DUKE COGEMA
STONE & WEBSTER

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Washington, DC 20555

18 February 2003
DCS-NRC-000128

Subject: Docket Number 070-03098
Duke Cogema Stone & Webster
Mixed Oxide Fuel Fabrication Facility
Responses to Financial Qualification, Fire Safety, Chemical Safety, Aqueous Processing, Material Processing and Ventilation Open Items/Additional NRC Questions on Construction Authorization Request (CAR) Revision

Reference: NRC to DCS letter dated 13 February 2003, *February 2003 Monthly Open Item Status Report*

Enclosed are responses to Nuclear Regulatory Commission (NRC) questions and open items related to the draft safety evaluation report (SER) for the Mixed Oxide Fuel Fabrication Facility (MFFF) identified in the referenced letter. Responses are provided in the subject areas of Financial Qualification, Fire Safety, Chemical Safety, Aqueous Processing, Material Processing and Ventilation. The enclosed responses are based on information discussed at public meetings with the NRC staff 10-12 December 2002, 15-16 January 2003, and 6-7 February 2003. Revisions to the Construction Authorization Request described in the attachment will be provided under separate cover letter.

If you have any questions, please contact me at (704) 373-7820.

Sincerely,

For Peter S. Hastings, P.E.
Manager, Licensing and Safety Analysis

Enclosure: Responses to Financial Qualification, Fire Safety, Chemical Safety, Aqueous Processing, Material Processing and Ventilation Open Items/Additional NRC Questions on Construction Authorization Request (CAR) Revision

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ENCLOSURE

Responses to Financial Qualification, Fire Safety, Chemical Safety, Aqueous Processing, Material Processing and Ventilation Open Items/Additional NRC Questions on Construction Authorization Request (CAR) Revision

Financial Qualification Open Items

FQ-01 **Provide detailed information on project design costs. (DSER Section 2.1.1)**

FQ-02: **Provide up-to-date financial information, including project costs and a financial statement. In your response, include a commitment to provide annual updates of this information. (new item)**

Response:

10 CFR §70.23(a)(5) requires, "where the nature of the proposed activities is such as to require consideration by the Commission, that the applicant appears to be financially qualified to engage in the proposed activities in accordance with the regulations in this part." A note under 10 CFR §70.22(a) indicates that "where the nature of the proposed activities is such as to require consideration of the applicant's financial qualifications to engage in the proposed activities in accordance with the regulations in this chapter, the Commission may request the applicant to submit information with respect to his financial qualifications." [emphasis added]

DCS believes that the nature of the proposed activities does not require consideration by the Commission of its financial qualifications. As noted in CAR 2.4, the MFFF Project is a fully funded U.S. Government project. Therefore, the specific financial resources and capabilities of DCS and its equity owners are not relevant to the determination of adequate financial resources to design and construct the facility. The DCS partner companies initially provided a temporary startup funding; most of that funding has been paid back to the partner companies. Other than that temporary startup funding, DCS is not relying on its financial resources, or those of any equity partner or parent company, to provide financing or funds for engineering or construction costs. These funds are provided directly through DCS' contract with the U.S. Government to carry out the national security mission to dispose of surplus plutonium.

Notwithstanding DCS' belief that the proposed activities do not require such consideration by the Commission, DCS nonetheless has previously provided information related to project costs and financial qualifications related to the construction of the MFFF, along with a proprietary financial statement providing information concerning DCS' financial condition.

In response to the open items indicated above, requesting additional detailed information on design cost, and periodic updates of financial information, DCS reiterates its belief that this information is not necessary to support the NRC Staff's conclusion that the applicant appears financially qualified. DCS is not a publicly held entity, and as such its financial statements are not publicly available and as noted above, are not relevant to the ability of the U.S. Government to carry out and fund the mission of surplus plutonium disposition. As the financial statements of DCS are not relevant to the determination of financial qualification, as noted above, a commitment to provide this information on a periodic basis is not warranted.

DCS' position is supported by prior Commission language confirming the intentional flexibility of 10 CFR Part 70 financial qualifications requirements. The Commission noted in 1997:

Financial Qualification Open Items (continued)

> "The fact that the Part 70 and Part 50 financial qualification provisions are written so differently is significant. Had the Commission intended the Part 50 standards and criteria to apply to all Part 70 applicants filing financial information, as the Board apparently believed, the regulations would have either restated the Part 50 criteria or incorporated them by reference. Part 70 does neither. Its shorter, more flexible language instead allows a less rigid, more individualized approach to determine whether an applicant has demonstrated that it is financially qualified to construct and operate an NRC-licensed facility...[further] we conclude that the Part 70 financial qualification regulations contemplate a case-by-case inquiry to determine whether an applicant "appears to be financially qualified." [SRM M971218B, 18 December 1997 Affirmation session]

DCS believes that the information already provided to NRC staff, along with the unique circumstances that the project is being performed under the direction and funding of the U.S. Government, warrants a determination that the applicant appears financially qualified pursuant to the regulation.

Action:

None.

FS-01: **The applicant did not provide sufficient justification that the C3 and C4 final HEPA filter could perform their safety function under fire/soot conditions. (DSER Section 7.1.5.5.)**

Response:

Provided as Attachment 1

Action:

None.

Financial Qualification Open Items (continued)

<u>FS-02</u>: **The applicant has not demonstrated that an adequate margin of safety has been provided for the fire barriers. (DSER Section 7.1.5.6.)**

Clarification of FS-02: Justify the lack of conservatism in selecting a 600°C criterion for flashover, since some room temperatures exceed 500°C and research indicates flashover can occur between 450°C and 600°C

<u>Response:</u>

As agreed to at the February public meeting:

> For construction authorization, DCS will provide an evaluation (heat flux method or alternative) of the 44 fire areas exceeding the 80% criterion where maximum temperature exceeds the E119 curve, using ultra-fast growth curve for solvent(s) and fast growth curve for everything else. DCS will draw a conclusion about the need to assess other areas, based on criterion of no changes to the fire barrier rating in the 44 areas evaluated.
>
> At the time of the license application, fire barrier performance under credible fire conditions (including flashover as applicable) will be demonstrated in the ISA, or barrier failure (unexpected) will be accounted for in consequence analyses.

<u>Action</u>:

No CAR changes are required.

Financial Qualification Open Items (continued)

<u>FS-07</u>: Clarify the difference between the terms "isolation valves" and "fire dampers."

<u>Response</u>:

For the C3 and C4 ventilation, the exhaust flow paths contain manual isolation dampers and valves, respectively, for fires. The ventilation inlet of the C4 also contains manual isolation valves. C3 inlet and other ventilation inlet and exhaust paths contain automatic fire dampers. The CAR currently suggests that some inlet paths are manual or automatic. This will be clarified to indicate that these are automatic fire dampers with the exception of the C4 inlet. This should provide the clarification that the term fire damper applies to automatically actuated fire dampers, and the term fire isolation valves will be used where the function is performed manually.

Additionally, the CAR discussion in 11.4.2.5.2, fourth paragraph, inadvertently refers to gloveboxes and fire-rated isolation dampers. This will be corrected to replace "glovebox" with "room" and to remove "isolation" and replace with "protective features" similar to the discussions for the high depressurization system. CAR 11.4.2.6.2 also refers to fire rated isolation dampers. This statement will be clarified as noted above.

<u>Action</u>:

Revise CAR 11.4 and CAR Chapter 7 to provide the clarifications noted above.

CS-05b: **Rather than reference TEEL levels, numerical values for which are subject to frequent updates and changes, provide commitment to and justification for specific hazardous chemical concentrations (or other exposure values) to meet 70.61 performance requirements.**

Clarification of CS-05b: DCS to revise CAR section to reflect consideration of latent health effects. DCS to provide additional information regarding indoor windspeed values used.

Response:

As discussed in the public meetings, DCS commits to the values in CAR Table 8-5. These values are based on the TEELs published as Revision 18.

The TEEL determination process considers latent health effects (i.e. cancer). The determination process (for TEEL-2 and TEEL-3 values) selects hierarchy-based values, if available, followed by toxicity-based values. TEEL-2 values are based on Emergency Response Planning Guideline (ERPG-2) values when available, or on Permissible Exposure Limits (PEL), Threshold Limit Values (TLV), or Recommended Exposure Limit (REL) ceiling (C) values, or on 5 x TLV- Time Weighted Average (TWA) values, in order of availability, followed by toxicity-based values. TEEL-2 values along with ERPG, PEL, TLV, or REL ceiling (C) values take into account latent health effects (i.e. cancer) where appropriate. TEEL-3 values are based on Emergency Response Planning Guideline (ERPG-3) values when available or on Immediately Dangerous to Life and Health (IDLH) values, in order of availability, followed by toxicity-based values. Since the ERPG committee considers latent health effects, TEEL-3 values also take into account latent health effects (i.e. cancer) where appropriate. TEEL-1 values are less than or equal to TEEL-2 values and ensure that exposures do not result in latent health effects.

Therefore, by using the TEEL values, identified in CAR Table 8-5 as limits, the chemical consequence analysis has taken into account latent health effects (i.e. cancer) from the two potential carcinogens at MFFF. A revision to the CAR to address latent health affects is being provided under a separate cover letter.

In a 22 January 2003 telecon, NRC requested information on the calculation approach used for evaluating the effects of indoor nitric acid spills to an external receptor (specifically, the applicability of the model at low wind speeds and if assumptions on wind speed were a design basis). The scoping studies of releases of nitric acid were performed at elevated temperatures from within the MFFF building to determine the impact to the site worker at 100 meters. The study modeled several releases under a variety of conditions and included parametric studies of nitric acid temperature and concentration, amount of material involved in the spill, size of the spill/room, and indoor wind speed. The 95^{th} percentile outdoor X/Q was used to transport the release once the release reached the outside of the building. No credit was assumed for building holdup, dilution within the ventilation system, or cooling of the spilled solution to the surroundings. Based on this study, it was determined that because the spill occurs indoors, releases of nitric acid at elevated temperatures result in low consequences to the site worker at 100 meters.

The principal parameters that ensure the results are low for all indoor releases are the spill/room size and the low indoor wind speed. These input parameters are not considered to be design basis values. They are based on the existing design, account for reasonably expected variations, and if the design were to be modified would require the analyses to be updated.

During final design and the ISA, DCS will confirm that chemical releases result in low consequences to the site worker at 100 meters. If specific characteristics need to be controlled to ensure acceptable chemical consequences to the site worker, then IROFS will be specified at that time.

With respect to the NRC's question on the applicability of the analysis to low wind speeds, two evaporation rate models were considered in assessing the chemical consequences of leaks and spills at the MFFF: (a) a model established by Kawamura and Mackay [1] and used as the default model by the ALOHA code and (b) a model taken from NUREG/CR-6410 [2]. The model which produces the greatest evaporation rate under the evaluated conditions is applied in the calculation of the chemical consequences. The dependence of the wind speed in these models is through the mass transfer coefficient, which is an expression based on a correlation to experimental data.

At low wind speeds, the evaporation rates from the ALOHA model produce the higher evaporation rates. The mass transfer coefficient in this model is based on a correlation developed by Mackay and Matsugu [3] for the total mass transfer from the bulk of a liquid to the atmosphere. This correlation conservatively assumes no concentration gradients exist in the liquid phase (i.e., no reduction of the evaporation rate as a result of changes in the liquid concentration), no inter-facial resistance to the mass transfer exists, and the liquid temperature remains constant (i.e., no evaporative cooling or no heat transfer to the surroundings). Using these assumptions, a general correlation was theoretically derived based on the wind velocity profile over the interface having a power law distribution ($1/7^{th}$ power law familiar for turbulent flow in pipes) and a specific pool diameter.

Experiments with isopropyl benzene were performed to establish the one remaining unknown "C" in the general correlation. To account for a system with a different evaporating liquid and hence, a different diffusivity characteristic, the "C" value was corrected using the Schmidt number. The resulting correlation for the mass transfer coefficient is:

$$k_m = 0.0292 U^{0.78} X^{-0.11} Sc^{-0.67}$$

where k_m is the mass transfer coefficient (m/h), U is the 10 m high wind speed (m/h), X is the pool diameter (m), and Sc is the evaporating chemical's Schmidt number in the air phase.

The implication of applying the aforementioned assumptions and this general theoretical derivation is that a generic and conservative mass transfer coefficient was established without significant limitations to the involved parameters (i.e., the wind velocity, the pool diameter, and the evaporated liquid). The two main limitations of the model are:

1. due to the use of the power law distribution, the flow over the pool should be turbulent and
2. due to the use of the Schmidt number to correct the "C" value, the diffusivity of the evaporated liquid should remain constant.

The second limitation imposes no restrictions on the wind speed, whereas the first limitation appears to restrict the wind speed and the pool size due to their direct relationship with the Reynolds number (i.e., Re = (pool length) x (wind speed)/(kinematic viscosity)). However if this first limitation is violated, the evaporation rate calculated from the above correlation will actually be conservative. This is evident when considering that at a low wind speed the shear at the liquid-vapor interface is significantly lower then that of a high wind speed and hence, less conducive to evaporation. Thus, the mass transfer coefficient correlation will produce evaporation rates that are greater than the actually expected rates at low wind speeds.

Evaporation rates produced using the above mass transfer coefficient correlation were then compared to experimentally measured rates for water, isopropyl benzene, and gasoline in air temperatures between 5 and 30°C and a wind-speed between 0 and 15 mph and to the theoretical mass transfer from a smooth flat plate. For water and isopropyl benzene, the results were in good agreement. However for gasoline, the calculated results were higher than those experimentally measured due primarily to the presence of liquid phase resistance and the varied volatility of the gasoline constituents (thereby violating the second limitation and an earlier assumption). For the theoretical mass transfer from a smooth flat plate, the calculated evaporation rate using the above correlation resulted in rates 1.25 times higher, thereby demonstrating that turbulent transfer conditions prevail.

A final check was performed to assure that the diffusive evaporation rate (occurring at zero wind speed) did not exceed the evaporation rate produced by the ALOHA model at low wind speeds for high concentration nitric acid (13.6 N) at an elevated temperature of 120 °C. The attached figure shows that very low wind speeds ($< 10^{-4}$ m/s) are required to reach evaporation rates comparable to the diffusive evaporation rate.

This information indicates that the evaporation rate model used to assess the chemical consequences of leaks and spills inside the aqueous polishing building is applicable for the evaluated low indoor wind speeds.

<u>Action</u>:

CAR 8.4.2 will be revised to reflect the consideration of latent health effects.

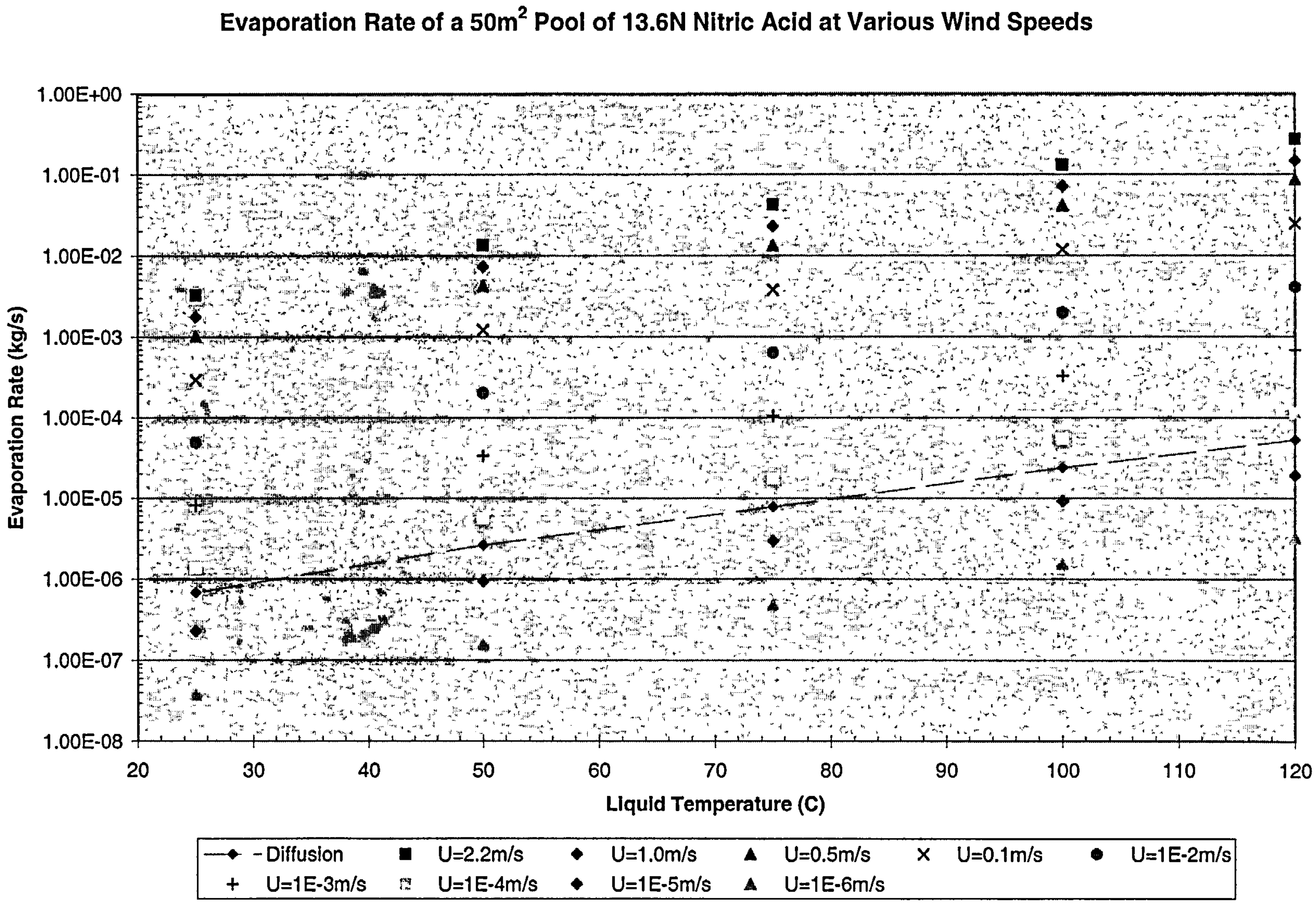
Chemical Safety Open Items (continued)

References:

[1] Kawamura, P.I. and Mackay, D. "The Evaporation of Volatile Liquids." *Journal of Hazardous Materials*, Vol. 15, pp. 343-364, 1987.

[2] NUREG/CR-6410, *Nuclear Fuel Cycle Facility Accident Analysis Handbook*, pp. B-22 – B-23, March 1998.

[3] Mackay, D. and Matsugu, R.S. "Evaporation Rates of Liquid Hydrocarbon Spills On Land and Water." *The Canadian Journal of Chemical Engineering*, Vol. 51, pp. 434-439, August 1973.


Evaporation Rate of a 50m2 Pool of 13.6N Nitric Acid at Various Wind Speeds
Evaporation Rate (kg/s)
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
20
30
40
50
60
70
80
90
100
110
120
Liquid Temperature (C)
- Diffusion
U=2.2m/s
U=1.0m/s
U=0.5m/s
U=0.1m/s
U=1E-2m/s
U=1E-3m/s
U=1E-4m/s
U=1E-5m/s
U=1E-6m/s

<u>CS-10</u>: A suitable design basis for habitability in the Emergency Control Room has not been identified. (DSER Section 8.1.2.6.1)

Clarification of CS-10: Provide information, not included in the information provided by DCS in CAR 11.4.11.1.6, on the design basis hazardous chemical concentrations at which the Emergency Control Room would be deemed "habitable" by DCS.

Response:

As identified in the CAR, Revision 1, Section 11.4.2.7.4, each emergency control room air intake is continuously monitored for hazardous chemicals. Upon detection of a hazardous chemical above allowable limits, the intake is automatically isolated and switched to the recirculation mode using a filtration unit with HEPA filtration and hazardous gas removal elements. If hazardous chemical concentrations above allowable limits are detected at both intakes, operators will don emergency self-contained breathing apparatuses.

Monitoring will be performed for those chemicals whose unmitigated release could result in control room concentrations above the TEEL-3 limit shown in CAR Table 8-5. The emergency actions, following a release, described above will be initiated when the chemical concentrations are at or below the TEEL-3 limit (CAR Table 8-5) for these chemicals. Specific setpoints will be determined during final design.

Initial control room habitability calculations indicate that, of the process chemicals maintained on site (including simple asphyxiants), releases of hydrazine monohydrate or nitrogen tetroxide could result in control room concentrations at or above the TEEL-3 limit (CAR Table 8-5). Calculations will be made during final design to verify the list of chemicals to be monitored.

Where a TEEL-3 value (CAR Table 8-5) is higher than an IDLH value for a given chemical, DCS will provide confirmation in the ISA that the TEEL-3 value (CAR Table 8-5) provides sufficient time to allow the control room worker to take protective action, or use the IDLH value as the limit. Where no IDLH value exists and the ISA evaluation cannot confirm that the TEEL-3 value (CAR Table 8-5) provides sufficient time to allow the control room worker to take protective action, DCS will identify an alternate value (such as the TEEL-2) for the limit that allows sufficient time for the worker to take protective action.

Action:

None.

Aqueous Process Open Items

<u>AP-02</u>: **With respect to the electrolyzer, the applicant's hazard and accident analysis did not consider fires and/or explosions caused by ignition of flammable gases generated by chemical reactions and/or electrolysis, such as from an overvoltage condition. This applies to the dissolution and silver recovery units (DSER Sections 11.2.1.2 and 11.2.1.10)**

Clarification of AP-02: Provide the lower flammability limit methodology and a Hanford report that supports the use of acid normality controls as design bases, as described at CAR 5.5.2.4.6.13.

<u>Response</u>:

The lower flammability methodology was discussed in the January public meeting and a response was provided at that time. The response is included below for convenience.

The copy DCS has of the Hanford report referenced above is designated "Official Use Only" by DOE under 10 CFR 810 and is restricted from being included in publicly available sources or cited in publicly available references. DCS is attempting to get this document evaluated for public release. In the mean time if NRC needs this document DCS recommends that NRC obtain this document directly from DOE. However, it should be noted the report only substantiates the statements made by DCS regarding the diminished production of hydrogen in increasingly acidic medium and was not relied upon by DCS.

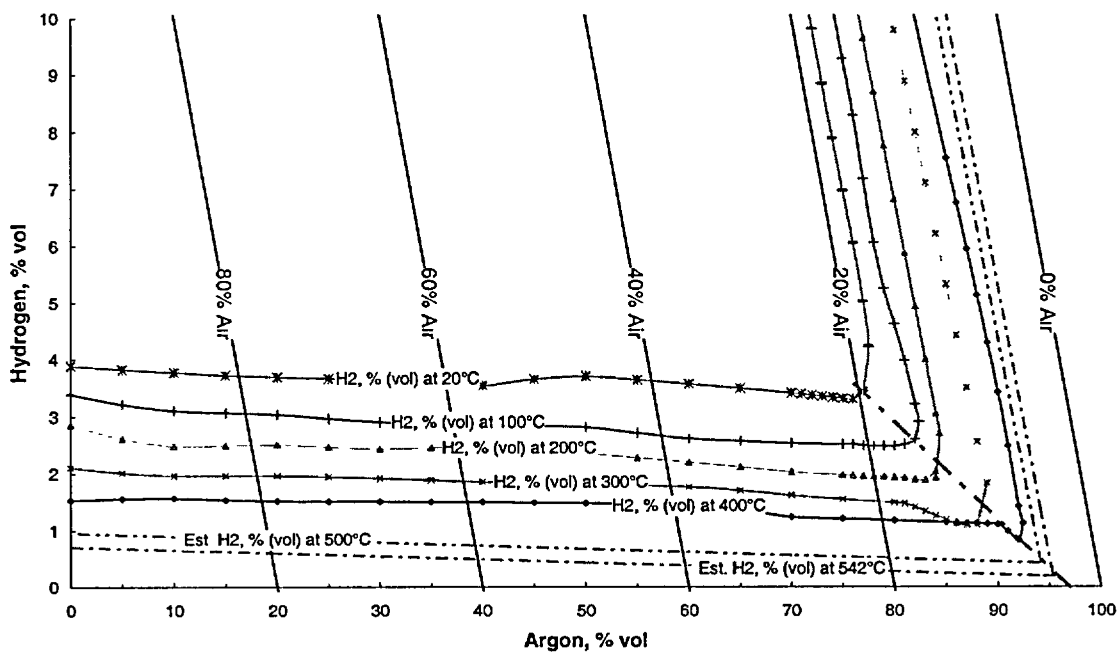
LFL Handout provided at the January 2003 public meeting:

To ensure that explosions are prevented within the Mixed Oxide Fuel Fabrication Facility (MFFF), the facility is designed such that 50% of the lower flammable limit (LFL) for combustible gases used, generated or evolved in the process is not exceeded outside of the process containment structures. In order to comply with this requirement, the systems are designed to dilute the accumulation of combustible gas to ensure that the concentration of combustible gas does not exceed 25% of the LFL or to take action when 25% of the LFL is reached. The safety threshold values of 50% and 25% LFL provide a sufficient margin to account for uncertainties in the actual LFL value and were chosen based on teaching from the National Fire Protection Association standards (principally NFPA 801-1998, NFPA-86-1995 and NFPA-86C-1995) and NUREG 1718. These values are based on LFL values that have been adjusted to account for changes in temperature, pressure and mixture composition.

An example of how these variations are used when determining an appropriate LFL value will be shown using hydrogen as the combustible gas. Pure hydrogen in air under standard reference conditions is flammable at concentrations between 4% (LFL) and 75% [upper flammable limit (UFL)] by volume. Mixtures that fall below the LFL are too lean to support combustion and mixtures that fall above the UFL are too rich to support combustion. The LFL and UFL values change under different conditions of temperature, pressure and gas composition. Because a higher risk is present when transitioning between lean and rich mixtures, the adopted safety strategy is to remain below the LFL when the combustible gas is outside of the process containment system (by leaks or accident).

At the MFFF, pure hydrogen is not used, so an evaluation of the mixed gas must be performed to determine an appropriate LFL. Instead of pure hydrogen, the MFFF uses a gas mixture consisting mainly of the inert gas argon with a small percentage of hydrogen. The LFL for hydrogen is not sensitive to changes in pressure below 100 atm, so changes in the LFL due to small changes in the local atmospheric pressure are ignored when determining the LFL. However, the LFL is affected by the addition of argon and changes in temperature. These changes are shown for argon- hydrogen-air mixtures in the figure below.

Flammability Limits of Argon-Hydrogen in Air at 1 bar and temperatures as shown
Data from Chemsafe (C) DECHEMAe V.14 10 2002



The concentration of argon is shown on the abscissa (x-axis). The corresponding hydrogen concentration is the ordinate value at the point that the argon concentration value intersects the flammability limit line. Thus at 0% argon, the figure shows that the LFL for hydrogen at 20°C is 4% by volume (i.e., the standard value). At elevated temperatures, say 120°C, which could be the result of an accident, the LFL could be as low as 3.3% hydrogen by volume, when the gas composition also consists of 75% argon and 21.7% air. Because this scenario represents the worst case credible environmental conditions for a leak of the hydrogen-argon gas into the sintering furnace room, the LFL thresholds for this scenario would be set at 1.6% (50% LFL) and 0.8% (25% LFL).

For diluents other than argon, such as water vapor or steam, the LFL values actually increase with increases in the diluent concentration. For these cases, the conservative assumption would assume the LFL for pure hydrogen in air and the standard value of 4% by volume would be used as the LFL. The thresholds would be 2% (50% LFL) and 1% (25% LFL). This value would be compared against the LFL for any other combustible gas and the lowest value used. The LFL for some vapors (e.g., gasoline) are combustible at concentrations of 1% by volume and lower. The thresholds for these cases would be 0.5% (50% LFL) and 0.25% (25% LFL). Ultimately, justification for the selected thresholds will be shown in the ISA.

Action:

None.

Material Processing Open Items

MP-01: **PSSC and design basis information associated with the pyrophoric nature of some UO_2 powders (DSER Section 11.3.1.2.1)**

Clarification of MP-01: Address uranium dioxide burnback in analysis of soot loading (FS-1).

Response:

At elevated temperatures, finely divided UO_2 can undergo further oxidation to higher uranium oxides, specifically U_3O_8. This reaction results in spontaneous heating of the oxide and is typically referred to as "burnback." UO_2 burnback is not expected to affect MFFF final HEPA filters for the following reasons:

- During normal operations, UO_2 is not expected to be present on the final HEPA filters because the Glovebox and VHD intermediate HEPA filters prevent any significant quantities of UO_2 powder from reaching the final HEPA filter housing, and the high strength roughing and prefilters remove nearly all of the remaining particles before they reach the final HEPA filters.
- During a fire, UO2 powder is just one of many potential embers. Large embers are removed by the high strength roughing and prefilters. The remaining micron size particles are either cooled by the time they reach the final HEPA filters or do not contain enough energy to degrade the performance of the final HEPA filters.
- The energy associated with the burnback phenomenon is small when compared to the energies involved in a MFFF area fire. The process unit containing the largest quantity of UO_2 is the Final Dosing Unit (520 kg UO_2). The energy generated by the oxidation of this quantity of UO_2 in a fire is approximately 50,000 Btu. The MFFF FHA assumes a Btu loading for this area of 134,701 Btu /ft^2 with an area of 1123 ft^2. This yields a total Btu loading of over 151 million Btu. The quantity of energy released as a result of burnback is negligible when compared to that involved in the process unit fire.

Action:

None.

MP-02: **PSSC and design basis information associated with the pyrophoric nature of some PuO_2 powders (DSER Section 11.3.1.2.3)**

Clarification of MP-02: Address the hazard posed by storing purified, calcined plutonium oxide in buffer storage that does not meet the DOE-STD-3013-2000 standard. The DCS analysis will address moisture content and storage time limits, as necessary.

Response:

Leakage from reusable cans is covered by the spill event discussed in CAR 5.5.2.3.6.4 (Load Handling Controls – C4 Confinement).

In the event radiolysis in the reusable can results in a buildup of pressure, the can lid is deterministically assumed to impact the glovebox. This event is included in CAR 5.5.2.3.6.2 AP/MP C3 Glovebox Areas. To mitigate this event, the Material Handling Control PSSC is used. In this case, material handling controls may include control of moisture content of the material, residence time of the canned material (e.g., in the range of months to years), and/or design pressure of the reusable can. The specific IROFS will be determined as part of the ISA.

CAR section 5.5.2.3.6.4 does not require revision; CAR section 5.5.2.3.6.2 and 5.6.2.3 (Material Handling Controls) will be revised as necessary to reflect this information.

Over-pressurization from the oxidation of Pu (III) oxalate contained within stored cans may be prevented through one of the following:

1. Controls on furnace parameters, such as furnace residence time and minimum temperature to ensure complete oxidation and moisture content of plutonium oxalate entering the furnace;
2. Experimental confirmation of the minimum moisture content accompanying Pu(III) at the exit of the furnace to prevent any over-pressurization due to the energy liberated during re-oxidation;
3. Measurement of Pu (III) content in the plutonium oxide powder.

The specific IROFS will be identified as part of the ISA.

Action:

CAR section 5.5.2.3.6.2 and 5.6.2.3 (Material Handling Controls) will be revised as necessary to reflect this information.

Ventilation Safety Open Items

VS-01: **Justify the use of a leak path factor of 1E-4 for two banks of HEPA filters under accident conditions (DSER Section 11.4.1.3)**

Response:

See Attachment 1

Action:

None.

Attachment 1

Response to NRC Open Item VS-1 and FS-1

1 Introduction

This response provides a summary of the information presented to the NRC during the January 15, 2003 meeting related to MFFF CAR open items FS-1 and VS-1. The objective of this information is to provide the MFFF safety strategy for the facility design and operation that protects the final HEPA filter from damage during and after potential fire events. This protection ensures a minimum HEPA filter efficiency of 99% across each stage and a minimum efficiency of 99.99% across two stages of HEPA filters in series. The information also demonstrates that the MFFF design incorporates a defense in depth philosophy and defense in depth features (features in addition to those IROFS required to satisfy the performance requirements of 10CFR70.61).

The information illustrates the following:

- HEPA filters are designed and tested to meet specific standards. This ensures HEPA filter design criteria and performance characteristics are well known and consistent.

- The factors that affect HEPA filter performance (efficiency and structural integrity) are well known. These factors and their impacts have been identified and quantified by numerous studies, tests, and analyses, and from evaluation of lessons learned from historical fires. Using this information, MFFF design and operational features have been provided to minimize the impact of these factors.

- The MFFF HVAC and fire protection systems are designed in accordance with applicable codes and standards, have many safety features (IROFS) to minimize the impact of the factors that affect HEPA filter performance, and are designed to satisfy the single failure criteria or equivalent. This ensures that the environment the HEPA filters are subjected to does not exceed the HEPA filter design criteria during all operating conditions including fire events.

- Systems analyses are being performed during final design to demonstrate that these safety features will perform their safety function when necessary. The systems analyses incorporate sufficient factors of safety to account for uncertainties in the data and to provide greater tolerance to the failure of facility design features and/or administrative controls. These analyses will demonstrate that the HEPA filters are not exposed to environments that exceed their design limits.

- Although the MFFF is designed to contain fires within a single fire area, the systems analyses are based on a fire involving two fire areas where appropriate. This provides additional margin to safety and accounts for multiple failures of non-safety and safety features during a fire.

- MFFF design incorporates room and glovebox fire suppression systems. MFFF operation includes trained staff and is supported by a full time fire brigade. However, the MFFF is designed to contain fires within a single fire area without the aid of these features. These features provide defense in depth by reducing the challenges to safety systems.

Also provided in this response (but not discussed in the NRC meeting) is a brief description of the MFFF filter test program. This program will provide verification of existing data and provide confidence in the applicability of the data to the MFFF filter housing design.

2 MFFF Final HEPA Filter and Housing Design

This section describes the MFFF final filter housings and associated filter components. A cross-section view of an MFFF filter housing is provided in Attachment A. The individual components are described below:

- Filter Housing and Ductwork Transitions: Stainless steel ductwork is fabricated in accordance with SMACNA Rectangular Industrial Duct Construction Standards (SMACNA 1980) and ERDA 76-21 (Burchstead et.al., 1976) duct construction level 4. Stainless steel housings are fabricated in accordance with ASME N509 (1989a) and contain provisions for in place aerosol testing of each HEPA filter stage.

- First Stage Roughing Filter: Structurally strong, stainless steel wire mesh with stainless steel frame. The filtration efficiency is 60% to 70% for particles from 3 to 10 μm in diameter and 10% - 20% efficient for particles 1 to 3 μm in diameter.

- Second Stage Roughing Filter: Structurally strong, stainless steel wire mesh interwoven with fiberglass. The filtration efficiency is 99% for particles greater that 2 μm in diameter.

- Prefilter: Class 1, (UL 900), constructed of wet laid micro fiberglass, formed corrugation filter media with an ASHRAE efficiency of 80 - 85%.

- HEPA Filter (two stage): high temperature, 304 stainless steel frame in accordance with ASME AG-1, Section FC (ASME 1997a). The filter media is glass (boron silicate microfiber) with waterproof binder and the filter pack sealant is high temperature silicone. The rated efficiency is 99.97% at 0.3 μm diameter. The filters are provided with 304 stainless steel face guards. The filters are capable of withstanding a differential pressure of greater than 10 inches H_2O during severe environmental conditions.

A description of the MFFF HVAC systems and associated design codes and standards is provided in Attachment A.

3 HEPA Filter Testing

The nuclear grade HEPA filter selected for the MFFF application is a separatorless design from Flanders Filters. Nuclear grade HEPA filters and filter media are subject to qualification tests as specified in ASME AG-1 (ASME 1997a) and ASME N509 (ASME 1989a) to ensure minimum performance standards. The HEPA filter tests specify criteria for efficiency and pressure drop at rated flow as well as resistance to rough handling, pressure, heated air, pinhole leaks and spot flame. Filter media qualification tests specify criteria for efficiency, tensile strength, water repellency, combustibility and flexing resistance. These qualification tests are performed before a manufacturer can sell a specific HEPA filter model.

Prior to shipment, each HEPA filter is tested at the manufacturer to certify that the filter has a minimum efficiency of 99.97% for 0.3 µm DOP aerosols at 100% and 20% of rated flow and that the HEPA filter has less than 1.3 inches H_2O pressure drop (ASME 1997a and ASME 1989a).

Once installed, all HEPA filters are tested for leaks and at least every eighteen months thereafter to ensure the filters have been installed properly and do not have leaks. The procedure for the leak tests are prescribed in ASME N510-1989 (ASME 1989b). Periodic visual inspections will also be performed in accordance with ASME N510-1989.

A common experimental observation that the measured HEPA filter efficiency decreases with increasing filter stage has led to the assumption that this is a real phenomenon. However, Bergman (2003) has reviewed the available data on the decreased HEPA filter efficiency and demonstrated the results are due to background radiation and not due to a basic property of multi-stage filtration. The results indicate that HEPA filter efficiency is the same for each stage of HEPA filters in series.

Thus, the design and testing of nuclear grade HEPA filters ensures the following performance criteria for each stage of HEPA filtration:

- Efficiency of 99.97% for 0.3 μm DOP particles at rated flow and at 20% flow
- Efficiency of 99.97% at 20% rated flow after exposure to moist air at 10 inches H_2O pressure for one hour

4 HEPA Filter Impacts

HEPA filter performance is dependent on two key characteristics, the efficiency and structural integrity of the HEPA filters. Numerous studies, tests, and analyses of HEPA filter performance and evaluations of previous fires have been performed to determine the factors that affect both the efficiency and structural integrity of HEPA filters and to quantify their impacts. These factors are summarized in NUREG/CR-6410, Nuclear Fuel Cycle Facility Accident Analysis Handbook and more completely described in Bergman et al (1994).

The MFFF design and safety strategy is to protect the final HEPA filters from the factors that can affect their performance so that they can operate within their known design range. The MFFF incorporates many features to accomplish this strategy. The factors that can affect HEPA filter performance and the MFFF engineered and administrative controls that minimize their effects are described below.

Attachment 1

4.1 Embers

Hot embers can be generated during a fire and consist of relatively large pieces of ash/burning material that separate from the room fire and potentially enter the ventilation system exhaust ducting. The embers could be entrained in the exhaust flow and carried along the ducting until they reach the HVAC system filter housing. Hot embers could melt or burn holes in HEPA filter media and ignite combustible material captured on the filters. Hot embers could reduce the efficiency of the HEPA filters and lead to fires that reduce their structural integrity.

Damage to the HEPA filters is prevented by upstream high strength stainless steel roughing filters and high efficiency, high strength stainless steel/glass fiber filters which capture the embers before they reach the HEPA filters.

4.2 Smoke/Soot

Smoke and soot are generated during a fire and consist of ash and other products of combustion. Smoke particles can range in size from 0.01 μm to 5 μm. Soot particles are formed by the agglomeration of smoke particles and moisture. The quantity of soot generated is dependent on the combustible material, type of fire and fire efficiency. Both smoke and soot can be entrained in the HVAC exhaust flow and could plug HEPA filters resulting in increased differential pressure across the filter and increased water adsorption on the filter. Water from combustion and fire protection systems (if any) could exacerbate HEPA filter plugging and cause a decrease in filter media strength. Soot loading does not reduce the efficiency of the HEPA filters, however failure of the HEPA filters could eventually occur if the filter differential pressures exceed HEPA filter capability for the weakened filter media.

Damage to HEPA filter structural integrity is prevented by upstream high strength filters which capture a large majority of the soot before it reaches the HEPA filters. These high strength filters are designed to withstand the increased differential pressure produced as a result of soot collection. The MFFF design will ensure that the amount of soot reaching the final filters results in a differential pressure rise across the HEPA filters of less than 10 inches of H_2O.

4.3 High Temperature

Exposure of HEPA filters to high air temperatures could result in a loss of both filter efficiency and strength as a result of damage to the filter media and the filter sealant that holds the media pack within the frame. The distortion of metal mounting hardware to the point where seals do not work properly could create filter bypass flowpaths. HEPA filter response to high temperature is provided in the following tables. These tables represent a collection of data obtained from various tests and experiments. Individual reference citations are provided in Bergman et al (1994).

Attachment 1

HEPA Filter Penetration,
Response to Elevated Temperature (Bergman et al, 1994)

Temperature	Effect on Filter Penetration
Increase from 25 °C to 200 °C	– 0.01% to – 0.001%
200 °C	.03% to 0.01%
240 °C for 6 hrs	0.01%
300 °C	0.12% to 0.01%
350 °C	0.4% to 0.03%
500 °C	0.9% to 0.2%
500 °C for 10-45 min	0.9% to 0.1%
538 °C	1.2% to 0.5%

Computed HEPA Filter Strength*,
Response to Elevated Temperature (Bergman et al, 1994)

Temperature	Effect on Filter Strength ΔP Threshold, inches H_2O	
	Avg	Range
200 °C (392 °F), 1 hr	44	25 - 54
300 °C (572 °F), 10 min	33	19 - 41
400 °C (752 °F), 1 hr	26	15 - 32
500 °C (932 °F), 10 min	13	8 - 16
500 °C (932 °F), 10 min	13	8 - 20

***Strength in inches H_2O computed from tensile strength measurements of the filter media at specified temperatures**

Damage to the HEPA filter performance from high temperature is prevented by air flow dilution. The MFFF HVAC systems are designed such that the airflow from any one fire area is just a small fraction of the total air flow of the systems. This ensures that the temperature of the air reaching the HEPA filters is less than 400 °F.

High temperatures also could potentially ignite dust collected in the HVAC ducting or on the HEPA filter face. Dust accumulation in HVAC ducts is prevented by supply air system prefilters and intermediate exhaust HEPA filters that minimize the quantity of dust introduced to facility and HVAC exhaust ducting respectively.

The HEPA filter efficiency and strength as a function of temperature in the two tables are derived primarily from the filter media properties. The media strength and efficiency decrease as the acrylic binder holding the fibers together burn off beginning at about 200°C and ending at about 350°C. Once the binder is burned off, the filter media can be exposed for longer times and higher temperatures with no further degradation.

Gilbert et al (1993, 1995) showed that the filter sealant is the weakest link in the filter assembly and the component most susceptible to temperature excursions. Although the fire retardant solid urethane is the most common sealant used in HEPA filters, it can burn in the heated air test (700°F) and leave a char residue with a leak path. Even more important, the charred residue can leave the filter media pack loose inside the filter housing. This does not occur with silicone sealant (such as used in the MFFF HEPA filters). If the loose HEPA filter is then subjected to smoke deposits or clogging by water, as may occur during fires, the increased pressure drop can push the filter pack out of the filter housing and result in total HEPA failure.

Gilbert et al (1993, 1995) conducted consecutive tests on the same HEPA filter of first exposing the HEPA filter to heated air at 700°F for five minutes and then to 10 inches H_2O differential pressure from humid air flow (greater than 95% relative humidity) for one hour. The significance of these studies is that the tests simulated severe fire conditions and the type of structural damage seen in real fires such as the 1969 and 1980 Rocky Flats HEPA filter fires. One of the tests on the HEPA filter with urethane sealant caused the filter pack to be slightly pushed out of the frame and was close to a filter blow out. The test sequence also demonstrated that the silicone sealant, such as used for MFFF HEPA filters, can eliminate the major cause of HEPA failure in fire conditions.

4.4 Water and Moisture

Exposure of HEPA filters to excessive moisture or water could result in loss of filter efficiency and loss of filter strength. The magnitude of these effects is dependent on other factors such as filter dust loading and age. Bergman et el (1997) showed that the water spray system in fire protection systems was a likely cause for multiple HEPA failures following a filter plenum fire. Moisture in the HVAC exhaust can originate either from normally humid air environments or from products of combustion due to facility fire, fire suppression systems, and fire fighting activities. The quantity of water generated by combustion depends on the nature and concentration of the substances being burned, the temperature of the exhaust stream, the amount of dilution air available in the ventilation duct, and the exhaust gas flow rates.

In general, high relative humidity exhaust passing the HEPA filters is not expected to significantly affect filter efficiency but has a major effect on the filter media strength. Data from Bergman et al (1994) show that a relative humidity of 100% has a negligible effect on HEPA filter efficiency if no structural damage occurs. However, high humidity, especially when the filter has some particle deposits, can cause structural failures like tears and media blow outs at the pleats at pressure drops in excess of 10 inches of water.

As the exhaust stream is cooled by dilution and contact with the duct walls, moisture will tend to condense and collect in the exhaust ducting. Remaining water droplets in the exhaust flow stream are removed by the mist elimination properties of the second stage roughing filter. As described previously, this filter is a structurally strong, stainless steel wire mesh interwoven with fiberglass. This high efficiency roughing filter is very effective in removing water mist and is frequently used as a mist eliminator to protect the downstream HEPA filter.

The following MFFF design features minimize the impact of moisture on the facility HEPA filters.

- Damage to the HEPA filter performance from moisture is prevented by air flow dilution. The MFFF HVAC systems are designed such that the airflow from any one fire area is just a small fraction of the total air flow of the systems.
- A dry agent (proprietary gas mixture) is used as a fire suppressant in the facility process areas.
- High strength stainless steel/glass fiber prefilters provided upstream of the facility HEPA filters act as mist eliminators.
- HEPA filter housings are not provided with cooling water spray. Review of past events has indicated that HEPA filter housing cooling water sprays may have damaged filters to a greater extent than the fire itself.

These features ensure that moisture reaching the HEPA filters is within the tested criteria and will not reduce the structural capability of the HEPA filters to withstand a differential pressure of 10 inches H_2O. We note that existing codes and standards require that all HEPA filters to withstand 10 inches H_2O of differential pressure under high moisture conditions.

4.5 Air Flow

HVAC system air flows that are higher than the system design basis could reduce HEPA filter efficiency and can impact the HEPA filter structural integrity by developing differential pressures that exceed the HEPA filter design criteria.

To ensure the integrity of MFFF HEPA filters, HEPA filter air flows and differential pressures are designed to meet the HEPA filter design criteria, and they will be monitored and controlled as necessary to stay within these criteria.

4.6 Aging

Aging of HEPA filters could result in reduced filter media strength, loss of filter media water repellency and the reduced capability of the filter to perform during high-stress accident conditions. Along with aging, other factors can also contribute to the slow degradation of filter strength and efficiency over time. These include humidity, wetting, and exposure to radiation and chemicals.

Bergman (1999) has analyzed a variety of studies on the strength of HEPA filter to establish the maximum life of HEPA filters. He showed that "under dry conditions, the filter media fail the required tensile strength or have very low burst strengths after 7-13 years, or an average of 10 years." Under wet or humid conditions the strength is significantly reduced, even after the filter has dried. Bergman estimated that restricting the filter life to 5 years in applications having potential water exposure will maintain the minimum filter requirements for the filter qualification such as the minimum strength of 10 inches H_2O under humid conditions. Note that the 5 and 10 year limits refer to the total filter life after manufacture, i.e. storage plus usage.

To prevent these factors from affecting the final filter ability to perform during the fire event, MFFF will implement the following administrative controls:

- Periodic filter visual inspection and surveillance leak testing in accordance with ASME N510-1989, Testing of Nuclear Air Treatment Systems.
- Monitoring of HEPA filter differential pressure and filter replacement at specified filter differential pressures.
- Filter replacement at specified time intervals in accordance with ASME AG-1 or following identified exposures to water or chemicals.

These administrative controls will ensure that HEPA filters are replaced as necessary to ensure that they can withstand a differential pressure of at least 10 inches of water.

4.7 Chemical Exposure

Chemical exposure can result in the degradation of HEPA filter media efficiency and strength. Chemical use is limited in the manufacture of fuel pellets and rods and is not expected to affect the VHD, HDE, and MDE HEPA filters. The aqueous polishing process uses an offgas system to vent process tanks and vessels. The vessel offgas is scrubbed before filtering to remove NOx constituents. Process gas scrubbing minimizes the effects of chemicals used in the aqueous polishing process on the process offgas HEPA filters. The measures described in the aging section will be used to minimize chemical effects on HEPA filter efficiency and strength.

4.8 Radiation

Radiation exposure can result in the degradation of HEPA filter media efficiency and strength. The provision of local HEPA filters (at glovebox) and intermediate HEPA filters prevents the accumulation of radioactive material on MFFF final HEPA filters. The measures described in aging section will ensure satisfactory HEPA filter efficiency and strength.

Attachment 1

5 Engineered Features and Administrative Controls

The MFFF is designed to contain fires within a single fire area, and to protect the final HEPA filters from the affects of a fire. DCS expects to implement the following engineered features and administrative controls to ensure the MFFF ventilation system HEPA filters are protected from the effects of fire and are capable of performing their assigned safety function.

5.1 Credited Features and Controls

The engineered features and administrative controls that DCS expects to credit to ensure the facility fire event satisfies the performance requirements of 10 CFR 70.61 include:

- High strength stainless steel mesh spark arrestors
- High efficiency high strength stainless steel/glass fiber prefilters
- Protected two-stage final HEPA filters with structural integrity of greater than 10 inches H_2O
- Multiple redundant ventilation fan systems
- Ventilation system design ensures adequate air flow dilution
- Ventilation system design ensures < 10 inches H_2O across HEPA filter elements
- Preventative maintenance to ensure HEPA filter integrity
- Low combustible loads
- Fire areas protected by 2 hr (minimum) rated fire barriers

5.2 Defense In Depth Features and Controls

DCS expects to implement the following defense in depth features to account for uncertainties associated with fire conditions and provide a greater tolerance of facility equipment failure:

- Fire protection program
- Fire detection systems
- Automatic fire suppression systems
- Parallel filter trains
- Fire-rated isolation dampers
- Filter element differential pressure monitoring
- MDE system

A short description of the fire protection program is provided in the following section.

5.3 Fire Protection Program

The fire protection program and fire protection systems at the MFFF provide protection against fires and explosions based on the principal and non-principal structures, systems, and components and defense-in-depth) practices. The multiple layers of protection provided by the

DID practices reduce the challenges to the HEPA filter elements from potential fires. These layers of protection fall under the following three aspects of fire protection: fire protection organization; fire protection features and systems, and manual fire fighting capability. Highlights of the program include the following:

- The fire protection program includes administrative programs and procedures to control the storage and use of combustible materials, to control of ignition sources, and to perform surveillances of fire barriers and doors. The fire protection program minimizes the probability and size of potential fires.
- The facility is composed of hundreds of small fire areas which are designed to contain a fire and prevent the spread of fires from one fire area to another. These fire areas effectively limit the radioactive material at risk for a fire event, as well as limit the potential quantity of material that could impact the final HEPA filters.
- The facility is designed with fire detection and suppression systems in most rooms and gloveboxes. Although these systems are designed to extinguish potential fires, they are not credited in the safety analysis or fire hazards analysis and thus provide defense in depth protection.
- The MFFF operations staff will receive formal fire protection program training and there will be an onsite fire brigade. These features reduce the probability of a fire as well as minimize the probability of small fires growing to large fires. Manual fire fighting is not credited in the safety analysis, thus provides an additional layer of defense in depth protection.

The Fire Hazards Analysis provides additional details of the MFFF Fire protection program.

6 Systems Analyses

The MFFF is designed to contain a fire within a single fire area. These fire areas effectively limit the radioactive material at risk for a fire event, as well as limit the potential quantity of material that could impact the mitigating confinement filters. To ensure that fires are limited to a single fire area, a number of systems analyses have been and will be performed.

6.1 Fire Hazards Analysis

A fire hazards analysis (FHA) has been performed to document MFFF-specific fire hazards, the fire protection features proposed to control those hazards, and the overall adequacy of fire safety at the MFFF. The MFFF FHA consists of an analysis of the fire hazards, identification of fire areas, development of the design-basis fire scenarios, and evaluation of anticipated consequences resulting in a determination of the adequacy of facility fire safety. The FHA is intended to (1) demonstrate that the multiple levels of fire protection provided will ensure adequate protection for the MFFF from fires and explosions, and (2) demonstrate the adequacy of the MFFF fire barriers. The MFFF FHA methodology divides the facility into individual fire areas and evaluates the fire safety of each fire area and of the facility as a whole.

In order to determine fire areas, each building of the MFFF is examined with respect to its operational activities. This determination of fire areas involves analyzing the facility layout and equipment for the potential impacts on the processes, the protection of IROFS, fire safety system design, and life safety. Based on this analysis, fire area boundaries are designated. Once the fire area determination is complete, the rating of the fire barriers surrounding each fire area is identified.

Each fire area is then analyzed to determine the fire risks (i.e., combustibles and ignition sources) present. The determination of fire severity and consequences is based on the maximum quantities of combustibles conservatively estimated to be present in the fire area (including transients), the impact of a fire on the IROFS, and the fire barriers' ability to contain the fire to the area of origin. For any fire area where the estimated fire severity is greater than or equal to 80% of the selected fire area rated design barrier, more detailed fire severity modeling is performed to confirm a minimum safety margin of at least 20% is maintained between the fire severity and the fire barrier rating. Fire severity modeling is also performed for fire areas as necessary to support the analyses of nuclear safety concerns.

For each fire area containing IROFS, the postulated design basis fire scenarios are determined by incorporating the fire hazards, ignition sources, and combustible materials. Finally, the adequacy of the fire protection systems of each fire area are assessed to determine whether the installed fire protection features are adequate to effectively control these risks. To verify the adequacy of the fire resistance of the fire barriers of a given fire area, it is conservatively assumed that no suppression system functions automatically, no manual initiation of fire suppression occurs, and all combustible material in a fire area is consumed by the postulated fire.

The following key assumptions are made in the analysis of MFFF fire hazards:

- An administrative fire safety program is in place that limits transient combustibles and controls ignition sources.
- Polycarbonate glovebox windows are used in the MFFF process gloveboxes and assumed to be combustible
- The fire loading of each fire area is conservatively assumed to include a quantity of transient combustible material.
- To verify the adequacy of the fire resistance of the fire barriers of a given fire area, it is assumed that no suppression system functions automatically, no manual initiation of fire suppression occurs, and all combustible material in a fire area is consumed by the postulated fire.

6.2 Fire Severity Modeling

Additional fire severity modeling is performed whenever the initial fire severity determinations reach or exceed the 80 percent criterion. The fire severity modeling uses advanced computational models to calculate the expected duration of the fire and the expected temperature-time curves for the proposed fire cases. To maximize the expected fire duration, a slow heat release rate curve is utilized. For the time-temperature modeling, depending on the nature of the combustibles that could be involved in a fire, the heat release rate curve will reflect either a fast fire or an ultrafast fire to maximize the thermal flux gradients across the fire barriers. The total thermal flux impingement on a fire barrier measures its susceptibility to failure by excessive thermal load or direct flame impingement. This modeling method results in more intense fires of shorter duration than the fire severity modeling used to determine the maximum fire duration.

The fire barriers consist primarily of cast-in-place concrete with steel reinforcing bars forming the columns, walls, floors and ceilings of the fire area. The remaining fire barrier components consist of architectural elements (e.g., fire doors, fire penetration seals, fire dampers). Windows are not present in fire barriers. Cast-in-place concrete has a long history of fire safety. Therefore, a fire severity determination that approaches (but does not exceed) 80 percent of the fire barrier rating coupled with the inherent conservatism in both the design and evaluation of combustible loads will ensure that the fire barriers are adequate even when considering potential uncertainties associated with the design basis fire.

6.3 Soot Loading

DCS is analyzing soot generation as a result of fire and its effects on the MFFF ventilation system filters. The objective of the analysis is to demonstrate the ability of the final HEPA filters to perform their safety function during postulated fire scenarios in the MFFF.

Variables considered in the evaluation include quantity and type of combustible material, fire efficiency, quantity of soot produced, quantity of soot reaching the filter housing, filter soot loading and resultant filter differential pressures. Preliminary results of the analysis show that first stage HEPA filters do not exceed 10 inches H_2O.

The following key assumptions are made in the MFFF HEPA filter soot analysis:

- The fire is assumed to involve the two largest MFFF fire areas containing the largest combustible load.
- The combustible materials within a fire area burn at an efficiency of 100%
- All generated soot is assumed to become airborne. Fifty percent of this airborne soot is assumed to enter the HVAC exhaust ducting.
- Soot loss by thermophoresis within the HVAC ducting is credited. Soot loss by gravitational settling within the HVAC ducting is not credited
- No credit is taken for soot removal by HVAC system intermediate filters
- The simplified Ballinger correlation is assumed to yield a conservative estimate of filter plugging potential. The ultimate determination of filter plugging potential will be made by HEPA filter testing

6.4 Temperature

The temperature of the exhaust gas entering the ductwork will determine the extent of filter damage, operability of fire protection components (e.g., fire dampers), ventilation system duct damage and fire propagation to other fire areas. The maximum estimated temperature leaving a compartment is calculated as part of the fire severity models. The temperature profile of the exhaust gases as they travel through the ductwork is calculated as part of the dilution flow analysis for the VHD, HDE, MDE, and POE systems. The exhaust gas temperatures are calculated by a simple mass-energy balance.

The following key assumptions are made in the MFFF exhaust flow dilution analysis:

- An affected area exhaust temperature 2300 °F is assumed
- No credit is taken for heat loss from the ducting by radiation, convection, conduction.
- The fire is assumed to involve two fire areas

The preliminary dilution analysis shows that exhaust gas temperatures at the final VHD, HDE, MDE, and POE system HEPA filters do not exceed 400 °F.

6.5 Moisture

Dilution of hot moist room air exhaust flow by cooler and drier building air will lower the relative humidity in the exhaust gas stream before the exhaust gas reaches the final HEPA filter units. If a sufficient amount of dilution air is added to the hot moist room air, the moisture in the exhaust air will remain above its dew point and be noncondensing. Noncondensing moisture has been shown to have a negligible impact on short term HEPA filter performance. The excess moisture in the hot room exhaust air is generated as part of the combustion processes and is in addition to the existing moisture in the air. The air from the two largest fire areas will be combined in the moisture analysis to ensure that the impact to the HEPA filters remains negligible. The analysis will identify the minimum dilution air ratio required to ensure that moisture does not become a concern.

7 Reliability and Single Failure Analysis

Reliability of the HVAC system components and single failure analysis of the PSSCs will be performed as part of the ISA. PSSC reliabilities will be estimated using known statistical data from many sources. Single failure analysis will look at propagation of events by the failure of single PSSC, e.g., fire doors, fire dampers.

8 HVAC Disturbance Analysis

The HVAC systems, except for the VHD system, will be analyzed for various air flow disturbances using the Arrow program developed by Applied Fluid Technology (AFT). The HVAC systems will be included in one network model. All fans and dampers, including fire dampers, will be included in the model. The types of analyses planned are:

- Loss of HSA supply fans.
- Accidental closure of major isolation dampers.
- Accidental closure of fire dampers in main ducts and in branch ducts.
- Operation during and after a tornado or seismic event.

A separate disturbance analysis is planned for VHD system which will be similar to the above analyses but will focus on glove box disturbances like:

- Closure in a glove box inlet or exhaust valves.
- Breach of confinement.
- The opening and closing of pressure relief valves and vacuum breakers.

9 Uncertainty Analysis

DCS has identified facility fire as the event posing the greatest threat to the MFFF HEPA filters. This is based on a combination of the energy available for particle dispersion within the facility and the severe environmental conditions to which the HEPA filters can be potentially exposed. Considering the fire event, DCS has determined appropriate HEPA filter efficiencies by evaluating known HEPA filter responses to specific impacts. To provide confidence in the capability of a HEPA filter to perform its safety function during a fire, uncertainties associated with the evaluation of these filter impacts must be addressed. To facilitate this discussion, the applicable aspects of these evaluations have been categorized and listed below. Uncertainties associated with each of these items are discussed in the following paragraphs.

- Identification of fire impacts
- Evaluation of HEPA filter response
- Interaction of fire impacts
- Fire analysis/modeling
- Failure of facility equipment

The types of fire impacts (temperature, smoke, water, etc.) that can affect facility HEPA filters have been identified over many years of HEPA filter operation and the evaluation of past facility fire events. A review of the literature and the lessons learned from fire events involving HEPA filters has resulted in the impacts listed and discussed in Section 4. DCS has a high confidence that all applicable HEPA filter impacts have been identified.

The effects of these impacts on HEPA filter performance have been documented in facility fire event reports and determined experimentally. A summary of HEPA filter test data has been prepared by Bergman et. al. (1994). This summary compiled the results of tests and experiments performed to determine the effects on HEPA filter strength and efficiency following exposure to high temperature, moisture, high differential pressure, etc. To ensure high confidence in the performance of HEPA filters exposed to these impacts, DCS has selected conservative acceptance criteria for the evaluation of impacts. For example, DCS has selected 400 °F as an acceptable limit for the evaluation of high HVAC exhaust temperature. The data provided in

Bergman et. al. (1994) show that filters subjected to temperatures well above 700 °F maintained structural integrity up to 15 inches H_2O (see Section 4.3). This conservative temperature limit coupled with an operating limit to maintain filter differential pressure less 10 inches H_2O ensures continued filter integrity in the event of fire. Similar conservative criteria are established in the evaluation of other HEPA filter impacts (see Section 6).

The data provided in Bergman et. al. (1994) evaluate the effects of single parameters on HEPA filter efficiency and structural integrity. Fire events, however, involve multiple impacts (e.g., high temperature and moisture). To address this interaction, the most conservative value of the involved parameters is selected. In addition, to minimize the interaction of long term factors such as age and radiation exposure, a program of periodic inspection and filter replacement will be implemented at MFFF (see Section 4.6).

Fire analysis/modeling is being performed to determine the extent to which fire impacts affect HEPA filter performance. These include analyses to determine exhaust temperature and soot quantity at the HEPA filter, fire severity and adequacy of fire barriers. To limit the uncertainty associated by these analyses, conservative assumptions are made concerning input data such as combustible loadings, maximum exhaust temperatures, soot quantities and deposition and the failure of fire barriers (e.g., more than one fire area involved in a fire). These analyses and the important conservative assumptions are discussed in Section 6.

To account for the uncertainty associated with the failure of IROFS, the single failure criterion or equivalent is utilized. Additionally, a defense in depth philosophy is utilized in the development of MFFF design. The facility features implementing this design philosophy are not necessarily credited in satisfying the performance requirements of 10 CFR 70.61, however they provide a greater tolerance to equipment failures, reduce challenges to safety equipment, and provide greater overall confidence that the MFFF final HEPA filters will perform their safety function during a fire. These features are described in Sections 5.2 and 5.3.

10 Lessons Learned

Relevant historical fire events have been evaluated and the lessons learned have been incorporated into the MFFF design. Some of the key features incorporated from these lessons learned and associated benefits are as follows:

- The HVAC systems are constructed of fire resistant material and HEPA filters are fire resistant. These features minimize the potential spread of fires into the HVAC systems and onto the HEPA filters.
- Water sprays are not used to protect the HEPA filters. Data from historical events show that water severely reduces the HEPA filter structural integrity.
- The MFFF is comprised of many fire areas and fires are designed to be contained with a single fire area. The use of numerous fires areas reduces the physical consequences and effects of fires and enables these effects to be more easily managed.

- The Final HEPA filters are protected from the impacts of a fire. This ensures that the HEPA filters operate in known conditions and thus provide known efficiencies.
- The MFFF HVAC system consists of redundant trains and multiple separate exhaust zones. These features provide defense in depth.
- The MFFF design is based on a defense in depth philosophy and defense in depth features. This enables the MFFF design and operation to handle small fires and design basis fires with adequate margin.

The use of lessons learned from historical fire events ensures the lessons from the past have been incorporated into the MFFF design and operations.

11 Unprotected HEPA Filter Response in Fire Conditions

Based on the studies of HEPA filter performance under various temperature, pressure and other accident conditions (Bergman 1994) and a detailed analysis of the 1980 Rocky Flats fire (Bergman 1997), it is possible to develop a scenario for the response of an unprotected HEPA filter to fire conditions. This exercise demonstrates that the HEPA filtration system will function at better than 99% efficiency for each HEPA filter even if the fire is much larger than computed and the protection systems upstream of the HEPA plenum do not function.

1. Increasing temperature (to 400°F-650°F) burns off the acrylic binder on the filter medium. This results in reduced filter strength to 15 inches H_2O and reduced efficiency to 99.6.% The high temperature also drives off the organic water repellency treatment, thereby allowing increased water to adsorb on the filter. Note that higher temperatures will not further reduce the filter media strength since all the organic material has been burned off.

2. Increasing temperature (to 700°F) burns the urethane sealant. This may result in a loose filter pack within the filter frame, a pressure resistance of 10 inches H_2O and an efficiency of 94%. Note that the pressure resistance may be even lower if more filter tests are conducted. For silicone sealant (such as used in MFFF HEPA filters), the sealant is not burned and the filter pack is secure. The filter strength is 15 inches and efficiency is 99.9%.

3. Soot and water loading on the HEPA filter increase the filter pressure drop until the pressure drop equals the fan capacity. Additional water from the fire protection system accelerates the pressure drop increase. This results in the filter media pack being blown out of the housing for the urethane sealant if the fan has more than 10 inches of pressure capacity. Note that the filter blow out may occur at lower pressures than 10 inches because limited tests were conducted. For the silicone sealant (such as used for MFFF HEPA filters), the filter pack will not blow out of the frame. At saturated water conditions and pressures of 10 inches and higher, it is possible for tears to occur in the filter media and the filter efficiency drop to 99%.

The sequence of steps described above are consistent with observed HEPA filter failures in the major fires that have occurred in DOE facilities. From an examination of the 1980 Rocky Flats fire, the key filtration features in this fire are (1) the burned urethane sealant on the top of the filter frame created a loose filter pack and (2) the water spray was applied to the filter bank and caused the filter packs to be blown out due to the increased differential pressure. Examination of the 1969 Rocky Flats fire showed a HEPA filter pushed back into the filter frame. The sealant had burned off completely from the filter frame and allowed the filter to be pushed back, but not yet blown out of the frame. Based on the analysis in this report, having a silicone sealant and restricting the filter pressure drop to 10 inches of water would have prevented the complete filter collapses seen in the 1969 and 1980 Rocky Flats fires.

12 MFFF HVAC Test Program

A series of HEPA filter soot loading capacity experiments are being conducted by the Clemson Environmental Testing Laboratory (CETL). The overall objectives of the experiments are to provide data on the performance of the prefilters and the HEPA filter as they are loaded with soot that will be generated from the incomplete burning of materials typical of those found in the MFFF processing areas. The tests are expected to determine the following:

- Differential pressure as a function of soot deposition
- Flow as a function of soot deposition
- Structural capability of the filter components as a function of soot deposition

These experiments will provide verification of existing data and provide confidence in the applicability of the data to the MFFF filter housing design.

13 Conclusion

The design and operation of the MFFF HVAC systems adequately protect the final HEPA during design basis fire events. Defense in depth design philosophy, conservative assumptions and analyses and an evaluation of event uncertainty provide reasonable assurance that final HEPA filters can maintain structural integrity and assumed leak path factor (10^{-4}) during design basis fire events. This approach also provides a greater tolerance to uncertainty and equipment failures.

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Attachment 1

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Attachment A

MFFF HVAC SYSTEMS

The MFFF HVAC System is comprised of the following systems:

- Process Vessel - Off gas Treatment Unit, KWG
- Very High Depressurization Exhaust System, VHD
- High Depressurization Exhaust System, HDE
- Process Cell Exhaust System, POE
- Medium Depressurization Exhaust System, MDE
- Supply System, HSA

The MFFF HVAC systems are designed to provide once- through ventilation of the MFFF to provide contamination control. Air flows from clean areas (Cl) to contaminated areas (C4 & process vessels) by maintaining differential pressure control. The typical air flow paths are:

C1 → C2 → process cells → process vessel

C1 → C2 → C3a → C3b → C4

Where Cl is the cleanest area and C4 and the process vessels are the most contaminated areas. In general, MFFF confinement systems and components (indicated above) interface with each other, with instrumentation and controls, and with normal, standby, and emergency power. A short description of each HVAC system is provided in the following sections.

Process Vessel Off-Gas Treatment Unit

The Process Vessel Off-Gas Treatment Unit (KWG) System maintains a negative pressure on connected process vessels and tanks, cleans off-gases collected from aqueous polishing units (including NO_x removal) and provides HEPA filtration prior to stack release.

This system handles a normal flow of approximately 180 cfm. The air is filtered by two final filter boxes containing metal mesh pre-filters and two stages of final HEPA filters. Each final filter box is rated at 100% of the system capacity to provide redundancy. A cooler and associated mist eliminator are provided upstream of the filters to remove moisture. The mist eliminator is followed by a heater to lower relative humidity prior to filtration. The system is served by two, 100% capacity exhaust fans.

A smaller system (100 cfm) vents the aqueous polishing pulsed columns. This system is also provided with redundant HEPA filter housings and exhaust fans. A heater is provided upstream of the HEPA filters to lower relative humidity, however, a cooler and associated mist eliminator are not required.

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Very High Depressurization Exhaust System

The Very High Depressurization Exhaust (VHD) System maintains a negative pressure differential between the C4 (glovebox) and C3 (process room) confinement zones, filters contaminants from glovebox exhaust gases/air prior to discharge through the exhaust stack and maintains an environment suitable for the manufacturing process. Fire-rated protective features are provided when ductwork passes through a fire barrier into another fire area.

This system handles a normal flow of approximately 3,600 cfm and can ramp up to handle an additional 450 cfm during a breach of confinement incident. The air is filtered by two final filter boxes containing metal mesh pre-filters and two stages of final HEPA filters. Each final filter box is rated at 100% of the system capacity to provide redundancy. There are four first stage, final filter elements in each filter box. The system is served by four, 100% capacity exhaust fans. At least one fan operates at all times using variable speed drive to maintain pressure control in the gloveboxes. The standby fans start automatically to maintain the required system pressure should the primary fan fail for any reason. All four fans are provided with battery back up power and emergency generator power for operation during and after a seismic event or loss of offsite power events.

High Depressurization Exhaust System

The High Depressurization Exhaust (HDE) System maintains a negative pressure differential between the C3 (process room) confinement zone and the C2 confinement zone, maintains an environment suitable for operating personnel, and filters contaminants from the exhausted air prior to discharge through the MOX Fuel Fabrication Building exhaust stack.

The ductwork incorporates manual and automatic dampers and controls to distribute and regulate the movement of air through each room. Fire-rated protective features are provided when ductwork passes through a fire barrier into another fire area.

This system handles approximately 78,000 cfm from 203, C3b process rooms. The process room exhaust is divided up between 15 intermediate filter rooms before entering the final HEPA filter boxes. The final filter boxes contain metal mesh pre-filters and two stages of HEPA filtration. There are ten filter boxes, five of which are on line with five in stand by, for redundancy. There are 120 first stage final filter elements in this system. The system is exhausted by two, 100% capacity exhaust fans. One fan is operating with one in standby mode. The operating fan maintains the design differential pressure using variable speed fan control. The standby fan starts automatically to maintain the required zone pressure should the primary fan fail for any reason. Both fans are supplied with emergency generator power after a seismic event or loss of offsite power events.

Process Cell Exhaust System

The Process Cell Exhaust (POE) System maintains a negative pressure differential between the process cell confinement zone and the C2 confinement zone, filters contaminants from process cell exhaust air prior to discharge through the exhaust stack, and maintains an environment suitable for the manufacturing process. Fire-rated isolation dampers or other protective features are provided when ductwork passes through a fire barrier into another fire area.

This system is designed to handle a normal flow of approximately 9,050 cfm from 19 process cells. The air is filtered by two final filter boxes containing metal mesh pre-filters and two stages of final HEPA filters. There are a total of eighteen first stage final filter elements in the final filter boxes. The system is served by two 100% capacity exhaust fans, one operating and one in standby. The operating fan maintains the design differential pressure using variable speed fan control. Both fans are supplied with normal and standby power and are not required during or after a seismic event or loss of offsite power events.

Medium Depressurization Exhaust System

The Medium Depressurization Exhaust (MDE) System maintains a continuous negative differential pressure between the C2 and C1 (environment) confinement zones, the exhaust air prior to discharge through the exhaust stack, maintains an environment suitable for operating personnel and provides a common exhaust stack for discharge of process vents and ventilation exhaust.

The ductwork incorporates manual and automatic dampers and controls to distribute and regulate the movement of air through each room. Fire-rated isolation dampers or other protective features are provided when ductwork passes through a fire barrier into another fire area.

The MDE system handles approximately 100,000 cfm from 200 C2 spaces. The final filter boxes contain metal mesh pre-filters and two stages of HEPA filtration. There are twelve filter boxes, eleven of which are on line with one in standby. There are a total of 96 first stage final filter elements in this system. The system is exhausted by two, 100% capacity exhaust fans. One fan is operating with one in standby mode. The operating fan maintains the design differential pressure using variable speed fan control. The standby fan starts automatically to maintain the required zone pressure should the primary fan fail for any reason. Both fans are supplied with normal power and are not required during or after a seismic event or loss of offsite power events.

Supply System

The Supply System (HSA) provides supply air to the C4 (gloveboxes), C3 (process rooms), process cell, and C2 (rooms) confinement zones and maintains an environment suitable for operating personnel and process/auxiliary equipment. The ductwork incorporates manual and automatic dampers and controls to distribute and regulate the movement of air to each room. Fire-rated isolation dampers or other protective features are provided when ductwork passes through a fire barrier into another fire area.

The Supply Air System supplies approximately 191,000 cfm of conditioned outside air through one stage of HEPA filters. The supply air fans draw air from the outside, through filters, heaters, and cooling coils, to condition the air for distribution. Supply airflow is maintained by one of two 100%-capacity fans. The fans operate under automatic air flow control using variable speed fan control. The stand by fan starts automatically should the primary fan fail to maintain the required flow under normal conditions. The fans are provided with normal and stand by electrical power and are not required during or after a seismic event or loss of offsite power event.

HVAC Design Codes and Standards

The following national standards, DOE Regulatory Guides and handbooks are applied to the HVAC systems and components:

- ERDA 76-21 Nuclear Air Cleaning Handbook, 2nd edition, applies to all sheet metal ductwork design, construction and testing, "bubble tight" isolation damper construction and testing, HEPA filter housing testing, and HEPA filter testing. All ductwork will be fabricated in accordance with the ductwork construction levels and leak rates, as defined by ERDA 76-21 Nuclear Air Cleaning Handbook section 5.2, for each of the systems.

- SMACNA (Sheet Metal & Air Conditioning Contractors National Association) HVAC Construction Standards - Metal and Flexible is used for the design of all non welded ductwork. SMACNA Rectangular Industrial Duct Construction Standard and SMACNA Round industrial Duct Construction Standards are used for the design of all welded ductwork.

- ASME - AG-1, Code on Nuclear Air and Gas Treatment, is applied to the design and testing of HEPA filters, HEPA filter housing, ductwork and pipe flexible connections and exhaust fans, when these components are IROFS.

- ASME B31.3 – 1996 Process piping, including 1998 Addenda, applies to the design and fabrication of all piping, valves and fittings associated with the primary, glove box, ventilation system (VHD).

- ASME N509 and N510 are applied to HEPA filter design and testing, HEPA filter housing design, construction and testing, and HEPA filter housing isolation Dampers.

- Regulatory Guide 3.12, General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants is applied to all ventilation systems to assure confinement of nuclear materials.

- NFPA 801 will be applied to the location of air-cleaning systems intakes and outlets to reduce contamination potential. Fresh-air inlets will be located to reduce the possibility of radioactive contaminants being introduced. Such inlets shall be located where it is most unlikely for radioactive contaminants to be present. Smoke, corrosive gases, and the non-radioactive substances that may be freed by a fire will be vented from their place of origin directly to a safe location. Radioactive materials that are released by fire will be confined, removed from the exhaust ventilation air stream, or released under controlled conditions. The ventilation system will be designed, located, and protected such that airborne corrosive products or contamination shall not be circulated

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- UL 555 will be applied to all supply system and tertiary exhaust system fire dampers. Modified fire and smoke dampers shall be installed in the exhaust ducts of class C3 and Process Cell rooms. Prior to modifications, the fire and smoke dampers shall be tested and approved in accordance with UL 555

Materials of construction are selected according to such safety considerations as strength to withstand normal and accident conditions; withstand any credible fire and explosion, corrosion resistance, particularly when associated with chemical processes; fire resistance; long operating life to avoid replacement of contaminated equipment; and smooth surface finish to aid in decontamination.

Cross-Section of MFFF HEPA Filter Housing