. (The manufacturer recommends the same frequency, but with internal resistance as an optional item.) And for yearly inspections, connector resistances, and AC ripple current and/or applied voltage will be checked and recorded. (The manufacturer recommends the same frequency, but with individual AC ripple current or voltage as an optional item.)

If test results are not within the acceptance limits, corrective actions will be taken as per the manufacturer's instructions. Otherwise, IEEE Std. 1188 Section 5.3 corrective actions, immediate and routine, will be followed. Additionally, MIT may contact the battery manufacturer for specific technical advice, including on-site inspection if needed.

RAI #6. *The LAR describes proposed revisions to TS 4.6. The proposed TS surveillance requirement states that a will be performed and revise the TS and/or SAR accordingly or explain why the discharge test is performed once every two years. It is not clear if the discharge test is a performance test, service test, or modified performance test. The modified performance test envelops both a performance test (i.e., for capacity) and service test (i.e., for capability). Clarify whether 1) a performance test and service test or 2) a modified performance test, TS is appropriate to ensure the quality of the emergency power system batteries, associated charger, and monitoring system.*

Response to **RAI #6**:

The biennial discharge test is a modified performance test, combining a performance test (for battery capacity) and a service test of the emergency power supply system equipment. It is performed at constant load for one hour, verifying battery capacity while also demonstrating system capability. We have included mention of this in the update to Section 8.2.2 of the SAR. – See Enclosure 5 SAR section 8.2 proposed markups, and Enclosure 6 SAR section 8.2 proposed text final version. The discharge test for the new batteries will continue to be performed every two years, based on IEEE Std. 1188-2005 Section 6.3 on performance testing.

RAI #7. *Provide a revised SAR markup for Chapter 8, including, but not limited to, addressing the service life and battery rating as well describing the charging and monitoring system related to the batteries in Section 8.2.2 (or other appropriate section) of the SAR.*

Response to **RAI #7**:

See Enclosure 5 SAR section 8.2 proposed markups, and Enclosure 6 SAR section 8.2 proposed text final version. Other than these section 8.2 pages, no SAR text requires updates.

In summary, these RAI responses and enclosures represent additional information identified in NRC Request for Additional Information dated March 18, 2021. The RAI responses and enclosures submitted herewith do not contain any proprietary information.

This RAI response submittal contains the following Enclosures:

Enclosure 1 IEEE 1188-2005 Test reporting conditions and results for tests performed for Order Number 2516069 at the Reynosa Facility of C&D Technologies.

Enclosure 2 C&D Technologies battery calculation report (five pages, including previously-submitted Rating Table).

Enclosure 3a "Installation and Operating Manual" for C&D Technologies msEndur II batteries (including previously-submitted introductory and Part 9 Maintenance pages).

Enclosure 3b MIT Reactor SAR Figure 8-1 normal & emergency electrical power distribution schematic.

Enclosure 3c Phoenix Broadband Technologies "Site Controller Unit PBT-PA-BMS-SC4".

Enclosure 4 HindlePower "AT30 Series Microprocessor Controlled Float Battery Charger".

Enclosure 5 MIT Reactor SAR section 8.2 "Emergency Electrical Power Distribution" (two pages, showing proposed markups).

Enclosure 6 MIT Reactor SAR section 8.2 "Emergency Electrical Power Distribution" (two pages, showing proposed text final version).

Sincerely,

Edward S. Lau, NE
Assistant Director of Reactor Operations
MIT Research Reactor

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 3/24/2021
Date

Signature

Enclosures: As stated.

cc: USNRC – Senior Project Manager
Research and Test Reactors Licensing Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

USNRC – Senior Reactor Inspector
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