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INTERIM STORAGE AND LONG TERM DISPOSAL OF RESEARCH REACTOR SPENT FUEL

N.C. IYER, * D.W. VINSON, R.L. SINDELAR, J.E. THOMAS AND T.M. ADAMS
Savannah River National Laboratory, USA

Abstract:

Aluminum clad research reactor spent nuclear fuel (SNF) is currently being consolidated in wet storage basins (pools). Approximately 20 metric tons (heavy metal) of aluminum-based spent nuclear fuel (Al-SNF) is being consolidated for treatment, packaging, interim storage, and preparation for ultimate disposal in a geologic repository. The storage and disposal of Al-SNF are subject to requirements that provide for safety and acceptable radionuclide release. The options studied for interim storage of SNF include wet storage and dry storage. Two options have also been studied to develop the technical basis for the qualification and repository disposal of aluminum spent fuel. The two options studied include Direct Disposal and Melt-Dilute treatment. The implementation of these options present relative benefits and challenges. Both the Direct Disposal and the Melt-Dilute treatment options have been developed and their technical viability assessed. Adaptation of the melt-dilute technology for the treatment of spent fuel offers the benefits of converting the spent fuel into a proliferation resistant form and/or significantly reducing the volume of the spent fuel. A Mobile Melt-Dilute system concept has emerged to realize these benefits and a prototype system developed. The application of the melt-dilute technology for the treatment of legacy nuclear materials has been evaluated and also offers the promise for the safe disposal of these materials.

Keywords: Al-based spent fuels; wet storage, basin storage, dry storage, repository disposal, melt-dilute, mobile system, high enriched spent fuel

*To whom correspondence should be addressed: Natraj C. Iyer, Savannah River National Laboratory, Aiken, SC 29808, USA; e-mail: natraj.iyer@srnl.doe.gov

Journal Information

1. Introduction

Aluminum clad research reactor spent nuclear fuel (SNF) is currently being consolidated in wet storage basins (pools). Approximately 20 metric tons (heavy metal) of aluminum-based spent nuclear fuel (Al-SNF) is being consolidated for treatment, packaging, interim storage, and preparation for ultimate disposal in a geologic repository. The sources of the Al-SNF are domestic research reactors (DRR), and foreign research reactors (FRR). This spent fuel contains uranium and highly enriched uranium (HEU) that originated in the United States of America (U.S.). The storage and disposal of Al-SNF are subject to requirements that provide for safety and acceptable radionuclide release. A number of alternative technologies have been developed to constitute the Al-SNF into a waste form acceptable for ultimate disposal in a geologic repository. These technologies include direct disposal using road ready packages and melt-dilute treatment of the highly enriched Al-SNF. The direct disposal technology offers the capability of treating and packaging the spent fuel in its existing form without altering the composition of the spent fuel. The melt-dilute treatment technology, on the other hand, offers the potential to dilute the HEU into a proliferation resistant form prior to packaging and disposal. The melt-dilute technology can also be readily adapted to treat many Department of Energy (DOE) legacy waste streams with significant process versatility and modularity. The legacy material waste streams include the following: depleted uranium, high enriched uranium, streams containing organic materials including metallurgical mounts, and streams containing small amounts of plutonium etc. This paper will provide an overview of the technologies developed in the U.S. for the geologic disposal of Al-SNF. It will also detail the development of alternative platforms for the emerging melt-dilute technology and its application to both spent fuel and legacy nuclear materials treatment.

2. Aluminum Research Reactor Fuel

The majority of the research reactor spent fuel assemblies consist of uranium-aluminum fuel cores encased in aluminum clad. The spent fuel consists of uranium aluminide particles in an aluminum matrix. Some fraction of the aluminum spent fuel assemblies in the inventory also have cores of uranium silicide, uranium oxide or uranium carbide particles in an aluminum matrix. The uranium enrichment ranges from 20 to 90% and the burn-up of the spent fuel ranges from 30 to 70%. Figure 1 shows typical geometries and configurations of aluminum clad fuel assemblies.

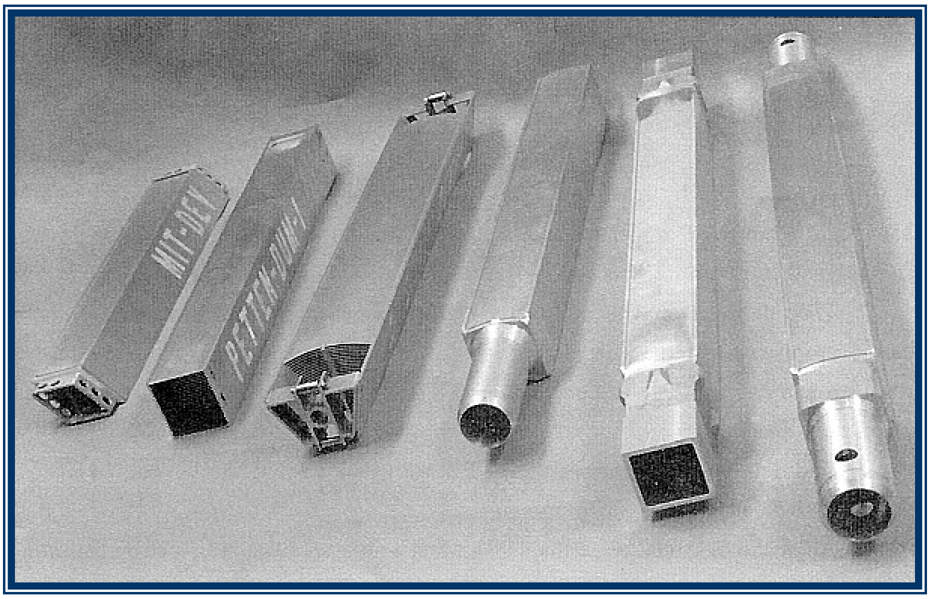

Figure 1 Aluminum clad spent nuclear fuel.

3. Interim Storage of Aluminum Spent Fuel

Interim storage of SNF will likely be needed for several decades since the licensing, construction and start-up of the geological repository is a long process. Dry storage in a monitored retrievable storage (MRS) facility and extended basin (wet) storage are the two alternatives for interim storage.

3.1. "WET" BASIN STORAGE

The Al-SNF may be stored directly in wet storage basins provided that the basin water chemistry controls are in place. The typical basin standards for wet storage of Al-SNF are listed in Table 1.

The wet basin chemistry limits are procedure limits and in order to ensure procedural compliance periodic water chemistry analyses are performed.

Table 1 Table of Basin Chemistry Standards and Present Conditions

Parameter	Limit	Typical Value
Conductivity	10 μmho/cm	1 μmho/cm
pH	5.5 to 8.5	6.2
Chloride	0.1 ppm	< 0.1 ppm (laboratory detection limit)
Cs-137	1000 dpm/ml	13 dpm/ml
Alpha	10 dpm/ml	< 1 dpm/ml (laboratory detection limit)
Tritium	1.0 μCi/ml	0.035 μCi/ml
Al	1.0 ppm	< 0.05 ppm (laboratory detection limit)
Cu	0.1 ppm	< 0.05 ppm(laboratory detection limit)
Fe	1.0 ppm	< 0.05 ppm(laboratory detection limit)
Hg	0.1 ppm	< 0.002 ppm (laboratory detection limit)

Initial laboratory testing has shown the above basin chemistry to be non-aggressive[1] and basin surveillance confirms that the present storage conditions are non-aggressive.[2]

Radionuclide release from exposed fuel meat in water storage is another issue that must be managed for wet basin storage. For example, a typical basin limits to release from Al-SNF in basin storage is 20.7 μCi/hr from an assembly for a large, well managed basin. Fuel can be cropped to expose the fuel meat if the expected release is below 20.7 μCi/hr. Maintenance of a wet basin at or below these level aids in ensuring that not only is water chemistry controlled to prevent fuel degradation but also limits the potential for personnel exposure/contamination events.

3.2. DRY STORAGE

Two distinct types of dry storage systems are envisioned: a "sealed system" which would store fuel assemblies in fully-sealed containers and a "non-sealed" system which would store assemblies in non-sealed containers or holders open to the environment of the facility. If a sealed system is used, the seal must be of adequate design to last the duration of the storage period (e.g. 50 years) or allowances (e.g., cost) must be made for resealing. The need for a sealed storage system, in a dry storage facility will be driven by the requirements of confinement barriers including the acceptable level of radionuclide release from a confinement barrier and the number of barrier layers. The cladding itself provides one such confinement barrier with the release of radionuclides limited by the criteria for acceptable degradation.

A sealed storage system is one in which a fully-sealed container enclosing one or more fuel assemblies is placed within a dry storage facility. The approach to avoid excessive degradation in a sealed system is to dry the contents to a level of free water (remaining in the container to-be-sealed) such that if all water is fully consumed by corrosion of the fuel, that: 1) the conditions of acceptable degradation are not exceeded; 2) the production of hydrogen does not pose a threat to post-storage retrieval due to build-up of hydrogen to levels that could result in a deflagration event; and 3) the production of hydrogen does not pose a threat to post-storage retrieval due to production of pyrophoric substances. The temperature (upper) limit is based on the most limiting non-corrosion degradation mechanism.

A non-sealed system is one in which fuel would be in contact with the ambient air in a dry storage facility (e.g. outside air temperature and relative humidity conditions). Since the corrosion of aluminum exposed to ambient air progresses at a slow rate, even at high humidities (up to 100%) at near room temperatures, storage in a non-sealed system is feasible in "non-dirty" atmospheres (those containing low chloride and sulphate compounds). It is not possible to produce high humidities (up to 100%) at high temperatures (up to 200°C) in a non-sealed system and therefore cladding materials would not experience the corrosion rates observed in corrosion testing program.[3]

The requirements for interim dry storage are based on providing for safe, retrievable storage. Retrievability is directly related to limiting degradation in a storage system. In developing the requirements for interim dry storage, limited fuel degradation was acceptable, consistent with the requirement of no gross rupture of fuel cladding during storage and post-storage handling since the fuel was assumed to be eventually removed from interim storage.

Fuel Drying for a Dry Storage System

The drying requirement for interim dry storage is based on avoiding hydrogen gas, H_2, build-up during storage in sealed canister. H_2 is generated through corrosion reactions. In a sealed storage system, H_2 build-up gives a more stringent limit for free water in the canister than does corrosion consumption of the material.

The total amount of water available for corrosion arises from three basic sources. These sources are (1) free water (which includes water in pits in the cladding, crevices, etc.); (2) waters of hydration on existing oxide; and (3) adsorbed waters on oxide and on aluminum. The amount of adsorbed water on the surface of a metal varies with the relative humidity and the temperature.

Volpe[4] determined that at 20°C, the amount of absorbed water is approximately 20 monolayers at 100% relative humidity. This is much less than the water of hydration in a 50 µm Boehmite film, assumed to be the initial condition of the cladding, and is therefore negligible.

Complete dehydration of the hydrated oxide layers is neither readily achievable nor necessary in drying. The waters of hydration from Boehmite (assumed to be released in storage due to radiolysis) for a film of 50 µm is assumed to be released and to corrode the aluminum cladding to form Al_2O_3. It does not recombine with the original Al_2O_3 left from dehydration of Boehmite. This results in 0.0002 inches of aluminum corrosion. Therefore, the maximum possible uniform consumption of aluminum dried to 1 ml per 0.1 m^2 of cladding surface in a sealed system is approximately 0.0003 inches.

The limiting drying criterion is designed to avoid hydrogen build-up. At temperatures above approximately 80°C, hydrogen build-up occurs in a closed system containing aluminum and water according to:[5]

$$2Al + 4H_2O = Al_2O_3 \bullet H_2O + 3H_2$$

Assuming the reaction goes to completion, 1 ml of H_2O yields 0.042 moles of H_2. The generation of hydrogen in the above mentioned reaction to produce boehmite bounds that for the reaction to produce gibbsite at temperatures below approximately 80°C.

A general formula can be derived to relate the volume fraction of free water to the hydrogen pressure for the reaction at completion:

$$\frac{\mathbf{FW}}{\mathbf{V}} = 292505 \frac{\mathbf{P_{H_2}}}{(273.15 + \mathbf{T})}$$

where FW is the free water volume in ml;
V is the volume of the container in m^3;
P_{H_2} is the pressure due to H_2 in atmospheres;
and T is the temperature in °C.

One impact of hydrogen buildup is the potential for an explosion hazard. The lower concentration limit of flammability of hydrogen is 4 percent by volume in air at room temperature. The lower concentration level for a sustained burn of hydrogen in air is approximately 9 percent by volume in air. The concentration level at which a hydrogen/air mixture is explosive is 18 percent. Therefore, the partial pressure of hydrogen must be below 0.59 psia or the ratio of free water (ml) to the volume of the container (m^3) must be kept below 39 to ensure that hydrogen at 4 volume percent of a container with air is not produced.

Another impact of hydrogen buildup is the potential for production of UH_3, a compound that is pyrophoric under certain conditions. Dispersoids such as UAl_x would not be reduced by expected hydrogen pressures to produce UH_3; however, oxides of uranium could be if the partial pressure of H_2O is low enough and the partial pressure of H_2 is high enough in an H_2O/H_2 system. However, because aluminum surrounds the oxides in the dispersoid fuel and does not allow direct contact with the fuel particles, this is not expected to result in significant production of UH_3.

Considering the potential for existing UH_3 on uranium metal fuels retrieved from basin storage, only uranium metal fuels may need to be stabilized. The INEL has developed a stabilization treatment with the technical bases[6] to convert UH_3 to uranium oxide. No significant amount of UH_3 is expected to be present on aluminum-based fuels. In addition, the stringent drying requirements ensure that the expected H_2 build-up is extremely low so that UH_3 production due to H_2 gas contacting exposed fuel meat is negligible.

Dryness Specification

To limit the H_2 build-up in a sealed canister to 4% by volume from free water, the maximum allowable free water (W_{water}, in grams) is expressed as a function of the free volume (V, cm^3) of the container.

$$W_{water} = 3.873\text{x}10^{-5}\ V$$

Vacuum Drying Specification

The Al-SNF must be vacuum dried to at least 5 torr at an internal chamber temperature of 25°C (77°F) or higher. The vapor pressure of water at 25°C (77°F) is 24 torr, and any free liquid water on the fuel will be vaporized before 5 torr is reached.[7] To ensure dryness, the vacuum pump should be isolated following drying and the chamber interior pressure must remain at or below 5 torr for 15 minutes to confirm dryness.

Drying tests using unheated vacuuming to dry an instrumented canister containing residual free water and a mock fuel assembly were reported in reference 7. These tests were successful at drying the assembly and canister, and showed that temperature, pressure, or relative humidity could be used as measures of free water removal. Applying a warm air purge during the vacuum drying improved the drying method. Recent field experience with two instrumented, shielded SNF test canisters indicates a continuous warm air purge (< 74°C (165°F)) under vacuum provides satisfactory dryness in a reasonable time interval. A canister containing one assembly and ~0.6 pints of water was dried to ~0.25 torr in 2.5 hours.

The vacuum pump should have a pumping speed of at least 100 cfm (cubic feet per minute) and a rated ultimate vacuum of at least 0.5 torr. An air-cooled vacuum pump is recommended to eliminate the need for cooling water disposal with a water-cooled pump. A water-sealed vacuum pump is recommended to eliminate the need for waste oil disposal with an oil-sealed pump. Redundant vacuum sensors should be provided as close as practical to the canister vacuum nozzle connection.

The warm air purge system should have a thermostatically controlled heater and a flow of at least 25 cfm. Temperature monitoring must be provided for air entering and exiting the canister. Direct temperature monitoring of the canister bottom is desired.

The drying temperature shall not exceed 250°C to avoid the potential for hydrogen blistering and gross cladding failure. The drying specification calls for a low-temperature heated-air vacuum drying. The lower temperature during the drying process helps avoid the potential for blistering of the Al-SNF materials caused by H_2 via vapor corrosion at high temperature (at and above 250°C).

4. Geologic Disposal Options for Aluminum Research Reactor Spent Fuel

The path envisioned for ultimate disposition of the Al-SNF assemblies involves transfer and treatment of wet-stored assemblies into an Al-SNF form suitable for the geologic repository. Two options include packaging the fuel in either a “direct” or “melt-diluted” form in a sealed canister. The canisters would be in a “road ready” package i.e. it would be suitable for interim storage for up to 40+ years prior to repository disposal. The canisters would be transported to the repository and placed into waste packages for ultimate disposition.

The qualification of the road ready package for either of these two options include documentation, analyses and/or validation of the spent fuel characteristics, criticality controls, corrosion performance and thermal analysis in the context of the repository performance assessment. The technical basis for the qualification and repository disposal of aluminum spent fuel has been developed for both the propose options.

4.1. DIRECT DISPOSAL TECHNOLOGY OPTION

Direct Disposal technology involves drying the spent fuel to remove the adsorbed and hydrated water, packaging and sealing the SNF in a canister which has a diameter of approximately seventeen inches and a length of approximately 120 inches. The storage criteria for aluminum SNF in a road ready package support the basis for both the interim storage and the repository storage requirements. The canister of fuel will be vacuum dried and back-filled with helium. The fuel will be separated in the canister with a basket containing neutron absorber materials. Three to four baskets would be stacked within each canister. After the canister is back-filled and sealed, it will be temporarily stored in horizontal concrete storage modules. Ultimately, the canisters will be shipped to a federal Mined Geologic Disposal System (MGDS) repository for final disposal. There each of the SNF canisters will be placed inside a larger waste package containing five Defense Waste Processing Facility (DWPF) High-Level Waste (HLW) canisters before being emplaced in the repository.

Exposure of Al-SNF forms to environments that may be present in the waste package will cause changes in the forms from their initial condition. Al-SNF degradation may result in release of radionuclides from the spent fuel matrix and reconfiguration of fissile species within the engineered barrier system (EBS). This may directly affect the performance of the proposed repository.

Degradation of the Al-SNF and reconfiguration of fissile materials controlled by the thermochemical stability and solubility of the many possible uranium compounds and rates of the many competing reactions has been extensively studied. Based on the natural occurrence of uranium bearing minerals within ore deposits in the western United States, thermochemical data, and the products formed during laboratory corrosion experiments, the hydrated oxides and silicates of uranium and hydrated aluminum oxides or alumino-silicates are the most likely final degradation products. The reconfiguration and redistribution of materials within the waste package have been analyzed to support the criticality analysis.

Neutron poison materials for loading in Al-SNF canisters have been assessed as a method for avoiding criticality with HEU SNF. Candidate materials include borated stainless steel, dispersions of europium oxide, gadolinium oxide, or samarium oxide in stainless steel, and cadmium. Mechanical properties, corrosion resistance, neutron absorption properties, cost and availability are the major factors evaluated for selection of a poison material. The preliminary bases for the direct co-disposal of Al SNF, in conjunction with neutron absorbers, in a geologic repository have been developed.

4.2. MELT-DILUTE TECHNOLOGY OPTION

The melt-dilute treatment process option has been developed for ultimate disposal of spent nuclear fuel from FRR and DRR in the monitored geologic repository (MGR). Most of these fuels contain HEU (>20% ^{235}U).[8] The melt-dilute treatment involves melting the SNF in a furnace and diluting with depleted uranium.

Figure 2 shows a schematic of the process. Dilution of the SNF to reduce the ^{235}U content of HEU to LEU levels (i.e. <20% enrichment) offers the primary benefit of reducing criticality potential. The product is an isotopically diluted SNF form that can be tailored to optimize the degradation characteristics by addition of aluminum or other elements. Significant benefits are also accrued from the ~70% volume reduction resulting in fewer canisters to be stored and shipped for repository disposal when compared to direct/co-disposal. Melt-dilute treatment also minimizes characterization requirements through erasure of the SNF's history and acquisition of in-process characterization data.

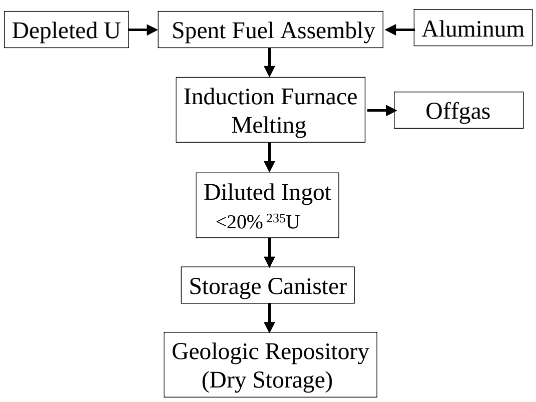

Figure 2 Process flow schematic for Melt-Dilute Process.

Advantages of diluting the uranium to below 20% ^{235}U and the eutectic composition include: 1) lower process operating temperatures, 2) minimum gravity segregation in the casting, 3) lower volume of off gas products and 4) lower associated process and materials costs. When compared to other dilution methods, the 20% dilution offers the greatest versatility because waste forms containing approximately 5-67 wt% uranium can be produced resulting in package volume reduction of up to 70%.

The Melt-Dilute treatment technology has been advanced through the construction, and start-up testing phase for a pilot-scale irradiated facility. The scale of the pilot facility is ideally sized for the treatment of the aforementioned spent fuel and legacy materials streams. Optimization of the design has lead to two off-gas system options: 1) traditional SRS off-gas design involving a combination of dry zeolite beds and HEPA filters or 2) a closed evacuated self-contained melting system. The pilot-scale facility design offers the opportunity to optimize design for SNF and legacy materials and installation of such units at multiple locations within the DOE complex. Alternatively, a transportable mobile unit is also envisioned for the treatment of spent fuel and/or legacy waste materials. Such a system will be capable of being readily adapted and modified to meet he requirements in different parts of the country or world, as necessary.

5. A Pilot Scale Melt-Dilute Facility

A pilot scale facility was constructed in a U.S. DOE Hazard Category 2 structure, shown in

Figure 3, to demonstrate the melt-dilute process.[9] The facility includes a control room where operators run and observe process operations while the furnace and associated equipment are located inside the hardened structure. The furnace is located inside a stainless steel box, which acts as the primary containment.

The floor plan for the facility is shown in Figure 4. Shown on the figure are the universal power supply, the crane aisle access corridor, the trailer well, furnace and associated equipment and the control room. The induction furnace is located behind a shield wall to protect operators from radiation during entry into the trailer well.

The SNF is brought to the facility in an 8-ton cask on a flatbed trailer. The roll-up door is opened and the trailer is backed into the trailer well. After removing the cask lid bolts, the trailer is removed and the door closed. Further operations are done remotely using the crane. After the cask lid is removed, the cask is moved to the unloading station where the fuel basket containing the spent fuel assembly is removed and moved to the furnace. The fuel basket tool is placed on guide pins located on top of a datum plate that is attached to the furnace; the fuel basket is then lowered into the graphite crucible containing the carbon steel liner. The unloading tool is then returned to the tool stand shown in Figure 5.

Figure 3 A Pilot-Scale Melt-Dilute Facility.

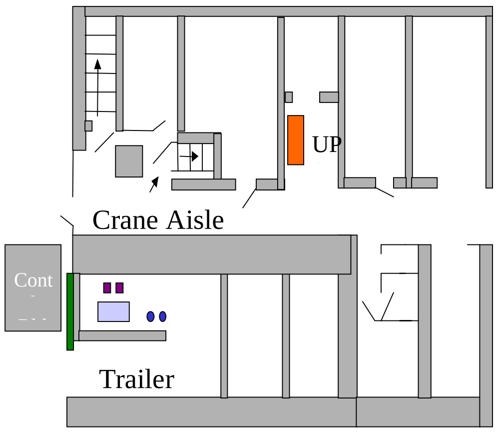

Figure 4 Layout of Pilot-Scale Melt-Dilute Facility.

Figure 5 Unloading Tool is returned to the Tool Stand

Next the equipment plate containing two melt samplers, the primary zeolite bed and the crucible camera is lowered on top of the furnace crucible as shown in Figure 6. The guide pins on the datum plate help guide the equipment plate to align the zeolite bed and crucible. The equipment plate engages a robot end-of-arm tool changer on the datum plate to connect pneumatic and electrical lines for operation of equipment on the equipment plate. The containment box lid is put onto the enclosure and clamped in place using pneumatic clamps.

The melt-dilute facility is operated from the control room. All operations are observed on video screens located on the console and operating parameters are displayed on the center video screen. The operator controls the induction furnace start-up and power levels, the airflow into the furnace containment box and through the zeolite bed. The pressure drop across the containment boundary is monitored to maintain a negative pressure so all airflow is from the room into the box. Dilution air from inside the box is used to cool hot offgas so the exit gas temperature is less than 50 ºC. A photograph of the operating console is shown in Figure 7.

Figure 6 Lowering the Equipment Plate onto the Furnace using the Overhead Crane.

The facility was fully operational and start-up testing began using aluminum assemblies. Several successful tests were made where data on the furnace, ventilation system, cooling water system, and uninterruptible power system was obtained. Furnace operations and all remote tooling functioned per design.

Figure 7 Control Room for Melt-Dilute Pilot-Scale Process.

6. Melt Dilute Treatment using A Mobile Platform

The melt-dilute technology was converted into a mobile platform to develop the Mobile Melt-Dilute facility (MMD) for treatment of fuels and/or legacy materials at storage locations in around the world; thereby, avoiding the costs of building separate treatment facilities at each site and avoiding shipment of enriched fuel assemblies over the road.[10-11] The Mobile Melter facility concept is based on SRNL tests, and modular pilot-scale facilities constructed at SRS for treatment of U.S. spent fuel and was developed in conjunction with Idaho national Laboratory (INL)[12]. Laboratory tests at SRNL have shown the feasibility of operating both a closed and a filtered off-gas system.

One concept for the MMD would be to build a facility that would utilize the closed system approach. A summary flowsheet schematic is shown in Figure 8. The MMD process simply involves 1) loading spent fuel assemblies in a canister with depleted uranium, 2) welding a lid on the canister, 3) drying and evacuating the canister, and 4) melting the HEU fuel assemblies and diluting the ^{235}U/U–aluminum alloy to less than 20% enrichment in ^{235}U.

After treatment, the sealed canister containing the solidified aluminum-uranium ingot can be placed in interim storage pending reprocessing or emplacement into long-term storage. Thus, HEU material can be treated using the MMD process to generate a safe and secure LEU ingot. As envisioned, the MMD system will be compact and staged on a transportable vehicle, with the capability to treat and encapsulate research reactor spent fuel at either the reactor or storage site.

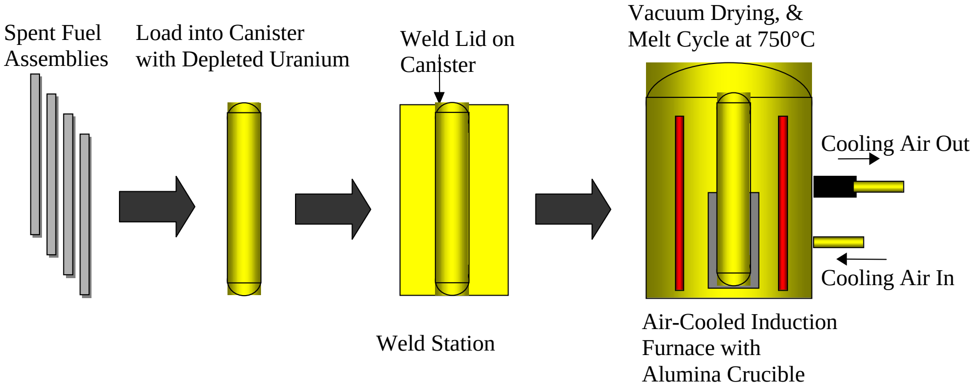

Figure 8 Schematic of simplified flowsheet for MMD process..

The furnace would be enclosed with an outer container or dome, similar to a reactor dome, to contain any volatile gases in the unlikely event the closed container leaked during melting. The dome may be designed to provide sufficient shielding so additional shielding may not be needed around the furnace area.

Ideally, only one element would be melted at a time, but the system could be designed to melt 4-6 elements per batch. With one element the recipe for dilution and alloy composition control would be easier. It is expected that the furnace and controls would be located in separate international shipping containers that could be easily loaded onto trailers and unloaded at the work site for assembly.

Loading and unloading of the furnace with spent fuel would be done remotely. Once the fuel assembly is brought to the MMD facility in a cask, it would be unloaded using a forklift or crane and placed onto a remote system to move it to the furnace. It is expected that the cask would provide radiological shielding while furnace loading, unloading and transporting the spent fuel.

The Mobile Melter can be transported in two over-the-road trailer assemblies. (Figure 9) This allows free movement between locations where spent fuel is stored, eliminating the need to transport fuel and minimizing fuel handling. Only the melter and control system will move along roadways, it is not necessary to move shielding or structures. If additional shielding for process activities is needed, it can be easily erected at the individual sites. In addition, the control and monitoring equipment are housed separately keeping the more costly equipment in a clean environment at all times. Should contamination of the melter become a problem, the furnace can be replaced at minimal cost.

Figure 10 shows how the equipment could be installed in shipping containers and staged at the storage facility. Inexpensive shielding, if needed, can be erected quickly and inexpensively with corrugated steel panels like those used to protect aircraft from strafing or ground attack. These panels can be erected to form cavities of predetermined thickness and filled with dirt. Control and power cables which must pass from the control unit to the melter can be installed through these cavities before they are filled, preventing “shine” along their paths. This shortens the setup time required to make the system operational, leaving only three things to do: position the trailers, connect the cables, and test the system.

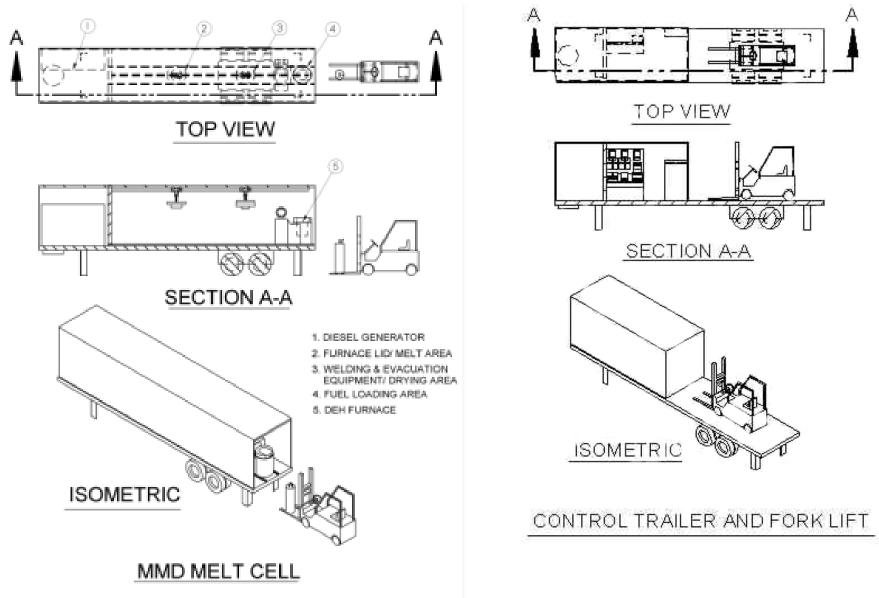

Figure 9 Sketch of MMD modular system layout.

The melter was originally conceived as a closed system using a condenser to trap volatilized material, but an offgas system was added to avoid a pressurized system containing radionuclides and to reduce the waste volume. In addition to the closed system, a system similar to the one developed at SRS could be designed for mobility. Such a system would reduce waste volume up to 70%.

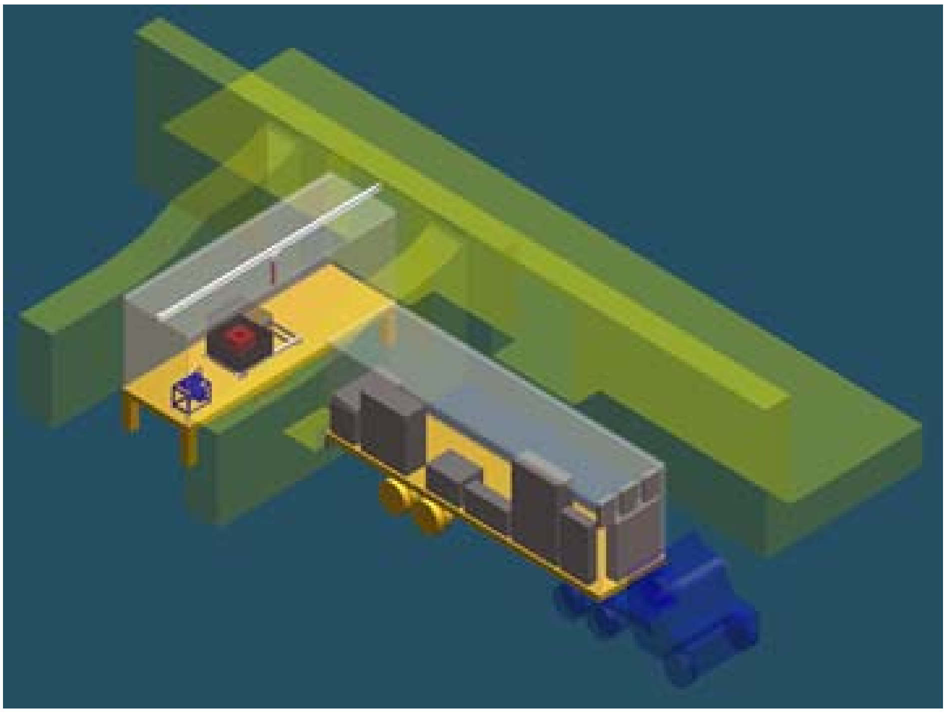

Figure 10 Modular Transportable Melt-Dilute System.

7. Melt-Dilute Treatment of Legacy Materials

There are currently various classes of nuclear materials that may have no defined disposition pathway. These materials include off-spec HEU (High Enriched Uranium) metal and oxides, surplus depleted and natural uranium, uranium-233, Pu-238 scrap, miscellaneous Pu-239 scrap, metal, and powder, and various spent nuclear fuel “cats & dogs.” Development of well-defined disposition pathways—which may include various stabilization, treatment, or disposition technologies—is paramount for an effective nuclear materials stewardship program. In order to achieve this goal, the most appropriate technology must be identified to ensure that efficient and effective management of the legacy materials inventory. One approach is to explore/evaluate currently existing stabilization, treatment, and disposal technologies with respect to their ability to handle diverse new/alternate feed streams.

The melt-dilute technology offers the potential to treat and dispose of many of the materials managed under the DOE-NMS program.[13-14] It is an attractive concept for the treatment of a variety of materials. The pilot scale design or the modular mobile design can be adapted to a “mini-batch” system that could be turnkey fabricated and staged at any of the end-user sites in need of treatment and disposition of nuclear materials or installed in a tractor trailer to make a mobile treatment system.

8. Summary

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Two options have also been studied to develop the technical basis for the qualification and repository disposal of aluminum spent fuel. The two options studied include Direct Disposal and Melt-Dilute treatment. The implementation of these options present relative benefits and challenges. Both the Direct Disposal and the Melt-Dilute treatment options have been developed and their technical viability assessed. Adaptation of the melt-dilute technology for the treatment of spent fuel offers the benefits of converting the spent fuel into a proliferation resistant form and/or significantly reducing the volume of the spent fuel. A Mobile Melt-Dilute system concept has emerged to realize these benefits and a prototype system developed. The application of the melt-dilute technology for the treatment of legacy nuclear materials has been evaluated and also offers the promise for the safe disposal of these materials.

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