DUKE COGEMA
STONE & WEBSTER

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U.S. Nuclear Regulatory Commission
Washington, DC 20555

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DCS-NRC-000132

Subject: Docket Number 070-03098
Duke Cogema Stone & Webster
Mixed Oxide (MOX) Fuel Fabrication Facility
Construction Authorization Request Change Pages

References:
1) P. S. Hastings (DCS) to Document Control Desk (NRC), *Docket Number 070-03098 Duke Cogema Stone & Webster Mixed Oxide (MOX) Fuel Fabrication Facility Construction Authorization Request Change Pages*, DCS-NRC-000131, 1 April 2003
2) P. S. Hastings (DCS) to Document Control Desk (NRC), *Docket Number 070-03098 Duke Cogema Stone & Webster Mixed Oxide (MOX) Fuel Fabrication Facility Responses to Site Description, Instrumentation, and Criticality Open Items/Additional NRC Questions on Construction Authorization Request (CAR) Revision*, DCS-NRC-000127, 11 February 2003
3) P. S. Hastings (DCS) to Document Control Desk (NRC), *Docket Number 070-03098 Duke Cogema Stone & Webster Mixed Oxide (MOX) 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*, DCS-NRC-000128, 18 February 2003

Enclosed are change pages for Duke Cogema Stone & Webster's (DCS) request for authorization of construction of the Mixed Oxide (MOX) Fuel Fabrication Facility. The enclosed change pages replace pages in the Construction Authorization Request as updated through Reference 1.

The enclosed change pages do not contain information which is considered to be proprietary to DCS. Enclosure 1 provides twenty-five copies of the change pages, which may be disclosed to the public. Enclosure 2 provides the page replacement instructions.

The changed pages are the result of additional clarifications to previously submitted open item responses (NCS-2, NCS-5, FS-1/VS-1 and CS-1) provided in References 2 and 3. Enclosure 3 contains revised responses related to open items NCS-5 and NCS-10 (Q10) (criticality), and FS-1 and VS-1 (HEPA filters).

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If I can provide any additional information, please feel free to contact me at (704) 373-7820.

Sincerely,

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

Enclosures:
1) Change Pages to the Mixed Oxide Fuel Fabrication Facility Construction Authorization Request (non-proprietary)
2) Construction Authorization Request 04/08/03 Update Instructions
3) Revised Open Item Responses

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Enclosure 1

Change Pages for Mixed Oxide Fuel Fabrication Facility Construction Authorization Request (non-proprietary)

25 copies enclosed

Enclosure 2
Construction Authorization Request
04/08/03 Update Instructions

Construction Authorization Request
04/08/03 Update Instructions

Remove	Insert
Volume 1 of 3	
List of Effective Pages	
Pages xxxvii (02/18/03), xxxviii (04/01/03)	Pages xxxvii (04/08/03), xxxviii (04/08/03)
Pages xxxix (04/01/03), xl (02/18/03)	Pages xxxix (04/08/03), xl (04/08/03)
Chapter 5 Integrated Safety Analysis	
Pages 5.5-37 (10/31/02), 5.5-38 (10/31/02)	Pages 5.5-37 (04/08/03), 5.5-38 (04/08/03)
Pages 5.5-133 (10/31/02), 5.5-134 (10/31/02)	Pages 5.5-133 (04/08/03), 5.5-134 (04/08/03)
Pages 5.6-9 (12/20/02), 5.6-10 (02/18/03)	Pages 5.6-9 (04/08/03), 5.6-10 (04/08/03)
Pages 5.6-15 (04/01/03), 5.6-16 (04/01/03)	Pages 5.6-15 (04/01/03), 5.6-16 (04/08/03)
Pages 5.6-17 (04/01/03), 5.6-18 (04/01/03)	Pages 5.6-17 (04/08/03), 5.6-18 (04/08/03)
Chapter 6 Nuclear Criticality Safety	
Pages 6-37 (10/31/02), 6-38 (02/18/03)	Pages 6-37 (04/08/03), 6-37a (04/08/03) Pages 6-37b (04/08/03), 6-38 (02/18/03)
Pages 6-53 (02/18/03), 6-54 (02/18/03)	Pages 6-53 (04/08/03), 6-54 (04/08/03)
Pages 6-55 (10/31/02), 6-56 (02/18/03)	Pages 6-55 (10/31/02), 6-56 (04/08/03)
Pages 6-59 (02/18/03), 6-60 (10/31/02)	Pages 6-59 (04/08/03), 6-60 (10/31/02)
Chapter 8 Chemical Process Safety	
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Pages 8-25 (10/31/02), 8-26 (10/31/02)	Pages 8-25 (04/08/03), 8-26 (10/31/02)

Construction Authorization Request
04/08/03 Update Instructions

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Pages xxxix (04/01/03), xl (02/18/03)	Pages xxxix (04/08/03), xl (04/08/03)
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Enclosure 3
Construction Authorization Request
Revised Open Item Responses

Nuclear Criticality Safety

Q10: **Section 6.4, ANSI/ANS-8.23. DCS changed the wording of this standard from "This standard is referenced as a basis for the design of MFFF processes and fissile material handling and storage areas. The standard provides guidance for minimizing risks to personnel during emergency response to a nuclear criticality accident outside reactors." Criticality accident emergency planning and response, while an important programmatic element, is not part of the safety basis." This seemed confusing to NRC.**

Response:

As shown in CAR and RAI-90:

"As discussed in Chapter 14, an NRC-approved Emergency Plan is not required for the MFFF. Nonetheless, MFFF operations will comply with the recommendations of ANSI/ANS-8.23-1997, without exception. While not considered part of the design basis of principal SSCs, this standard provides guidance for minimizing risks to personnel during emergency response to a nuclear criticality accident outside reactors."

(Note that a CAAS does not prevent or mitigate design basis events, and is therefore not considered a principal SSC.) (CAR Section 6.4).

Action:

Clarify the CAR as follows:

1. Change the title of Section 6.4 from "DESIGN BASES" to "DESIGN BASES FOR PRINCIPLE SSCs."

2. Add a new section 6.5 to the end of chapter 6 text entitled "DESIGN BASES FOR NON-PRINCIPLE SSCs."

3. Move the two paragraphs under the Section 6.4 entitled "ANSI/ANS-8.23..." to the new Section 6.5.

4. Delete the two paragraphs referred to in the above item from Section 6.4 and delete the heading "ANSI/ANS-8.23..." as well.

(These actions have been completed per DCS 18 February 2003 submittal of changed pages).

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NCS-5: **"The definition of 'highly unlikely' for criticality hazards"**

DSER 6.1.4.2: "The staff has determined that the definition of the DCP (taken from ANSI/ANS-8.1-1983 (R1988)) is insufficiently detailed to support the conclusion that criticality is necessarily 'highly unlikely' to occur...In the public meeting on March 27, 2002, the applicant presented a summary description of a methodology for determining acceptable likelihoods for criticality accidents. While the method appears to approximately agree with the appropriate acceptance criteria, the staff requested that a more detailed description of the plan be submitted. The applicant has not yet submitted this description. Therefore, the definition of 'highly unlikely,' and the appropriate level of protection against accidental criticality in 10 CFR 70.64, has not been adequately resolved and is considered an open item."

Response:

In the March 2002 meeting, DCS provided a generic proof indicating that compliance with our other commitments with regard to the demonstration of IROFS effectiveness for all credited IROFS and event scenarios effectively provides a qualitative demonstration that high-consequence events are highly unlikely without further analytical demonstration. This discussion was consistent with the response to RAI question 39.

In a recent CAR revision, section 5.4.3 was updated to reflect the additional details discussed above, and to be consistent with the previous Staff agreements surrounding the response to RAI 39. The updated language focuses primarily on the analyses conducted as part of the ISA process, analyses which will demonstrate that the application of DCS' commitments provide for effective qualitative demonstration of meeting the highly unlikely threshold (consistent with the generic proof discussed above, but not including the specific frequency domain analysis). These analyses (i.e., of the demonstration of the effectiveness of IROFS) will be applied to each event sequence with the potential to exceed 10 CFR §70.61 requirements (including criticality events, without regard to actual dose consequences). The analyses verify that single failure criterion or double contingency principle is effectively applied, that there are no common mode failures, that the IROFS will be effective in performing their intended safety function, that the conditions that the IROFS will be subjected to will not diminish the reliability of the IROFS, and also identify and verify appropriate IROFS failure detection methods. Each of the event sequences and the accompanying specific measures provided by the aforementioned deterministic criteria will be documented in the ISA and summarized in the ISA summary. This combination of analyses will demonstrate that the likelihood requirements of 10CFR70.61 are satisfied.

Specifically, the nuclear criticality safety evaluations contain the following information:

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1. For each event for which a potential criticality is credible, the following will be described and analyzed to demonstrate adherence to the double contingency principle:

    a. Description of the potential event

    b. Control challenge

    c. Methods of prevention

    d. Listing of potential initiating event

    e. At least two independent IROFS controls to prevent the event including the safety functions of the controls

    f. Description of redundancy and diversity

    g. Description of safety margin involved

    h. Description of failure mode, detection of failure, and surveillance

2. For each IROFS control identified in item 1 above, the following will be described:

    a. Description of the IROFS control

    b. Listing of the safety functions for the control

    c. Quality classification (e.g., QL-1a or QL-1b)

    d. Process Operating Range and Limits

    e. Emergency Capabilities

    f. Testing and Maintenance

    g. Environmental Design Factors (as applicable)

    h. Natural Phenomena Response

    i. Instrumentation and Controls required

    j. Applicable Codes and Standards

    The NCSEs will reference/summarize analyses, as necessary, that demonstrate that the IROFS are effective and perform the intended function.

3. For each event for which a potential criticality is credible as described in item 1, the event will be shown to be highly unlikely as follows:

    a. Cross correlation with the events as described in item 1 above including description of the initiating event,

b. Summary description of each of the IROFS controls with cross reference to the IROFS information (item 2 above),

c. Description and justification of the failure of each of the IROFS being unlikely,

d. Description of failure detection or safety margin involved providing justification that the potential event is highly unlikely to occur.

For passively controlled units such as tanks, vessels, and storage areas for which the failure of the equipment is not credible to fail, this means that a potential event is not credible. For this to be true, the following will be shown:

a. The passively controlled component will be specified to be quality level QL-1a.

b. The passively controlled equipment will be evaluated and shown to be sub-critical under all credible process conditions.

c. The passively controlled equipment will have management measures to ensure that the configuration is controlled and unchanging under the facility's configuration management program.

For other units for which potential events are credible, the basic criteria for judging that the event is highly unlikely is as follows:

1) At least two independent robust (i.e., unlikely to fail) controls are provided.

2) Active or passive engineered controls are unlikely to fail. This determination will be based on consideration of all applicable "available and reliable" qualities per NUREG 1718 including those discussed in Section 2 above; also the controls will be classified at least QL-1b.

3) Administrative controls are robust and unlikely to fail. This determination will be based on consideration of all applicable "available and reliable" qualities per NUREG 1718 including those discussed in Section 2 above; also administrative controls must be simple and unambiguous.

4) For each independent control (each independent and unlikely to fail) described above, there will also be one of the following:

   i. A means to detect a failure of the control on a period (e.g., of one month or less), as justified in the NSCEs; or

   ii. A safety margin will be shown that demonstrates that multiple (3 or more) failures of each independent robust control (used for double contingency protection) would not result in a loss of sub-criticality; or

   iii. Other means, with justification, to demonstrate that failure of the set of independent controls are highly unlikely. These means will be shown to provide comparable assurance to the failure detection or safety margin described above. The list of any system in this

category will be included in the ISA Summary for NRC review and approval.

The rationale for demonstration an event is highly unlikely is to be provided in the NCSEs and summarized in the ISA Summary.

Action:

Add the following text after the second paragraph in Section 6.3.5.4 in the CAR:

As noted in Section 5.4.3, each potential credible criticality event sequence will be shown to be highly unlikely by the application of deterministic criteria. In particular, to demonstrate that criticality events are highly unlikely, the nuclear criticality safety evaluations will contain the following information:

1. For each event for which a potential criticality is credible, the event will be described and analyzed to demonstrate adherence to the double contingency principle.
2. For each IROFS control identified, the IROFS will be shown to be effective and perform the intended function.
3. For each event for which a potential criticality is credible, the event will be shown to be highly unlikely as follows:
   a. Summary description of each of the IROFS controls with cross reference to the IROFS information
   b. Description and justification of the failure of each of the IROFS being unlikely,
   c. Description of failure detection or safety margin involved providing justification that the potential event is highly unlikely to occur.

For passively controlled units such as tanks, vessels, and storage areas for which the failure of the equipment is not credible to fail, this means that a potential event is not credible. For this to be true, the following will be shown:

a. The passively controlled component will be specified to be quality level QL-1a.
b. The passively controlled equipment will be evaluated and shown to be sub-critical under all credible process conditions.
c. The passively controlled equipment will have management measures to ensure that the configuration is controlled and unchanging under the facility's configuration management program.

For other units for which potential events are credible, the basic criteria for judging that the event is highly unlikely is as follows:

1. At least two independent robust (i.e., unlikely to fail) controls are provided.
2. Active or passive engineered controls are unlikely to fail. This determination will be based on consideration of all applicable "available and reliable" qualities per NUREG 1718; also the controls will be classified at least QL-1b.
3. Administrative controls are robust and unlikely to fail. This determination will be based on consideration of all applicable "available and reliable" qualities per NUREG 1718; also administrative controls must be simple and unambiguous.
4. For each independent control (each independent and unlikely to fail) described above, there will also be one of the following:
    a. A means to detect a failure of the control on a period (e.g., of one month or less) as justified in the NCSEs, or
    b. A safety margin will be shown that demonstrates that multiple (3 or more) failures of each independent robust control (used for double contingency protection) would not result in a loss of subcriticality; or
    c. Other means, with justification, to demonstrate that failure of the set of independent controls are highly unlikely. These means will be shown to provide comparable assurance to the failure detection or safety margin described above. The list of any system in this category will be included in the ISA Summary for NRC review and approval.

The rationale for demonstrating an event is highly unlikely is to be provided in the NCSEs and summarized in the ISA Summary.

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HEPA Filters (VS-1, FS-1)

NRC Questions and Responses to DCS 18 February 2003 submittal (Reference 3)

(NOTE: References to sections, attachments, etc., within the NRC questions below refer to Reference 3)

1. Attachment 1, Section 1, 5th bullet In the sentence, "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," what is meant by the term "where appropriate"? What fire areas have we analyzed and why does DCS believe they represent a conservative analysis? What were the results of the analyses? What margin of safety exists? Does the soot loading analysis include dust on the prefilters that would get passed down in the event of failure during the event (i.e., glovebox/intermediate filters fail and their loading is transferred down to the final filters)?

1a. What is meant by the term "where appropriate" (based on a fire involving two fire areas where appropriate)?

MFFF is designed to limit fire to one fire area. "Where appropriate" is intended only as a figure of speech, and designates where two fire areas are assumed in the evaluation of HVAC filter soot loading and exhaust temperature. Assuming two fire areas provides significant margin.

1b. What areas were analyzed and why does DCS believe they represent a conservative analysis?

The two fire areas (not necessarily adjacent) with the highest soot loading are selected to evaluate the effects of HEPA filter soot loading. The inclusion of two fire areas is conservative since the MFFF is designed to contain fires within a single fire area.

1c. What were the results of the analysis?

Preliminary results of the MFFF HEPA filter soot loading and fire area exhaust flow dilution analyses indicate that the MFFF final HEPA filters are adequately protected against severe conditions (heat and soot) and are capable of performing their safety function in the event of fire. Final demonstration will be provided as part of the ISA.

1d. Does the soot loading analysis include dust on the prefilters that would get passed down in the event of failure during the event (i.e. glovebox/intermediate filters fail and their loading is transferred down to the final filters)?

The effect of dust on the VHD or HDE final filters as a result of intermediate HEPA filter failure is judged to be negligible when compared to soot loading effects. Debris from structurally damaged intermediate filters would be caught by the high strength

roughing filter and the high strength steel/glass fiber pre-filter. These high strength pre-filters will withstand a complete collapse of the glove box/intermediate filters. Effects of this dust and debris will be confirmed in MFFF HEPA filter soot loading analyses in support of the ISA.

2. Section 4.1, Embers: What is the size of the embers referred to in section 4.1? Provide a statement regarding efficiency versus size to show that embers cannot or do not get through the filters. Provide any data that backs up the size assumed (provide a range of sizes).

   Although no specific studies on size distribution of embers were found, the embers are commonly defined as large pieces (visible, > 100 μm) of hot ash or burning material generated during a fire. These embers could be captured in the room exhaust flow and carried in the exhaust duct toward the system HEPA filters. Heavier embers would be removed from the ventilation flow by gravity, while smaller embers are extinguished within a short distance and therefore do not pose a threat. All embers cool as they move through the HVAC ducting.

   To prevent embers from affecting the MFFF final HEPA filters, two stages of non-combustible roughing filters are provided upstream of the HEPA filters. The first stage is a structurally strong, stainless steel wire mesh filter with stainless steel frame. This filter has a 60-70% efficiency for particles in the 3 μm to 10 μm diameter range and a 10-20% efficiency for particles in the 1 μm to 3 μm diameter range. The second roughing filter is a structurally strong, stainless steel wire mesh interwoven with glass fiber with a stainless steel frame. This filter has an efficiency of 99% for particles greater than 2 μm in diameter. All embers are stopped by these two stages of non-combustible roughing filters.

   The energies associated with these embers is insignificant when compared to the energy levels of the original fire and are not sufficient to significantly increase ventilation air flow temperatures.

3. Section 6.4, Temperature: If embers ignite the roughing (or others) filters, can it impact the temperature at the final HEPA filters? Basically, why is the HEPA filter protected from a fire on the 1st or 2nd stage roughing filters?

   Dust is not expected to be collected on any of the final filter elements because of the upstream intermediate HEPA filters, and therefore there is no mechanism for embers igniting the roughing filters. However, assuming that dust somehow collected on the prefilter elements just upstream of the final HEPA filter elements, it may be possible to ignite and burn the dust if hot embers deposited on the dust. However, the amount of fuel loading due to the deposited dust is so low that the temperature rise from burning dust will not damage the filter elements. The filter elements in question are the stainless steel roughing filters and the stainless steel/glass fiber filters located upstream of the

final HEPA filter elements (1st or 2nd stage roughing filters). They are designed to be noncombustible and structurally strong enough to withstand the full differential pressure of the exhaust fans.

Combusting a conservative quantity of dust (1 kg) on the 1st or 2nd stage roughing filters is not expected to impact the ability of the final HEPA filters to perform their safety function for the following reasons:

- Limited combustible load (dust), insufficient heat release to significantly raise the air temperature;
- Flames cannot propagate beyond the second prefilter, and most likely not the first prefilter.
- Distance between the roughing filters and the final HEPA filters;
- Cooling effect of dilution air; and
- Temperature qualification of the final HEPA filters.

Thus, in the unlikely event that dust or some other combustible material is present in large quantities (approximately 1 kg) on the prefilter elements, and this material were to ignite and burn, the final HEPA filters would not be exposed to severe conditions and would still effectively filter the exhaust gas stream and prevent releases. Combustion of dust on the 1st or 2nd stage roughing filters and the effect on MFFF final HEPA filters will be confirmed by the fire area exhaust flow dilution analysis.

4. Section 6.3, Soot Loading: Has DCS corrected previous errors in the application of the simplified Ballinger equation? NRC would like assurances that the equation has been used correctly and corrections have been made (appropriate size for filter used, etc.).

   The Ballinger correlation is used to estimate the soot loads that would produce pressure drops that would cause HEPA filter burst failures because the amount of soot that would create these high pressure drops is different than the amount of standardized dust with which HEPA filters are rated. This correlation allows DCS to quantify the likelihood of soot causing a HEPA filter burst failure. The Ballinger correlation referenced by DCS has been corrected and modified to correspond to standard nuclear grade HEPA filters with twice the soot capacity of the filters referenced by Ballinger. The original Ballinger correlation was obtained from tests performed at the Japan Atomic Energy Research Institute (JAERI) Fire/Filter Facility using half-size HEPA filter elements. The load versus differential pressure correlation was empirically derived by Hashimoto and Nishio at JAERI. Tests performed in the United States by Gaskill, Fenton and others have been found to yield similar correlation factors but the results are sensitive to flow velocities, smoke composition, gas stream moisture content and filter size.

Because of these uncertainties, the nature of fires, and the uncertainties that exist with the various empirical models used to estimate the amount of soot produced by a given fire, DCS will confirm the bounding nature of the modified Ballinger correlation through a series of tests to be performed at the Clemson Environmental Test Laboratory (CETL). The results of these tests will be used to confirm the final design of the facility ventilation system. It should be noted that the current filter design relies on the stainless steel and stainless steel/glass fiber prefilter elements upstream of the HEPA filter elements to capture and hold the majority of the soot generated during a fire. This will significantly lower the soot load seen by the HEPA filter elements. The significant shift of soot loading from the HEPA filters to the robust stainless steel roughing filter and stainless steel/glass fiber prefilter greatly reduces the impact of soot loading on HEPA filters and the reliance on the Ballinger equation. Current estimates with the additional stainless steel/glass fiber prefilter indicates that soot loads would have to be many times their expected values before the HEPA filters are impacted. Margin is also built into the flow capacities of the existing fan and filter unit designs. These factors make it unlikely that additional design changes will be required. However, even if additional capacity is found to be necessary, the existing rooms allow for expansion within the existing floor area.

5. Section 12, MFFF HVAC Test Program: How will results of Clemson Environmental Test Lab (CETL) soot loading tests be incorporated into the MFFF safety analysis? How will DCS factor this into the construction phase of the project? (Will it impact the construction phase?)

   Planned soot loading experiments will be performed at CETL during the summer of 2003. Experimental results will be used to confirm the conclusions of the MFFF HEPA filters soot loading analysis.

   The results of the soot loading tests are not expected to impact the MFFF construction phase.

6. Attachment A: The HVAC system information provided in Attachment A does not seem to be consistent with Attachment 1, Section 2. For example, what is meant by the following Very High Depressurization Exhaust System statement: "There are four first stage, final filter elements in each filter housing"? Please provide an explanation of the 1st stage final filter elements.

   The filter units in the Very High Depressurization Exhaust System (VHD) are assembled from a combination of engineered and standardized components. The size of the filter unit and number of standardized components depends on the specified airflow capacity. The VHD filter units consist of a structure (called the housing) that contains a number of standard-size filter elements depending on the overall air flow capacity of the filter unit. The standard full-size nuclear grade filter elements are rated for various flow rates up to 1,500 cfm of air. By arranging these filter elements in an array within the housing, the

capacity of the filter unit can be increased to handle flows greater than the capacity of a single filter element. The capacity of the filter unit is equal to the capacity of each filter element multiplied by the total number of filter elements in the array, e.g., a 2 x 2 array would have 4 times the capacity of a single filter element. When these arrays are arranged in series, each array is called a stage.

The HEPA filter elements in the VHD final filter housings are arranged in a 2 high x 2 wide array. There are two stages of final HEPA filtration in each VHD filter housing. The first stage of the VHD final HEPA filter housing is a 2 high by 2 wide array consisting of four (4) standard full-size HEPA filter elements, each filter element operating in parallel with the other 3 filter elements. The second stage of VHD final HEPA filter housing is also a 2 x 2 array with four (4) second stage full-size HEPA filter elements down stream of the first stage.

7. Attachment A, High Depressurization Exhaust System: What is meant by "intermediate filter room?"

   An intermediate filter room is a C3b room that contains several single stage intermediate HEPA filter housings connected to either the C3b room supply or C3b room exhaust ducts. These intermediate filters provide a HEPA filter separation between the C2 and C3 confinement systems and prevent the migration of airborne contamination through the duct system. The number of single stage HEPA filter housings in each intermediate filter room depends on the location of the room in the facility and the number of C3b rooms ducted to each intermediate filter room.

8. Attachment A, Supply System: Are prefilters provided upstream of the supply system HEPA filters?

   There are two sets of prefilters upstream of the supply system (HSA) HEPA filters. The first set is a 35% ASHRAE roughing filter followed by an 85% ASHRAE dust filter. These filters also protect the cooling coil fins from being plugged with atmospheric dust.

9. Section 6.3, Soot Loading: What is the justification for the assumption that 50% of soot generated during the fire is deposited in the room?

   The MFFF soot loading calculation uses a soot loss coefficient of 0.5 based on input from four references that support a "soot loss coefficient" of 0.5 (50 % of soot remains in room):

   Marcel Ballinger, et al., "Aerosol Released in Accidents in Reprocessing Plants," Nuclear Technology, Vol. 81, pp 278 - 292, May 1988.

   E. Horman, "Analysis of Fire and Explosion Accidents in a Fuel Reprocessing Plant," Los Alamos National Laboratory, Proceedings of the CSNI Specialist

Meetings on Interaction of Fire and Explosion with Ventilation Systems in Nuclear Facilities, April 25 - 28, 1983.

F.R. Krause, "Fire Source Simulation," Los Alamos National Laboratory, Proceedings of the CSNI Specialist Meetings on Interaction of Fire and Explosion with Ventilation Systems in Nuclear Facilities, April 25 - 28, 1983.

William C. Hinds, "Aerosols Technology," John Wiley, Second Edition, 1998.

The primary source is Krause (1983), which used data generated from Tewarson for horizontal and vertical solid fires.

10. Section 6.3, Soot Loading: What is the justification for using the Ballinger equation (based on solvent) to estimate HEPA soot loadings resulting from a plastics (polycarbonate) fire?

    DCS has judged that the combustion of solvent provides a representative soot generation value. Other HEPA filter soot loading data are also being investigated. Evaluation of this additional data will be included in the MFFF soot loading analysis. Soot generation as a result of combusting MFFF-specific materials (and impact to MFFF HEPA filters) will be determined empirically by CETL.

11. Section 12, MFFF HVAC Test Program: How many runs will be performed as part of the CETL HEPA filter soot loading tests?

    The soot loading test plan is currently being developed. At the present time four experimental runs are planned.

12. CAR Table 5.6-1: The following safety function is assigned to the C4 Confinement System. "Provide design features to ensure that final C4 HEPA filters are not impacted by fire." Should this safety function also be assigned to the C3 Confinement System?

    The subject safety function was carried over inadvertently from a previous CAR version. This safety function will be deleted as it is included in the current C4 safety function, "Remain operable during design basis fire and effectively filter any release." This same safety function is also assigned to the C3 Confinement System.

13. Section 6, Systems Analyses: What is the justification for addressing flashover (deflagration and impacts to final HEPAs) in an HVAC duct in the ISA?

    Addressing flashover/deflagration in the ISA is acceptable because the ISA analyses will be confirmatory to qualitative analyses that have already been performed for the safety assessment of design bases of principal SSCs for construction authorization.

While involvement of all combustibles in a given fire area was assumed for the purposes of conservative selection of fire barrier rating, analysis of fires that could actually occur (i.e., in the FHA) does not result in flashover in the HVAC ducting.

The potential fires in most fire areas are typically small and non-propagating; further, the duration of these fires is anticipated to be short relative to the rating of the fire barriers of the fire area, and the fires themselves have a low heat release rate and/or a low heat flux. These fires will have minimal impact on their surroundings within the fire area. Additionally, since the fire barriers surrounding these fire areas have a minimum fire rating of two hours, the penetrations of these barriers are routinely inspected, and any fire doors in these barriers are self-closing, there should be no impact from such fires on surrounding fire areas. Accordingly, based on the lack of continuity of combustibles, flashover conditions do not occur.

Even for those fire areas where the fire could involve the entire fire area (i.e., switchgear, control, and MCC rooms), the barriers surrounding these fire areas (which are typically fire-rated for three hours) ensure that the effects of the fire are contained to the fire area itself. (Note that the fire areas where the fire could involve the entire fire area did not include any fire areas containing dispersible radioactive materials.)

Flashover conditions have been deterministically "forced" in discrete fire modeling analyses to confirm the adequacy of fire barriers pursuant to the closure of NRC Open Item FS-02. However, the conditions that result in flashover are not believed to be credible based on the MFFF design.

For the ISA, additional analyses will be performed to confirm the qualitative conclusions of the FHA as well as demonstrate that fires do not spread from one fire area to another. In the unlikely event that the results of detailed analyses indicate flashover/deflagration can occur in the ductwork, the analyses will either conclude the consequences are acceptable, or the design will be changed as necessary. It is anticipated that any such changes would not significantly impact the final facility design.

14. Will the measures described in Section 4.6 of Attachment 1 be used to minimize chemical effects on HEPA efficiency and strength? Will these measures be identified as principal SSCs? Will they be added to Chapter 5 of the CAR?

    The measures described in Section 4.6 of Attachment 1 will be used to minimize chemical effects on HEPA efficiency and strength. These measures (tests and inspections) discussed in Section 4.6 will be implemented as periodic surveillances required to demonstrate the facility HEPA are capable of performing their safety function. Required periodic surveillances of all MFFF IROFS will be provided in the ISA. DCS does not plan to revise the CAR to include these measures as principal SSCs.

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controls ensure that a system initially composed of TBP and nitric acid will not runaway and result in over-pressurization of the process vessel.

An additional consideration is the accumulation of organic by-products formed through hydrolysis reactions of TBP. Most notably, butanol and butyl nitrate have been identified as potential by-products that could liberate significant energy when undergoing oxidation. Thus, controls are established to ensure that significant quantities of butanol and/or butyl nitrate do not build up in the process (i.e., in process vessels containing oxidizing agents and potentially exposed to high temperatures). Furthermore, energetic byproducts formed from TBP degradation may also be generated via radiolysis. Consequently, the exposure time of TBP to radiological materials is limited to ensure that unacceptable quantities of butanol and butyl-nitrate do not accumulate in the system from radiolysis.

Additional details pertaining to the identified principal SSCs are presented below. Additional information on the mechanism and safety evaluation for this event is presented in Section 8.5.

Offgas Treatment System

A prerequisite for a runaway reaction is for the energy generation to exceed the heat removal from the system. Venting provides a mechanism by which energy may be effectively transferred from the system and also serves to limit the extent of the energy generation, by allowing for the evacuation of the reactants via evaporation. The heat transfer mechanism afforded by venting is given by providing an exhaust path for evaporated water and nitric acid, which carry off heat from the system. In addition, venting limits the degree of completion of the hydrolysis reactions by allowing the reactants, nitric acid, and by-products (butanol and butyl nitrate) formed through TBP hydrolysis to evaporate from the system. Furthermore, an open system will not lead to higher temperatures prior to the boiling of water and nitric acid and hence, result in diminished reaction rates and energy generation rates compared to a closed system. Thus, the safety function of the offgas treatment system is to provide an exhaust path for aqueous phase evaporative cooling in process vessels, thereby providing a mechanism for heat removal. An additional safety function of the offgas treatment system is to provide venting of vessels/equipment that potentially contain TBP and its associated by-products to prevent over-pressurization in the case of excessive oxidation of TBP and/or its degradation products.

Process Safety Control Subsystem

The process safety control subsystem ensures temperatures in process vessels, which may contain organics, are limited to ensure that the rate of energy generation given by the hydrolysis of TBP and associated oxidation reactions is limited. Control of the energy generation in a system initially containing TBP and nitric acid is effectively given by the rate of hydrolysis of TBP. In addition to the control of temperature, the residence time of organics in the presence of oxidizers, such as nitric acid, and radiation fields is also controlled to limit the quantity of degraded organics that may buildup in the system either through hydrolysis and/or radiolysis.

Chemical Safety Control

Certain diluents could undergo nitration or radiolysis, introducing more reactive byproducts that could facilitate a runaway reaction. The properties of the diluent have been recognized as contributing a role in the early "red oil" runaway reactions and may have also contributed to the Tomsk event (Section 8.5 provides more details of these events). The diluent may provide both an energy source and a mechanism by which the heat transfer characteristics are degraded (e.g., during heating above a threshold temperature, diluents have been shown to exhibit foaming). Consequently, to provide reasonable assurance that these phenomena do not occur, an additional safety function for chemical safety control is to ensure that a diluent is utilized that does not contain cyclic chain hydrocarbons.

5.5.2.4.6.8 AP Vessel Over-Pressurization Explosion

Over-pressurization of AP tanks, vessels, and piping are postulated as the result of increases in the temperature or exothermic chemical reactions of solutions in, or entering into, tanks or vessels, or as a result of excessive addition of fluids into high temperature environments (e.g., calcining furnace).

To reduce the risk to the public, site worker, facility worker, and the environment associated with this postulated explosion group, a safety strategy utilizing prevention features is adopted. The principal SSCs identified to implement this safety strategy include the fluid transport systems, offgas treatment system, and chemical safety controls. The safety function of the fluid transport systems is to ensure that process vessels, tanks, and piping are designed to prevent process deviations from creating over-pressurization events that result in the release of radioactive material. The safety function of the offgas treatment system is to provide an exhaust path for the removal of gases in process vessels thereby preventing over-pressurization conditions. The safety function of the chemical safety controls is to ensure control of the chemical makeup of the reagents and ensure segregation/separation of vessels/components from incompatible chemicals.

5.5.2.4.6.9 Pressure Vessel Over-Pressurization Explosion

This group involves vessels that are identified as pressure vessels. Explosion events related to pressure vessels arise from the MFFF support systems due to the presence of pressurized gas bottles, tanks, or receivers (pressure vessels) within these systems. These pressure vessels could over-pressurize and explode, impacting primary confinements and resulting in a release of radioactive material.

To reduce the risk to the public, site worker, facility worker, and the environment associated with this postulated explosion group, a safety strategy utilizing prevention features is adopted. The principal SSCs identified to implement this safety strategy are the pressure vessel controls. The safety function of the pressure vessel controls is to ensure that primary confinements are protected from the impact of pressure vessel failures.

Table 5.5-19. Principal SSCs and Associated Safety Functions for all Receptors for the Explosion Event Type (continued)

Explosion Group	Principal SSC	Safety Function
HAN Explosion [Process vessels containing HAN and hydrazine nitrate with NO_x addition]	Chemical Safety Control	Ensure concentrations of HAN, hydrazine nitrate, and hydrazoic acid are controlled to within safety limits
	Offgas Treatment System	Provide an exhaust path for the removal of gases in process vessels
	Process Safety Control Subsystem	Control the flow rate into the oxidation column
Hydrogen Peroxide	Chemical Safety Control	Ensure that explosive concentrations of hydrogen peroxide do not occur
Solvent Explosion	Process Safety Control Subsystem[a]	Ensure the temperature of solutions containing solvents is limited to temperatures within safety limits
	Process Cell Fire Prevention Features[a]	Ensure that fires in process cells are highly unlikely
	Offgas Treatment System[a]	Provide an exhaust path for the removal of gases in process vessels
TBP - Nitrate (Red Oil) Explosion	Offgas Treatment System	Provide an exhaust path for aqueous phase evaporative cooling in process vessels, thereby providing a mechanism for heat removal
		Provide venting of vessels/equipment that potentially contain TBP and its associated by-products to prevent over-pressurization in the case of excessive oxidation of TBP and/or its degradation products
	Process Safety Control Subsystem	Ensure the temperature of solutions containing organic is restricted to temperatures within safety limits in order to limit the rate of energy generation Limit the residence time of organics in process vessels containing oxidizing agents and potentially exposed to high temperatures and in radiation fields

Table 5.5-19. Principal SSCs and Associated Safety Functions for all Receptors for the Explosion Event Type (continued)

Explosion Group	Principal SSC	Safety Function
TBP - Nitrate (Red Oil) Explosion (continued)	Chemical Safety Control	Ensure a diluent is used that does not contain cyclic chain hydrocarbons
AP Vessel Over-Pressurization	Fluid Transport Systems	Ensure that vessels, tanks, and piping are designed to prevent process deviations from creating over-pressurization events
	Offgas Treatment System	Provide an exhaust path for the removal of gases in process vessels
	Chemical Safety Control	Ensure control of the chemical makeup of the reagents and ensure segregation/ separation of vessels/components from incompatible chemicals
Pressure Vessel Over-Pressurization	Pressure Vessel Controls	Ensure primary confinements are protected from the impact of pressure vessel failures (bulk gas, breathing air, service air and instrument air systems)
Hydrazoic Acid Explosion	Chemical Safety Control	Ensure the proper concentration of hydrazine nitrate is introduced into the system Ensure that hydrazoic acid is not accumulated in the process or propagated to units that might lead to explosive conditions
	Process Safety Control Subsystem	Ensure the temperature of solutions potentially containing hydrazoic acid is limited to prevent an explosive concentration of hydrazoic acid from developing

Table 5.6-1. MFFF Principal SSCs

Principal SSC	Safety Function	SA Design Basis Reference
3013 Canister	Withstand the effects of design basis drops without breaching	11.4.11
3013 Transport Cask	Withstand the design basis fire without breaching	11.4.11
	Withstand the effects of design basis drops without release of radioactive material	
Backflow Prevention Features	Prevent process fluids from back-flowing into interfacing systems.	11.8.7
C2 Confinement System Passive Barrier	Limit the dispersion of radioactive material	11.4.11
C3 Confinement System	Provide filtration to mitigate dispersions from the C3 areas	11.4.11
	Remain operable during design basis fire and effectively filter any release	
	Limit the dispersion of radioactive material	
	Provide exhaust to ensure that temperature in the 3013 canister storage structure is maintained within design limits	
	Provide cooling air exhaust from designated electrical rooms	
C4 Confinement System	Maintain a negative glovebox pressure differential between the glovebox and the interfacing systems	11.4.11
	Maintain minimum inward flow through small glovebox breaches	
	Remain operable during design basis fire and effectively filter any release	
	Ensure that C4 exhaust is effectively filtered	
	Operate to ensure that a negative pressure differential exists between the C4 glovebox and the C3 area	
	Contain a chemical release within a glovebox and provide an exhaust path for removal of the chemical vapors	

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Chemical Safety Controls*	Ensure that explosive concentrations of hydrogen peroxide do not occur	5.6.2.1
	Ensure a diluent is used that does not contain cyclic chain hydrocarbons	
	Ensure that hydrazoic acid is not accumulated in the process or propagated to units that might lead to explosive conditions	
	Ensure metal azides are not introduced into high temperature process equipment	
	Ensure the sodium azide has been destroyed prior to the transfer of the alkaline waste into the high alpha waste of the waste recovery unit	
	Ensure the valance of the plutonium prior to oxalic acid addition is not VI	
	Ensure that nitric acid, metal impurities, and HAN concentrations are controlled and maintained to within safety limits	
	Ensure concentrations of HAN, hydrazine nitrate, and hydrazoic acid are controlled to within safety limits	
	Ensure the proper concentration of hydrazine nitrate is introduced into the system	
	Ensure control of the chemical makeup of the reagents and ensure segregation/ separation of vessels/components from incompatible chemicals	

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Material Handling Controls*	Prevent impacts to the glovebox during normal operations from loads outside or inside the glovebox that could exceed the glovebox design basis	5.6.2.3
	Prevent potential overpressurization of the reusable plutonium oxide cans, due to radiolysis or oxidation of Pu (III) oxalate, and its subsequent impact to the glovebox	
	Prevent load handling events that could breach primary confinements	
Material Handling Equipment	Limit damage to fuel rods/assemblies during handling operations	11.7.7
	Prevent impacts to the glovebox through the use of engineered equipment	
Material Maintenance and Surveillance Programs*	Detect and limit the damage resulting from corrosion	5.6.2.4
MFFF Tornado Dampers	Protect MFFF ventilation systems from differential pressure effects of the tornado	11.4.11
Missile Barriers	Protect MOX Fuel Fabrication Building and Emergency Generator Building internal SSCs from damage caused by tornado- or wind-driven missiles	11.1.7
MOX Fuel Fabrication Building Structure (including vent stack)	Maintain structural integrity and prevent damage to internal SSCs from external fires, external explosions, earthquakes, extreme winds, tornadoes, missiles, rain, and snow and ice loadings	11.1.7
	Withstand the effects of load drops that could potentially impact radiological material	
MOX Fuel Transport Cask	Withstand the design basis fire without breaching	11.4.11
	Withstand the effects of design basis drops without release of radioactive material	
Offgas Treatment System	Provide an exhaust path for the removal of gases in process vessels	11.4.11

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Offgas Treatment System	Provide an exhaust path for aqueous phase evaporative cooling in process vessels, thereby providing a mechanism for heat removal	8.5 and 11.4.11
	Provide venting of vessels/equipment that potentially contain TBP and its associated byproducts to prevent over-pressurization in the case of excessive oxidation of TBP and/or its degradation products	8.5 and 11.4.11
Pressure Vessel Controls*	Ensure that primary confinements are protected from the impact of pressure vessel failures (bulk gas, breathing air, service air, and instrument air systems)	11.9.5
Process Cells	Contain fluid leaks within process cells	11.4.11
Process Cell Entry Controls*	Prevent the entry of personnel into process cells during normal operations	5.6.2.5
	Ensure that workers do not receive a radiological or chemical exposure in excess of limits while performing maintenance in the AP process cells	
Process Cell Fire Prevention Features	Ensure that fires in the process cells are highly unlikely	7.5.3
Process Cell Ventilation System Passive Boundary	Provide filtration to limit the dispersion of radioactive material	11.4.11
Process Safety Control Subsystem		System design basis provided in 11.6.7. As necessary, basis for parameters provided as shown
	Prevent the formation of an explosive mixture of hydrogen within the MFFF facility associated with the use of the hydrogen-argon gas	8.5
	Ensure isolation of sintering furnace humidifier water flow on high water level	11.4.11 (See Sintering Furnace)
	Ensure the temperature of solutions containing HAN is limited to temperatures within the safety limits	8.5

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Process Safety Control Subsystem (continued)	Control the flowrate into the oxidation column	8.5
	Ensure the temperature of solutions containing organic is restricted to temperatures within safety limits in order to limit the rate of energy generation	8.5
	Limit the residence time of organics in process vessels containing oxidizing agents and potentially exposed to high temperatures and in radiation fields	8.5
	Ensure the temperature of solutions potentially containing hydrazoic acid is limited to prevent an explosive concentration of hydrazoic acid from developing	8.5
	Limit and control conditions under which dry-out can occur	8.5
	Ensure the temperature of solutions potentially containing metal azides is insufficient to overcome the activation energy needed to initiate the energetic decomposition of the azide	8.5
	Ensure the normality of the nitric acid is sufficiently high to ensure that the offgas is not flammable and to limit excessive hydrogen production	8.5
	Warn operators of glovebox pressure discrepancies prior to exceeding differential pressure limits	11.4.11
	Shut down process equipment prior to exceeding temperature safety limits	11.4.11
	Ensure the temperature of solutions containing solvents is limited to temperatures within safety limits	8.5
	Ensure the flow rate of nitrogen dioxide/ dinitrogen tetroxide is limited to the oxidation column of the purification cycle	8.5
	Maintain sintering furnace within design limits	11.4.11

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Seismic Monitoring System and Associated Seismic Isolation Valves	Prevent fire and criticality as a result of an uncontrolled release of hazardous material and water within the MFFF Building in the event of an earthquake	11.6.7 – for system 11.8.7 – for valves
Sintering Furnace	Provide a primary confinement boundary against leaks into C3 areas	11.4.11
Supply Air System	Provide unconditioned emergency cooling air to the storage vault and designated electrical rooms	11.4.11
Transfer Container	Withstand the effects of design basis drops without breaching	11.4.11
Waste Containers	Ensure that hydrogen buildup in excess of limits does not occur while providing appropriate confinement of radioactive materials	11.4.11
Waste Transfer Line	Ensure that the waste transfer line is protected from activities taking place outside the MOX Fuel Fabrication Building	10.5
	Prevent damage to the line from external fires, explosions, earthquakes, extreme winds, tornadoes, missiles, rain, and snow and ice loadings	10.5

* Administrative control

Oak Ridge National Laboratory, June 2002,) have shown that additional, already published experiments also can be used for criticality benchmark validation purposes since they exhibit similar characteristics to MOX powder to be utilized at the MFFF.

6.3.5.4 Nuclear Criticality Safety Evaluations

As part of the initial design process, before starting a new operation with fissionable materials, or before an existing fissionable material operation is modified, NCSEs are performed to ensure that the entire process will be subcritical under both normal and credible abnormal conditions. NCSEs are documented with sufficient detail, clarity, and lack of ambiguity to allow independent evaluation and judgment of results. NCSEs identify the controlled nuclear and process parameters and their associated limits upon which criticality safety depends.

Thus, NCSEs form the basis for criticality safety for operations in which fissionable material is handled. That is, each NCSE evaluates a respective operation to determine credible accident sequences and identifies sufficient controls such that double contingency protection is provided in those cases in which a criticality is credible. Utilizing the results of validated calculational methodologies, the NCSEs demonstrate that both normal and accident conditions meet the required minimum margin of subcriticality. Finally, the IROFS to provide double contingency protection, along with criticality accident sequences, are identified in NCSEs. Features that are required to ensure that the criticality controls identified in the NCSE are sufficiently available and reliable are provided through the implementation of management measures such as procedures, training, maintenance procedures, and surveillance.

As noted in Section 5.4.3, each potential credible criticality event sequence will be shown to be highly unlikely by the application of deterministic criteria. In particular, to demonstrate that criticality events are highly unlikely, the nuclear criticality safety evaluations will contain the following information:

1. For each event for which a potential criticality is credible, the event will be described and analyzed to demonstrate adherence to the double contingency principle.
2. For each IROFS control identified, the IROFS will be shown to be effective and perform the intended function.
3. For each event for which a potential criticality is credible, the event will be shown to be highly unlikely as follows:
   a. Summary description of each of the IROFS controls with cross reference to the IROFS information
   b. Description and justification of the failure of each of the IROFS being unlikely,
   c. Description of failure detection or safety margin involved providing justification that the potential event is highly unlikely to occur.

For passively controlled units such as tanks, vessels, and storage areas for which the failure of the equipment is not credible to fail, this means that a potential event is not credible. For this to be true, the following will be shown:

a. The passively controlled component will be specified to be quality level QL-1a.

b. The passively controlled equipment will be evaluated and shown to be sub-critical under all credible process conditions.

c. The passively controlled equipment will have management measures to ensure that the configuration is controlled and unchanging under the facility's configuration management program.

For other units for which potential events are credible, the basic criteria for judging that the event is highly unlikely is as follows:

1. At least two independent robust (i.e., unlikely to fail) controls are provided.
2. Active or passive engineered controls are unlikely to fail. This determination will be based on consideration of all applicable "available and reliable" qualities per NUREG 1718; also the controls must be classified at least QL-1b.
3. Administrative controls are robust and unlikely to fail. This determination will be based on consideration of all applicable "available and reliable" qualities per NUREG 1718; also administrative controls must be simple and unambiguous.
4. For each independent control (each independent and unlikely to fail) described above, there will also be one of the following:

   a. A means to detect a failure of the control on a period (e.g., of one month or less) as justified in the NCSEs; or

   b. A safety margin will be shown that demonstrates that multiple (3 or more) failures of each independent robust control (used for double contingency protection) would not result in a loss of subcriticality; or

   c. Other means, with justification, to demonstrate that failure of the set of independent controls are highly unlikely. These means will be shown to provide comparable assurance to the failure detection or safety margin described above. The list of any system in this category will be included in the ISA Summary for NRC review and approval.

The rationale for demonstrating an event is highly unlikely is to be provided in the NCSEs and summarized in the ISA Summary.

An approved design configuration requires criticality safety design input. Figure 6-2 presents an overview of the steps involved in developing an MFFF NCSE. During preliminary design, criticality safety calculations are performed to justify a preliminary design concept. These calculations assess both the normal operating and assumed accident conditions. Where practical, criticality is precluded by demonstrating that the design is subcritical without the need to implement controls, or by making appropriate design changes to render criticality non-credible. In those cases in which it is not practical to make criticality non-credible, criticality control parameters are selected and limits on these parameters are established.

6.3.5.5 Design Control

Criticality safety during design and operation is ensured for the MFFF through design and administrative practices. MFFF design and safety features are documented and controlled through the implementation of a rigorous configuration management program (see Section 15.2). Criticality safety calculations and NCSEs are maintained up to date and consistent with existing facility process and design features and administrative practices. The configuration management program ensures the following:

- Reports validating the method for analyzing criticality are maintained consistent with criticality safety documentation provided in criticality safety calculations and NCSEs.
- NCSEs are maintained consistent with existing facility process and design features and administrative practices and rely only on validated calculational methods.

- Credible optimum conditions (i.e., most reactive conditions physically possible) for each controlled parameter are assumed in criticality safety calculations and NCSEs unless specified controls are implemented to limit the controlled parameter to a specified value or range.
- Variability and uncertainty in a process condition and the subcritical limit are established and considered when applying computational methods to specific design applications.
- Surveillance programs are established and implemented to ensure the continued efficacy of supplemental neutron-absorber materials (e.g., borated concrete or cadmium) during the operational life of the MFFF.
- During license operation, the configuration management program meets the requirements of 10 CFR §70.72, including review of changes for potential criticality concerns.

6.3.6 ISA Commitments

During development of the ISA, criticality controls credited in the NCSEs will be identified and evaluated, and a more detailed description of the CAAS will be provided. This information will be reflected in the license application for possession and use of SNM and/or its accompanying ISA Summary, as appropriate. Section 6.4 provides additional details.

6.4 DESIGN BASES FOR PRINCIPAL SSCs

This section discusses the design bases requirements applicable to the design and operation of criticality safety SSCs. These requirements may be modified during the final design phase in accordance with the configuration management system, described in Section 15.2.

Principal SSCs are described in Chapter 5 of this document. Specific IROFS associated with criticality safety will be identified in the ISA.

Criticality in the MFFF will be prevented. The design features, administrative controls, and management measures to ensure that criticality is prevented will be described in the ISA Summary submitted with the license application for possession and use of SNM. Under normal and credible abnormal conditions, nuclear processes will be designed to be subcritical, including the use of a safety margin, which will account for computational bias, uncertainties, and an appropriate administrative safety margin. The design will provide for criticality control including adherence to the double-contingency principle.

A CAAS will be included in the MFFF design in accordance with the design criteria described earlier in this chapter. (Note that a CAAS does not prevent or mitigate design basis events, and is therefore not considered a principal SSC.)

The Nuclear Criticality Safety Program for the MFFF will be in accordance with Regulatory Guide 3.71. Regulatory Guide 3.71 has been developed to provide guidance on complying with the applicable portions of NRC regulations, including 10 CFR Part 70, by describing procedures for preventing nuclear criticality accidents in operations involving handling, processing, storing, and transporting SNM at fuels and material facilities. This regulatory guide endorses specific nuclear criticality safety standards drafted by Subcommittee ANS-8 (Fissionable Materials

Table 6-1. Preliminary Definition of Reference Fissile Medium and Control Methods for Principal AP Process Units (Continued)

Criticality Control Unit	Control Method													Comments
	Physicochemical Characteristics (PC)	Mass (M)	Geometry (G)	Density (D)	Isotopics (I)	Reflection (R)	Moderation (MN)	Concentration (C)	Interaction (IN)	Neutron absorber (A)	Volume (V)	Heterogeneity (H)	Process variable	
KDD Dissolution/Dechlorination														
Electrolyzer	NO $PuO_2 + H_2O$	NO	YES	YES [1,9] $d \leq 7$	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	NO	Mass control credited when cooling coil leaks (IROFS failure)
Dechlorination Columns	NO $PuO_2 + H_2O$	NO	NO	YES [1,9] $d \leq 7$	NO [1] $^{240}Pu \geq 4\%$	NO	NO	YES	TBD [2]	NO	NO	NO	NO	
Reception tank	NO $PuO_2 + H_2O$	NO	YES slab	YES [1,9] $d \leq 7$	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	NO	
PuO_2 filter	NO $PuO_2 + H_2O$	NO	YES Cylin -der	YES [1,9] $d \leq 7$	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	NO	NO	NO	NO	Double control to guarantee absence of PuO_2 in downstream equipment.
Dilution and sampling tank	YES $Pu(NO_3)_3 + H_2O$ [3,8,11]	NO	YES Slab	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	PC	^{235}U isotopic controls are employed only for downstream purposes such that $^{235}U<35\%$

Table 6-1. Preliminary Definition of Reference Fissile Medium and Control Methods for Principal AP Process Units (Continued)

Criticality Control Unit	Control Method													Comments
	Physicochemical Characteristics (PC)	Mass (M)	Geometry (G)	Density (D)	Isotopics (I)	Reflection (R)	Moderation (MN)	Concentration (C)	Interaction (IN)	Neutron absorber (A)	Volume (V)	Heterogeneity (H)	Process variable	
UO2 Dissolution														
Buffer Tank	YES $Pu(NO_3)_3$ + H_2O [3,6]	NO	NO	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	YES [7]	TBD [2]	NO	NO	NO	NO	
KDB Dissolution Unit														
Electrolyzer	NO PuO_2 + H_2O	NO	YES	YES [1,9] $d \leq 7$	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	NO	
Reception tank	NO PuO_2 + H_2O	NO	YES slab	YES [1,9] $d \leq 7$	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	NO	
PuO_2 filter	NO PuO_2 + H_2O	NO	YES Cylin -der	YES [1,9] $d \leq 7$	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	NO	NO	NO	NO	Double control to guarantee absence of PuO_2 in downstream equipment.
Dilution and sampling tank	YES $Pu(NO_3)_3$ + H_2O[3,8, 11]	NO	YES Slab	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	PC	^{235}U isotopic controls are employed only for downstream purposes such that $^{235}U<35\%$
Buffer Tank	YES $Pu(NO_3)_3$ + H_2O [3,6]	NO	YES Annul -ar	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cole-manite concrete	NO	NO	NO	Colemanite concrete is a type of borated concrete.

Table 6-1. Preliminary Definition of Reference Fissile Medium and Control Methods for Principal AP Process Units (Continued)

Criticality Control Unit	Control Method													Comments
	Physicochemical Characteristics (PC)	Mass (M)	Geometry (G)	Density (D)	Isotopics (I)	Reflection (R)	Moderation (MN)	Concentration (C)	Interaction (IN)	Neutron absorber (A)	Volume (V)	Heterogeneity (H)	Process variable	
Purification Unit														
Feeding Tank	YES $Pu(NO_3)_3 + H_2O$ [3,6]	NO	YES Annul -ar	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cole-manite concrete	NO	NO	NO	Colemanite concrete is a type of borated concrete.
Purification pulsed columns: +Extraction +Scrubbing +Diluent washing column 2100	YES $Pu(NO_3)_3 + H_2O$ [3,6]	NO	YES Cylin -der	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	NO	NO	NO	NO	
Purification pulsed columns: +Pu stripping +U scrubbing +Diluent washing column 3100	YES $Pu(NO_3)_3 + H_2O$ [6]	NO	YES Cylin -der	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	NO	NO	NO	NO	

Table 6-1. Preliminary Definition of Reference Fissile Medium and Control Methods for Principal AP Process Units (Continued)

Criticality Control Unit	Control Method													Comments
	Physicochemical Characteristics (PC))	Mass (M)	Geometry (G)	Density (D)	Isotopics (I)	Reflection (R)	Moderation (MN)	Concentration (C)	Interaction (IN)	Neutron absorber (A)	Volume (V)	Heterogeneity (H)	Process variable	
Purification Unit (Continued)														
Pu barrier mixer settlers	YES $Pu(NO)_3$ + H_2O [3,6]	NO	YES	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	NO	
U stripping + diluent washing mixer settlers + U reception	YES $UO_2(NO_3)_2$ + H_2O [6]	NO	YES	NO	NO [1] $^{235}U \leq 35\%$	NO	NO	NO	TBD [2]	Yes	NO	NO	NO	
U vessel (TK 5300)	YES $UO_2(NO_3)_2$ + H_2O [6,12]	NO	YES Annul -ar	NO	NO [1] $^{235}U \leq 35\%$	NO	NO	NO	TBD [2]	YES Cole-manite concrete	NO	NO	NO	Colemanite concrete is a type of borated concrete. ^{235}U isotopic controls are employed only for downstream purposes such that $^{235}U<1\%$
Oxidation columns	YES $Pu(NO_3)_3$ + H_2O [3,6]	NO	YES Cylin -der	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	NO	NO	NO	NO	
Pu Rework Tanks	YES $Pu(NO_3)_3$ + H_2O [3,6]	NO	YES Slab	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	NO	
Rafinates Reception, and Recycling, Control Tanks	YES $Pu(NO_3)_3$ + H_2O [3,6]	NO	YES Annul -ar	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cole-manite concrete	NO	NO	NO	Colemanite concrete is a type of borated concrete.
Slab settler	YES $Pu(NO_3)_3$ + H_2O [3,6]	NO	YES Slab	NO	NO [1] $^{240}Pu \geq 4\%$	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	NO	

Table 6-1. Preliminary Definition of Reference Fissile Medium and Control Methods for Principal AP Process Units (Continued)

Criticality Control Unit	Control Method													Comments
	Physicochemical Characteristics (PC)	Mass (M)	Geometry (G)	Density (D)	Isotopics (I)	Reflection (R)	Moderation (MN)	Concentration (C)	Interaction (IN)	Neutron absorber (A)	Volume (V)	Heterogeneity (H)	Process variable	
Offgas Treatment Unit														
Offgas Treatment	NO [TBD]	NO	NO	NO	NO	NO	NO	YES [7]	TBD [2]	NO	NO	NO	NO	
Liquid Waste Reception Unit														
Liquid Waste Reception	NO [TBD]	NO	NO	NO	NO	NO	NO	YES [7]	TBD [2]	NO	NO	NO	NO	
Sampling Unit														
Sampling Unit	NO [TBD]	NO	NO	NO	NO	NO	NO	YES [7]	TBD [2]	NO	NO	NO	NO	

NOTES:

[1] Parameter value ranges indicated are selected for use in criticality design calculations to encompass credible optimum conditions without reliance on process variable controls.
[2] To be determined (TBD). Analysis of interaction between components to be evaluated to confirm spacing requirements, or determine if additional criticality control design features or management measures are required to address interaction.
[3] Actual chemical form of Pu Nitrate is $Pu(NO_3)_4$ for most process steps, which is less reactive than $Pu(NO_3)_3$.
[4] Actual chemical form is a mixture of Pu Oxalate and Pu Nitrate. Either chemical form is less reactive than PuO_2F_2.
[5] Interaction limited by geometry (hopper spacing) and cadmium coating of hoppers.
[6] The absence of a more restrictive material is controlled in an upstream unit, which prevents any means of adverse chemical form change.
[7] Concentration controlled by upstream or connected units.
[8] The presence of up to 2% uranium (93.2 w/o ^{235}U) is considered in the evaluation.
[9] Maximum bounding density value is controlled by upstream measurement.
[10] Density value which has been shown to be conservative for identical operations in LaHague. Values will be confirmed during the facility startup test program.
[11] Dilution of ^{235}U to a maximum enrichment of 30% (35% evaluated) occurs in this unit. In all cases, the presence of ^{235}U is bounded by the assumed isotopics of the Pu considered.
[12] Dilution of ^{235}U to a maximum enrichment of 1% is controlled in this unit.

Table 6-2. Preliminary Definition of Reference Fissile Medium and Control Methods for MP Process Units

Criticality Control Unit	Control Method													Comments
	Physicochemical Characteristics (PC)	Mass (M)	Geometry (G)	Density (D)	Isotopics (I)	Reflection (R)	Moderation (MN)	Concentration (C)	Interaction (IN)	Neutron absorber (A)	Volume (V)	Heterogeneity (H)	Process variable	
Receiving Area														
PuO_2 3013 storage pit	NO PuO_2 + H_2O	NO M ≤ 5 kg per container	YES	NO [1] d ≤ 11.46	NO [1] $^{240}Pu \geq 4\%$	NO [2]	NO [1] $H_2O \leq 1\%$ inside containers	NO	NO [2]	NO	NO	NO	NO	-Incoming plutonium container I D. is verified to confirm mass, isotopics, and powder moisture assumptions listed.
PuO_2 Can Opening and Handing Unit	NO PuO_2 + H_2O	YES	NO	YES [1,10] d ≤ 7	NO [1] $^{240}Pu \geq 4\%$	NO	YES	NO	NO	NO	NO	NO	NO	
PuO_2 buffer storage	NO PuO_2 + H_2O	NO M ≤ 2.5 kg per container [13]	YES	YES [1,10] d ≤ 3.5	NO [1] $^{240}Pu \geq 4\%$	NO [2]	NO	NO	NO [2]	YES Borated concrete	NO	NO	NO	
Primary dosing (including master blend homogeniz-ing)	NO PuO_2 + UO_2 + H_2O	YES	NO	YES [1,6] PuO_2 and $UO_2 \leq$ 3.5; Recy-clable Scrap ≤ 4.6	YES $^{240}Pu \geq 4\%$[1]	NO	YES [4]	NO	NO	NO	NO	YES	M,I, MN [4]	-Mass of PuO_2 per jar is controlled. -The relative quantity of PuO_2 and UO_2 is controlled; used in downstream units -Homogeneity of master blend is required by downstream units.

gravitational forces producing convection in this phase. Downward heat transfer between the phases, therefore, involves conduction, rather than convection, and heat removal is consequently lower. This description represents the limiting system from the perspective of selecting a minimum initiation temperature for a runaway reaction.

DCS has selected a design basis temperature of 135°C to limit the heat generation rate. This design basis temperature is based on the experimentally determined minimum initiation temperature for a ***closed*** system and is derived from isothermal experimental conditions. Furthermore, selection of this design basis temperature ensures that the selected diluent (discussed below) will not undergo degradation and lower the minimum initiation temperature of a runaway reaction.

Based on experimental evidence, the exclusion of cyclic chain hydrocarbons in diluents indicates that temperatures far in excess of 135°C are necessary to initiate runaway reactions in *open* systems containing nitric acid. Experimental evidence also suggests that diluents containing a large fraction of cyclic hydrocarbons (i.e., ~20—30% naphthenes) undergo significant nitration at temperatures lower than corresponding systems composed of both TBP and diluent. Therefore, the nature of the diluent is relevant in establishing the temperature at which systems composed of TBP/diluent begin to "run away." The use of C_{10}-C_{13} branched chain hydrocarbons (aliphatic diluent HPT) in the AP process optimizes both the plutonium decontamination factor and the nitration resistance to ensure an adequate safety margin associated with the operation of the process. Consequently, DCS has identified the properties of the diluent as the safety function of the chemical safety control principal SSC. The design basis for this chemical safety control principal SSC is to utilize a diluent that does not contain cyclic chain hydrocarbons.

DCS has also identified the offgas treatment system as a principal SSC. The safety function of the offgas treatment system is to provide venting of vessels/equipment that may potentially contain TBP and its associated by-products to prevent over-pressurization in the case of excessive oxidation of TBP and/or its degradation products. The design basis value for this principal SSC is selected to be consistent with experimental results (e.g., 8×10^{-3} mm^2/g of organic). The use of venting implies control of the bulk quantity of organics that may be present in a given vessel. However, for the majority of vessels DCS has limited the volume of the vessel so as to not require this limitation (i.e., tanks are considered full of organics and hence, no limitation of organic content is necessary). Note that as an additional protection feature, DCS has implemented the following features to preclude the transfer of bulk quantities of organic to heated equipment:

- A diluent washing pulsed column for washing the extracted plutonium aqueous stream
- A diluent washing pulsed column for washing the extraction process unloaded feeding solution ("raffinates stream")
- A diluent washing mixer-settler for washing the extracted uranium aqueous stream
- A diluent washing mixer-settler for washing the aqueous phase containing TBP degradation products from solvent recovery.

In those few cases where the vent area to mass ratio is not satisfied, the offgas treatment system is still credited as a principal SSC. However, in this case the safety function of this principal SSC is to provide an exhaust path for aqueous phase evaporative cooling in process vessels,

thereby providing a mechanism for heat removal. This implies that the required venting for mass transfer is much less than that required for pressure relief during a "runaway" reaction. This principal SSC is utilized in conjunction with the process safety control subsystem to ensure that the rate of energy generation does not exceed the rate of heat removal. Thus, the design basis of the offgas treatment system for this case is to relieve 1.2 times the combination of energy generation and energy input to the system. This safety function of the offgas treatment system is the primary means for satisfying the performance requirements of 10 CFR 70.61.

In addition, because gases are released during the chemical reactions, foaming may be possible. Foaming in the organic phase occurs as self-heating accelerates due to the gases generated. Significant amounts of foam could limit the effectiveness of the vent. In addition, foam can be thermally isolated from the rest of the system because of its insulating qualities. A foaming mass that is undergoing an exothermic reaction may therefore attain a higher temperature than a liquid in contact with a heat sink, such as water. When a cyclic diluent was utilized in past red oil incidents, foaming is believed to have occurred prior to a runaway condition. Again, the selection of a diluent containing no cyclic hydrocarbons and limitations on the temperature are implemented as principal SSCs to limit foaming and provide reasonable assurance that the vents remain effective.

8.5.1.5.6 Impact of Tomsk-7 Event

On April 6, 1993, at the Tomsk-7 nuclear fuel processing facility located in Siberia, Russia, there purportedly were two sequential explosions that caused physical damage to the facility and contaminated the facility and the surrounding area. The explosions appear to be due to the "red oil" phenomenon associated with nitric acid, TBP, and the hydrocarbon diluent used by the Russians, and was initiated by actions that constituted violations to operating procedures and operating conditions unlikely to occur at the MFFF. Inadequate venting was also a likely contributor in the explosion.

The Tomsk-7 event identified a new mechanism to the TBP degradation/red oil formation phenomenon. This arose from the apparent initiation of an energetic runaway reaction in the vicinity of 90°C, far below the previously observed minimum temperature for a runaway TBP hydrolysis-limited reaction. Several investigators postulated that the accumulation of two degradation products, butanol and butyl nitrate, may have been responsible for the lower initiation temperature. Experimental results have verified that these two degradation products of TBP can, in the presence of concentrated nitric acid, release significant energy at temperatures far less than 135°C. Significant buildup of degraded organics is not expected at the MFFF (i.e., solvent is routinely used and regenerated as part of normal operations, and most degraded organics are destroyed during normal operation). Nonetheless, such a buildup is conservatively postulated.

Butanol, a TBP degradation product, is rapidly and completely converted to butyl nitrate at temperatures of 110°C to 120°C, and is oxidized further to butyric acid, propionic acid, and acetic acid when contacted with moderate to strong (6M to 15.8M) nitric acid. Butyl nitrate oxidation begins as solutions with 10M to 15.8M nitric acid are heated to between 52°C and 85°C, and these reactions are strongly exothermic. The heat of reaction for butanol oxidation has been determined to be -466 cal/g (-1948 J/g) of butanol based on a 1:1 butanol to nitric acid

ratio. The negative heat of reaction favors the formation of butyl nitrate in this reaction equilibrium. Additional experimental results indicate that even at a fairly low concentration of nitric acid (0.8M), butanol is converted to butyl nitrate at about 100°C.

Thus, in order to determine whether the accumulation of TBP degradation products butanol and butyl nitrate can provide the initial energy release via oxidation to raise the organic phase temperature to above 135°C, a determination of the quantity of each species in solution must be obtained (unlike the pre-Tomsk-7 operating assumption that, in the formulation of a model to describe TBP degradation at elevated temperatures, the oxidation reactions proceeded much more rapidly than the hydrolysis reaction and consequently degradation products did not build up).

To determine the quantity of degraded organics necessary to raise the temperature of the bulk organic to 135°C, the minimum initiation temperature for a runaway reaction, the total quantity of organic necessary support a runaway reaction in an open system is calculated utilizing the vent-to-organic-mass ratio described above. A heat balance is then utilized to calculate the quantity degraded organic necessary to elevate the bulk organic temperature to 135°C.

Preliminary analyses have indicated that the organic mass in a vessel or tank must be limited to on the order of 30 kg of organic material. Based on conditions that could be encountered during unlikely extended shutdowns, the mass of degraded organics necessary to elevate the bulk organic temperature to the 135°C is a few kilograms. The total degraded organic/TBP mass is given by the production rates from both radiolysis and hydrolysis minus the amount of degraded organic lost to the system from evaporation and oxidation via the nitric acid. These preliminary analyses indicate the degraded mass is reached in on the order of years. Consequently, the principal SSCs are established to provide reasonable assurance that significant quantities of butanol and/or butyl nitrate do not build up in the process. The design basis for these controls is limiting the residence time of organics in the presence of oxidizers such as nitric acid (i.e., in process vessels containing oxidizing agents and potentially exposed to high temperatures), and radiation fields, to limit the quantity of degraded organics that may buildup in the system either through hydrolysis and/or radiolysis.

8.5.1.6 Pyrophoricity of Uranium and Plutonium

Both plutonium and uranium metals are pyrophoric and readily ignitable when existing in a finely divided form. When these metals are present in large or massive forms they do not present a significant fire risk. When these metals exist in the dioxide form (e.g., PuO_2 and UO_2) they are relatively stable and not considered pyrophoric. The MFFF only handles these materials in the dioxide form.

While the fire risk associated with the dioxide forms of U and Pu is low, hazards associated with handling of these materials do exist. Uranium dioxide can undergo further oxidation to higher oxides resulting in spontaneous heating. Sub-stoichiometric plutonium oxides formed by incomplete or partial oxidation of plutonium metal can be pyrophoric. These hazards are described below.

8.5.1.6.1 UO_2

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." In the past, this phenomenon has been associated with fires at fuel fabrication facilities handling UO_2. In these events, the oxidizing uranium powder was believed to be heated by some mechanical failure (i.e., friction) which initiated the burnback reaction and released heat. Combustible materials such as transfer hoses and boots then provided the fuel to support a fire.

In addressing this hazard, the SA has identified UO_2 spontaneous heating as a cause for fire in a glovebox. Also, the heat generated by the burnback phenomenon has been considered in the thermal analysis of facility gloveboxes as described in Section 5.5.2.1.6.9. The specific power of UO_2 oxidation is taken into account using the following design basis values:

- If $T < 74°C$ (165.2°F) then $P_{ox} = 0$ W/kg (0 W/lb) of UO_2,
- If 74°C (165.2°F)$< T <$ 340°C (644°F) then $P_{ox} = 1.1$ W/kg (0.499 W/lb) of UO_2,
- If $T > 340°C$ (644°F) then $P_{ox} = 4.63$ W/kg (2.1 W/lb) of UO_2

where T is the powder temperature.

Although not identified as principal SSCs to address this specific hazard, the following features of the UO_2 storage/handling processes provide additional protection:

- UO_2 delivered to the MFFF site and stored in steel drums, double bagged under a N_2 atmosphere
- UO_2 maintained in a N_2 atmosphere throughout the process
- Fire detection and suppression systems provided for gloveboxes (CO_2 injection) and process rooms (clean agent)
- Use of noncombustible or nonflammable materials for process equipment construction and furnishing

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