UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C. 20555-0001

May 3, 2002

MEMORANDUM TO: Maggalean W. Weston, Senior Staff Engineer
ACRS

FROM: Dana A. Powers, Chairman
Reactor Fuels Subcommittee, ACRS

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEE ON REACTOR FUELS, APRIL 10, 2002, ROCKVILLE, MD

I hereby certify that, to the best of my knowledge and belief, the minutes of the Reactor Fuels subcommittee meeting on the Mixed Oxide Fuel Fabrication Facility construction authorization request and the Department of Energy announced changes to the facility issued May 3, 2002, are an accurate record of the proceedings for that meeting.

Dana A. Powers 3 May 2002

Dana A. Powers, Chairman Date

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C. 20555-0001

May 3, 2002

MEMORANDUM TO: Dana A. Powers, Chairman
Reactor Fuels Subcommittee, ACRS

FROM: Maggalean W. Weston, Senior Staff Engineer
ACRS

SUBJECT: WORKING COPY OF THE MINUTES OF THE ACRS SUBCOMMITTEE ON REACTOR FUELS, APRIL 10, 2002, ROCKVILLE, MD

A working copy of the minutes for the Reactor Fuels subcommittee meeting on the Mixed Oxide Fuel Fabrication Facility construction authorization request and the Department of Energy announced changes to the facility is attached for your review. Please provide me with any comments that you might have.

Attachment:
As Stated

CERTIFIED BY DR. DANA A. POWERS
May 3, 2002

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
REACTOR FUELS SUBCOMMITTEE
MIXED OXIDE (MOX) FUEL FABRICATION FACILITY
ROOM T-2B3, 11545 ROCKVILLE PIKE
ROCKVILLE, MARYLAND
APRIL 10, 2002
MEETING MINUTES

The ACRS subcommittee on Reactor Fuels held a meeting on April 10, 2002, with representatives of Duke Cogema Stone and Webster (DCS) and the NRC staff to discuss the Mixed Oxide (MOX) Fuel Fabrication Facility construction authorization request (CAR) and the Department of Energy (DOE) announced changes. The meeting was open to the public. Mrs. Maggalean W. Weston was the cognizant ACRS staff engineer and designated federal official (DFO) for this meeting. The meeting was convened by the Reactor Fuels Subcommittee Chairman, Dr. Dana A. Powers, at 8:38 a.m. and adjourned at 4:28 p.m. on April 10, 2002.

Attendees

Attendees at the meeting included ACRS members and staff; NRC staff; a member of the Advisory Committee on Nuclear Waste (ACNW); representatives of the Department of Energy (DOE), Duke Cogema Stone & Webster (DCS); and members of the public as follows:

ACRS-ACNW Members/Staff

D.A. Powers, Chairman	T.S. Kress, Member	S.L. Rosen, Member
M.V. Bonaca, Member	G.M. Leitch, Member	J.D. Sieber, Member
F.P. Ford, Member	M.N. Levenson, ACNW	W.J. Shack, Member
G.L. Johnson, Invited Expert	M.W. Weston, DFO	

NRC Staff

Bill Gleaves, NMSS	Tim Harris, NMSS	Wilkins Smith, NMSS
David Brown, NMSS	John Hull, OGC	Tim Kobetz, ACRS
Rex Wescott, NMSS	Margaret Chatterton, NMSS	Tim Johnson, NMSS
John Calvert, RES	Herman Graves, RES	Christopher Tripp, NMSS
Fred Burrows, NMSS	Donnie Harrison, NRR	Andrew Persinko, NMSS
Alex Murray, NMSS	Brian Smith, OEDO	Joseph Glitter, NMSS
Sharon Steele, NMSS	Tamara Powell, NMSS	

DOE/DCS

David Alberstein, DOE	Peter Hastings, DCS	Gary Kaplan, DCS
Patrick Rhoads, DOE	Don Silverman	Gary Bell, DCS
Ron Jackson, DCS	Jon Tanner, DCS	

Members of the public were also in attendance at this meeting. A list of those attendees who registered is attached to the Office Copy of these minutes.

Presentations and Discussion

The presentations to the subcommittee and the related discussions are summarized below. The presentation slides and handouts used during the meeting are attached to the Office Copy of the minutes.

Chairman's Comments

Dana Powers, Subcommittee Chairman, convened the meeting. He stated that the purpose of the meeting was to discuss the MOX Fuel Fabrication Facility (MOX FFF) construction authorization and the DOE announced changes to the application for this facility. He noted the presence of Milton Levenson, a member of the Advisory Committee on Nuclear Waste who will serve as a member of the subcommittee and Gary L. Johnson of the Lawrence Livermore Laboratory an invited expert on electrical systems and instrumentation and control.

Industry Presentation

The DCS presentation was made by Peter Hastings, Ron Jackson, Jon Tanner, and Gary Bell. The presentation continued with the following topics:

- Introduction
- Changes to the Surplus Plutonium Disposition Program
  - Processing of "Alternate Feedstock" (material previously slated for immobilization)
  - Waste Solidification
  - Changes to the Environmental Report and Construction Authorization Request and Safety Assessment
- Electrical System Overview
- Instrumentation and Control System Overview

Subcommittee Comments

Introduction
Changes to the Surplus Plutonium Disposition Program

Mr. Hastings discussed changes to the program which included two primary unrelated changes. The plutonium disposition mission originally consisted of a two-pronged approach whereby some surplus plutonium material was scheduled for processing through the Pit Disassembly and Conversion Facility (PDCF) and then sent to MOX FFF for production of MOX fuel. The second prong was to send the other material through the plutonium immobilization plant. The plutonium immobilization plant facility has been canceled. Therefore, the two elements of the program changes are to process some material originally slated for immobilization and the second is to solidify waste at the Savannah River Site (SRS) instead of processing that material through SRS tank farms. The changes to the facility to accommodate the alternate feedstock (material originally scheduled for immobilization) will involve some changes to the design. With the exception to some changes to the aqueous polishing line to remove some additional impurities and some powder pretreatment changes, there is minimal impact to the remainder of the facility. The facility change results in a delay in the schedule also. There are four types of

alternate feedstock, three which cause changes in the aqueous polishing purification process. Type 1 is similar to the current feedstock, require very few changes, and amounts to about 1000 kilograms of plutonium. Type 2 contains additional salts, but no chlorides and is about 1000 - 1200 kilograms of plutonium. Type 3 contains both salts and chlorides and is about 3800 - 4000 kilograms. It is where the significant process changes occur. Type U has limited depleted or enriched uranium content and is only a couple of hundred kilograms.

- Mr. Sieber asked how does the processing of more material impact the expected lifetime of the facility. The response was that the contracted capacity was originally 33 metric tons of plutonium which is in excess of the 25.6 metric tons originally slated for MOX. The facility will now handle the scope of material addressed in the Russian agreement of 34 tons, which is only 1 additional ton.

- Dr. Kress asked if separate processing were necessary for each of the feedstocks. The response was yes.

- Dr. Powers indicated that the complexity of the operation has increased with the changes and so should the potential for human error. The response was that this is something that should be looked at.

- Dr. Powers asked about the impact of September 11, 2001 on the thinking about the facility. The response was that the DOE and NRC are evaluating the current design basis threat.

- Dr. Powers commented that the environmental impact statement should address deactivation and decommissioning of the facility itself. The response was that he could not recall the extent to which they treat deactivation and that decommissioning is not in the scope of DCS.

- Dr. Kress commented that the increase of material to the contract value could be viewed as a reduction in margin. The response was that they did not think so.

- Dr. Levenson asked if there is a safety connotation if one feedstock is run through the process system for another feedstock. The answer was that it was not an immediate problem. Dr. Powers disagreed with the response.

Electrical System Overview

Mr. Ron Jackson presented an overview of the electrical system and the design basis for the system. He explained that the electrical distribution system has several voltage levels and two independent feeds from off-site with automatic transfer. The design basis consists of sufficient capacity and capability to meet all operating modes of the facility, no single failure vulnerability, and electrical and physical separation for items relied on for safety (IROFS).

- Mr. Gary Johnson asked about the off-site power system. The response was that the power feeds come from SRS via South Carolina Gas and Electric.

- Mr. Rosen asked if the safety analysis is fundamentally deterministic. The response was yes.

- Mr. Rosen asked about the consequences of a loss of power. The response was that the aqueous polisher parts shut down safely.

- Mr. Johnson asked if the design basis for the confinement system assumes no power or is power required. The response was active confinement for the fans require power.

- Mr. Johnson asked what type of maintenance problems could be expected given the large number of batteries throughout the station. The response was that the packaged uninterrupted power supply (UPS) are sealed type units and are relatively maintenance free. The station type batteries would require the normal maintenance that every plant goes through.

- Dr. Powers asked under a maintenance bypass configuration, what are the impacts of a transient on the AC power system in case of a loss of outside AC. The response was that the power would come back up when the diesels were back up and the process would simply stop.

- Dr. Powers asked what ultimate design basis earthquake was being considered when looking at seismic requirements. The response was that they are using the design basis earthquake from Regulatory Guide 160 anchored at 0.2Gs.

- Dr. Powers asked what happens to the permissive system when power is lost. The response was that the computers used for the permissive systems are on UPS.

Instrumentation and Control (I&C)

Mr. Jon Tanner presented the information on I&C. He discussed the design basis and its origination, the standards used for the design of the control system,and an overview of the functional requirements for use in the I&C system. The design requirements of 10 CFR 70.64 are used for the control system. The systems are designed to provide multiple layers of control and instrumentation for process and plant parameters so that if something goes wrong something else is there to take its place to keep things working properly.

- Mr. Johnson asked if there is a diversity philosophy associated with the multiple layers of control. The response was that diversity is not required.

- Mr. Johnson asked to what extent are multiple control rooms provided to address the potential need to evacuate one of the control rooms as a result of some facility problem. The response was that the ability exists.

- Mr. Johnson asked what are the provisions for isolating one control room from the other electrically and for resolving any conflicting control demands. The response was that the two emergency control rooms are completely separate.

- Mr. Levenson asked if there are enough light elements among the impurities to impact the neutron dose due to alpha N that one might expect from this material. The response was that they did not have an answer.

- Mrs. Weston asked if there would be a set of operating rules for this facility such as technical specifications for nuclear power plants. The response was yes.

- Dr. Powers asked how tolerant to contamination with alpha generating materials are the digital system being used. No response was made.

NRC Presentation

The NRC presentation included input from NRR and RES as summarized below.

The NRC presentation was made by Drew Persinko, Rex Wesott, Dave Brown, Alex Murray and Sharon Steele, all of NMSS as summarized below.

The presentation continued with the following topics:

- Impact of DOE Announced Changes to the MOX FFF
- Summary of Unresolved Items
- Radiological Consequences
- Chemical Safety
- Fire Protection

Subcommittee Comments

During the above discussions, subcommittee members commented on these topics as summarized in the following subsections.

Impact of DOE Announced Changes to the MOX FFF

Mr. Drew Persinko, NMSS, talked about the impact of the DOE announced changes on the staff's review of the MOX FFF. He indicated that NMSS still intended to issue a draft SER at the end of April 2002 for the CAR submitted to NRC in February 2001. The SER will not include DOE announced changes. A supplemental environmental report from DCS is expected in July 2002 and a supplemental CAR in October 2002. NMSS intends to issue a draft environmental impact statement (EIS) for public comment in February 2003, a revised draft SER in April 2003, a final EIS in August 2003, and a final SER and construction licensing decision in September 2002.

- Mr. Rosen asked when the Committee would see the independent safety analysis (ISA). The response was that the ISA is a part of the licensing application which the licensee said would be submitted in the fall of 2003.

Summary of Unresolved Items

Mr. Persinko summarized some of the open items excluding those being presented as a part of the other presentations. Some of these are the sensitivity of equipment used for measurements of radioactivity of soil samples, the analysis performed for aircraft hazards did not include projected future travels or any aspects of September 11, nuclear criticality safety, confinement and fluid systems, classification of seismic isolation valves, and corrosion.

- Dr. Powers asked if the introduction of multiple feeds has increased the opportunity for inadvertent admission to the systems of corrosive materials. The answer was that there are outstanding issues on corrosion in general.

Safety Analysis

Mr. Rex Wescott, the safety analysis reviewer, discussed the safety assessment of the design basis to identify the hazards and events associated with the design and operations. The review is also designed to identify the specific design basis and the principal structures, systems, and components (PSSCs) required to mitigate or prevent the identified hazards and events.

- Dr. Bonaca asked if the analysis would provide input to the functional requirements of the safety systems that would have to respond to these events. The answer was yes.

- Mr. Leitch asked if security for the MOX FFF separate f rom the SRS. The response was that they plan to rely on the SRS. Dr. Powers asked if the staff looked at the event history of DOE facilities and La Hague. The response was that there was some from DOE facilities, but not from La Hague.

Radiological Consequences

Mr. Ronald Brown, the radiation safety reviewer, talked about the applicant's consequence assessment methodology, and the results. The applicant assumed a 99% efficiency for each stage of the high-efficiency particulate air (HEPA) filtration.

- Mr. Sieber asked how chronic or day to day events were evaluated and what impact they have on the environment. The response was that the less likely events were the ones addressed in this review.

- Dr. Kress asked how was the damage ratio arrived at. The response was that the damage ratio was assumed to be one.

- Dr. Powers asked if wind tunnel test would be done on the facility. The response was that it was not anticipated.

- Mr. Leitch asked if past accidents at similar facilities had been considered in reviewing the MOX FFF. The response was that staff had tried to learn from the lessons in reviewing the safety of this facility.

Chemical Safety

Mr. Alex Murray, chemical safety reviewer, discussed the previous ACRS meeting, the basis and conduct of the SER review, the main findings, and significant open items.

- Dr. Powers asked how the strategy being employed compared with strategies adopted by DOE for avoiding the problem of red oil. The response was that it is less restrictive.

- Mr. Levenson asked if the argon hydrogen should be controlled to more than or equal to a 91 to 9 ratio rather than less. The response was that it is believed that it should be 9 percent or less hydrogen and argon.

- Mr. Johnson asked if the PSSCs are implemented by safety controllers, emergency controllers or something else that might not be an active instrumentation and control system. The answer was that the parameters that have been proposed typically would be controlled by code safety I & C systems.

Fire Safety

Ms. Sharon Steele, the fire protection reviewer, discussed the MOX FFF strategy for fire safety, the basis and conduct for the SER review, the main findings, and the unresolved issues. The six event categories for fire are aqueous polishing process cells, aqueous polishing/MOX processing glovebox areas, C2 areas (tertiary confinement - low containment risk) external fires, facility wide systems, and facility (beyond fire areas).

- Mr. Sieber asked if a fire in a glove box could spread to another glove box. The response was that there are features to mitigate the spread.

- Dr. Powers asked what is the design basis for fire protection. The response was that the design basis is no release of radioactivity as a result of fires, the ventilation and control systems to function during a fire, the building to survive a fire, fires are highly unlikely in process cells.

- Mr. Rosen asked about the protocol for the fire brigade. The response was that DCS was committed to do a baseline design and staffing criteria for a fire brigade, in addition to the SRS fire department.

- Dr. Powers asked what's the inventory of normal paraffinic hydrocarbon in the facility. The response was on the order of several hundred gallons for the facility, and it might be under 100 within an individual cell.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C. 20555-0001

May 3, 2002

MEMORANDUM TO: ACRS Members

FROM: Maggalean W. Weston, Senior Staff Engineer
ACRS/ACNW

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEE ON REACTOR FUELS ON THE MIXED OXIDE FUEL CONSTRUCTION AUTHORIZATION REQUEST, MAY 3, 2002, ROCKVILLE, MD

The minutes of the Reactor Fuels subcommittee meeting on the Mixed Oxide Fuel Fabrication Facility construction authorization request and the Department of Energy announced changes to the request held on April 10, 2002, have been certified as the official record of the proceedings of that meeting. A copy of the certified minutes is attached.

Attachment: As stated

cc via Email: J. Larkins
S. Bahadur
H. Larson

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
REACTOR FUELS SUBCOMMITTEE
MIXED OXIDE (MOX) FUEL FABRICATION FACILITY (FFF)
ROOM T-2B3, 11545 ROCKVILLE PIKE
ROCKVILLE, MARYLAND
APRIL 10, 2002

-AGENDA-

	SUBJECT	PRESENTER	TIME
I.	Introductory Remarks Subcommittee Chair	D. A. Powers, ACRS	8:30-8:35 a.m.
II.	Impact of DOE Announced Changes on the MOX FFF	Duke Cogema Stone & Webster (DCS)	8:35-9:30 a.m.
III.	Electrical Instrumentation and Control	DCS	9:30-10:15 a.m.
IV.	Impact of DOE Announced Changes on the MOX FFF	Drew Persinko, NMSS	10:15-10:45 a.m.
		****BREAK****	10:45-10:45 a.m.
V.	Summary of Unresolved Items	Drew Persinko, NMSS	10:45-11:30 a.m.
VI.	Safety Analysis	Rex Wescott, NMSS	11:30-12:15 a.m.
		****LUNCH****	12:15-1:15 p.m.
VII.	Radiological Consequences	Dave Brown, NMSS	1:15-2:00 p.m.
VIII.	Chemical Safety	Alex Murray, NMSS	2:00-2:45 p.m.
		****BREAK****	2:45-3:00 P.M.
IX.	Fire Protection	Sharon Steele, NMSS	3:00 p.m.
X	Discussion and Adjournment		4:00-5:00 p.m.

Note: Number of copies of presentation materials to be provided to the ACRS - 35.

ACRS CONTACT: Maggalean W. Weston, mww@nrc.gov or (301) 415-3151.

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE MEETING ON REACTOR FUELS - MOX FFF

APRIL 10, 2002
Date

PLEASE PRINT

ATTENDEES PLEASE SIGN-IN FOR THE MEETING

NAME	AFFILIATION
Patrick Rfoads	US Dept of Energy
Sam Steiman	MPR Associates
Daniel Horner	McGraw-Hill
Don Silverman	Morgan Lewis | DCS
Peter Hastings	DCS
Norman Fletcher	NNSA
Gary Kapcan	DCS
Gary Bell	DCS
Don Jackson	DCS
Edwin Lyman	NCF
David Albertstein	LANL/DOE
Jon Tanner	DCS

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE MEETING ON REACTOR FUELS - MOX FFF

APRIL 10, 2002
Date

NRC STAFF SIGN IN FOR ACRS MEETING

PLEASE PRINT

NAME	NRC ORGANIZATION
Jack Kramer	RES/DSARE/REAHFB
✓JOHN A. CALVERT	RES/DET/ERAB
✓David Brown	NMSS/FCSS
✓JOSEPH GITTER	NMSS/FCSS
✓TIM JOHNSON	NMSS/FCSS
Mike Lamastra	NMSS/FCSS
✓Rex Wescott	NMSS/FCSS
✓Chris Tripp	"
✓Margaret Chatterton	"
✓Donnie Harrison	NRR/DSSA/SPSB
✓Tim Harris	NMSS/DWM
✓Brian Smith	OEDO
✓Tamara Powell	NMSS/FCSS
✓Bill Gleaves	NMSS/FCSS
TIM KOBETZ	ACRS
✓ALEX MURRAY	NMSS/FCSS.
✓FRED BURROWS	NMSS/FCSS
✓WILKINS SMITH	NMSS/FCSS
✓John Hull	OGC
✓HERMAN GRAVES	RES/DET/ERAB
✓Sharon Steele	

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE MEETING ON REACTOR FUELS - MOX FFF

APRIL 10, 2002
Date

NRC STAFF SIGN IN FOR ACRS MEETING

PLEASE PRINT

NAME	NRC ORGANIZATION
✓ A Persinko	NMSS

MWW

DUKE COGEMA
STONE & WEBSTER

Mixed Oxide Fuel Fabrication Facility (MFFF)

ACRS Briefing on
Surplus Plutonium Disposition
Program Changes

Duke Cogema Stone & Webster

10 April 2002

DUKE COGEMA
STONE & WEBSTER

Agenda

- Introduction
- Changes to SPD Program
  - Processing of "alternate feedstock" (material previously slated for immobilization)
  - Waste solidification
  - Changes to ER and CAR

DUKE COGEMA
STONE & WEBSTER

Introduction

- Program changes
  - Process some materials previously slated for immobilization
  - Solidification of waste in lieu of processing through SRS waste tanks
- Changes to facility necessitates delay in completion of design, but licensing basis not significantly impacted
  - Design addition to facility to insert new AP process step
  - Remainder of facility largely unaffected
  - Minimal environmental and safety impacts anticipated

DUKE COGEMA
STONE & WEBSTER

Changes to Surplus Plutonium Disposition Program

DUKE COGEMA
STONE & WEBSTER

Summary of Program Changes

- Processing of some materials previously slated for immobilization
  - Total resulting quantities
    - 25.6 MT Pu through Pit Disassembly and Conversion Facility
    - ~6.4 MT Pu originally slated for immobilization
    - ~2 MT Pu future allocation
    - Total 34 MT Pu (consistent with Russian agreement)
  - Material originally slated for immobilization includes impurities that require additional processing
- Waste processing of high-α and uranium waste streams
  - Processing & solidification at SRS facility off the MFFF site
  - In lieu of processing through SRS HLW waste tanks
  - Responsive to concerns about adding to SRS HLW waste tank volumes
- Overall net reduction in environmental impact of MFFF and connected/related activities

DUKE COGEMA
STONE & WEBSTER

"Alternate Feedstock" General Material Characteristics

- Material will be unclassified when received at MFFF
- Feed material will be PuO_2 provided in DOE-STD-3013 containers
- Pu isotopics in same range as material described in existing design (i.e., Pu-240 < 9%)
- Weapons grade Pu isotopics and uranium content well characterized prior to delivery and consistent with PDCF specs
- Accurate impurity characterization may not be available

DUKE COGEMA
STONE & WEBSTER

"Alternate Feedstock" Impurity Characteristics

- Current baseline impurities
  - Characterized by americium, gallium, uranium ("PDCF spec")
- Alternate Feed Type 1: similar to current baseline PDCF feed
- Alternate Feed Type 2: feed with salts, without chlorides
  - Main impurities : aluminum, calcium, chrome, copper, iron, tantalum, magnesium, silver, manganese, potassium, silicon
- Alternate Feed Type 3: feed with salts and chlorides (~half of material)
- Alternate Feed Type U: Limited DU or EU content

Total Pu weight ~ 6,000 kg

DUKE COGEMA
STONE & WEBSTER

"Alternate Feedstock" Process and Equipment Modifications

Powder Pretreatment (MP)
Purification (AP)

DUKE COGEMA
STONE & WEBSTER

Changes to MP Powder Pretreatment

- Receiving/storage of 3013 containers unchanged
- Powder pretreatment process (all powders)
  - Ball milling to reduce grain size (2 units)
  - Powder density measurement unit
  - Chemical characterization (verify impurities)
  - Pretreatment buffer storage
    - Store reusable cans before and after milling, waiting for laboratory results
    - Maintain capacity with similar design to buffer storage between AP and MP
- Addition of re-canning function (packaging analyzed PuO_2 in 3013 containers)
- Additional laboratory equipment
  - Sampling glove box after ball milling step
  - Gloveboxes for sample dissolution and preparation
  - Gloveboxes for analysis of impurities

DUKE COGEMA
STONE & WEBSTER

Changes to AP Purification Process

- PDCF Powder type and Powders with Salts
  Type 1 and 2 Feedstock
  - Process and Equipment : no change vs normal Feedstock (PDCF Feedstock)
  - Impact on the Process Design : limited
- **Type 3 Feedstock**
  - Remove chloride to achieve plutonium nitrate solution in agreement with process requirements and polished PuO_2 in agreement with fuel specification; also precludes corrosion problems in downstream equipment

DUKE COGEMA
STONE & WEBSTER

Changes to AP Purification Process (continued)

- Process changes to remove chloride
  - For process material and fuel specification purposes and to limit corrosion
  - Feedstock solution electrolyzed in two steps (dissolution after Cl removal)
  - Filter off-gas, wash to convert Chlorine into NaCl
  - Process developed/implemented in La Hague UCD plant to treat scrap material with chloride content and extract Pu
- Additional equipment
  - Two dissolution lines (same type equipment as existing processes)
    - One feeding hopper and one electrolyzer each
    - Two filters each with appropriate slab tanks
  - Washing column with soda, chloride salts liquid waste storage tanks
  - U stripping column

DUKE COGEMA
STONE & WEBSTER

Changes to AP Purification Process (continued)

- Changes to AP area
  - Footprint increase in the AP area
  - Reconfiguration of interior spaces and equipment
  - HVAC changes to accommodate room changes and new gloveboxes
- Changes to waste characteristics
  - Additional salts
  - Increase in raffinates volume (by a factor of ~1.5) resulting in increase of ~10% of overall volume of high-α liquid waste
  - Increase of ~10% in low-level liquid waste volume (rinsing)
  - Increase in silver content due to the impurity impact on the efficiency of the silver recovery unit

DUKE COGEMA
STONE & WEBSTER

Licensing Impacts

DUKE COGEMA
STONE & WEBSTER

Changes to Environmental Report

- Revise to address "Alternate Feedstock"
  - No immobilization
  - MFFF will receive ~6 MT feed material not matching original PDCF specification
  - MFFF expects to process 34 MT Pu
- Revise to reflect changes in SRS waste processing
  - High-α waste and stripped uranium waste will be solidified by SRS instead of transfer to F-Area Tank Farm
  - New waste processing building (not on MOX site but within F-Area) for MOX and PDCF wastes
- Also revise to incorporate ER RAI responses and clarifications

DUKE COGEMA
STONE & WEBSTER

Changes to ER: "Alternate Feedstock"

- Describe processing changes
  - Powder processing equipment to prepare the feedstock for chemical processing
  - Minor chemical processing changes to add chloride removal
  - Storage for resulting waste (mainly chlorides, other salts)
  - Building footprint increases <10% to accommodate additional equipment
- Effluents
  - Airborne effluents will contain trace amounts of chlorine, well below regulatory levels
  - Clean condensate and storm water effluents remain unchanged

DUKE COGEMA
STONE & WEBSTER

Changes to ER
"Alternate Feedstock" (continued)

- Continue to transfer waste to SRS for processing and disposition
  - Liquid waste volumes anticipated to increase ~10% overall
  - Solid waste volumes should not change
- Impacts of changes expected to be bounded by existing analyses for public and worker dose calculations for normal and accident analyses

DUKE COGEMA
STONE & WEBSTER

Changes to ER Waste Processing

- Change to SRS waste processing strategy for high-α and uranium waste streams from MFFF
  - Processing and solidification at SRS facility off the MFFF site
  - Replaces SRS F-Area Outside Facility and use of HLW waste tanks
  - Responsive to concerns about adding to SRS HLW waste tank volumes
- Conceptual design underway (by DOE)
  - Receive waste from MFFF and PDCF
  - MFFF piping of waste streams largely unaffected (no substantive impact on CAR)
- MFFF and PDCF waste stream characteristics
  - MFFF raffinate and PDCF sources
  - Stripped uranium

DUKE COGEMA
STONE & WEBSTER

Changes to ER
Waste Processing (continued)

- Environmental impacts
  - Construction of waste processing building
  - Normal and accident releases (airborne and liquid effluents)
  - Transportation impacts for waste
  - Disposal impacts

DUKE COGEMA
STONE & WEBSTER

ER Conclusion

Changes to ER from "alternate feedstock" and waste solidification result in insignificant:

- changes in the types and amounts of any effluents that may be released offsite
- increase in individual or cumulative occupational radiation exposure
- increase in the potential for or consequences from radiological accidents
- MFFF construction impact and minimal impact from construction of new waste processing building

DUKE COGEMA
STONE & WEBSTER

Changes to CAR and Safety Assessment

- Revise to address "Alternate Feedstock"
  - Update facility, processes, system descriptions:
    - MOX Receiving and Decanning
    - AP Dissolution and other small changes
    - Facility layout
    - Waste stream(s)
  - Confirm safety analyses are bounding for new processes
- Only minor revision to overall description anticipated for waste changes
- Also revise to incorporate CAR RAI responses and clarifications

DUKE COGEMA
STONE & WEBSTER

Changes to CAR and Safety Assessment (continued)

- Anticipated impacts on existing operations
  - CAR safety assessment made conservative bounding assumptions
  - Consequences of changes expected to be bounded by existing analyses
    - Existing events identified in the CAR expected to be representative of any new events identified as a result of new process
- New PSSCs (if any) will be identified

DUKE COGEMA
STONE & WEBSTER

Mixed Oxide Fuel Fabrication Facility (MFFF)

ACRS Briefing

Electrical and Instrument & Control Systems Overview

Duke Cogema Stone & Webster

10 April 2002

DUKE COGEMA
STONE & WEBSTER

Electrical System Overview

Ron Jackson

Electrical System Introduction

DUKE COGEMA
STONE & WEBSTER

- Electrical Distribution
  - 13.8kV/4.16kV
  - 480V
  - 120 V AC UPS
  - 125 V DC
- Design Basis - IROFS (summarized from NUREG-1718)
  - Sufficient capacity and capability
  - No single failure vulnerability
  - Electrical and physical separation
  - Adequate protective relaying and breaker control
  - Status monitoring capability
  - Test, calibration, and in-service surveillance capability
  - Proper equipment qualification, quality assurance, and reliability
  - Adequate design for natural phenomena

DUKE COGEMA
STONE & WEBSTER

Capacity and Capability

- Two physically independent 100% capacity feeders from SRS
- Medium voltage distribution sized for 100% capacity
- Three potential power sources
  - Normal Off site source (redundant 100%)
  - Standby diesel generators (two 50%)
  - Emergency diesel generators (redundant 100%)
- High resistance grounded Wye 480 V system
  - Allows continued operation with single ground fault
  - Limits ground fault current magnitude
  - Limits transient overvoltages

DUKE COGEMA
STONE & WEBSTER

Capacity and Capability (continued)

- Standby diesel generators
  - Non-IROFS critical electrical loads: sintering furnace, C2 ventilation, life safety loads
  - All emergency loads
  - 24-hour storage tank capacity
  - Automatic start on loss of voltage
- Emergency diesel generators
  - Loading: IROFS loads, vital UPS, HD fans
  - Automatic start after time delay on loss of voltage or degraded voltage
  - 7 day storage tank capacity

DUKE COGEMA
STONE & WEBSTER

Capacity and Capability (continued)

- Dedicated 480 V VHD Fan UPS
- Vital UPS
- Normal UPS
- 125 VDC Normal Batteries
- 125 VDC Emergency Batteries

DUKE COGEMA
STONE & WEBSTER

Single Failure Criteria (IROFS)

- Emergency systems are redundant
- Physical separation
- Electrical independence
- Support systems redundant and separate

Electrical and Physical Separation (IROFS)

DUKE COGEMA
STONE & WEBSTER

- Separation criteria
  - Minimum criteria IEEE 384-92 outside gloveboxes
    - Separation distance determined by area hazards
    - Barriers used where < minimum separation
  - Redundant electrical equipment in separate rooms and areas
- Minimum separation distance
  - Non-hazard area
    - Open tray - 1ft. Horizontal and 3ft. Vertical
    - Enclosed raceway - 1 inch
  - Limited hazard area
    - Open tray - 3 ft. Horizontal and 5ft. Vertical
    - Enclosed raceway - 1 inch
  - Hazard area
    - Only a single division of class 1E circuits allowed in the area

DUKE COGEMA
STONE & WEBSTER

Adequate Protective Relaying and Breaker Control

- Protective philosophy
  - Remove faulted equipment
  - Automatic supervision of manual/automatic operations
  - Initiate automatic operations or switching for shutdown or continued safe operation
- Local and remote distribution system control and monitoring

DUKE COGEMA
STONE & WEBSTER

Test, Calibration, and In-Service Surveillance

- Diesel generators
  - Synchronized to source and fully loaded
  - Redundant emergency diesels
  - Two standby diesels, one in service during maintenance
- Switchgear/MCCs
  - Drawout construction
  - Redundant loads divided between buses
  - Alternate feeds for non-emergency buses
- UPS
  - Manual bypass for maintenance

DUKE COGEMA
STONE & WEBSTER

Equipment Qualification and Natural Phenomena

- Equipment qualification
  - IROFS equipment provided under 10 CFR 50 Appendix B QA program
  - Seismic qualification per IEEE 344-87
  - Environmental qualification per IEEE 323-83 (mild environment)
- Natural phenomena
  - Emergency system
    - Qualified to design basis earthquake per IEEE standards
    - Installed in seismically designed building
    - Protected from tornado and missile damage
  - Standby diesel generator
    - Designed for UBC seismic requirements

DUKE COGEMA
STONE & WEBSTER

Instrumentation & Control System Overview

Jon Tanner

DUKE COGEMA
STONE & WEBSTER

Design Basis

- Regulatory requirements
  - Performance requirements and IROFS concept of 10CFR70.61
  - Design requirements of 10CFR70.64(a)(10)
    - Design must provide for inclusion of instrumentation and control systems to monitor and control behavior of IROFS
  - Defense in Depth 10 CFR 70.64(b)

- Industrial safety requirements, standards, and practices
  - IEEE nuclear power standards
  - 29CFR1910

DUKE COGEMA
STONE & WEBSTER

Design Basis (continued)

- General criteria
  - Fully automated
    - Modern technology and industrial practice
    - Ensure minimal product variability
    - Minimal personnel exposure to process
  - Minimal manual intervention
- Criteria summarized from NUREG 1718 (SRP)
  - I&C system components can be tested periodically
  - Electrical, physical, and control/protection separation
  - No single failure vulnerability
  - Provisions so that components fail in a safe failure mode
  - Status monitoring of the behavior of IROFS SSCs
  - Maintain functionality when subjected to natural phenomena

DUKE COGEMA
STONE & WEBSTER

IROFS Control Systems

- Applicable standards
  - IEEE 603 *IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations*
  - IEEE 7-4.3.2 *IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations*
  - IEEE 379 *IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Safety Systems*
- Example criteria
  - Safety systems maintain plant parameters within acceptable limits. The control portions of each safety system are comprised of more than one safety group, any one of which can accomplish the safety function.
  - Application of single-failure criterion

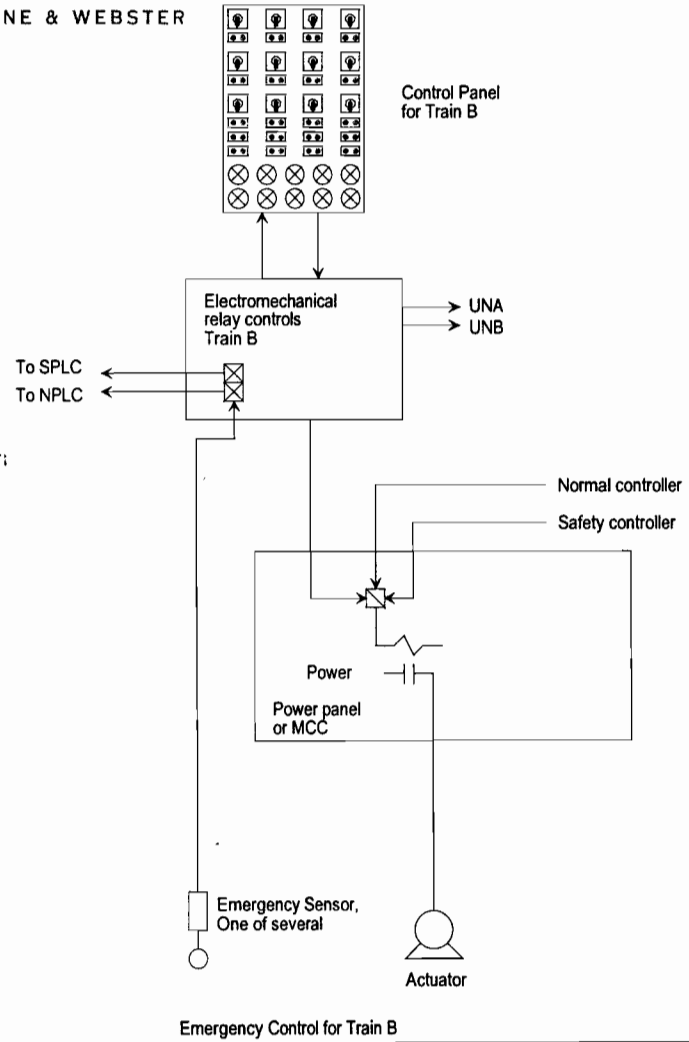
DUKE COGEMA
STONE & WEBSTER

Instrumentation

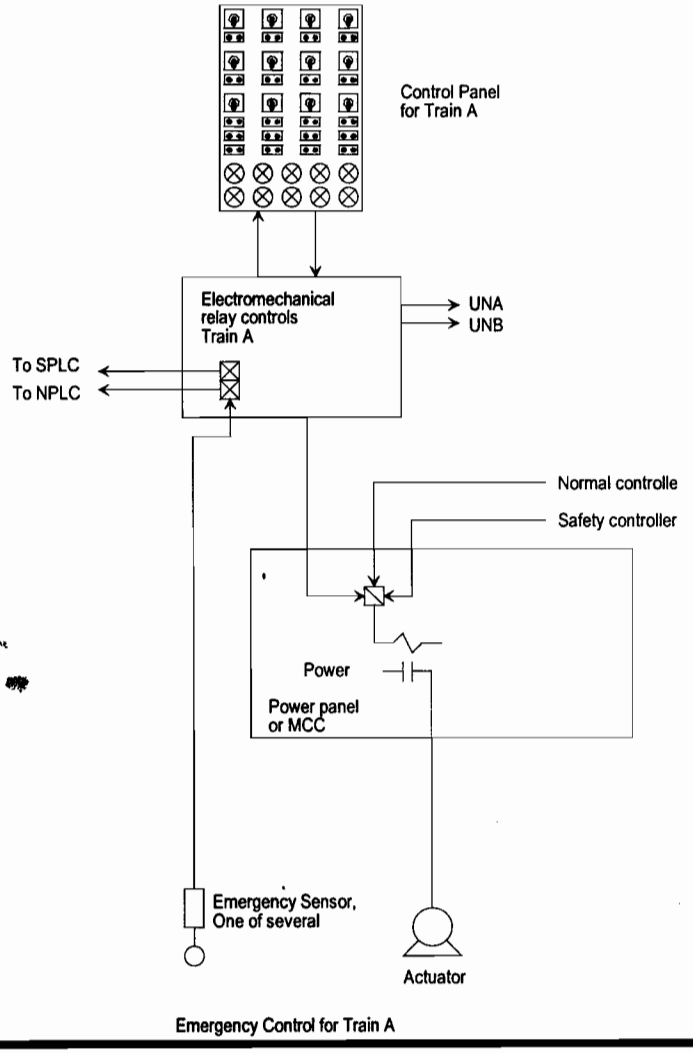
- Monitor variables and systems over anticipated ranges for normal operation, anticipated operational occurrences, and accident conditions
- Display instrumentation provides accurate, complete, and timely information pertinent to safety system status
- Displays represent process equipment schematically
- Displays current equipment status and provides the choice of allowable control actions

Emergency Control System Configuration

DUKE COGEMA
STONE & WEBSTER



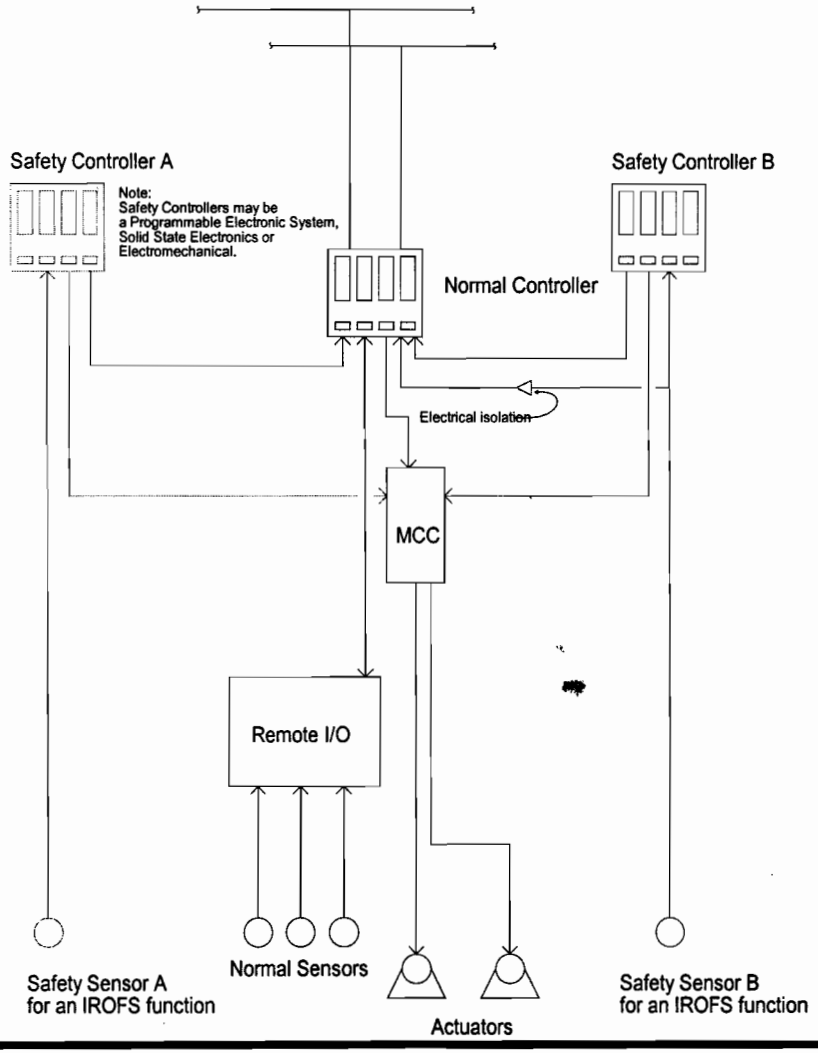
Emergency Control for Train B



Emergency Control for Train A

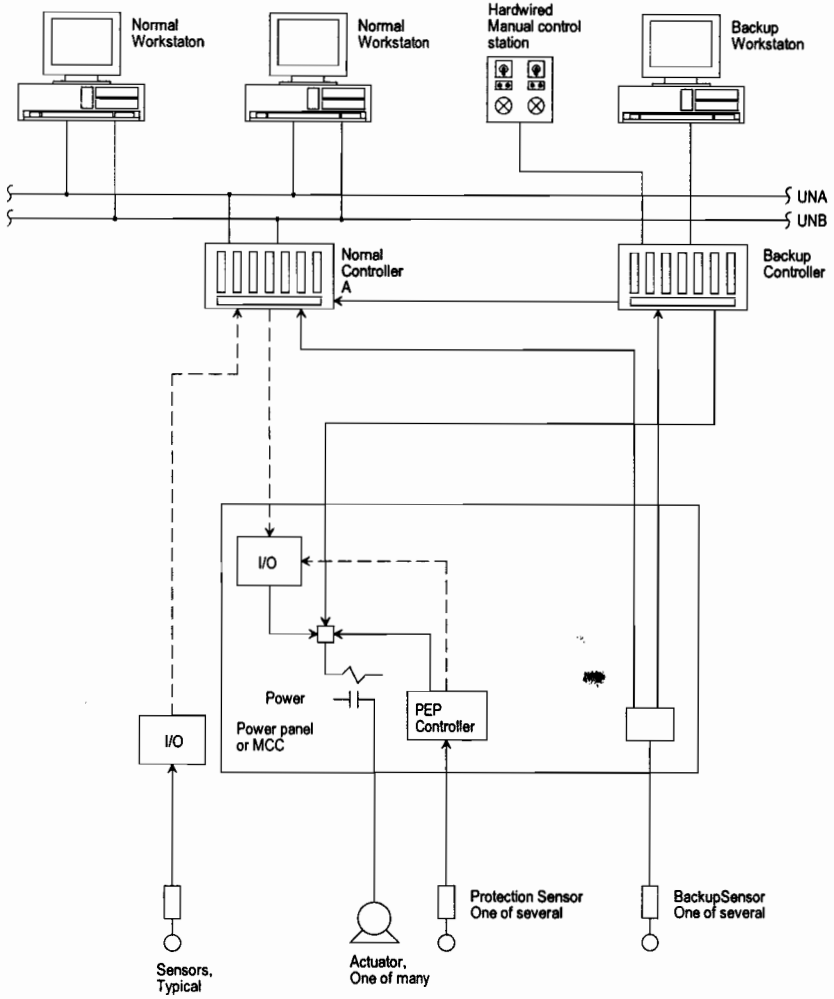
DUKE COGEMA
STONE & WEBSTER

Process & Manufacturing Unit Controller Configuration



DUKE COGEMA
STONE & WEBSTER

Utility Functional Unit Controller Configuration



Functional utility unit - Typical

Impact of DOE-Announced Changes on Staff Review of MOX Fuel Fabrication Facility

Andrew Persinko
MOX Project Manager

Schedule

- Issue draft SER for construction 4/30/02
- Receive supplemental Environmental Report 7/15/02
- Receive supplemental Construction Authorization Request 10/02

Schedule

Continued

- Issue draft EIS for public comment 2/03
- Issue revised draft SER 4/03
- Issue final EIS 8/03
- Issue final SER and construction licensing decision 9/03

Summary of Impacts of DOE-Announced Changes

- Staff did not issue draft EIS in 2/02 as planned
- Delay issuance of final EIS and SER by approximately one year
- Staff will issue a revised draft SER
- Areas mostly affected - safety analysis, chemical safety

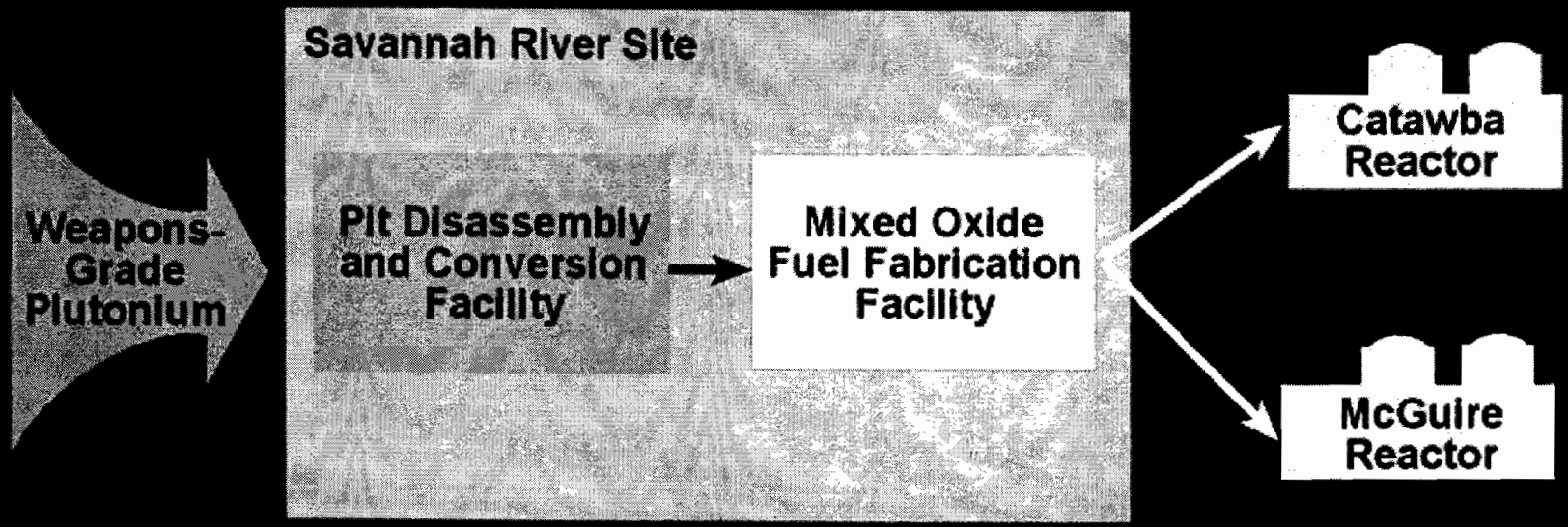
Summary of Staff Review

Andrew Persinko
MOX Project Manager

Overview

- Two step licensing
- Construction: Approve "Design Basis" of principal structures, systems, and components, Quality Assurance Program(10 CFR 70.23(b)) / Baseline Design Criteria (10 CFR 70.64)
- QA Program SER issued 10/1/01
- Open Items (other than safety analysis, radiological consequences, chemical safety, fire protection)
- More detailed presentations

NRC Role in Regulating Mixed Oxide Fuel

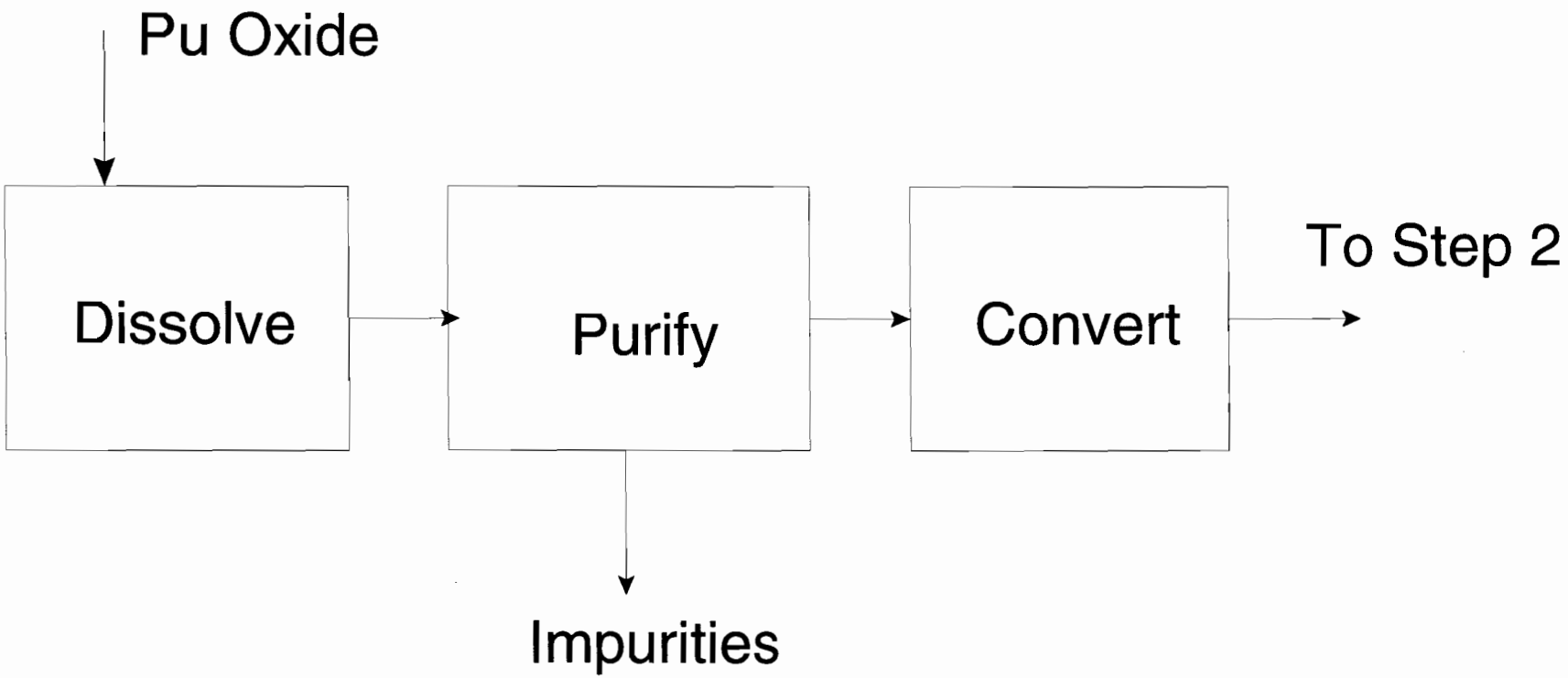


Yellow = NRC regulated

Blue = DOE regulated

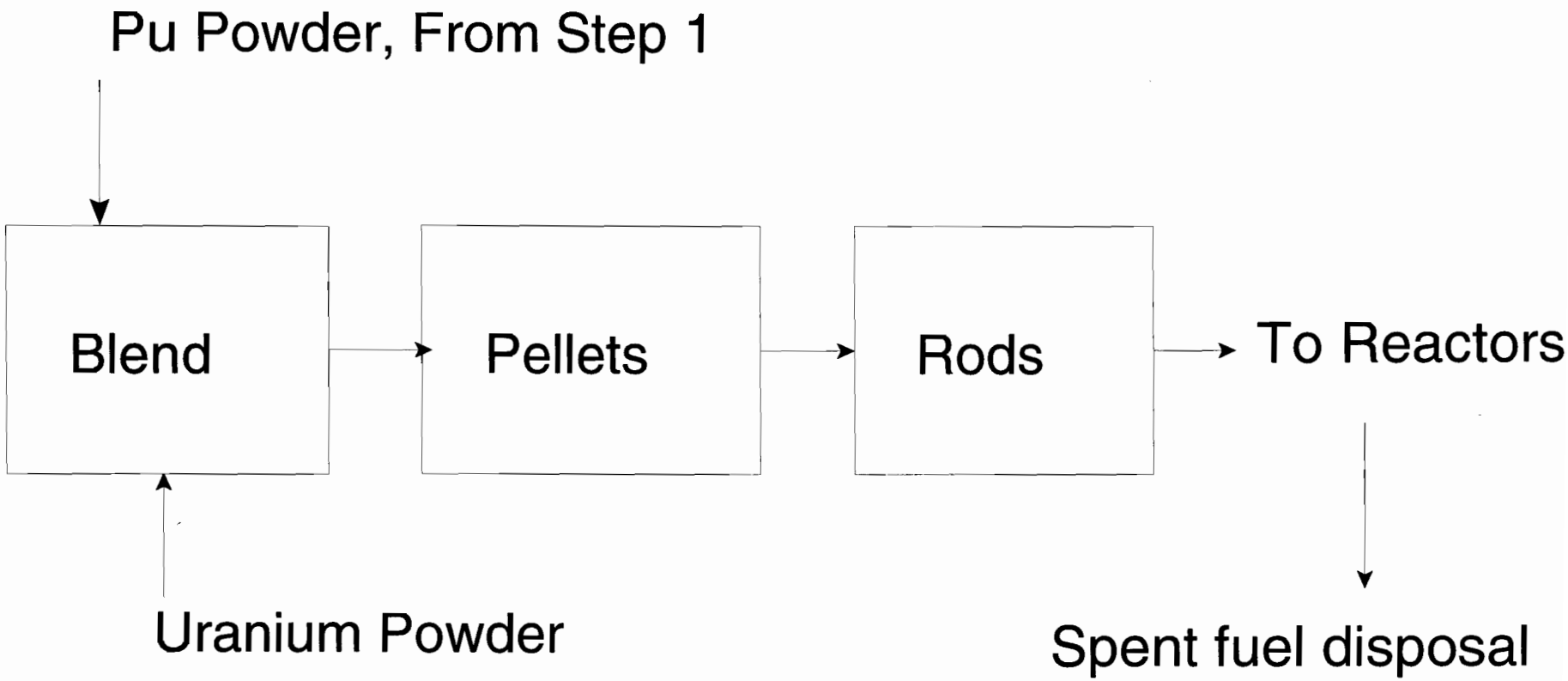
THE MOX PROCESS

STEP 1: Purify Plutonium
(Aqueous Polishing)



THE MOX PROCESS

STEP 2: Fuel Fabrication



Summary of Open Items

Excluding Safety Analysis, Radiological Consequences, Chemical Safety, Fire Protection

- Site description
- Nuclear criticality safety
- Confinement
- Fluid systems

Safety Assessment

Rex Wescott

Overview

- Purpose
- Scope
- Review Criteria
- Results

Purpose of Safety Assessment Review

- Review Hazards Analysis
- Define Potential Issues in Context of Performance
  - Unidentified events.
  - Additional information needs (strategies)
- Assure a Multi-discipline Technical Approach Where Necessary

Scope of Safety Assessment Review

- Natural Phenomena Hazards
- External Man-made Events
- Process Hazards
  - Worker Consequences
  - Public and Site Worker Consequences
  - Environmental Consequences

Scope of Safety Assessment Review

- Process Hazard Categories
  - Loss of Confinement
  - Fire
  - Load Handling
  - Explosion
  - Chemical
  - Criticality

Review Criteria

- Likelihood Applied to natural phenomenon
- Acceptability of Deterministic Approach
- Use of Safe and Accepted Practices
- Availability of Mitigation and/or Prevention PSSCs

Review Results

Events Not Identified by Applicant

- Steam Explosions
- Non-fire related failure of glovebox windows
- Flammable gas from electrolysis
- Solvent waste container breach outside of restricted area
- Hydrogen explosion outside of sintering furnace airlock
- Titanium Fires

Review Results

Strategies Requiring Additional Information

Not inclusive

- Seismic Isolation valves
- Process Safety I&C System
- Sintering furnace leak (facility worker only)
- Fire propagation through pneumatic transfer tubes
- HAN/Hydrazine
- TBP-Nitrate (Red Oil) } explosions
- Laboratory Explosion (facility worker only).
- Consequence Analysis HEPA Filter Efficiency

Safety Assessment: Radiological Consequences

David Brown

Safety Assessment: Radiological Consequences

Overview

- The staff's review of the applicant's radiological consequence calculations includes evaluation of:
  - Source term calculations.
  - Facility worker dose estimates.
  - Downwind consequence calculations.
  - How the applicant's safety strategy reduces the risk to each receptor.

Safety Assessment: Radiological Consequences

Applicant's Proposed Methodology

- Applicant's accident source terms are based on NUREG/CR-6410, "Nuclear Fuel Cycle Facility Accident Analysis Handbook" (5-Factor Formula).

- The downwind consequences are based on using a 95th percentile χ/Q using data from the Savannah River Site H- area meterological tower.

- Receptors include the facility worker, site worker (100m), public (8 km) and the environment outside the restricted area.

Safety Assessment: Radiological Consequences

Staff's Review: Summary

- Staff verified by comparison to NUREG/CR-6410 that the methodology for accident source term calculations is acceptable.
- Staff verified by independent calculation that the applicant used reasonably conservative values for χ/Q.
- Staff verified by independent calculation that the risks from controlling accident sequences are reduced by the applicant's safety strategy.

Safety Assessment: Radiological Consequences

Staff's Review: Source Terms

- The staff reviewed the applicant's derivation of accident source terms, including values for:
  - Material-at-risk (MAR)
  - Damage ratio (DR)
  - Atmospheric release fractions (ARFs)
  - Respirable fractions (RFs) (OPEN)
  - Leak path factors (LPFs) (HEPA filters) (OPEN)

Safety Assessment: Radiological Consequences

Staff's Review: Atmospheric Dispersion

- The staff evaluated values for χ/Q:
  - ARCON96 for the site worker and the environment, with credit for building wake effects.
  - MACCS2 for the public.
  - The staff accepts the applicant's χ/Q values for the site worker and the public. However, the safety assessment for environmental protection was not acceptable to the staff.

Safety Assessment: Radiological Consequences

Staff's Review: Safety Strategy

- The staff independently evaluated whether the applicant's safety strategy would reduce the risk posed by controlling events:
  - For the facility worker, the staff requested clarification of the PSSC "Training & Procedures" (or Worker Action) as it pertains to loss-of-confinement events. (OPEN)
  - The staff's review of the safety strategy for environmental protection is ongoing. (OPEN)

Safety Assessment: Radiological Consequences

Staff's Review Conclusions: OPEN ITEMS

- The staff requested clarification of how the facility worker would become aware of a sintering furnace loss-of-confinement event.

- The staff have not accepted the applicant's use of 99.99% for HEPA filter efficiency during severe conditions.

- The staff have not completed review of the applicant's revised safety assessment for environmental protection.

Summary

Safety Assessment: Radiological Consequences

- The staff expects the applicant to provide clarification of the facility worker safety strategy for certain loss-of-confinement events.
- The applicant must justify the 99.99% HEPA filter efficiency for severe conditions.
- The staff will continue its review of the safety assessment for environmental protection.

Chemical Safety

Alex Murray

Overview

- Previous ACRS Meeting
- SER Review: Basis and Conduct
- Main Findings
- Significant Open Items

Previous ACRS Meeting

- Discussed process, proposed PSSCs/DBs, and status of review.
- Specific Issues: administrative controls, high alpha wastes, electrolyzers, red oil, U assay.

SER Review: Basis and Conduct

- Basis: CAR, RAIs, info on docket, ER/EIS activities, Public Meetings/Summaries.
- Conduct: 10 CFR 70, NUREG-1718 (SRP), other RGs, NUREGs.
- Review: open literature, DOE, independent calculations, CPI/nuclear practice.
- Codes/guidance: ASME, NFPA, CCPS.

Main Findings (Chem safety)

Essentially the same as November Meeting

- Few chemical PSSCs, DBs identified.
- General lack of specificity for PSSCs, DBs.
- Applicant documents: More PSSCs, DBs may be needed.
- Administrative controls.

Summary of Significant Open Items

- Red Oil Issues (TBP-Nitrate).
- HAN/Hydrazine.
- Electrolyzers/Dissolution.
- Waste Area.
- Chemical Release Modeling.
- Sintering Furnace.

Red Oil

- Applicant: Single DB of temp. < 135°C.
- No direct measurement, control, or cooling.
- Staff requested additional information from applicant.

Red Oil

Staff Review

- Red oil reactions occur with organics in nitrate media.
- Several reported explosions over 50 years.
- Hanford, SRS, Tomsk; tens of gallons involved.
- Extensive work - 1950s, 1960s, 1990s.
- Hard to duplicate complete phenomena in lab tests.

MFFF Areas With Potential for Red Oil

- 3 Evaporators (OML and Acid Recovery).
- Associated Tankage.
- Purification Area.
- Solvent Recovery.

Red Oil

Staff Conclusion

- Single temperature control may not be adequate.
- Additional PSSCs, DBs may be needed.
- Awaiting additional information from applicant.

HAN/Hydrazine

- Applicant: Identified HAN and azide hazards.
- Primarily admin. controls on concentration.
- Other PSSCs, DBs may be needed.
- Potentially affects Purification, Solvent Recovery, and Waste areas.

HAN/Hydrazine

Staff Review

- Several events at DOE facilities and manufacturers.
- 1997 - Hanford Event at PFP.
- DOE investigation led to HAN guidelines.

HAN/Hydrazine

Staff Conclusions

- Proposed administrative controls may not be adequate.
- Additional PSSCs, DBs may be needed.
- Awaiting additional information from applicant.

Electrolyzers

Proposed by Applicant

- Important - generates silver to dissolve PuO2, recycles silver (2 MFFF areas).
- Overtemperature/fire hazard identified.
- Single PSSC of temp control (< 70°C).
- Hydrogen limit (Pu Radiolysis).

Electrolyzers

Staff Review and Conclusions

- Other PSSCs, DBs may be needed.
- Assurances needed.
  - System will shutdown as planned.
  - Other hazards: e.g., electrolytic hydrogen, metal fires.
- Awaiting additional information from applicant.

Waste Area

- High alpha waste system
  - Additional PSSCs and DBs may be needed.
  - Inventories not identified.
- Waste Management Program Changes.
- Staff will re-evaluate after receiving information on impacts of changes.

Chemical Release Modeling

NRC regulates chemical effects on radiological safety

- Impact on radiological safety under review.
  - - Emergency control room protected.
  - - Other operator safety actions not specified.
  - - Awaiting additional response from applicant.
- Applicant has not identified PSSCs or DBs for chemical releases/events.
- Several chemicals (N_2H_4, N_2O_4, HNO_3, NH_2OH) could exceed safe limits.

Sintering Furnace

Staff Review

- High temperature operation with Ar/H2 and water cooling.
- General hazards are fires and explosions.
- Several gas sensors identified as PSSCs.
- Hydrogen flow not terminated under all off-normal conditions.
- Additional PSSCs and DBs may be needed for steam explosions.
- Discussions continuing with applicant.

Summary

- Staff issues similar to previous ACRS meeting.
- Staff has identified open items in the chemical safety area.
- Staff will review additional responses from the applicant as they are submitted.

Background Slide

Red Oil

Tomsk Event

- Most recent - 1993.
- Involved a tank, nominally at 45-50°C.
- Immiscible layers stratified.
- Thermally isolated, became reactive.
- Two explosions: liquid and gas phases.
- Significant damage, contamination; no injuries.

Fire Safety

Sharon Steele

Overview

- MOX Strategy for Fire Safety
- SER Review: Basis and Conduct
- Main Findings
- Unresolved Issues

MOX Strategy for Fire Safety
Six Event Categories for Fire:

- Aqueous Polishing Process cells
- Aqueous Polishing / MOX processing glovebox areas
- C2 areas (tertiary confinement - low contamination risk)
- External facility fires
- Facility wide systems
- Facility (beyond fire areas)

MOX Strategy for Fire Safety

MOX Fuel Fabrication Building Fire Protection Strategy by Event Categories

Fire Protection Strategy (Principal SSC)	AP Process cells	AP/MP C3 areas w/ glove-boxes	C2 Area				Outside the Fuel Fab. Building	Facility wide systems	Facility Fire Areas
			Canister, fuel rod, transfer container	Transport casks	Waste Container	Final C4 HEPA filter			
Fire Barriers	PSSC	PSSC	PSSC	PSSC	PSSC	PSSC	PSSC	PSSC	PSSC
Combustible loading controls			PSSC	PSSC		PSSC			
Automatic Detection/ Suppression		PSSC							
Process cell Fire Prevention Features	PSSC								
Confinement barriers (3013, MOX)				PSSC					
C4 confinement system						PSSC			
C3 confinement system		PSSC							
MOX Fuel Fabrication Building							PSSC		
Emergency Diesel Generator Building							PSSC		
Emergency Control Room Air Conditioning							PSSC		
Waste Transfer line							PSSC		
Facility Worker Action		PSSC			PSSC			PSSC	PSSC

SER Review: Basis and Conduct

- Basis: CAR, RAI, Polycarbonate report, Preliminary Fire Hazards Analysis.
- Conduct: 10 CFR 70, NUREG-1718 (SRP), RGs.
- Review: Open literature, DOE "Fire Protection Design Criteria."
- Codes/guidance: NFPA 801, "Facilities Handling Radioactive Materials."
- Focus: Fire protection features and systems, PSSCs, design basis.

Main Findings

Fire Safety

- Fire safety strategy is generally acceptable, because:
  - PSSCs - protect radioactive materials
  - Additional protective features
  - Protection of redundant PSSCs (electrical independence and separation per IEEE 384)
  - Fire area separation (NFPA 801)
  - Preliminary Fire Hazards Analysis (not a basis of review)

Unresolved Issues

Fire Safety

- Design basis criteria for gloveboxes window panels (to assure stated mechanical, fire and seismic properties are valid).
- Soot loading analysis for the final filters (primary and secondary confinement).
- Margin of safety for fire barriers.
- Propagation of hot gas through pneumatic transfer tubes.

Summary

Fire Safety

- PSSCs and design bases generally acceptable
- Applicant will provide more information on:
  - Glovebox design basis criteria.
  - Soot loading analyses
  - Methodology: margin of safety for fire barrier
  - Methodology: propagation of hot gas