11.3 MIXED OXIDE PROCESS SYSTEM DESCRIPTION AND REVIEW

11.3.1 CONDUCT OF REVIEW

This section of the draft Safety Evaluation Report (DSER) contains the staff's review of the Mixed Oxide (MOX) Process (MP) safety described by the applicant in Chapter 11.2 of the Construction Authorization Request (CAR), with supporting process safety information from Chapters 5, 8, and 11 of the CAR (Reference 11.3.3.7) The objective of this review is to determine whether the chemical process safety principal structures, systems, and components (PSSCs) and their design bases identified by the applicant provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents. The staff evaluated the information provided by the applicant for chemical process safety by reviewing Chapter 8 of the CAR, other sections of the CAR, supplementary information provided by the applicant, and relevant documents available at the applicant's offices but not submitted by the applicant. The staff also reviewed technical literature as necessary to understand the process and safety requirements. The review of MP safety design bases and strategies was closely coordinated with the review of the radiation and chemical safety aspects of accident sequences described in the Safety Assessment of the Design Bases (see Chapter 5.0 of this DSER), the review of fire safety aspects (see Chapter 7.0 of this DSER), and the review of plant systems (see Chapter 11.0 of this DSER).

The staff reviewed how aqueous polishing process and chemistry information in the CAR addresses or relates to the following regulations:

- Section 70.23(b) of 10 CFR states, as a prerequisite to construction approval, that the design bases of the PSSCs and the quality assurance program be found to provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents.

- Section 70.64 of 10 CFR requires that baseline design criteria (BDC) and defense-in-depth practices be incorporated into the design new facilities or new processes at existing facilities. It specifically addresses quality standards; natural phenomena hazards; fire protection; environmental conditions and dynamic effects; emergency capability; inspection, testing and maintenance; criticality control; instrumentation and controls; and defense-in-depth-practices.

The review for this construction approval focused on the design basis of chemical process safety systems, their components, and other related information. For each chemical process safety system, the staff reviewed information provided by the applicant for the safety function, system description, and safety analysis. The review also encompassed proposed design basis considerations such as redundancy, independence, reliability, and quality. The staff used Section 8 of NUREG-1718, "Standard Review Plan for the Review of an Application for a Mixed Oxide (MOX) Fuel Fabrication Facility" (Reference 11.3.3.8), as guidance in performing the review. As stated on page 8.0-2 of NUREG-1718, information contained in the application should be of sufficient quality and detail to allow for an independent review, assessment, and verification by the NRC reviewers.

At U.S. Nuclear Regulatory Commission (NRC) licensed facilities, as stated in the NRC "Memorandum of Understanding between the Nuclear Regulatory Commission and the Occupational Safety and Health Administration: Worker Protection at NRC-licensed Facilities," (Federal Register. Vol. 53, No. 210, October 31, 1998, pp. 43950-43951), the NRC oversees chemical safety issues related to (1) radiation risk produced by radioactive materials; (2) chemical risk produced by radioactive materials; and (3) plant conditions that affect the safety and safe handling of radioactive materials, and, thus, represent an increased radiation risk to workers. The NRC does not oversee facility conditions that result in an occupational risk but do not affect the safe use of licensed radioactive material.

The NRC staff reviewed the CAR submitted by the applicant for the following areas applicable to process safety at the construction approval stage and consistent with the level of design (NUREG-1718, page 8.0-8):

- MP Description.
- Hazardous Chemicals and Potential Interactions Affecting Licensed Materials.
- MP Chemical Accident Sequences.
- MP Chemical Accident Consequences.
- MP Safety Controls.

Additional documentation from the applicant and the literature was reviewed as necessary to understand the process and safety requirements. In addition, the CAR incorporates the BDC of 10 CFR 70.64(a) into the design and operations of the proposed facility (see CAR, page 5.5-53), and applicable sections of the CAR are intended to demonstrate compliance with these BDCs.

The staff utilized the guidance provided by Chapter 8.0 of NUREG-1718 for assistance in determining the compliance of the application with the regulation. The evaluation used the guidance of Section 8.4 of NUREG-1718 for determining acceptance with 10 CFR Part 70, consistent with a construction approval stage and the level of the design. The evaluation is summarized in the sections that follow.

11.3.1.1 System Description of the MP Process

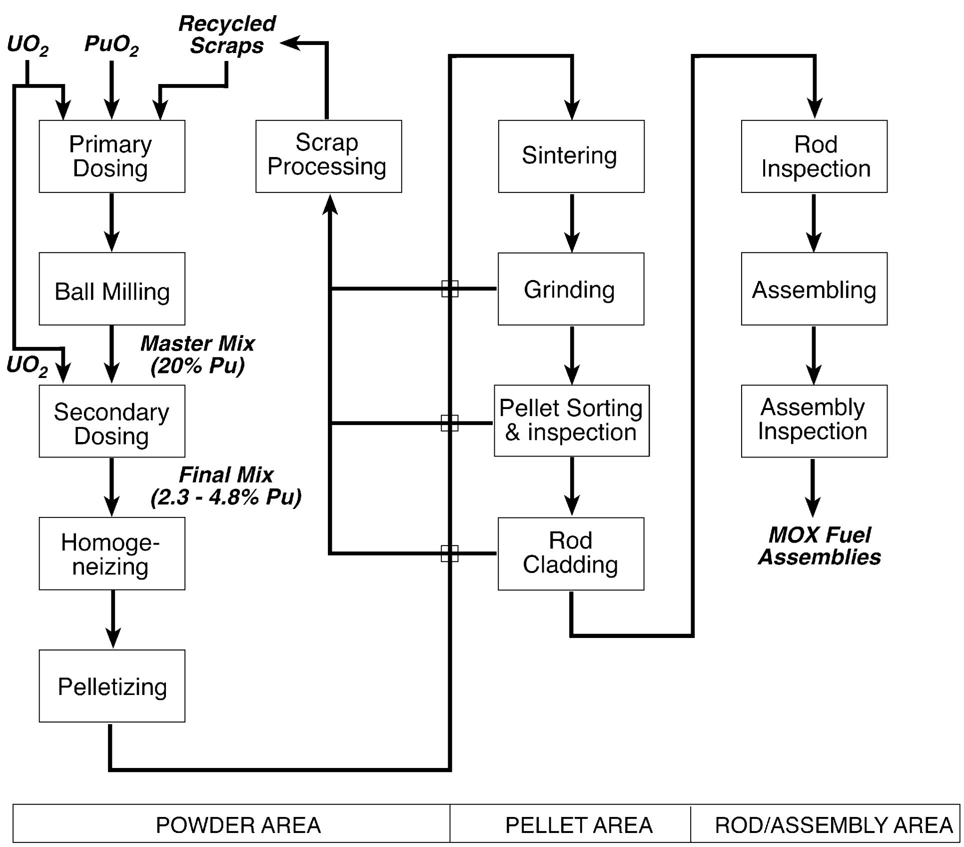
This section provides a description and overview of the MP, including design, operational, and process flow information. This information is provided to support the hazard and accident analysis provided in Chapter 5, as well as to assist in understanding the overall design and function of the MOX Process.

The MP Area receives polished PuO_2 from the aqueous polishing (AP) process, depleted UO_2 (i.e., uranium depleted in the uranium-235 isotope below the natural assay of 0.71 percent), and the required components for assembling light-water (LWR) MOX assemblies. The process mixes the plutonium and uranium oxides to form MOX fuel pellets. The pellets are loaded into fuel rods, which are then assembled into MOX fuel assemblies for use in commercial reactors. The MP Area is designed to process up to 70 MTHM (uranium plus plutonium) annually. The safety functions of the PSSCs associated with the MP process are discussed in Chapter 5 of the CAR.

The Mixed Oxide Fuel Fabriction Facility (MFFF) uses the A-MIMAS process for the manufacture of MOX fuel assemblies. A-MIMAS uses a two-step, dry mixing process. In the first step, the PuO_2 powder is mixed with depleted UO_2 and recycled scrap powder to form a primary blend (master blend) with approximately 20 percent PuO_2 content of the total mass. This mix is then micronized—reduced in particle size into a very fine powder. In the second step, the primary blend is forced through a sieve and poured into a jar and mixed with more depleted UO_2 and scrap powder to obtain the final blend with the specified plutonium content (typically around 5 percent of the heavy metal content). The maximum PuO_2 content in the final blend is 6 percent of the total mass. The two-step mixing process is used to ensure a consistent product.

The MP process consists of 38 process units or systems divided into five areas corresponding to the different segments of the process (see Figure 11.3-1).

Figure 11.3-1. Overview of MP



Receiving Area - This area includes truck unloading, PuO_2 container handling, counting, and storage before and after transfer to the aqueous polishing (AP) line. The function of the Receiving Area is to receive, unload, and store PuO_2 and UO_2 powder. The Receiving Area is comprised of the following discrete units:

- UO_2 Receiving and Storage Unit.
- UO_2 Drum Emptying Unit.
- PuO_2 Receiving Unit and PuO_2 3013 Storage Unit.
- PuO_2 Buffer Storage Unit.

Powder Area - This area has equipment for dosing MOX powder at the specified plutonium content in two steps for homogenizing and for pelletizing. The Powder Area receives UO_2 and PuO_2 powders and produces a mixture of specific plutonium content suitable for the production of MOX fuel pellets. The Powder Area is composed of the following units:

- PuO_2 Container Opening and Handling Unit.
- Primary Dosing Unit.
- Primary Blend Ball Milling Unit.
- Final Dosing Unit.
- Homogenization and Pelletizing Unit.
- Scrap Processing Unit.
- Scrap Milling Unit.
- Powder Auxiliary Unit.
- Jar Storage and Handling Unit.

Pellet Process Area - In this area, MOX pellets are sintered, ground, and sorted. The function of the Pellet Process Area is to receive, store, process, and handle fuel pellets. The Pellet Process Area is composed of the following units:

- Green Pellet Storage Unit.
- Sintering Units.
- Sintered Pellet Storage Unit.
- Grinding Units.
- Ground and Sorted Pellet Storage Unit.
- Pellet Inspection and Sorting Units.
- Quality Control and Manual Sorting Units.
- Scrap Box Loading Unit.
- Pellet Repackaging Unit.
- Scrap Pellet Storage Unit.
- Pellet Handing Unit.

Fuel Rod Process Area - In this area, pellets are loaded into rods and the rods are inspected. The function of the Fuel Rod Process Area is to assemble, inspect, and store fuel rods. The Fuel Rod Process Area is composed of the following units:

- Rod Cladding and Decontamination Units.
- Rod Tray Loading Unit.
- Rod Storage Unit.
- Helium Leak Test Unit.
- X-Ray Inspection Units.
- Rod Scanning Unit.
- Rod Inspection and Sorting Unit.
- Rod Decladding Unit.

Assembly Area - In this area, rods are loaded into assemblies and the assemblies are inspected and stored. The functions of the Assembly Area are to receive fuel rods and the required fuel assembly components and to assemble, inspect, and store completed MOX fuel assemblies. The Assembly Area is composed of the following units:

- Assembly Mockup Loading Unit.

- Assembly Mounting Unit.
- Assembly Dry Cleaning Unit.
- Assembly Dimensional Inspection Unit and Assembly Final Inspection Unit.
- Assembly Handling and Storage Unit.
- Assembly Packaging Unit.

A detailed description of each unit is provided in DSER Appendix B.

11.3.1.2 Staff Review of MP Process Safety

11.3.1.2.1 Potential UO_2 Pyrophoricity and Burnback Concerns

MP uses depleted uranium dioxide powder to blend with the plutonium dioxide and to form the matrix for the MOX review. Uranium dioxide powders are handled in conventional nuclear fual fabrication facilities. The staff review noted a potential concern regarding the pyrophoric nature (sometimes referred to as burnback) of some fine uranium dioxide powders that can result in oxidation, damage to equipment, and a potential release path (Reference 11.3.3.9). This is a known potential concern, as such a rapid oxidation has occurred in an NRC licensed facility. The applicant provided additional information on UO_2 powders in response to RAI 49 (Reference 11.3.3.2) and identified temperature design bases for materials of construction in the MFFF but not for the fuel powders. Documentation for powder processing areas was reviewed during an in-office review and no PSSCs or design bases were found to address this potential hazard (Reference 11.3.3.10). The applicant provided supplemental information on the subject (Reference 11.3.3.4). The applicant stated UO_2 is processed as a fine powder at low temperatures and within inert atmospheres, and, thus, burnback does not occur during normal operations. The applicant states burnback should occur during offnormal conditions if the inert atmosphere has been replaced by air (the applicant has not currently identified a safety function for the inert atmosphere). The applicant indicates burnback has been taken into account in the thermal analysis of the MFFF during offnormal conditions, and cites the RAI 49 response. No PSSCs or design bases are identified by the applicant to address burnback concerns. The staff notes that the thermal analyses are not presented in the responses. The staff concludes that a potential pyrophoric reaction or burnback of uranium dioxide cannot be dismissed because it has occurred previously during fine UO_2 powder processing. This could potentially impact several units in the MP area that handle fine UO_2 powder by itself or blended with plutonium dioxide. Such a burnback event could result in the release of large quantities of uranium oxides (a chemical toxicity concern), the release of plutonium powders from the commingled blend, and/or initiate other loss of confinement events such as fires. The staff has identified PSSC and design basis information associated with the pyrophoric nature of some UO_2 powders as an open item. This concern applies to all units handling UO_2 powders in air. The applicant needs to provide additional design basis information or provide sufficient justification that none are necessary.

11.3.1.2.2 Potential PuO_2 Heating Effects

The staff has reviewed plutonium handling areas for potential chemical safety concerns. The review noted a concern with the potential heat generation by the plutonium dioxide; plutonium in the glovebox environment can easily reach equilibrium temperatures of 80^{o}C (Reference 11.3.3.1, Section 2.6.3.1). The applicant provided supplementary information in an RAI response (Reference 11.3.3.2, RAI 49), and provided a summary of the design bases for decay heat and temperatures. The specific heat loads for plutonium were identified as:

- Unpolished plutonium: 2.899 W/kg of unpolished PuO_2 powder.

- Polished plutonium: 2.181 W/kg of polished PuO_2 powder.

Using values from the literature (Reference 11.3.3.1), the staff review estimates heat loads of 2.5-3.5 W/kg PuO_2, depending on the isotopic ranges used. Thus, the applicant values are reasonable.

The applicant identified temperature design bases for materials of construction in the facility; these are reproduced as Tables 11.3-1 and 11.3-2 (Reference 11.3.3.2, RAI 49). The response identified the storage rooms, storage gloveboxes, and larger production units as having potentially large heat loads. The applicant's response mentions that the temperature design bases of Tables 11.3-1 and 11.3-2 will be met during normal operations, but might be exceeded during incidents where ventilation is not maintained for the PuO_2 Storage Area and the handling and storage tunnel. The applicant states this will be revisited during final design and the ISA, and specific requirements identified as needed. The staff notes these design basis and commitment are consistent with accepted practice and finds the approach to be acceptable.

Table 11.3-1: Applicant's Design Basis Temperature Criteria

Material	Situation	
	Normal Operating Temperature, C	Hypothetical Maximum Operating Temperature, C
Ordinary Concrete	60	100
Stainless Steel	425	425
BPP #9	80	100
BPP #10	100	100
NS41 Silicone Elastomer	180	180
Polycarbonate (Lexan)	35 (thermal cycling) 50	70
BPP = Borated Polyethylene Plaster		

Table 11.3-2: Applicant's Additional Temperature Design Basis Criteria for Personnel Protection

Material	Normal Operating Temperature Limit, ^oC
Borate (colemanite) concrete	80
Kyowaglas - storage - operating	80 35
Fuel rods, pellets, and cladding	60

11.3.1.2.3 Potential PuO_2 Pyrophoricity and Burnback Concerns

The staff also expressed concerns with the potential pyrophoric nature of plutonium. Depending on conditions, plutonium can form varying oxides, some of which can be pyrophoric. In general, plutonium oxides with oxygen contents lower than the dioxide are potentially pyrophoric (Reference 11.3.3.1, Section 2.6.3.2). Supplemental information provided by the applicant (Reference 11.3.3.4) stated that PuO_2 is stable in air. The applicant did not identify any PSSCs or design bases. The staff conducted a brief literature review and found that PuO_2 is often present as a substoichiometric oxide (i.e., PuO_2-x) and prone to absorb moisture unless it has been calcined and held at a temperature of circa 900°C for 2 hours to stabilize (ceramicize) the material (Reference 11.3.3.1, Section 2.7). Unstabilized plutonium dioxides may exhibit pyrophoric reactions in air, due to its substoichiometry or the radiolysis of absorbed water, which could lead to a loss of confinement and release or initiate other events, such as fires. Furthermore, at the February 13, 2002, public meeting, the applicant stated that a review was underway to determine if unstabilized PuO_2 would be received by the facility. The staff review of the calcining section of the AP process (see DSER Section 11.2) did not identify any PSSCs or design bases for ensuring that stabilized PuO_2 powder would be produced. Thus, the staff concludes that the applicant's proposed approach will not provide adequate assurances of preventing potential pyrophoric events with PuO_2. The staff has identified PSSC and design basis information associated with the pyrophoric nature of some PuO_2 powders as an open item. This applies to all open (unclad or uncontainerized) plutonium handling areas. The applicant needs to provide additional design basis information or provide sufficient justification that none are necessary.

11.3.1.2.4 Sintering Furnace Concerns

The staff requested clarification and more information on the controls around the sintering furnaces, including the hydrogen detectors, as this appears to involve a complex mixture of hydrogen detectors, oxygen sensors, and pressure controls. In response (Reference 11.3.3.2, RAI 124), the applicant provided a diagram that showed part of the intended control range of hydrogen in argon was flammable in air and stated that the sensors would detect hydrogen and, at 25 percent of the lower flammability limit (LFL), would terminate hydrogen flow at the hydrogen/argon mixing station. In addition, fire detector(s) in the room would detect any fire and alarm, but would not terminate hydrogen flow. DCS has not completed the detailed design of the system. DCS explained that the sintering furnace would not be in a glovebox and the room functioned as confinement; the sintering room and the furnace would become the PSSCs for confinement (Reference 11.3.3.2, RAI 124). DCS has not performed any coverage or location/distance analyses for sensors and detectors. DCS stated they would verify that a hydrogen leak from the furnace would be detected and terminated by pressure detection. DCS expected that, between the H_2 monitors and pressure sensors, an H_2 leak would be detected and flow terminated (Reference 11.3.3.3 and 11.3.3.10).

The applicant indicated hydrogen sensors in the room would detect any leaks and would terminate the flow of hydrogen flow to the furnace. In addition, pressure controls would detect any loss of pressure in the furnace due to a leak and also terminate the hydrogen flow (Reference 11.3.3.10). The staff expressed concerns about the potential for small leaks to result in hydrogen burning that might go undetected and exacerbate radionuclide releases. Regarding sensor placement and coverage, the staff requested the applicant to review industry standards for guidance. Regarding the airlocks, the applicant stated there would be interlocks to prevent both doors (inner and outer) from opening at the same time. In addition, hydrogen sensors in the airlocks and oxygen sensors in the furnace would detect their respective gases and terminate the hydrogen flow; all of these would be PSSCs. The applicant provided supplemental information on PSSCs and design bases in the sintering furnace area which identified additional PSSCs and design bases (Reference 11.3.3.5). However, hydrogen flow would not be terminated by sensors in the room and the hydrogen mixture would continue to flow under overpressurization conditions. The staff is also concerned that, without adequate controls, airlock operation and/or furnace cooldown can introduce atmospheric oxygen that initiates reactions with the hot MOX pellet, resulting in aerosolizing of the plutonium. The staff has identified PSSC and design basis information associated with the sintering furnace as an open item.

The sintering furnace has water-cooled walls. The in-office review of the preliminary hazard analysis (PHA) and preliminary accident analysis (PAA) did not find a potential steam explosion included (Reference 11.3.3.10). The applicant provided supplemental information on potential steam explosions (Reference 11.3.3.4). The applicant states steam explosions have been identified during the MFFF safety analysis as a credible event. Although the applicant did not explicitly analyze a steam explosion in the CAR, an explosion in the sintering furnace was identified in event PT-4. Ongoing safety analyses by the applicant have identified three types of scenarios that can lead to a steam explosion: entry of water from the water cooling loop, entry of water from the humidifying loop, and steam generation within the water cooling systems. The applicant mentions that a steam explosion involving a water-cooled furnace has previously occurred at Los Alamos National Laboratory (LANL), but this involved internal cooling coils while the proposed furnaces would have external cooling coils. The applicant further states that a cooling water leak will be demonstrated to be highly unlikely, specific items relied on for safety features will be identified for the humidifying loop, and relief valves will render steam pressurization of the cooling water loop to be highly unlikely. Supporting information to demonstrate a highly unlikely likelihood is not included in the response.

The staff reviewed the additional information. The staff notes that CAR event PT-4 is explicitly identified as a hydrogen explosion in the furnace; steam is not mentioned. The supplemental information from the applicant does not identify any PSSCs or design bases to address potential steam explosions. However, the response implies that items with safety functions may be necessary, such as a level controller, flow detector, relief valves, and coolant system (integrity). The staff has identified PSSC and design basis information associated with the potential steam explosion in the sintering furnace as an open item. The applicant needs to provide additional design basis information or provide sufficient justification that none are necessary.

11.3.2 EVALUATION FINDINGS

In Section 11.3.7 of the CAR, DCS provided design basis information for the MP process that it identified as PSSCs for the MFFF. Based on that the staff's review of the CAR and supporting information provided by the applicant relevant to the AP process, the staff finds that, due to the open items discussed above and listed below, DCS has not met the BDC set forth in 10 CFR 70.64(a)(3), for explosions, and (a)(5), for chemical safety. Further, until the open items are closed, the staff cannot conclude, pursuant to 10 CFR 70.23(b), that the design bases of the PSSCs identified by the applicant will provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents.

The open items are as follows:

- PSSC and design basis information associated with the pyrophoric nature of some UO_2 powders (DSER Section 11.3.1.2.1) (MP-1)

- PSSC and design basis information associated with the pyrophoric nature of some PuO_2 powders (DSER Section 11.3.1.2.3) (MP-2).

- PSSC and design basis information associated with the sintering furnace regarding potential steam explosions (DSER Section 11.3.1.2.4) (MP-3).

- PSSC and design basis information associated with the sintering furnace regarding potential explosions in the room due to a hydrogen leak (DSER Section 11.3.1.2.4) (MP-4).

DCS has provided additional information concerning open items identified by the staff as MP-1, 2 and stated that it will provide additional information concerning open items identified by the staff as MP-3 (Reference 11.3.3.11). Because the information was provided recently, the staff has not completed its review.

11.3.3 REFERENCES

11.3.3.1. Department of Energy (U.S.) (DOE) DOE Std 1128-98, "Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities." DOE: Washington, D.C. June 1, 1998.

11.3.3.2. Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Response to Request for Additional Information, August 31, 2001.

11.3.3.3. Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Clarification of Responses to NRC Request for Additional Information, January 7, 2002.

11.3.3.4. Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission RE Clarification of Responses to NRC Request for Additional Information, DCS-NRC-000083, February 11, 2002.

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11.3.3.6 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Clarification of Responses to NRC Request for Additional Information, April 23, 2002.

11.3.3.7. Ihde, R, Duke Cogema Stone & Webster, letter to W. Kane, U.S. Nuclear Regulatory Commission, RE. Mixed Oxide Fuel Fabrication Facility—Construction Authorization Request, February 28, 2001.

11.3.3.8. Nuclear Regulatory Commission (U.S.) (NRC). NUREG-1718, "Standard Review Plan for the Review of an Application for a Mixed Oxide (MOX) Fuel Fabrication Facility." NRC: Washington, D.C. August 2000.

11.3.3.9 Nuclear Regulatory Commission (U.S.), Washington, D.C. Information Notice 92-14, "Uranium Oxide Fires at Fuel Cycle Facilities." NRC: Washington, D.C. February 21, 1992.

11.3.3.10 Persinko, A., U.S. Nuclear Regulatory Commission (NRC), memorandum to E.J. Leeds, NRC, RE 11/27-29/01 In-Office Review Summary of DCS Construction Authorization Request Supporting Documents for the MFFF, December 18, 2001.