INL/CON-16-38589
PREPRINT

Experimental Fuels Facility Re-categorization Based on Facility Segmentation

Nuclear & Facility Safety Workshop

Troy P. Reiss and Jason Andrus

July 2016

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U.S. Department of Energy
National Laboratory
operated by
Battelle Energy Alliance

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Troy P. Reiss
Jason Andrus
Battelle Energy Alliance, Idaho National Laboratory
Troy.Reiss@inl.gov, *Jason.Andrus@inl.gov*

Abstract

The Experimental Fuels Facility (EFF) (MFC-794) at the Materials and Fuels Complex (MFC) located on the Idaho National Laboratory (INL) Site was originally constructed to provide controlled-access, indoor storage for radiological contaminated equipment. Use of the facility was expanded to provide a controlled environment for repairing contaminated equipment and characterizing, repackaging, and treating waste. EFF is also used for research and development services, including fuel fabrication.

EFF was originally categorized as a less-than-Hazard-Category-3 (LTHC-3) radiological facility based on facility operations and facility radiological inventories. Newly planned program activities identified the need to receive quantities of fissionable materials in excess of the single parameter subcritical limit in ANSI/ANS-8.1, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors" (identified as "criticality list" quantities in DOE-STD-1027-92, "Hazard Categorization and Accident Analysis Techniques for Compliance with Department of Energy (DOE) Order 5480.23, Nuclear Safety Analysis Reports," Attachment 1, Table A.1).

Since the proposed inventory of fissionable materials inside EFF may be greater than the single parameter sub-critical limit of 700 g of U-235 equivalent, the initial re-categorization was Hazard Category (HC) 2 based upon a potential criticality hazard. This paper details the subsequent facility hazard categorization performed for the EFF. The categorization was necessary to determine the need for further safety analysis in accordance with 10 *Code of Federal Regulations* (CFR) 830, Subpart B, "Safety Basis Requirements."

Based on the segmentation argument presented in this paper, the final hazard categorization for the facility is LTHC-3. Department of Energy Idaho (DOE-ID) approval of the final hazard categorization determined by the hazard assessment document (HAD) was required per the DOE Supplemental Guidance for DOE-STD-1027-92 based on the proposed downgrade of the initial facility categorization of HC-2.

1. INL/MFC Background

INL is a government-owned reservation located in southeastern Idaho (see Figure 1), approximately 25 miles west of Idaho Falls, Idaho. INL was first established in 1949 as the National Reactor Testing Station (NTS) used for a construction and testing area for various experimental and research reactor programs, reactor fuels, structural components, materials, and reactor safety programs. The INL site covers an area of approximately 890 mi^2. INL is currently operated by Battelle Energy Alliance, LLC (BEA) under a 10-year contract with DOE. Current missions of INL include developing nuclear reactor technologies and supporting national security programs, advanced fuel development, spent fuel treatment, and other science and technology programs.

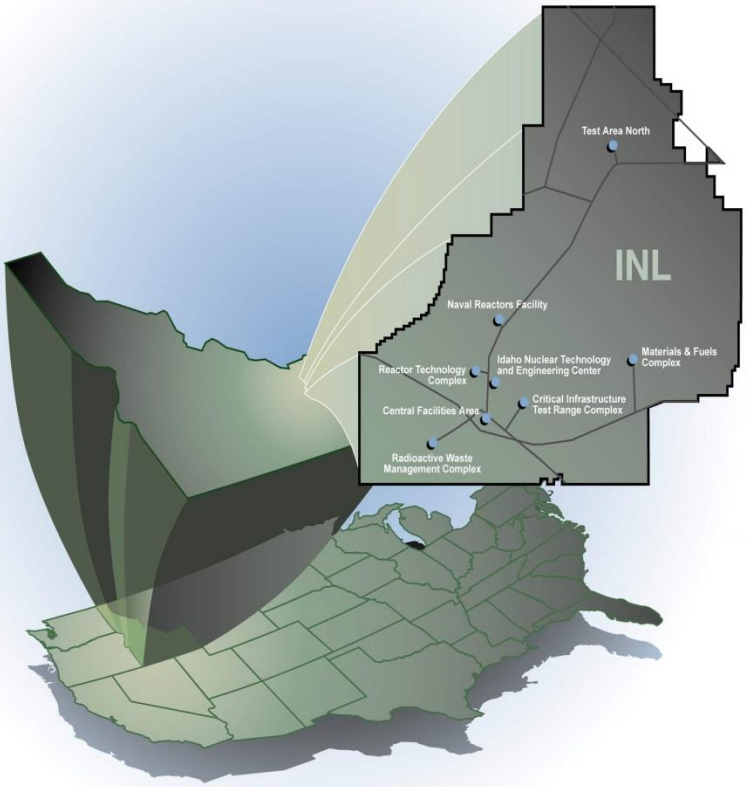

Figure 1. Location of the INL Site.

MFC is the easternmost facility located on INL. Formerly known as Argonne National Laboratory –West and operated by the University of Chicago, the MFC site covers an area of approximately 890 acres. Construction of the MFC site began in the mid-1950s with the Experimental Breeder Reactor-II (EBR-II) and support facilities, following the successful demonstration of the EBR-I reactor which is also located on the INL reserve. The EBR-II program, which is no longer in operation, was developed for research and development of liquid metal fast breeder reactor technology. Facilities currently operated at MFC include the following:

- The Fuel Conditioning Facility (FCF) is adjacent to the EBR-II facility. During EBR-II operations, this inert atmosphere hot cell facility was used as a support facility for subassembly dismantling, as well as fuel reprocessing and fuel pin casting for return to the reactor. The current mission of FCF is to process and stabilize EBR-II fuel from reactor programs.

- The Hot Fuel Examination Facility (HFEF) is an inert atmosphere hot cell facility. HFEF was constructed to support irradiated fuel and hardware examination programs for EBR-II and other DOE complex-wide projects. The Neutron Radiography Reactor (NRAD) is a 250 KW Training, Research, and Isotope, General Atomics (TRIGA) reactor located within HFEF.

- The Transient Reactor Test Facility (TREAT), located one mile west of the main MFC compound, is an air-cooled uranium-oxide reactor, which was used in reactor fuels and materials safety experiments using short, controlled bursts of high power nuclear energy. TREAT is currently shutdown and in the process of restarting.

- The Zero Power Physics Reactor (ZPPR) was designed for studying the properties of liquid-metal reactor cores at low power. When operational, experimental cores were built in ZPPR by hand-loading plates of reactor material into drawers. These reactor materials include uranium, plutonium, sodium, and stainless steel. Since the shutdown of EBR-II, FMF has been converted to a multiuse research and development (R&D) facility.

- The Laboratory and Office (L&O) Building consists of small hot cells, gloveboxes, waste-form-development equipment, and general-purpose chemistry laboratories. The Analytical Laboratory (AL) is located within the L&O. The mission of AL is to provide chemical, radiochemical, and physical measurements in support of MFC and INL nuclear and environmental programs.

- The Fuel Manufacturing Facility (FMF) was constructed in 1986 to house fuel manufacturing operations in support of EBR-II. Since the shutdown of EBR-II, FMF has been converted to a multiuse R&D facility.

- The Space and Security Power Systems Facility (SSPSF) provides the capability for assembly and acceptance testing of radioisotope power systems (RPS) to be used in National Aeronautics and Space Administration (NASA) deep space missions and

other security applications relying on an integral, secure, and long term power source.

- The Radioactive Liquid Waste Treatment Facility (RLWTF) processes low-level radioactive liquid waste generated at MFC. The facilities supported by RLWTF are EBR-II, HFEF, TREAT, ZPPR, FCF, and AL. RLWTF is capable of evaporating approximately 227,000 L (60,000 gal) of radioactive liquid annually; the resulting residue is low-level radioactive solid waste which is packaged and stored in an environmentally acceptable form for interim-storage or shallow-land burial.

- Several LTHC-3 facilities perform various post irradiation examinations and R&D of fuel. This includes EFF.

Figure 2 is an aerial view showing the major MFC facilities discussed above.

Figure 2. MFC major facilities.

2. Experimental Fuels Facility Description

Facility Description

EFF (MFC-794) was originally constructed to provide controlled-access, indoor storage for radiological contaminated equipment. Use of the facility was expanded to provide a controlled environment for repairing contaminated equipment and

characterizing, repackaging, and treating waste. Recently, EFF has taken on a new mission to also be used for R&D services, including fuel fabrication.

EFF is a pre-engineered metal building consisting of two large rooms with painted metal wall panels, metal roof panels, and structural-steel support frames. The west side (room) of the building is the original structure. It was designed and constructed in 1975 and can be accessed through a personnel door or a large roll-up door on the west end of the building. An extension to the original building (east room) was completed in 1983. This east side of the building is taller than the west side and can also be accessed by a personnel door or a roll-up door on the east side of the building. EFF normal power supply is a 480 Vac, three-phase, 800 ampere. The east side and the west side are separated by a wall with a rollup door and a personnel door.

A separate ventilation system supports each side of EFF, the east and west sides. Gloveboxes that could create particulate have pre-filters in the ventilation lines upstream of the main high-efficiency particulate air (HEPA) filter bank that are monitored for fissionable material build up. These pre-filters prevent fissionable material from migrating to the main ventilation filter banks supporting each respective side. Hold up within the ventilation system is accounted for and tracked.

Operations in the EFF facility may involve chemical research; machining; small-scale R&D; physics research; instrumentation research; computer applications; fuel fabrication; processing and characterization of non-irradiated nuclear materials; Resource Conservation and Recovery Act (RCRA) permit activities; and treatment, storage, and/or disposal (TSD) activities. Specific details regarding EFF are provided in the subsections below. Figure 3 shows the floor plan for EFF.

East Side

The east side of EFF is equipped with a two-ton bridge crane, various pieces of process equipment, hoods, and gloveboxes. The east room is insulated and environmentally controlled with electrical space heaters and an air handling unit. EFF is equipped with a dry pipe fire suppression system (covering both the east and west sides), which if initiated will activate a local building alarm and a remote alarm at the INL Fire Department. The east lab floor is sloped to two circular collection sumps for accumulation of water in the event of fire suppression system activation.

West Side

The west end was used for storage of contaminated equipment but has been converted to an experimental fuels development capability. A ventilation system has been added to accommodate several pieces of equipment to be used in the development process. The ventilation and HEPA filtration system for the west side is independent of the east side ventilation and HEPA filtration. The fans and final HEPA filters for the exhaust ventilation systems are located on the exterior northwest side of EFF under the existing over hang. A grated floor trench is used as a catch basin in the event of fire suppression system activation. There are no level indicators or alarms associated with this trench. The west

side ties into the electrical and fire protection systems of the east side. The compressor, control valve, actuation system, and alarm equipment for the fire suppression system are housed in a small heated room in the northwest corner of EFF. Access to this room is via an exterior door on the northwest side of the building.

Cask Pad

The cask storage pad is directly adjacent to the north wall of EFF. This storage area is a concrete/asphalt area that uses part of the overhanging EFF roof for partial protection from the elements.

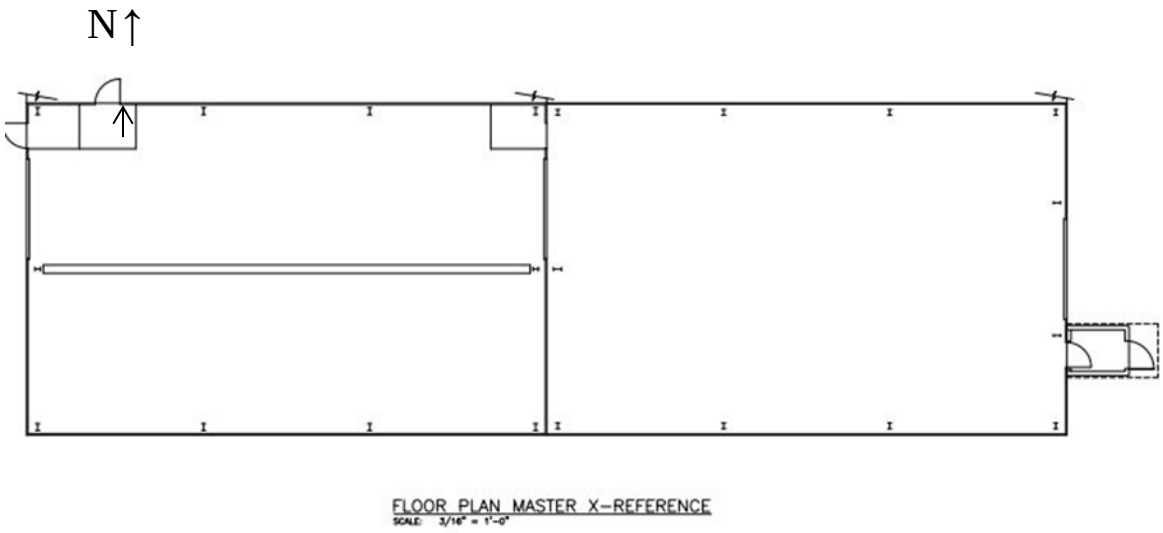

Figure 3. Layout of EFF.

To support the new program and the possibility of segmentation for criticality purposes, an analysis was performed to determine the thickness of a wall that would preclude criticality. From the analysis, a gypsum wall approximately 18 in. thick, extending from the floor to the ceiling, has been constructed over the pre-existing wall between the east and west sides of the building to provide greater separation between the two sides. A berm was constructed along the floor of the west wall of the east side where the roll-up door and a man door are to prevent comingling of fissionable material from one side with the other in the event of firefighting or other events that may add large amounts of water to the facility. The roll-up door and personnel door are still present, but the roll-up door has been enclosed and electrically disconnected within the newly constructed wall, and the man door has been barricaded closed with the berm. It should be noted that the floor grade for the east side is above the floor grade in the west side. The difference in grade necessitated the berm on the east side to prevent the comingling of fissionable material in scenarios involving water. Figure 4 shows the newly constructed wall in EFF and Figure 5 shows the berm that was installed.

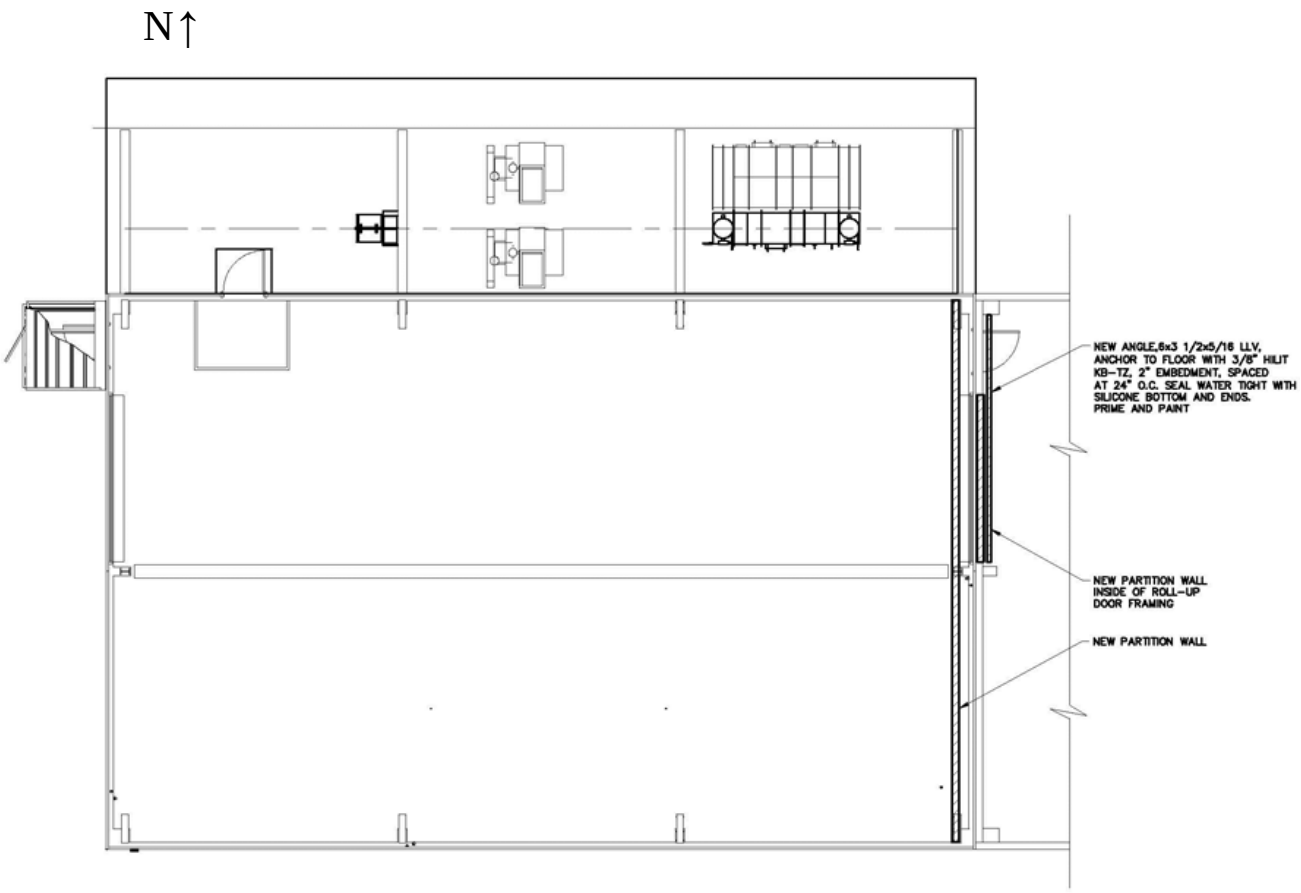

Figure 4. Layout of MFC-794 west side room showing newly constructed wall.

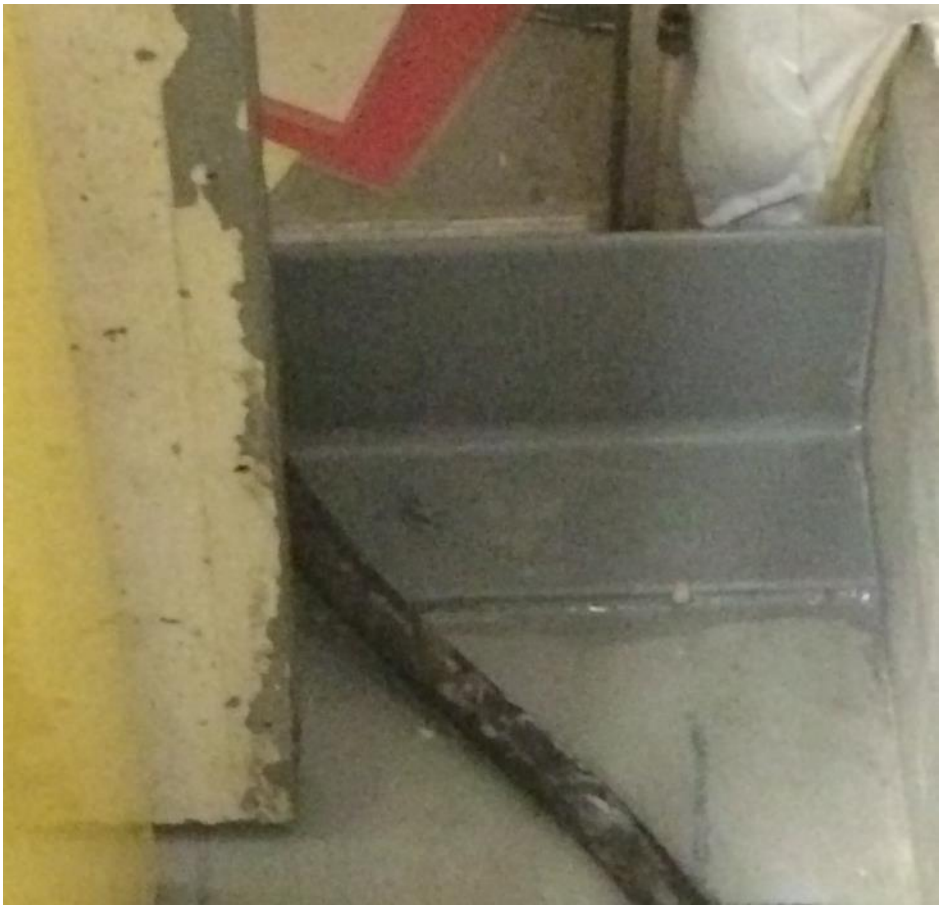

Figure 5. View of berm in northwest corner of east side.

3. Proposed Activity

EFF was previously categorized as a LTHC-3 radiological facility. Planned program activities have identified the need to receive quantities of fissionable materials in excess of the single parameter subcritical limit in ANSI/ANS-8.1, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors" (identified as "criticality list" quantities in DOE-STD-1027-92, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports," Attachment 1, Table A.1).

Since the proposed inventory of fissionable materials inside EFF may be greater than the single parameter sub-critical limit of 700 g of U-235 equivalent, the initial re-categorization was HC-2 based upon a potential criticality hazard. This paper details the facility hazard categorization performed for EFF. The categorization was necessary to determine the need for further safety analysis in accordance with 10 CFR 830, Subpart B, "Safety Basis Requirements."

4. Hazard Categorization

The hazard categorization process is performed to determine the level of safety analysis, safety basis documentation, and review and approval required to support operation of the facility. Hazard categorization, as required by 10 CFR 830, is performed using the methodology described in DOE-STD-1027-92. The hazard categorization is performed by making a direct comparison of the radiological material inventory within the facility or activity to the HC-3 threshold quantity values (TQVs) listed in DOE-STD-1027-92.

The hazard categorization is also limited to the criticality fissionable material inventory single parameter mass limits of 500 g for U-233, 700 g for U-235, and 450 g for Pu-239, as provided in the note at the bottom of Page A-12 of DOE-STD-1027-92. Both the radiological material inventory and the fissionable material inventory limitations must be met. DOE-STD-1027 Supplemental Guidance requires: "If segmentation of a facility is being considered for the purpose of categorization based upon the potential for criticality, then the segmentation must prevent not only physical interaction of fissile material operations, but also neutronic interaction between operations."

The facility is further categorized by comparing quantities of radiological material inventory to the reportable quantities in Appendix B of 40 CFR 302.4, "Designation of Hazardous Substances."

If the radiological material inventory of the facility does not exceed the threshold quantities for HC-3 in DOE-STD-1027-92, the facility is categorized as a "radiological facility" for the purpose of safety analysis. However, if the radiological material inventory of the facility also does not exceed the criteria in Appendix B of 40 CFR 302.4, the facility is then further designated as an "other facility" for the purpose of safety analysis.

DOE-STD-1027-92 allows certain exclusions from a facility's radiological material inventory when determining the hazard categorization of a facility or activity:

A. Sealed radioactive sources that are engineered to pass the Special Form testing specified by the Department of Transportation (DOT) in 49 CFR 173.469, "Tests for Special Form Class 7 Materials," or testing specified by American National Standards Institute (ANSI) N43.6, "Sealed Radioactive Sources, Categorization," may be excluded from summation of a facility's radioactive inventory.

B. Hazardous materials used in exempted, commercially available products should not be considered part of a facility's inventory. These materials are described in 10 CFR 30.11-19, "Rules of General Applicability to Domestic Licensing of Byproduct Material," and include timepieces, illumination devices, thermostats, electron tubes, microwave receiver tubes, etc.

C. Material contained in DOT Type B shipping containers (with or without overpack) may also be excluded from summation of a facility's radioactive

inventory if the Certificates of Compliance are kept current and the materials stored are authorized by the certificate.

D. These exclusions do not apply to fissionable material in the determination of HC-2 status relative to criticality.

Radiological Material Inventory

Radiological materials are located in EFF on the east side, west side, and EFF cask pad in a variety of containers. Radioactive material operations in EFF include fuel fabrication and processing and characterization of non-irradiated nuclear materials. The containers on the cask pad may include metal containers, drums, casks, cargo containers, cask equipment, and wooden boxes typically painted with fire-retardant paint. Material in EFF is typically stored in plastic bags, storage cabinets, drums, etc. The quantity of radiological material stored in EFF is controlled administratively by procedures. The quantity of radiological material is tracked by Nuclear Operations personnel by maintaining a current inventory of radiological materials as identified in DOE-STD-1027 using the Sum of Ratios Inventory Tracking Database. Inventory totals are checked before a transfer of material to ensure that the HC-3 TQV sum-of-ratios value will not exceed 1.0. Uncharacterized containers need to be evaluated prior to being received at the facility. All transfers are conducted in accordance with applicable procedures.

The radioactive material inventory in EFF as of February 17, 2015, provided by facility personnel, is shown in Table 1.

Table 1. EFF radioactive material inventory on 02-17-2015.

Location	Nuclide	Quantity (g/Ci)	HC3 TQVs (g)	Ratio	40 CFR 302.4 RQs (Ci)	Ratio
East Side and West Side	U234	5.17E+00/3.23E-02	6.70E+02	7.71E-03	1.00E-01	3.23E-01
	U235	5.90E+02/1.27E-03	1.90E+06	3.10E-04	1.00E-01	1.27E-02
	U238	6.70E+04/2.25E-02	1.30E+07	5.15E-03	1.00E-01	2.25E-01
Cask Pad*†			-	3.21E-02	-	1.46E+00
		Sum of the Ratios =		4.53E-02		2.02E+00

* The list of isotopes for the cask pad is shown in the tracking database information loaded in in the INL electronic document management system (EDMS) as supporting documentation, EFF-Inventory-2-17-15.

† The cask pad 40 CFR 302 ratio is calculated by taking a ratio of the cask pad with the EFF HC-3 ratios multiplied by the reportable quantity (RQ) ratio.

All activities within EFF (which includes the cask pad) shall maintain the radiological inventories below the DOE-STD-1027-92 HC-3 TQVs. Based on nuclide inventory and a simple ratio, the radiological material inventory of the facility exceeds the criteria in Appendix B of 40 CFR 302.4 and is classified as a "radiological facility." Therefore, EFF is classified as an LTHC-3 radiological facility based on limiting the radiological inventory.

Fissionable Material Inventory

The EFF facility maintains fissionable material in accordance with INL Criticality Safety Program procedures. EFF is segmented into two criticality control areas (CCAs), the east side and the west side. The cask pad is not within either CCA and is only used to store contamination levels of fissionable material. Any fissionable material stored within EFF contributes to the fissionable material inventory for the side in which it is located and contributes to the radiological material inventory for the whole facility. The quantity of fissionable material allowed in the west side of EFF shall not exceed 700 g moderated fissionable equivalent (MFE) where MFE = ^{235}U mass + 2(^{233}U mass + Pu mass). The quantity of fissionable material allowed in the east side of EFF shall not exceed 700 g MFE. Fissionable material is transferred and stored in accordance with INL procedures. The quantity of fissionable material in either side of EFF is tracked and controlled by Nuclear Operations personnel.

Inventory totals are checked for each transfer of material both into and out of EFF to ensure that HC-3 TQV sum-of-ratios and fissionable material limits will not be exceeded by the transfer. All transfers are conducted according to applicable procedures. A criticality safety program is in place to ensure compliance with the technical basis for precluding criticality-limited fissionable material inventory.

Segmentation

As described, EFF is one facility divided into an east side and a west side. EFF will consist of two CCAs (east side and the west side) with each CCA limited to 700 g MFE. The cask pad is not within either CCA. In order for the facility to consist of two CCAs, with each CCA allowing 700 g MFE, the following provision from the supplemental guidance to DOE-STD-1027 must be met:

> *If segmentation of a facility is being considered for the purpose of categorization based upon the potential for criticality, then the segmentation must prevent not only physical interaction of fissile material operations, but also neutronic interaction between operations.*
>
> *Section 4.3 of the supplemental guidance goes on to say that a radiological facility may have a Criticality Safety Program and preclude the potential for criticality through the use of only "high-level controls.*

It was determined early in the process that the scope of the planned program activities would re-categorize EFF as HC-2 facility and the segmentation argument was considered. It was conceived that since there was already a wall between the two rooms,

then the wall could be made thicker to prevent physical and neutronic interaction between materials. Additionally, it was concluded that a berm was needed to prevent physical interaction of material in the event of a facility fire.

The east side CCA and the west side CCA are physically separated by a wall. ECAR-2569, "Criticality Safety Evaluation for the Experimental Fuels Facility (EFF)," determined that the neutronic interaction between two moderated spheres is not significant at approximately 14 in. The wall between the east side and west side has been verified in Inspection Report, IR# 31751-CFP12-IR1, "New Wall Construction," to have a thickness of greater than 14 in. A berm has been constructed along the west end of the floor of the east side CCA in front of the roll-up and personnel doors. The berm will prevent fissionable material from migrating from the east side CCA to the west side CCA due to firefighting activities or other events that may add large amounts of water to the facility. The physical configuration of the facility prevents physical and neutron interaction between fissionable material from the two CCAs. Due to the physical separation and control upon the limited amount of fissionable material allowed in each CCA, no credible criticality scenarios exist.

5. Accident Considerations

The types of accidents that could affect the facility segmentation are fire events and seismic events.

Major Facility Fire

It is considered in a fire event that the wall will not survive the fire, but the fire will not increase the migration of fissionable material from one side to the other. Loss of the wall will not affect the hazard categorization because there is one limit for both sides of the facility. In addition, the berm, as discussed above, will prevent the migration of fissionable material in water between the east and west side.

Seismic Events

The potential airborne material released in a seismic event is considered to be small compared to the limit, and given the small quantities of material and physical facility barriers, it is judged that there will not be any migration of fissionable material between the east and west side in a seismic event.

6. Controls

Controls are developed for EFF to maintain the facility categorization. ECAR-2569 derived engineered controls for the thickness of the wall and for a berm. These engineered features are listed in this document as assumptions of the current facility configuration that allow the EFF to be categorized as LTHC-3 and are not derived as controls in this document. The controls developed in this document for EFF are listed below:

A. The radiological material inventory shall be tracked and controlled such that the HC-3 TQV sum-of-ratios value for EFF (i.e., the east side, west side, and cask pad) does not exceed 1.0.

B. The quantity of fissionable material shall be tracked and controlled such that the east side of EFF does not exceed 700 g MFE.

C. The quantity of fissionable material shall be tracked and controlled such that the west side of EFF does not exceed 700 g MFE.

7. Summary

EFF has a new mission and the amount of fissionable material may be greater than the single parameter sub-critical limit of 700 g of U-235 equivalent; the initial re-categorization is HC-2 based upon a potential criticality hazard. A hazard categorization was performed, and EFF is classified as an LTHC-3 radiological facility based on limiting the radiological inventory. The physical configuration of the facility prevents physical and neutron interaction between fissionable material from the east and west sides of EFF. Based on the calculated HC-3 TQV sum of ratios, the segmentation argument, and the radiological and fissionable material inventory limits detailed in Section 7, the final facility categorization for the EFF facility is LTHC-3 "radiological." The concurring authority of this hazard categorization is DOE-ID.

8. References

10 CFR 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," *Code of Federal Regulations*, Office of the Federal Register, June 1998.

10 CFR 830, Subpart B, "Safety Basis Requirements," *Code of Federal Regulations*, Office of the Federal Register, January 2003.

40 CFR 302.4, "Designation of Hazardous Substances," *Code of Federal Regulations*, Office of the Federal Register, July 2002.

49 CFR 173.469, "Tests for Special Form Class 7 Materials," *Code of Federal Regulations*, Office of the Federal Register, December 2005.

ANSI/ANS-8.1, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," American National Standard, 1998 Reaffirmed 2007.

ANSI N43.6, "Sealed Radioactive Sources, Categorization," American National Standards Institute, 1997.

DOE-STD-1027-92, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports," U.S. Department of Energy, December 1992 (including Change 1, September 1997).

ECAR-2569, “Criticality Safety Evaluation for the Experimental Fuels Facility (EFF),” Rev. 0, January 22, 2015.

EFF-Inventory-2-17-15, “EFF Sum of Ratios Inventory Tracking Database as of 02 17 2015.”

Inspection Report, IR# 31751-CFP12-IR1, “New Wall Construction,” April 22, 2014.

U.S. Department of Energy, Office of Health, Safety, and Security, Office of Nuclear Safety and Environment, “Supplemental Guidance for DOE Standard 1027, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports,” May 2007.