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Title:

EVALUATION OF EXISTING UNITED STATES' FACILITIES FOR USE AS A MIXED-OXIDE (MOX) FUEL FABRICATION FACILITY FOR PLUTONIUM DISPOSITION

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ABSTRACT

A number of existing United States' facilities were evaluated for use as a mixed-oxide fuel fabrication facility for plutonium disposition. These facilities include the Fuels Material Examination Facility (FMEF) at Hanford, the Washington Power Supply Unit 1 (WNP-1) facility at Hanford, the Barnwell Nuclear Fuel Plant (BNFP) at Barnwell, S.C., the Fuel Processing Facility (FPF) at Idaho National Engineering Laboratory (INEL), the Device Assembly Facility (DAF) at the Nevada Test Site (NTS), and the P-reactor at the Savannah River Site (SRS). The study consisted of evaluating each facility in terms of available process space, available building support systems (i.e., HVAC, security systems, existing process equipment, etc.), available regional infrastructure (i.e., emergency response teams, protective force teams, available transportation routes, etc.), and ability to integrate the MOX fabrication process into the facility in an operationally-sound manner that requires a minimum amount of structural modifications.

INTRODUCTION

One of the options under review for disposition of surplus plutonium is the fabrication of the material into mixed-oxide (MOX) fuel and subsequent burning in nuclear reactor facilities. Potential reactor facilities include existing light-water reactors (LWRs), partially-completed LWRs, new advanced or evolutionary LWRs, or CANDU heavy-water reactors. Each of these reactor types has specific MOX fabrication and bundle assembly requirements. It is the responsibility of the Nuclear Fuels Technologies project to evaluate the requirements with regard to MOX fabrication and bundle assembly, resolve any uncertainties that might inhibit implementation, and produce the data required to initiate a Title I design of a MOX fabrication facility. Inherent in this responsibility is evaluation of MOX fabrication facility requirements and options with regard to facility construction and operation. In order to reduce the capital requirements of constructing a new MOX fabrication facility, the use of existing facilities, modified to meet the MOX fabrication requirements, has been suggested. Therefore, the purpose of this paper is to provide an evaluation of the suitability of existing facilities for modification and use as a MOX fabrication facility capable of meeting the needs of the disposition program so that follow-on efforts to develop more detailed conceptual designs can be initiated.

FACILITY REQUIREMENTS

The requirements for a MOX fabrication facility fall into five main categories:

- Process space requirements
- Physical security requirements
- Structural integrity requirements
- Personnel safety requirements
- Infrastructure requirements

A brief description of each of these areas is given below.

Process Space Requirements

The MOX fabrication facility requires adequate space to house the fuel fabrication process lines, as well as supporting functions such as materials receiving and storage, waste management, general administration, and security. Only those functions involving special nuclear material (SNM) need to be contained within a category I facility. However, the support operations need to be near the fabrication operations. The exact amount of space required depends on the reactor type selected due to variations in fuel bundle size, required heavy-metal throughput, and process line requirements (i.e., some reactors require a combination of fuel fabricated with depletable neutron absorbers and without absorbers presents; hence, two separate fabrication lines are required for these operations to avoid cross-contamination). Table 1 gives estimates for process space requirements that should accommodate all reactor options.

Physical Security Requirements

Clearly defined physical barriers, such as fences, walls, and doors must be used to control, impede, or deny access to the protected area (PA) which contains the MOX fabrication facility. The PA perimeter must be defined by two 8-ft security fences, separated by a 30-ft clear zone that contains a Perimeter Intrusion Detection Alarm System (PIDAS). The perimeter lighting must comply with the latest DOE Orders (5632.7 series) and be compatible with both visual observation by security police officers and an event-actuated closed circuit television system (CCTV). The perimeter lighting must be powered by commercial power and provided back-up through a back up generator. A detection system must be installed (using up-to-date technology) at all PA/Material Access Area (MAA) boundaries, vaults, and vault-like rooms to signal attempted intrusion, unauthorized attempt at access, or other anomalous situation. This detection system must include access control facilities at each portal, where

TABLE 1. PROCESS SPACE REQUIREMENTS

Process	Estimated Space Required (sq.ft.)
Receiving Bay	2000
PuO2 Storage	3000
UO2 Storage	7000
Miscellaneous Parts Storage	3000
PuO2 Purification	12000
Feed Material Preparation	4000
Fuel Pellet Fabrication	25000
Fuel Rod Fabrication	5000
Fuel Bundle Assembly	20000
Materials Recycle	5000

the identity of each employee is verified. A computerized entry control system must maintain a real time record of all persons present in the PA and MAA. Any alarm anomaly must be displayed on a console in the central alarm station (CAS). To meet security requirements, intersite shipment of the plutonium-bearing material will be by Special Security Transport (SST) throughout the disposition operation. Therefore, the MOX fabrication facility must have the ability to receive SST shipments in a secure manner.

Structural Integrity Requirements

The MOX fabrication facility must be designed for earthquake generated ground accelerations in accordance with Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards, UCRL-15910, with applicable seismic hazard exceedance probability of $2x10^{-3}$ for General Use (Performance Category 1), $1x10^{-3}$ for Low and Moderate Hazard (Performance Category 2 and 3), and $2x10^{-4}$ for High Hazard (Performance Category 4) structures. All plant structures must be designed for wind or tornado load criteria at specific DOE sites in accordance with UCRL-15910 and the corresponding facility usage and performance goals. Wind loads will be based on the annual probability of exceedance of $2x10^{-3}$ for General and Low Hazard (Performance Category 1 & 2), $1x10^{-3}$ for the Moderate Hazard (Performance Category 3) and $1x10^{-4}$ for the High Hazard (Performance Category 4) structures. The sites for which tornadoes are the viable wind hazards must be designed for the annual probability of exceedance of $2x10^{-5}$, UCRL-15910. All facilities and buildings should preferably be located above the critical flood elevation (CFE) from any potential flood source (river, dam, levee, precipitation, etc.). Otherwise, the site/facility must be hardened to mitigate the effects of the flood source.

Personnel Safety Requirements

Fire protection features for the plant and its associated support buildings must be in accordance with DOE Orders and the National Fire Protection Association (NFPA) Fire Codes and Standards. The HVAC system design for the facility must meet all general design requirements in accordance with DOE 6430.1B, Section 1550, and ASHRAE guides. Pressure differentials must be maintained between areas so that air flows from noncontaminated areas into areas of potentially higher contamination levels. Differentials must be maintained by automatically controlled zone ventilation systems that are equipped with redundant, independent emergency power supplies. The facility must contain an adequate number of high efficiency particulate air (HEPA) filters to exhaust the process air through. Confinement and containment of nuclear material must be provided for the MOX fabrication facility by the building structure and the ventilation system.

Infrastructure Requirements

Protective force staffing levels and operational capabilities must be sufficient to neutralize the DOE postulated adversary threats. These personnel must be trained to meet compliance with appropriate human reliability programs (e.g., PAP and PSAP). Adequate waste management facilities must be present. Waste management involves the collection, assaying, sorting, treatment, packaging, storage, and shipment of radioactive, hazardous and mixed wastes from plutonium operations, and hazardous and non hazardous waste from the support facilities. The waste management products include radioactive and nonradioactive wastes, including solid transuranic, low-level, and mixed wastes, hazardous liquids and solids, and nonhazardous, nonradioactive solid wastes such as compacted industrial and sanitary waste, and recyclable materials; and liquid wastes such as reclaimed water and rain. Adequate utilities must be present to support facility operations. Finally, sufficient transportation infrastructure must be present to support the required number of shipments to and from the MOX fabrication facility.

Requirements Summary

Consequently, to determine the adequacy of a existing facility for use as a MOX fabrication facility, the following questions must be resolved:

• Does the facility have adequate space in which to perform the MOX fabrication operations for all potential reactor types? Does the facility have additional space which might be available for other plutonium operations (i.e., pit disassembly and conversion, metal-to-oxide conversion, etc.)?

• Does the facility meet DOE security requirements for a Category I facility including fencing, the presence of a PIDAS zone, adequate perimeter lighting, and alarm and other security equipment?

• Does the facility meet all DOE structural requirements for a Category I facility, including the guidelines for earthquake design, wind and tornado design, flood protection, fire protection, and material containment/confinement?

• Does the facility have an adequate HVAC system including differential pressure areas and HEPA filters?

• Does the facility have an existing emergency response force, waste treatment facilities, sufficient utilities, and transportation infrastructure?

FACILITY DESCRIPTIONS

Fuel Materials Examination Facility (FMEF)

The FMEF was built during the late 1970's and early 1980's as a major addition to the breeder reactor technology development program at the Department of Energy's Hanford Reservation. The FMEF facility design was initiated in 1978 and underwent several major changes in scope as a result of changes in the direction of the DOE's breeder reactor development programs. The initial design concept, called Fuels and Materials Examination Facility (FMEF), was to destructively and nondestructively inspect irradiated fuel materials from the U.S. DOE Research and Development Breeder Reactor projects being developed at that time (the Fast Fuels Test Facility (FFTF) and the Clinch River Breeder Reactor Plant (CRBRP)). The first facility scope revision occurred in April 1979. This consisted of combining a second breeder reactor development facility with the FMEF. This facility, the High Performance Fuels Laboratory (HPFL), was to produce breeder reactor fuel assemblies for the FFTF and the CRBRP. It included fabrication of high-exposure and spiked fuels for proliferation resistance. During 1979, the U.S. Government's proliferation policy was changed. The need for a HPFL type of fuel fabrication was eliminated. This caused an official change to the Secure Automated Fabrication (SAF) line in October 1980. Further changes in the DOE Breeder Reactor Program direction resulted in a facility scope reduction in October 1983, removing the irradiated fuel examination functions (however, the cells and liners are already installed for this type of work). During 1983, modifications to the shops and storage portion of the Entry Wing for FFTF fuel assembly fabrication (pins to assemblies) were incorporated into the construction of that portion of the building. The Fuel Assembly Area was then established and configured to support fuel pin inspection, assembly, and storage. Low-exposure, SAF-fabricated driver fuel pins would be transferred to the Fuel Assembly Area for final processing. With the demise of the DOE Breeder Reactor Program, the SAF Project was canceled. At the present time, the Department of Energy has permanently shut down the FFTF and all missions associated with the FMEF have been canceled. No radioactive material was ever handled within the FMEF.

Fuels Processing Facility (FPF)

The original mission of the Fuel Processing Facility (FPF) was to reprocess spent nuclear fuel, primarily naval fuel, and to recover the highly enriched uranium. It was to have replaced an existing uranium extraction facility which had operated for thirty years. The facility would have housed the processes necessary to receive and process dissolver product solutions from several other facilities, including: the Fluorinel Process Area, the aluminum dissolver, the electrolytic dissolver, and the Hot Chemistry Laboratory. These processes would have provided three cycles of solvent extraction, product denitration, and final product storage. Processes would also have been in place to provide such support functions as effluent management, surge volume and intercycle product storage, process solvent recovery, process solution makeup, uranium salvage, and solid waste handling.

Construction was begun on the facility in 1986, under the Fuel Processing Restoration project, and phased out in 1992-93, under an order from then Secretary of Energy James Watkins. Construction was terminated prior to the completion of several components critical for occupancy. These components include such systems as permanent electricity, lighting, fire protection and ventilation. The exterior, however, is 100 percent complete, and the structure contains the utility systems necessary to allow personnel to enter the building. The interior of the structure has been completed to a point that it could be adapted to a number of uses. No radioactive material was ever introduced into the FPF. The structure was designed, constructed, and inspected in compliance with a quality assurance program that met ASME NQA-1. Activities within the structure are currently limited to surveillance, preventive maintenance, and equipment storage.

Washington Nuclear Power Unit 1 (WNP-1)

WNP-1 was designed in the mid-1970's and early 1980's to be a 1250 megawatt-electric generating station powered by a pressurized-water nuclear steam supply system. It is located on approximately 972 acres at the Hanford Reservation site near Richland, Washington. Construction of the plant started in December of 1975 and was suspended in April of 1982 because of the reduced demand for electricity and the high cost of borrowing money to continue construction. The plant is approximately 65% complete, with 94% of the structural construction complete, 60% of the mechanical construction complete, 48% of the electrical construction complete, and 67% of the HVAC construction complete. A rigorous preservation program is in place to maintain the major installed equipment in good condition for eventual operation. Licenses and permits are also being maintained and documentation is stored on site.

Barnwell Nuclear Fuel Plant (BNFP)

The original mission of the Barnwell Nuclear Fuel Plant (BNFP) was as a special purpose reprocessing plant, designed for reprocessing zirconium or stainless steel clad light water reactor fuel, aged 160 days or more, with burnups of less than 40,000 MWD/ton. The throughput of the plant was designed to be 1,500 MTU/year. The bulk of the radioactive waste material separated from the recovered product was to be contained within the facility. Facility products were to be uranium and plutonium nitrate solutions. The facility was also designed to be capable of recovering neptunium and (with minor equipment changes) other by-products by reprocessing the acidic high-activity fission product waste solutions in discrete campaigns when normal facility operations were suspended. Irradiated fuel elements were to be received at the Separations Facility in shielded casks via rail or truck. The fuel was to be removed from the casks and stored under water. From there, a modification of the Purex process was to be utilized, including a chop-leach headend with semicontinuous nitric acid dissolution of the fuel assembly oxide core to form feed for tributyl phosphate liquid-liquid extraction.

In 1968, a construction permit was applied for by Allied Chemical Corporation to locate the plant in Barnwell, South Carolina. Construction was begun in January, 1971. In February of 1970, Gulf Energy and Environmental Systems, a subsidiary of Gulf Oil Corporation, had an interest in reprocessing, and negotiated a 50-50 partnership in the formation of Allied Gulf Nuclear Services. In 1974, a partnership between Gulf Oil Corporation and Scallop Nuclear, Inc. (a company within the

Royal Dutch/Shell Group) led to the formation of General Atomic, Co. The name of the partnership was subsequently changed to Allied-General Nuclear Services (AGNS), who now owns and controls the site. Major construction on the facility was completed in 1976.

Changes in the US nuclear policy forced the closure of the facility before it was ever operational. However, a series of tests, with and without uranium, were run in 1976 and 1978. These tests were to provide data in support of DOE contract studies in the areas of safeguards (nuclear materials control and accountability) and alternative fuel cycles. Beginning in August of 1978, uranium was transferred from the UF_6 Conversion Facility to the Separations Plant, which was started and operated at flow-sheet values. Dissolver operations were simulated, and tests were performed on plutonium column efficiency, the concentrators, the transfer to the UF6 plant, shutdown, and inventory. The tests were terminated in September of 1978.

Device Assembly Facility (DAF)

The Device Assembly Facility (DAF) was designed as a facility at the Nevada Test Site (NTS) for consolidation of Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL) nuclear-explosive operations. It also was to have provided state-of-the-art safety and security features, which are essential elements for the conduct of future operations. The DAF was designed to protect the environment and to minimize health and safety risks to workers and the public. The operations generally were to include assembly, disassembly or modifications, staging, transporting, and testing. Nuclear explosive operations also were to have included maintenance, repair, retrofit, and surveillance. The mission of the DAF was to provide the necessary facilities to satisfy the needs of the DOE nuclear testing program as carried out through the efforts of the design laboratories. A nuclear explosive assembly is generally a one-of-a-kind experiment that is designed by either LLNL or LANL to confirm the design, to validate safety and reliability, and to better understand the dynamics and other phenomena that occur during the nuclear process.

P-Reactor

P-reactor is one of five production reactors located at the Savannah River Site (SRS) built during the 1950s for the production of nuclear materials for defense programs The P-reactor was the second reactor to be constructed at the SRS. The reactor became operational in 1954 and operated until 1988 when it was shut down for safety upgrades. In 1991, the reactor was placed in cold standby. The facilities in P Area have not been extensively cannibalized and work remains to fully deactivate the reactor.

The original SRS buildings and structures were designed and constructed before current nuclear codes or standards were developed, or the current NRC seismic classification established. As a result, the design criteria used was a blast-resistant classification that was developed to resist bomb attack. In this classification, a Class I blast resistant construction was designed for a static live load of 1000 lbs/ft^2 acting simultaneously on gross areas of the outside face of exterior walls and roofs. The foundations and building anchorage were checked for overturning produced by the 1000 lbs/ft^2 load acting only on one face at a time. Because the loads imposed on the structures by the blast pressures are greater or equal in magnitude than the loads generated by earthquake or tornado conditions, the Class-I structures should qualify as Category I structures, but this will have to be verified.

FACILITY EVALUATIONS

Fuel Materials Examination Facility (FMEF)

The FMEF was modified during its construction to support a MOX fabrication mission, and although the fabrication throughput for the original FMEF fabrication mission is much smaller than that required for the disposition program (the SAF line was designed to produce approximately 6 tonnes of heavy metal per year, compared with the 50-150 tonnes per year required for plutonium disposition), the facility layout is conducive to such a mission, has adequate space to support the larger throughput required, and most of the required infrastructure is already in place. The main deficiencies of the FMEF is that it does not contain handling equipment or storage racks for LWR fuel bundles, and it does not have liquid radioactive waste treatment capabilities at the 400 site. The FMEF does have secure fuel-storage locations which could be used for CANDU fuel bundles, but which are too small to accommodate the LWR fuel bundles. With regard to the liquid radioactive waste treatment, the FMEF does have storage tanks, and the Hanford site does have liquid radioactive waste treatment capabilities, so the waste may be simply shipped from the FMEF to a treatment site within the Hanford reservation.

Fuels Processing Facility (FPF)

The FPF has the advantage of not being fully completed, and thus there is little equipment within the facility that must be removed, and more open space is available. In addition, the FPF has much of the existing support structure required, such as a waste treatment system, existing PIDAS zone and protective force, existing SNM vault, and an existing backup generator. The main disadvantage of the FPF is that in its present configuration, there is insufficient space within the hardened areas to contain the plutonium operations. Thus, an additional floor will have to be added to the process cells, and a hardened roof must be added to the maintenance area to provide for sufficient operating space (there are other possible ways of modifying FPF to obtain the required process space, but they all will involve the addition of hardened surfaces). The FPF does have the unique characteristic of having other facilities located at the Idaho Chemical Processing Plant (ICPP) which could support other plutonium disposition operations, making the ICPP a good candidate for co-location of operations.

Washington Nuclear Power Unit 1 (WNP-1)

WNP-1 has the advantage of possessing a huge amount of potential processing space (approximately 250,000 sq. ft.), and with the exception of security, has almost all of the required support infrastructure, including LWR fuel handling and storage equipment. However, because WNP-1 was nearly completed when construction was suspended, a large amount of equipment would have to be removed to make the required space available, and the HVAC would have to be re-zoned to support the fabrication operations.

Barnwell Nuclear Fuel Plant (BNFP)

The BNFP has the advantage of being located adjacent to the Savannah River Site, and can draw on its experienced workforce and infrastructure. However, the BNFP was actually completed and a number of operational tests conducted before operations were ceased. This introduces two problems in that much of the existing equipment within the BNFP would have to be removed, and some of this material is potentially contaminated due to the nature of the tests that were performed. In addition, significant structural modifications would be required to make BNFP suitable for MOX fabrication. Also, because BNFP is an older facility, much of the existing support structures would have to be replaced or repaired, and even utilities must be reconnected to the facility. Finally, although BNFP is located adjacent to the Savannah River Site, it does not currently possess the required support operations (security, waste treatment, etc.) at the BNFP location, although most of these could be added with little difficulty.

Device Assembly Facility (DAF)

The DAF has the advantage of being a new facility with considerable open space, but is most likely too small and would have to be expanded. DAF is strong with regard to existing security infrastructure, but lacks most of the other support systems required for MOX fabrication. However, the DAF is better suited for a pit conversion mission, which is closer to its original mission. However, the lack of a waste (both radioactive and explosives) treatment facility still remains a large drawback for the use of this facility.

P-REACTOR

The P-reactor has the advantage of being in the heart of the Savannah River Site, and able to take full advantage of all the support infrastructure available including facilities for other plutonium processing activities which could support other plutonium disposition operations (making P-reactor and SRS a good candidate for co-location of operations), existing security, and experienced work force. Areas exist within the reactor building, most notably the assembly area and surrounding rooms, which could be easily adapted to meet a MOX fabrication mission. The main disadvantage of the P-reactor is the age of the facility which will require that the building be re-qualified as a Category I facility.

CONCLUSIONS

All of the facilities reviewed could be modified for use as a MOX fabrication mission. Although this document can be used as an initial reference point to compare the facilities, more detailed cost and design studies are required in order to make a definitive comparison. In general, however, several conclusions can be reached:

1) The use of existing facilities can result in significant cost savings over building a new MOX fabrication plant. However, savings in initial capital costs should not be overemphasized to the point that operational difficulties are created. Some facilities might require less capital investment to convert to a MOX fabrication mission, but then introduce significant operational problems due to poor layouts, excessive transportation requirements, etc.

2) The supporting infrastructure is at least as important as the actual building itself. Future conceptual design efforts should focus on making maximum use of the existing infrastructure at the various sites.

3) All sites examined have the potential to support multiple operations that are required for the plutonium disposition effort. The suitability of each site should be evaluated for these various missions, and the practicality of locating multiple operations at a single site should be investigated. Co-location of facilities could result in significant operational cost savings due to a reduction in duplicate support operations.