UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

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May 15, 2003

MEMORANDUM TO: William M. Dean, Assistant for Operations
Office of the Executive Director for Operations

FROM: Robert C. Pierson, Director
Division of Fuel Cycle Safety and Safeguards
Office of Nuclear Material Safety and Safeguards

Subject: PRESENTATIONS TO RF GOSATOMNADZOR, MAY 26-30, 2003

In accordance with Management Directive 3.9 and subsequent OEDO guidance, information is provided below regarding a presentation to be made while on foreign travel. The information does not involve policy issues. The information is for your transmittal to Commissioner Assistants, for information.

Meeting: Department of Energy meeting with RF Gosatomnadzor on plutonium disposition
Place: Moscow, Russia
Dates: May 19-23, 2003
Author: Margaret Chatterton, Christopher Tripp
Title: "NRC Review of the Mixed Oxide Fuel Fabrication Facility"

ADAMS
Accession #:ML031320016

cc:
Martin J. Virgilio, NMSS
Margaret V. Federline, NMSS
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B/2

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DATE	05/ 12 /03		05/ 12 /03		05/ 13 /03		05/ 15 /03	

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NRC Review of the Mixed Oxide Fuel Fabrication Facility

Meeting with RF Gosatomnadzor
May 2003

Margaret Chatterton and Dr. Christopher S. Tripp
U.S. Nuclear Regulatory Commission

Workshop Agenda

- Day 1: Introduction and Criticality Safety Concepts
- Day 2: NRC Regulatory Framework
- Day 3: NRC Review of NCS Issues in the MFFF CAR
- Day 4: NRC Review of Validation/Subcritical Margin
- Day 5: Status of NRC Review and Future Topics

Day 1 Agenda

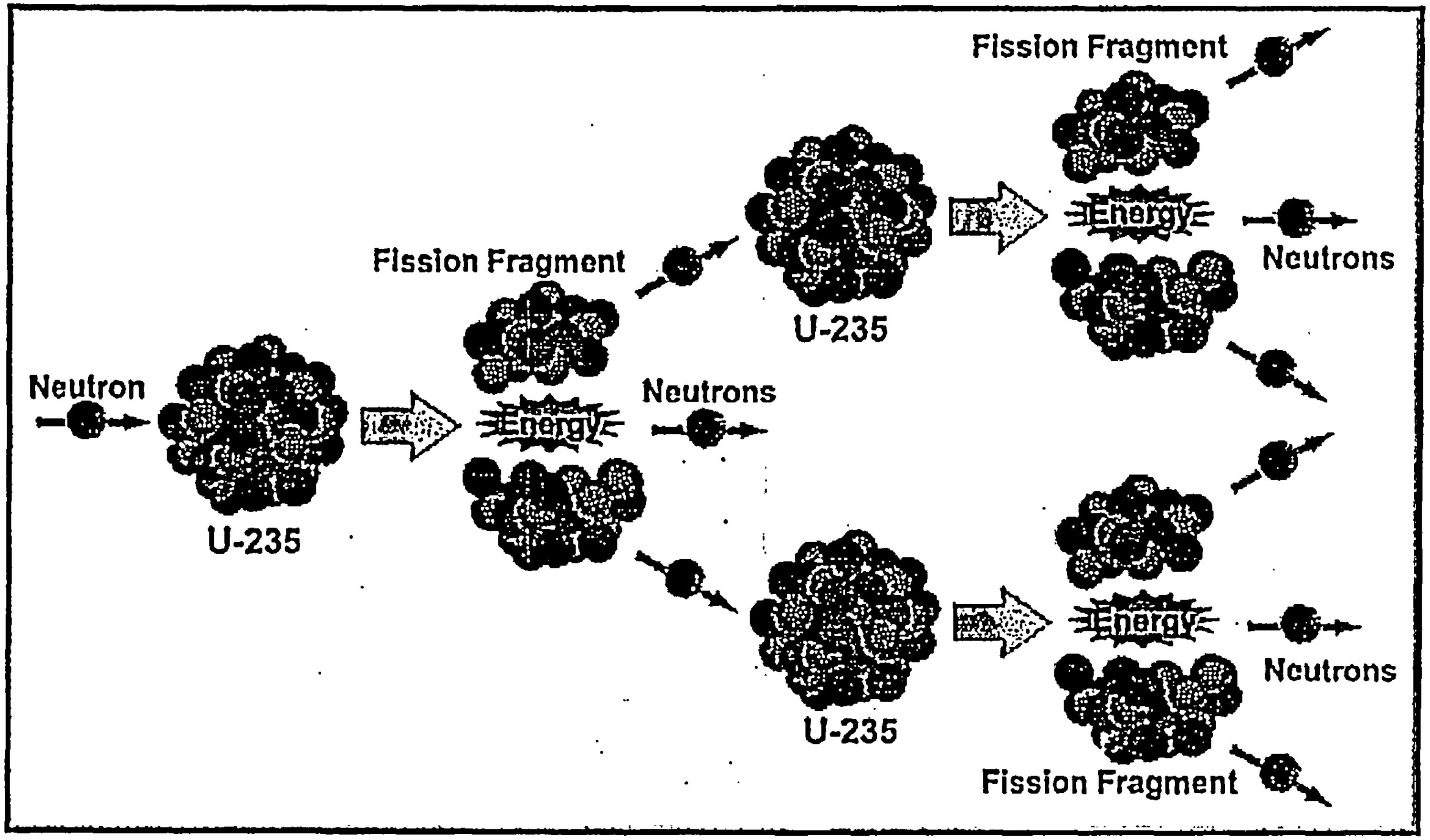
- Introduction to NRC Regulations
- Nuclear Criticality Safety (NCS) Basic Concepts
- Aspects of Plutonium / Mixed Oxide (MOX)
- Dominant NCS Risks and Issues
- End-of-day Question-and-Answer Session

Nuclear Criticality Safety Basic Concepts

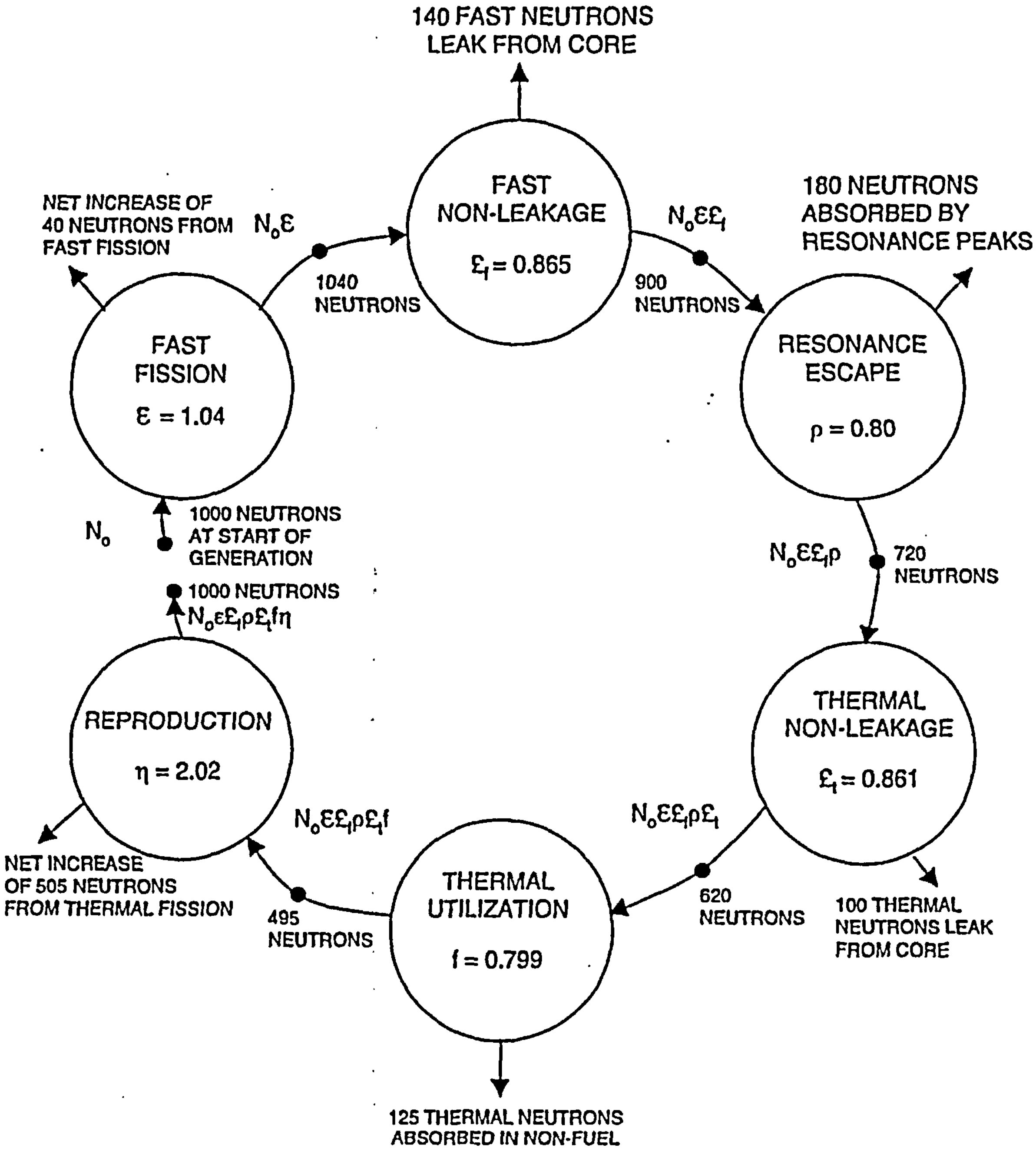
- Definition: Nuclear criticality safety (NCS) is the prevention or termination of inadvertent nuclear chain reactions for fissionable material operations in non-reactor environments
- $$k_{eff} = \frac{\text{(neutron production)}}{\text{(total neutron absorption + neutron leakage)}}$$
- $k_{eff} = 1$ Critical
- $k_{eff} < 1$ Subcritical
- $k_{eff} > 1$ Supercritical

Nuclear Criticality Safety Basic Concepts

Neutron Production = Neutron Multiplication :
(1 Neutron In, More Neutrons Out)



Example Neutron Life Cycle with k_{eff}= 1, *Critical*



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Nuclear Criticality Safety Basic Concepts

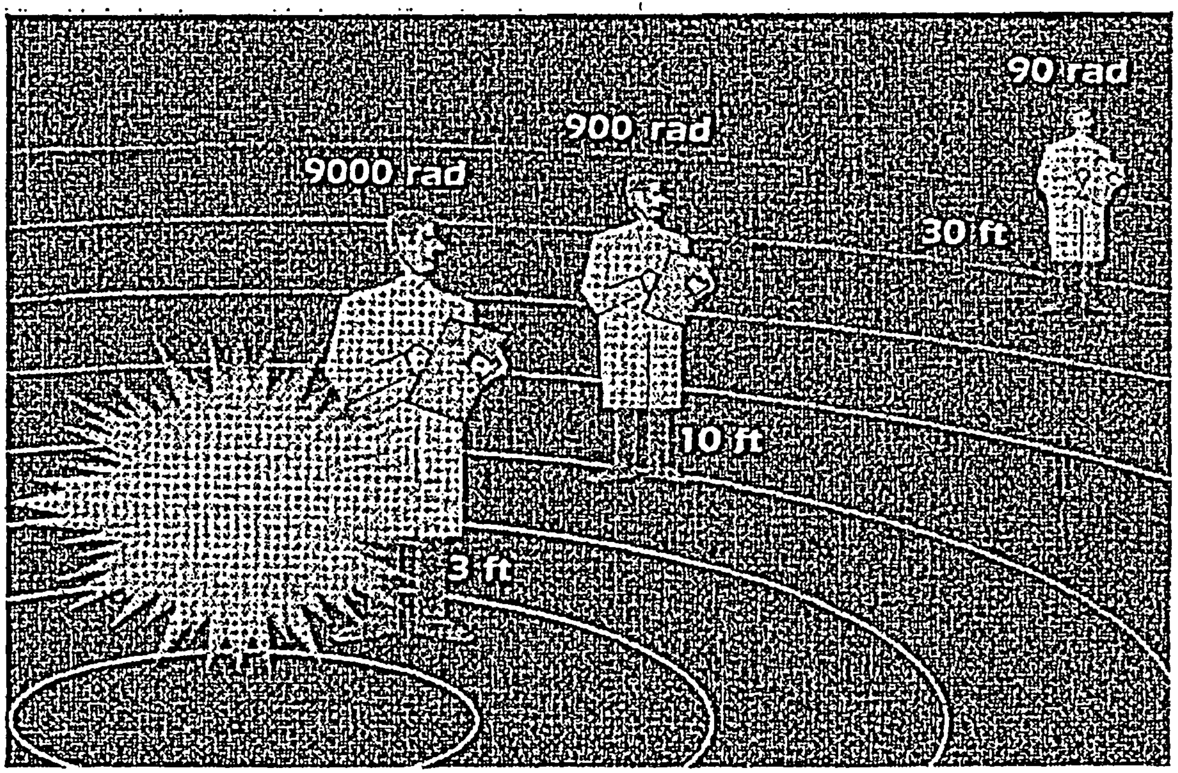
- **Criticality Evaluations:**
  - **Uncertainties in**
    - Experimental Data
    - Calculations
  - **Operational Scenarios**
    - Normal Conditions
    - Credible Abnormal Conditions

Nuclear Criticality Safety Basic Concepts

- Process plant criticality accidents:
  - Aqueous solutions
  - Pu
  - HEU
- Criticality yields: approaching 10^{18} fissions
- Consequences: acute radiation to workers
- Most recent criticality accident
  - Japan (1999)
  - 2 worker fatalities

Nuclear Criticality Safety Basic Concepts

Decrease in Radiation Dose with Distance from Criticality Accident ~ 3 x 10^{17} fissions



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Nuclear Criticality Safety Basic Concepts: Analysis Procedure

- Definition of process/operations
- Hazards and scenario development
- Controlled parameters
- Subcritical limits
- Controls
- Management measures

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Nuclear Criticality Safety Basic Concepts: Hazards and Scenario Development

- What-If
- What-If Checklist
- Hazard and Operability Analysis (HazOp)
- Failure Modes and Effects Analysis (FMEA)
- Fault Tree Analysis
- Event Tree Analysis

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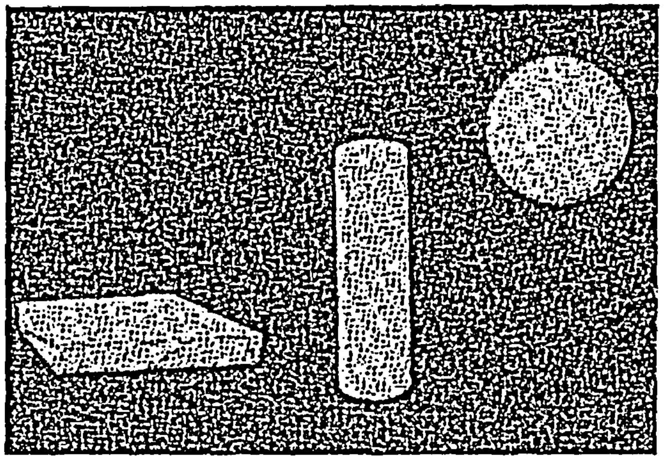
Nuclear Criticality Safety Basic Concepts: Controlled Parameters

- Geometry
- Mass
- Density
- Isotopics
- Reflection
- Moderation

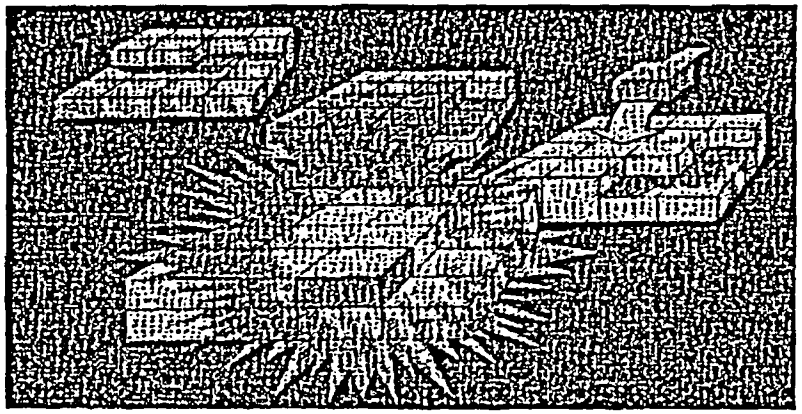
- Concentration
- Interaction
- Neutron absorbers
- Volume
- Heterogeneity
- Process variable

Nuclear Criticality Safety Basic Concepts: Examples of Controlled Parameters

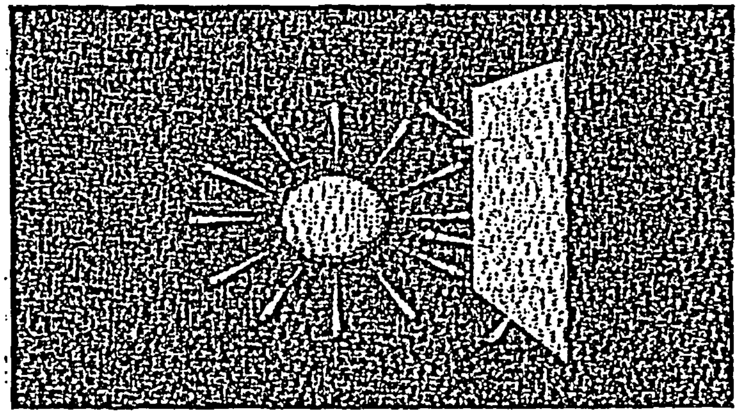


Geometry

Mass



Reflection



Nuclear Criticality Safety Basic Concepts: Control Types

- Passive Engineered
- Active Engineered
- Enhanced Administrative
- Simple Administrative

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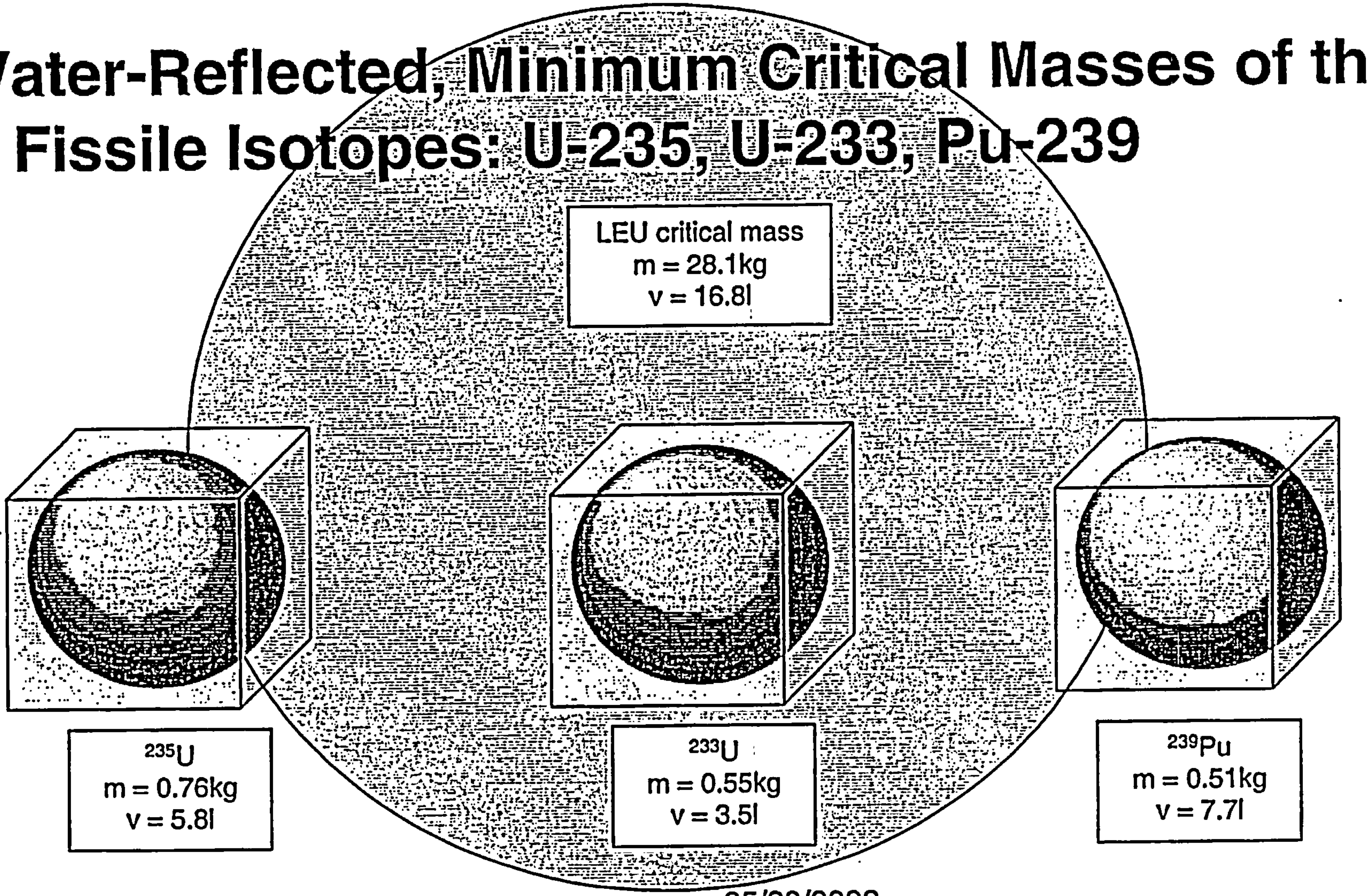
Nuclear Criticality Safety Basic Concepts: Management Measures

- Engineered Controls
  - ➢ Configuration Management
  - ➢ Maintenance
  - ➢ Surveillance
  - ➢ Functional Testing...
- Administrative Controls
  - ➢ Training and qualification
  - ➢ Procedures
  - ➢ Postings
  - ➢ Records Management
  - ➢ Audits and Investigation...

Unique Aspects of Pu/MOX Processing

Water-Reflected, Minimum Critical Masses of the Fissile Isotopes: U-235, U-233, Pu-239



LEU critical mass
m = 28.1kg
v = 16.8l

^{235}U
m = 0.76kg
v = 5.8l

^{233}U
m = 0.55kg
v = 3.5l

^{239}Pu
m = 0.51kg
v = 7.7l

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Unique Aspects of Pu/MOX Processing

- Plutonium Chemistry:
  - Effect of Pu chemistry on process flow
  - Effect of Pu chemistry on system k_{eff}

Unique Aspects of Pu/MOX Processing

- Effect of Plutonium Chemistry on Process Flow
  - Up to six positive valence states
  - Valence depends on acidity, temp, etc.
  - Pu can compound with up to 4 nitrate radicals
  - Need to keep Pu out of solvent extraction raffinate stream
  - Pu compounds include oxides, oxyfluorides and oxalate-nitrate mixtures

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Unique Aspects of Pu/MOX Processing

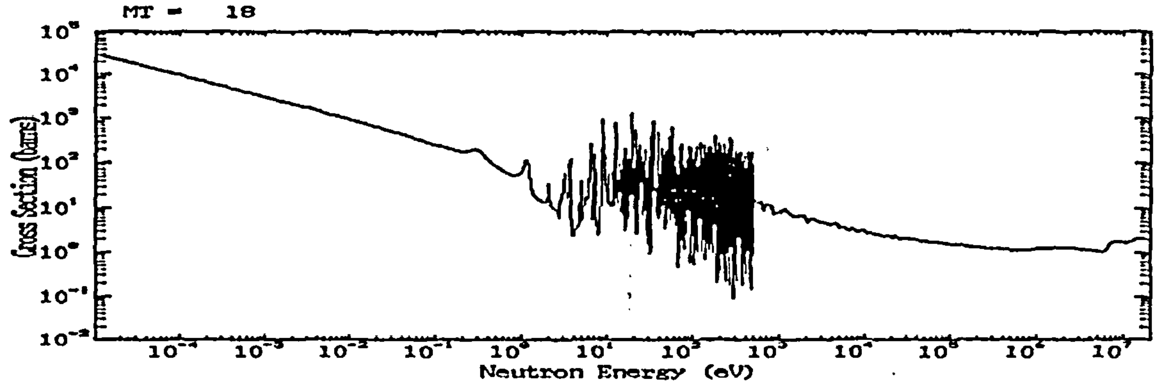
- Effect of Plutonium Chemistry on System k_{eff}
  - ➢ Neutron absorption by:
    - » Nitrogen
    - » Hydrogen
    - » Fluorine
    - » Oxygen
    - » Carbon
  - ➢ Nitrogen absorption can increase allowable limits by factors of three or four
  - ➢ 3 nitrate radicals assumed instead of 4
  - ➢ More reactive oxyfluoride compound assumed for mixtures of oxalate and nitrate

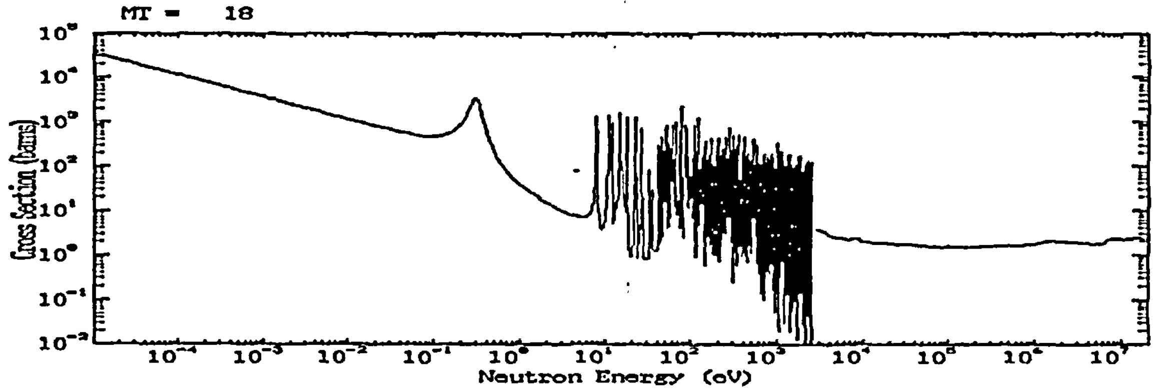
Unique Aspects of Pu/MOX Processing: Plutonium/MOX Isotopics (Assay) Control

- Isotopic mixture that has to be controlled:

Uranium Processing Plant	MOX Plant
$^{235}U/U$	^{239}Pu
	^{240}Pu
	^{241}Pu
	$^{235}U/U$
	U/Pu

Unique Aspects of Pu/MOX Processing: Fission Cross Sections





Unique Aspects of Pu/MOX Processing:
Plutonium Physical Characteristics

Density Control

- PuO_2 lower density (more porous) than UO_2.
- After PuO_2 and UO_2 blended, difficult to predict final density.

Dominant NCS Risks and Issues

- Historic risks
- Bounding assumptions
- Isotopic Blending of PuO_2 and UO_2
- Limited US industry experience
- Meeting performance criteria
- Criticality code validation

Dominant NCS Risks and Issues: Historic Risk

- 21 of the 22 total known world process nuclear criticality accidents occurred with HEU or Pu in solutions or slurries*
- Aqueous polishing (AP)
  - ➢ Dissolution
  - ➢ Purification
  - ➢ Conversion

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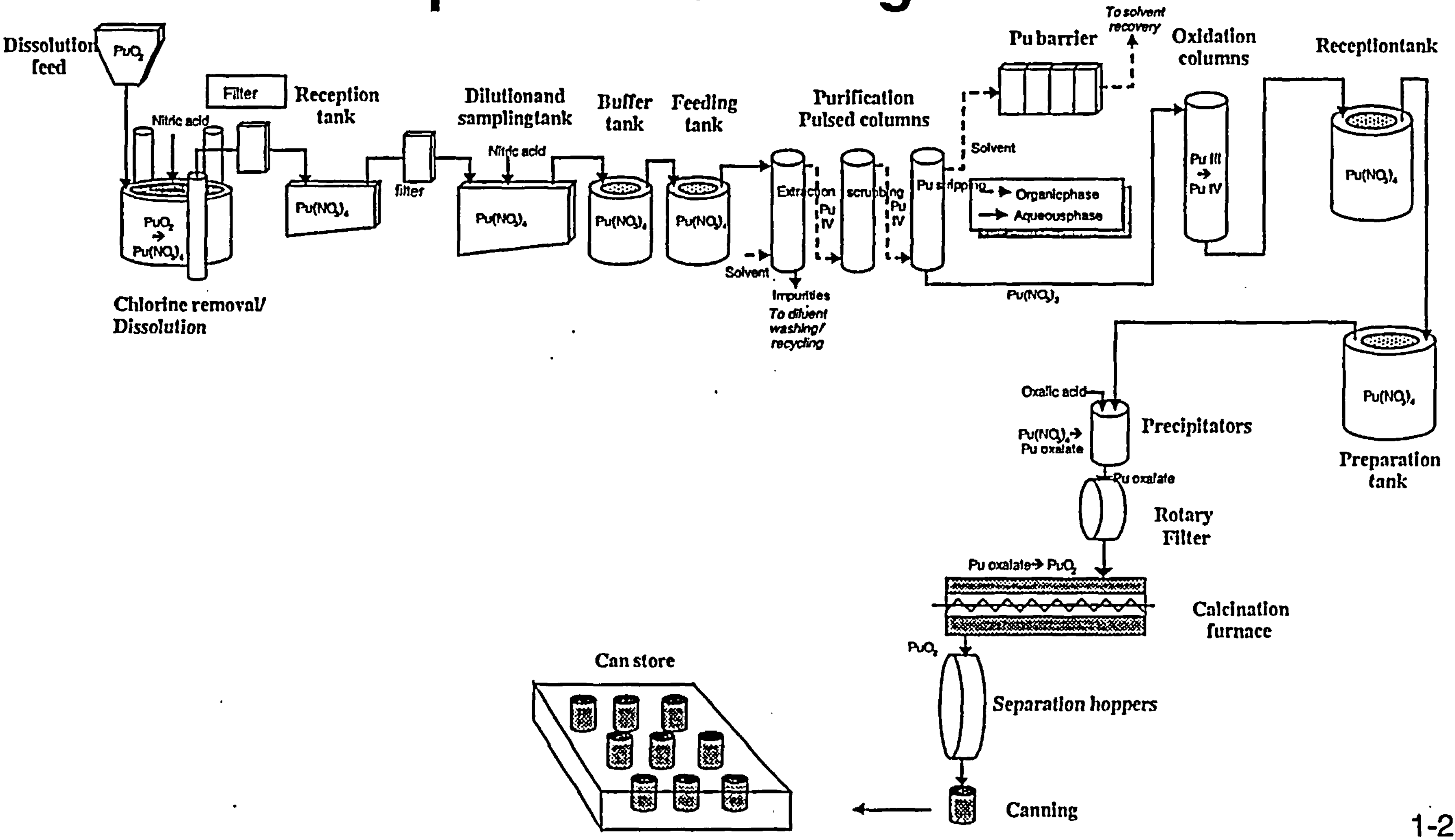
* TP McLaughlin, et al, *A Review of Criticality Accidents*, 2000 Revision, LA-13638, May 2000

Dominant NCS Risks and Issues: Historic Risk

Overview of Aqueous Polishing Process



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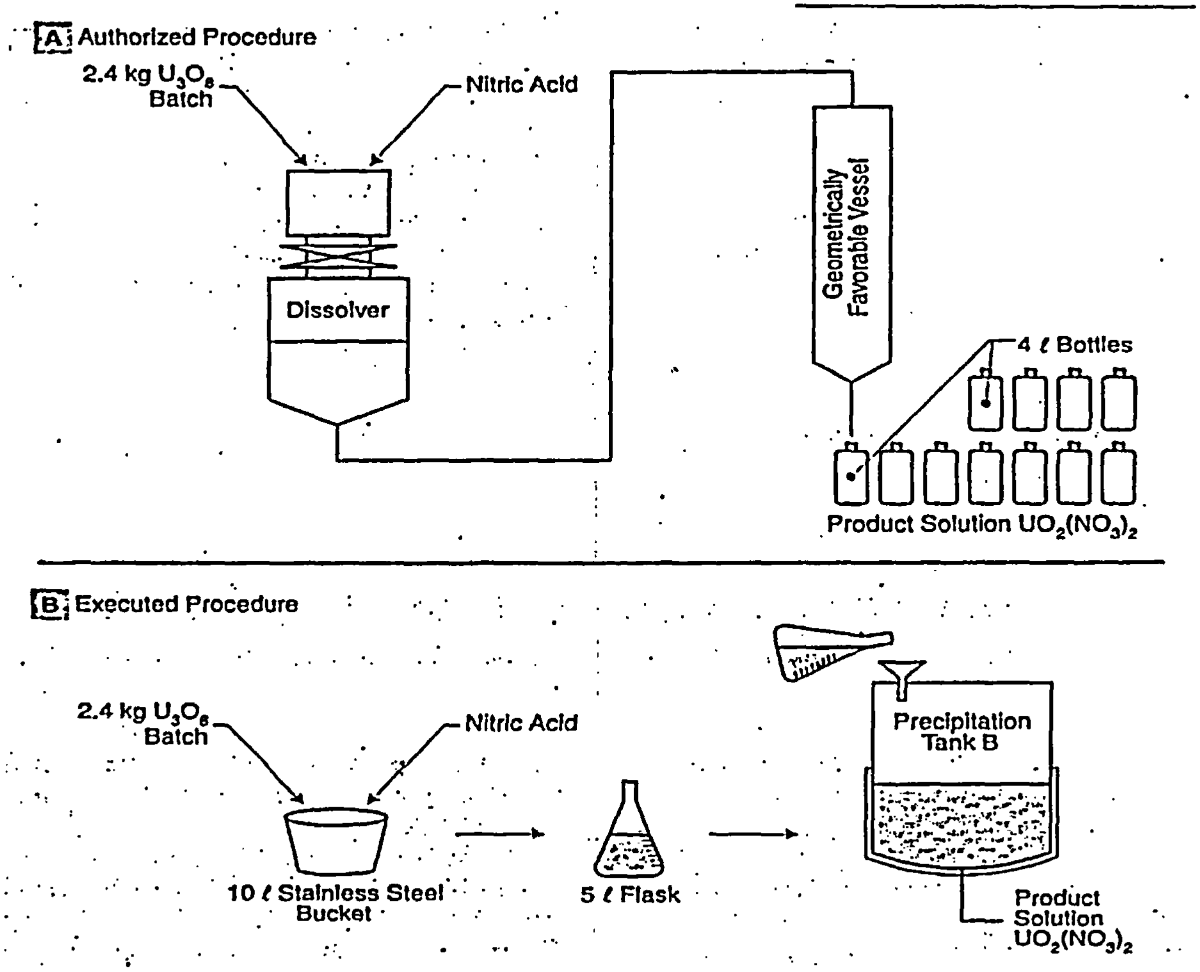
Dominant NCS Risks and Issues: Historic Risk

29 September 1999 Dissolution Mishap at the JCO Facility

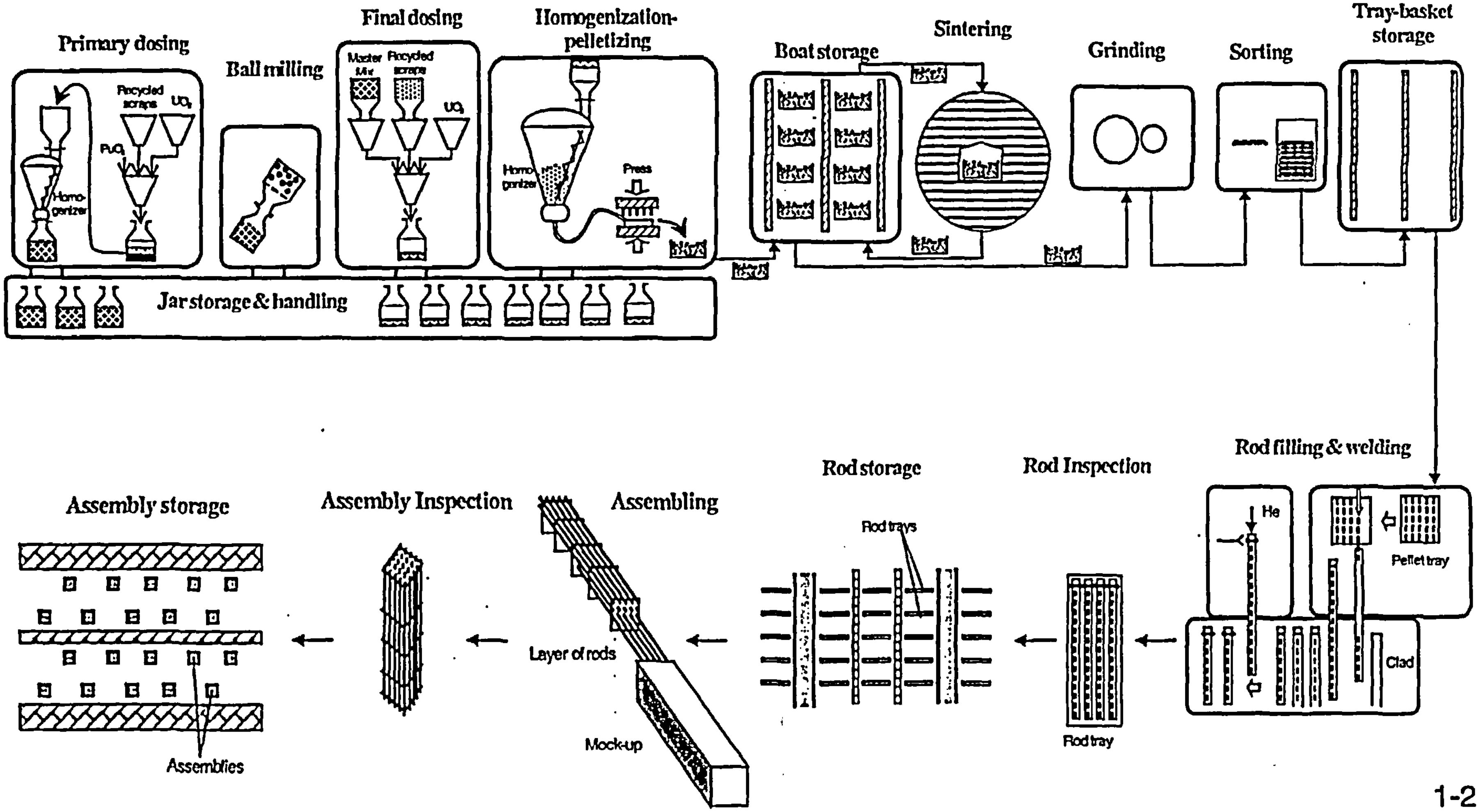


Dominant NCS Risks and Issues: Historic Risk

- MOX Process (MP)
  - Powder blending
- Lesser risks
  - Pellet production
  - Rod production
  - Fuel assembly production

Dominant NCS Risks and Issues: Historic Risk

Overview of the MOX Process (MP)



Dominant NCS Risks and Issues: Historic Risk

	Low H/(U+Pu)	High H/(U+Pu)
Mass	6.4 kg MOX @ H/(U+Pu) ~ 100	60 kg MOX @ H/(U+Pu) ~ 0.1
Volume	17L MOX @ H/(U+Pu) ~ 40	1927L MOX @ H/(U+Pu) ~ 0.1

Moderation Spans broad spectrum, from:

- Damp, H/(U+Pu) ~ 0.1 (~0.33 wt% H_2O)
- Solutions, H/(U+Pu)   1500

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Dominant NCS Risks and Issues: Historic Risk

MOX Mass (kg) versus H/U+Pu

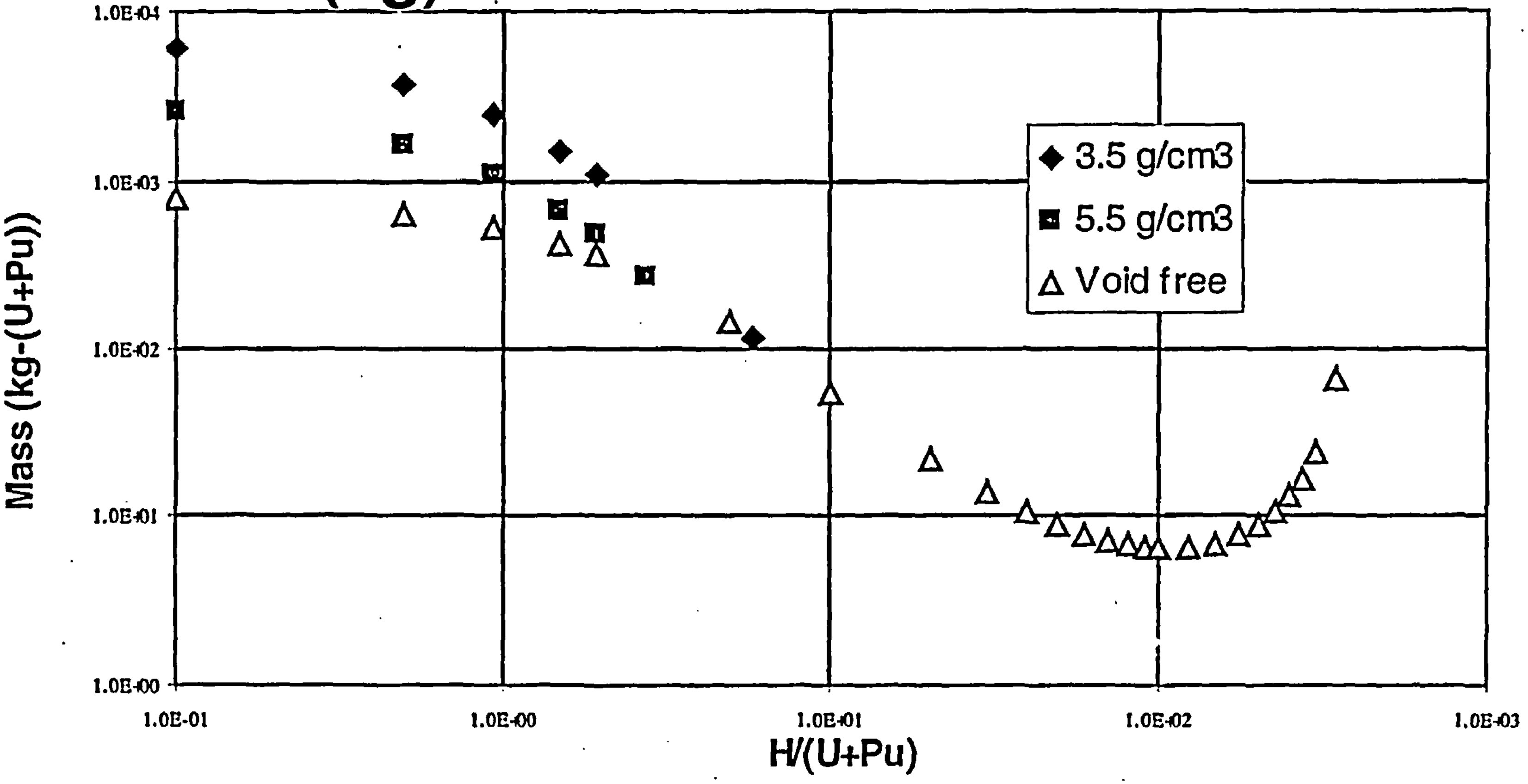

Figure A.2.c.6 U+Pu Mass (^{235}U/U=0.3%, ^{239}Pu/Pu=95%, Pu/(U+Pu) = 12.5%, Water reflector 30.0 cm)

Dominant NCS Risks and Issues: Historic Risk

- Particularly sensitive operations include:
  - ➢ Any operation that can lose geometry/volume control
  - ➢ Any operation that can lose moderation control
  - ➢ Ancillary equipment/operations that could accumulate critical quantities

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Dominant NCS Risks and Issues: Historic Risk

- Areas of highest NCS risk
  - ➢ Aqueous Polishing
  - ➢ Powder Handling
  - ➢ Blending
- Based upon "Unmitigated Risk"

Dominant NCS Risks and Issues

- Isotopics:
  - Analysis based on bounding assumptions
  - Changes during MOX Process (blending)
- Density:
  - Initially assumed full theoretical (11.46 g/cm^3)
  - Changes several times during process

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Dominant NCS Risks and Issues: Effect of Isotopic Blending of PuO_2 and UO_2

- Relative isotopics important to NCS
- Credited downstream of Blending
- Homogeneity of mixed oxides very important

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Dominant NCS Risks and Issues: Limited US Industry Experience

- Reprocessing:
  - Never had a MOX economy
  - Progress stopped mid-1970's (Presidential and Congressional decision to stop support of AGNES plant in Barnwell, SC)
  - Closure in mid-1980's of Idaho Chemical Processing Plant
- Pu processing:
  - Limited development work stopped mid-1970's
  - Some MOX fuel burned in US reactors

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Dominant NCS Risks and Issues: Meeting Performance Criteria

- Integrated Safety Analysis (NUREG-1513 and NUREG-1718)
- Application of the Double Contingency Principle (10 CFR Parts 70.4 and 70.64(a)(9))

Dominant NCS Risks and Issues: Criticality Code Validation

- Paucity of available experimental data
- Loss of experimental facilities
- Need for:
  - Increased flexibility
  - Increased fissile load
- Public attention to justifying margins of safety
- As operations move closer to upper subcritical limit (USL), scrutiny increases

Dominant NCS Risks and Issues: Criticality code validation

- Validation Requirements:
  - Determine calculational bias
  - Determine uncertainties
  - Establish area of applicability
  - Establish margin of subcriticality
  - Prepare a written report

(Reference: Section 4.3 of ANSI/ANS-8.1 - 1998.)

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End-of-Day 1 Questions-and-Answers Session

NRC FORM 8C
(7-94)
NRCMD 3.57

COVER SHEET FOR CORRESPONDENCE

USE THIS COVER SHEET TO PROTECT ORIGINALS OF MULTI-PAGE CORRESPONDENCE

NRC Review of the Mixed Oxide Fuel Fabrication Facility

Meeting with RF Gosatomnadzor
May 2003

Margaret S. Chatterton
U.S. Nuclear Regulatory Commission

Day 2 Agenda
NRC Regulatory Framework for NCS

- 10 CFR 70, Domestic Licensing of Special Nuclear Material
- NUREG-1718, Standard Review Plan for MOX Fuel Fabrication Facility
- American National Standards Institute (ANSI) / American Nuclear Society (ANS) Series 8 Standards
- NRC Regulatory Guide 3.71, Nuclear Criticality Safety Standards for Fuels and Materials Facilities
- Regulatory Differences Between MFFF and Traditional U.S. Fuel Cycle Facilities Licensed by NRC
- End-of-day Question-and-Answer Session

NRC Regulations Pertaining to MFFF

- 70.22 Contents of Applications
- 70.23 Requirements for the Approval of Applications
- 70.24 Criticality Accident Requirements
- 70.61 Performance Requirements
- 70.62 Safety Program
- 70.64 Basic Design Criteria
- 70.65 Integrated Safety Assessment
- 70.72 Change Process

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Nuclear Criticality Safety Regulations

- Criticality Accident Requirements: 70.24
- Performance Requirements: 70.61(b) and (d)
- Baseline Design Criteria: 70.64(a)(9)

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70.24 Criticality Accident Requirements

- Apply if amount of SNM exceeds
  - 700 gm Uranium 235
  - 450 gm Plutonium
- Qualified monitoring system
  - Gamma or neutron-sensitive radiation detectors
  - Audible alarms
  - Capable of detecting a criticality
  - Coverage by two detectors
- Emergency Procedures

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70.61 Performance Requirements

- 70.61(b) Criticality is Highly Unlikely
- 70.61(d) Under Normal and Credible Abnormal Conditions
  - All nuclear processes are subcritical
  - Including use of an approved margin of subcriticality
- Preventive controls and measures
  - Primary means of protection

70.64 New Facility and Process Requirements

- 70.64(a)(9) Double Contingency Principle
  - Two
  - Unlikely
  - Independent
  - Concurrent
  - Changes in process conditions
  - Before criticality possible

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Standard Review Plan (SRP) for the Review of an Application for a Mixed Oxide (MOX) Fuel Fabrication Facility: NUREG-1718

- Guidance for review and evaluation
  - ➢ Construction
  - ➢ Operational applications
    - » Possess special nuclear material (SNM)
    - » Use special nuclear material (SNM)
  - ➢ License amendments
  - ➢ License renewal applications

SRP for the Review of MFFF: NUREG-1718

- Ensures the quality and uniformity
- Improves communication and understanding of review and regulatory process
- Regulatory guidance for applicants and staff

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Contents of the SRP for MOX Facilities

- Purpose of the review
- Responsibility for the review
- Areas of review
- Acceptance criteria
- Review procedures
- Evaluation findings
- References

SRP for the Review of MFFF: NUREG-1718

- Purpose of Review
  - ➢ Organization for implementing NCS program
  - ➢ NCS program to ensure safe operation of facility
  - ➢ Adequate controls & limits on parameters
  - ➢ Accident sequences
    - » Identified in the Criticality Safety Evaluations (CSEs)
    - » Documented in the (Integrated Safety Analysis) ISA

SRP for the Review of MFFF: NUREG-1718

- Responsibility for Review
- Reviewers
  - Nuclear process engineer
  - Chemical safety reviewer
  - Project manager and fuel cycle inspector

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SRP for the Review of MFFF: Areas of Review

- Organization and Administration
  - Administrative organization of NCS program
    - Authority
    - Responsibilities
    - Experience and education required
- Management Measures
  - Management functions SRP Sections 15.1-15.8
  - Implementing requirements
    - 10 CFR 70.64 (Baseline Design Criteria)
    - 10 CFR 70.72 (Facility Change and Change Process)

SRP for the Review of MFFF: Areas of Review (continued)

- Technical Practices
  - NCS controls and limits
  - Adequate safety margin for limits on controlled parameters
  - NCS methods validated
  - Identification of NCS controls for each parameter
  - Safety basis documentation
  - Section 5.3 (ISA Summary) related to NCS
  - Operability of Criticality Accident Alarm System (CAAS) and emergency response procedures

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SRP for the Review of MFFF: NUREG-1718

- Acceptance Criteria
- Regulatory Requirements 10 CFR Part 70
  - 70.22, 70.24, 70.61, 70.62, 70.64, 70.65, 70.72, and Appendix A
- Regulatory Guide 3.71
  - “Nuclear Criticality Safety Standards for Fuels and Materials Facilities”

American National Standards Institute/American Nuclear Society 8 Series Standards (ANSI/ANS-8.xx)

- Consensus Standards Specific to Criticality Safety
- Developed by Working Groups
  - ➢ Industry Representatives
    - » NRC Licensees
    - » DOE Facilities
  - ➢ Regulatory Representatives
    - » NRC
    - » DOE

ANSI/ANS-8 Standards

- ANS Standards Subcommittee 8, “Operations with Fissionable Materials Outside Reactors”
  - National Standards
  - Prevention and mitigation of criticality accidents
- Standards approved by
  - ANS Committee N-16 (Nuclear Criticality Safety)
  - American National Standards Institute (ANSI)

ANSI/ANS-8 Standards

- NCS Standards contain
  - Introduction
  - Scope
  - Definitions
  - Criteria
  - References
  - Appendices
  - Tables
- Standards reviewed every 5 years

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ANSI/ANS-8 Standards

- Key words
  - Shall = requirement
  - Should = recommendation
  - May = permission

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ANSI/ANS Criticality Standards

- ANSI/ANS-8.1-1983 (Reaffirmed in 1988), "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors"
- ANSI/ANS-8.3-1997, "Criticality Accident Alarm System"
- ANSI/ANS-8.5-1996, "Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material"
- ANSI/ANS-8.6-1983 (Reaffirmed in 1995), "Safety in Conducting Subcritical Neutron-Multiplication Measurements In Situ"

ANSI/ANS Criticality Standards

- ANSI/ANS-8.7-1998, "Guide for Nuclear Criticality Safety in the Storage of Fissile Materials"
- ANSI/ANS-8.9-1987 (Withdrawn 2001), "Nuclear Criticality Safety Criteria for Steel-Pipe Intersections Containing Aqueous Solutions of Fissile Materials"
- ANSI/ANS-8.10-1983 (Reaffirmed in 1999), "Criteria for Nuclear Criticality Safety Controls in Operations With Shielding and Confinement"
- ANSI/ANS-8.12-1987 (Reaffirmed in 2002), "Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors"

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ANSI/ANS Criticality Standards

- ANSI/ANS-8.15-1981 (Reaffirmed in 1995), "Nuclear Criticality Control of Special Actinide Elements”
- ANSI/ANS-8.17-1984 (Reaffirmed in 1997), "Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors”
- ANSI/ANS-8. 19-1996, "Administrative Practices for Nuclear Criticality Safety"
- ANSI/ANS-8.20-1999, "Nuclear Criticality Safety Training"

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ANSI/ANS Criticality Standards

- ANSI/ANS-8.21-1995 (Reaffirmed in 2001), "Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors”
- ANSI/ANS-8.22-1997, "Nuclear Criticality Safety Based on Limiting and Controlling Moderators”
- ANSI/ANS-8.23-1997, "Nuclear Criticality Accident Emergency Planning and Response"

US NRC REGULATORY GUIDE 3.71: Nuclear Criticality Safety Standards for Fuels and Material Facilities

- Purpose
  - Provide guidance
  - Describe procedures
- Endorsement of specific standards
- Consolidates and replaces previous guidance
- Procedures & methodology generally acceptable

US NRC REGULATORY GUIDE 3.71 (Continued)

- Not substitute for NCS analysis
- Commitment to standard
  - ➢ All operations in accordance with requirements
  - ➢ Recommendations not followed; then justification

US NRC REGULATORY GUIDE 3.71 (Continued)

- **Deviations/Modifications from Standards**
  - **ANSI/ANS-8.1 Section 4.3.6 validation details**
    - Adequacy of margins of subcriticality
      - Bias
      - Criticality parameters
    - Demonstrate range of variables
    - Demonstrate trends in bias for extensions

US NRC REGULATORY GUIDE 3.71 (Continued)

- Deviations/Modifications from Standards
  - ➢ ANSI/ANS-8.3
    - » Section 4.2.1
      - – Standard - evaluation
      - – Regulatory Guide - requires
    - » Section 4.5.1
      - – Standard - 1 detector
      - – Regulatory Guide - 2 detectors
    - » Section 5.6
      - – Standard - documenting different minimum accident
      - – Regulatory Guide - specifies system requirements

US NRC REGULATORY GUIDE 3.71 (Continued)

- Deviations/Modifications from Standards
  - ➢ **ANSI/ANS-8.10**
    - » Section 4.2.1
      - – Standard - source strength and release estimates by analysis
      - – Regulatory Guide - specifies source strength and releases; less conservative requires justification
  - ➢ **ANSI/ANS-8.17**
    - » Standard - allows burnup credit
    - » Regulatory Guide - burnup credit only by measurement

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Regulatory Acceptance Criteria

- Organization and Administration
  - ➢ Commits to ANSI/ANS 8.1 and 8.19
  - ➢ NCS independent of operations
  - ➢ Commits to NCS postings
  - ➢ Commits to Policy, "All personnel shall report defective NCS conditions to the NCS function, directly or through a designated supervisor, and take no further action not specified by approved written procedures until NCS has analyzed the situation."
  - ➢ Commits to policy of instilling a safety ethic

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Regulatory Acceptance Criteria (Continued)

- Management Measures
  - Training
    - ANSI/ANS 8.19 and 8.20
    - Process variables if credited for NCS
    - Postings
  - Procedures
    - ANSI/ANS 8.19
    - Postings and procedures controls

Regulatory Acceptance Criteria (Continued)

- Management Measures
  - **Audits and Assessments**
    - » ANSI/ANS 8.19
    - » Annual reviews
    - » Committee to conduct and document NCS walkthroughs
      - – Weaknesses
      - – Corrective actions

Regulatory Acceptance Criteria (Continued)

- Technical Practices
  - **Analytical Methodology**
    - ANSI/ANS 8.1
    - Intent of Regulatory Guide 3.71 on validation report
      - Adequacy of subcritical margin
      - Determination of area of applicability (AOA)
      - Use of codes within AOA
      - Justification for extensions

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Regulatory Acceptance Criteria (Continued)

- Validation Report
  - **Documented, reviewed, and approved**
  - **Contents**
    - Description of theory
    - Description of AOA - range of values
    - Description of computer codes, assumptions, techniques
    - Description of verification of math operations
    - Description of benchmarks
    - Description of bias, uncertainty in bias, uncertainty in methods
    - Description of software and hardware

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Regulatory Acceptance Criteria (Continued)

- Validation Report
  - ➢ In configuration management program
  - ➢ Commits to perform NCS evaluations
  - ➢ Commits to assuming credible optimum conditions
  - ➢ Commits to variability and uncertainty in setting safety limits

Regulatory Acceptance Criteria (Continued)

- Additional technical practices
  - ➢ CSEs main source of adequate criticality controls
  - ➢ CSEs provide safety basis
  - ➢ Controls from CSEs are Items Relied on for Safety (IROFS) (ISA Summary)
  - ➢ Single NCS control maintains 2 or more parameters - considered only 1 component for DCP
  - ➢ Commits to "No single credible event or failure could result in a criticality accident."
  - ➢ Commits to preferred use of passive engineered controls

Regulatory Acceptance Criteria (Continued)

- Additional technical practices (continued)
  - ➢ Controls and control parameters into management measures
  - ➢ Commits to describing control parameters for each NCS process
  - ➢ Parameters controlled by measurement
    - » Reliable methods
    - » Reliable instruments

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Regulatory Acceptance Criteria (Continued)

- Methods of NCS control
  - Passive geometry preferred
  - Commitment to passive geometry whenever possible
  - Justification if not passive geometry
  - Controls to establish limits = IROFS
  - Interactions fully evaluated

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Regulatory Acceptance Criteria (Continued)

- Mass control
  - ➢ Mass limits for given weight percents
    - » Weight of material
    - » Physical measurements
  - ➢ Theoretical densities used
  - ➢ Measurements = instruments subject to Quality Assurance (QA)
  - ➢ Overbatching possible; single batch limited to largest overbatch safely subcritical
  - ➢ No overbatching; single batch limited to safely subcritical

Regulatory Acceptance Criteria (Continued)

- Geometry control
  - ➢ All dimensions verified
  - ➢ All credible transfers to unfavorable geometry
    - » Evaluated
    - » Controls (IROFS)
  - ➢ Large single units - conservative margin of safety
  - ➢ Mechanisms for change evaluated

Regulatory Acceptance Criteria (Continued)

- Density control
  - ➢ Process variable controls = IROFS
  - ➢ Process characteristics controlled
  - ➢ Measurements = instruments in QA

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Regulatory Acceptance Criteria (Continued)

- Isotopics control
  - Uranium enrichment, Plutonium concentration, ratio of Pu to U
  - Different isotopic mixtures
    - Label and segregate
    - Labels & postings - distinctive and clear
    - Based on dual independent sampling and analysis
  - Measurements = instruments in QA

Regulatory Acceptance Criteria (Continued)

- Reflection control
  - Wall thickness and reflecting material bounding
  - Minimal equivalent 1 inch tight filling water jacket
    - account personnel
    - transient incidental reflection
    - justified for less
  - Testable personnel barrier if loss of reflection control = criticality
  - Full water reflection = 12 inches water

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Regulatory Acceptance Criteria (Continued)

- Moderation control
  - Commits to ANSI/ANS 8.22
  - Process variable controls identified as IROFS
  - Measurements = instruments in QA
  - Design sufficient to preclude moderation
  - Sampling – dual independent
  - Firefighting procedures restrict moderators
  - Limits on firefighting agents in CSE and ISA
  - Favorable geometry drains

Regulatory Acceptance Criteria (Continued)

- Concentration control
  - Process controls identified as IROFS
  - Controls to preclude higher concentration
  - Tanks – closed and locked
  - Sampling – dual independent
  - If concentration only control for unfavorable geometry
    - Robustness of controls when transferring
    - Precautions to avoid precipitating agents
  - Surveillance ensures controls effectiveness
  - Measurements = instruments in QA

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Regulatory Acceptance Criteria (Continued)

- Interaction control
  - ➢ Engineered design with minimal spacing
    - » Structural integrity
    - » Periodic inspections
  - ➢ Spacing by procedures
    - » Postings
    - » Visual indicators – painted lines
    - » Justification required
  - ➢ Follow ANSI/ANS 8.7

Regulatory Acceptance Criteria (Continued)

- Neutron absorber control
  - ➢ Commits to ANSI/ANS 8.5 for Borosilicate-glass Raschig rings
  - ➢ Commits to ANSI/ANS 8.21 for fixed absorbers
- Heterogeneity control
  - ➢ Process variable controls IROFS in CSE and ISA
  - ➢ Computer models validated with benchmark experiments
  - ➢ Assumptions on physical scale based on observed physical characteristics

Regulatory Acceptance Criteria (Continued)

- Volume control
  - Geometric devices restrict SNM volume
  - Engineering devices limit SNM accumulation
  - Measurements = instruments in QA
  - Volume limited to % of critical volume
    - » Spherical geometry
    - » Optimal concentration
    - » Full water reflection

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Regulatory Acceptance Criteria (Continued)

- Subcriticality of operations
  - ➢ Commits to ANSI/ANS 8.1,8.5,8.7,8.9,8.10, 8.12, 8.15, 8.21 and 8.22
  - ➢ Justification for minimal subcritical margin
    - » Normal conditions
    - » Credible abnormal conditions
  - ➢ Rigorous definition of abnormal conditions
  - ➢ Less conservative margin commensurate with & offset by unlikelihood
  - ➢ Commits to K-subcritical = 1.0 – bias – margin

Regulatory Acceptance Criteria (Continued)

- **Subcriticality of operations (continued)**
  - **Commits to control parameter operating limits**
    - Adequate margin
    - Studies of sensitivity
  - **Subcritical limit calculations with AOA of method**
  - **Documentation in CSE**
  - **Benchmark experiments similar to applications**
    - Physical characteristics
    - Neutronic characteristics

Regulatory Acceptance Criteria (Continued)

- Baseline design criteria
  - Commits to double contingency principle
  - "Unlikely" consistent with ANSI/ANS 8.1
  - 2 parameter control preferred
  - Means for detecting and correcting failures
  - "Highly unlikely" –
    - Time interval to detect
    - Time interval to correct failure

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SRP for the Review of MFFF

- Review Procedures
  - ➢ Two step review process
    - » Construction Approval
    - » License to Possess and Use SNM

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SRP for the Review of MFFF

- **Acceptance review**
  - **Primary reviewer determines if application addresses areas of review**
- **Safety evaluation**
  - **Against acceptance criteria**
  - **Identify and resolve all issues**
    - Requests for Additional Information (RAIs)
    - Responses to RAIs
  - **Document findings in Safety Evaluation Report**

Regulatory Differences Between MFFF and Other Fuel Cycle Facilities Licensed by NRC

- New facility licensed under new Part 70
- Plutonium facility
  - 70.22(f)
  - 70.23 (a)(8) and (b)
    - Construction approval

NRC Regulatory Framework

- End-of-day Questions-and-Answers Session

NRC FORM 8C
(7-94)
NRCMD 3.57

COVER SHEET FOR CORRESPONDENCE

USE THIS COVER SHEET TO PROTECT ORIGINALS OF MULTI-PAGE CORRESPONDENCE

NRC Review of the Mixed Oxide Fuel Fabrication Facility

Meeting with RF Gosatomnadzor
May 2003

Dr. Christopher S. Tripp
U.S. Nuclear Regulatory Commission

Day 3 Agenda

- NRC Review of NCS Issues in the MFFF CAR
- End-of-day Question-and-Answer Session

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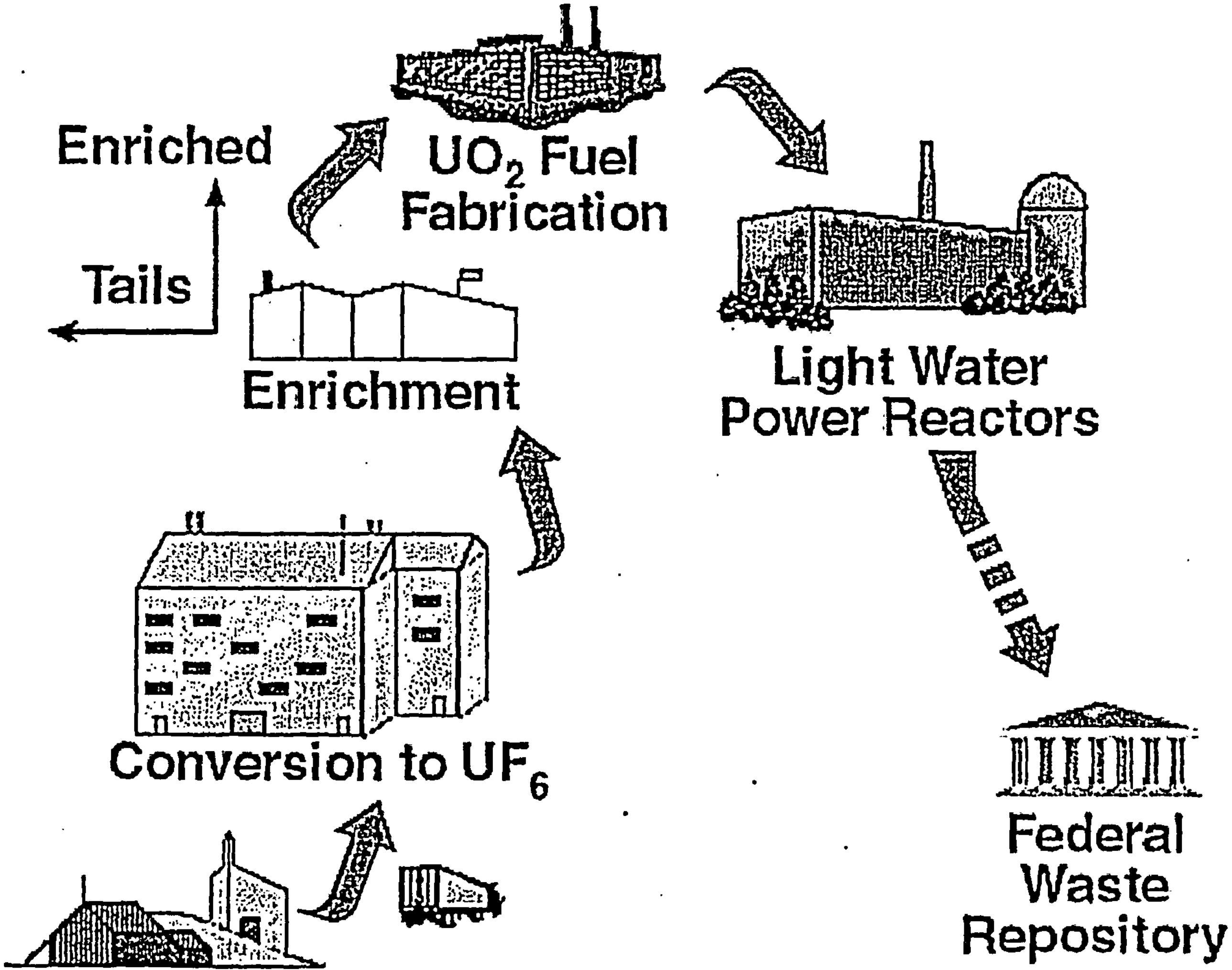
Overview of Current Fuel Cycle



UO_2 Fuel Fabrication

Light Water Power Reactors

Enriched

Tails

Enrichment

Conversion to UF_6

Uranium Mines & Mills

Federal Waste Repository

Process Familiarization

- Construction application for MOX had several unique aspects:
    - Little regulatory experience with MOX
    - First new application under 10 CFR Part 70
    - Unique aspects related to Pu-processing facility (70.23(b)).
    - Unique aspects related to new facility (70.64).

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Process Familiarization

- Training on MOX process at Los Alamos National Lab (LANL)
  - Pu metallurgy
  - Pu Chemistry
  - Fire Protection
  - Processing Methods
  - Confinement/Ventilation
  - Radiological, Chemical, and Nuclear Safety
- Site visits by technical reviewers, managers, and Project Manager
- Briefing by COGEMA on plans for U.S. facility

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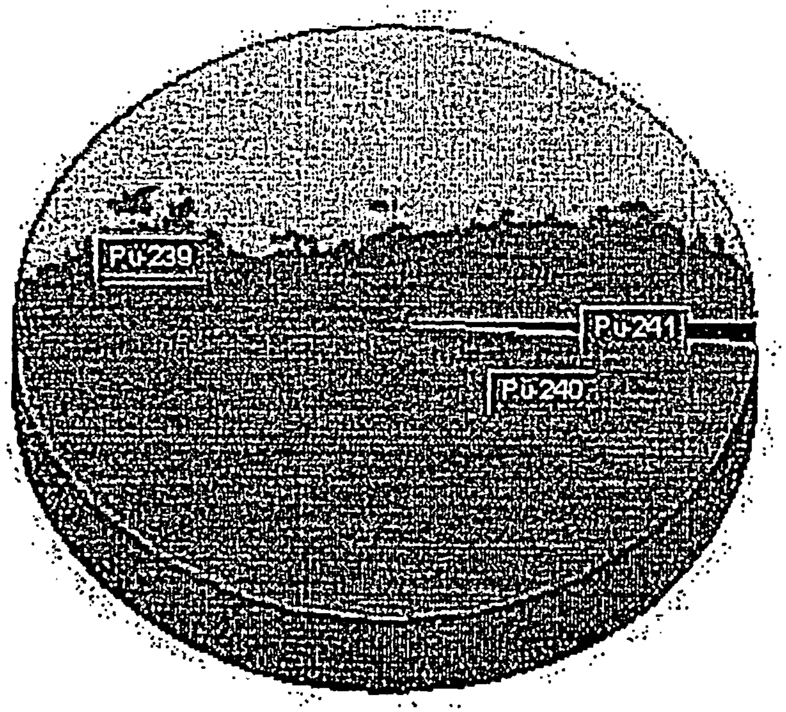
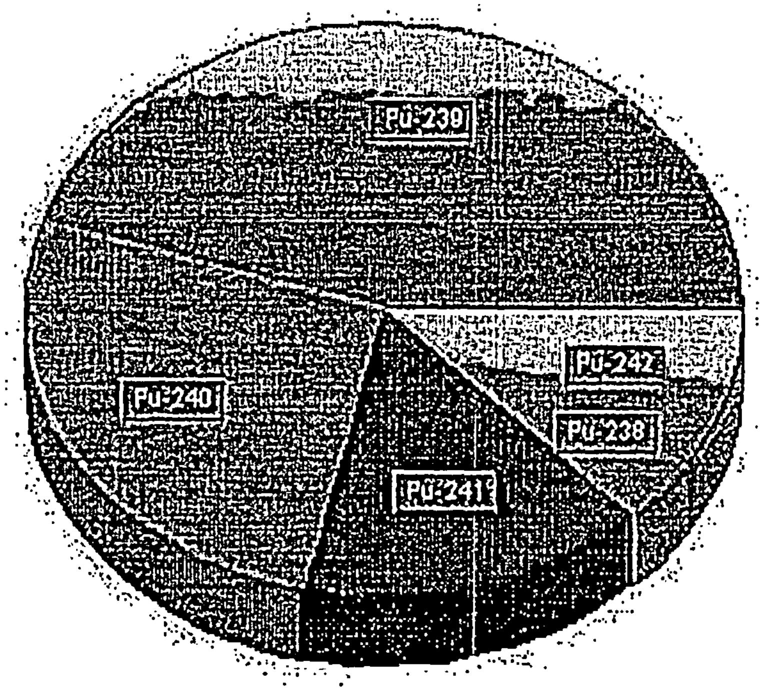
"Americanization" of MOX Fuel Cycle

- U.S. MOX Fuel Fabrication Facility (MFFF) a combination of following two processes:
  - LaHague: Aqueous Polishing of Spent Nuclear Fuel, Immobilization
  - MELOX: Fabrication of purified PuO_2 powder into MOX assemblies
- Use of weapons-grade vs. reactor-grade Pu:
  - Advantages: Fewer impurities, no need for hot cells & immobilization
  - Disadvantage: Less favorable isotopic mix for nuclear safety

Comparison of Weapons-Grade and Spent Fuel



Weapons-Grade Pu



Reactor-Grade Pu

Design Bases for the MFFF

- Fuel Facility Licensing (Part 70)
  - 50.4 definition of "Design Bases" not applied to most FF
  - Baseline Design Criteria (BDC) apply to new FF
  - Part 70 Performance-Based
  - Unique processes/designs
  - Unique license conditions
  - No Technical Specifications
  - No standard failure database

Design Basis of the MFFF

- “Reasonable assurance”: Not possible to guarantee acceptability without detailed process-specific information
- Burden on applicant to provide acceptable design at the OL stage. Must be in conformance with approved design bases
- Design basis = basis for the design. That information needed to provide reasonable assurance of an acceptable design

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Design Bases of the MFFF

- Proposed and justified design bases based on regulations
- Agreed upon in public meeting with DCS held January 2001
- 10 design bases for nuclear safety
- Mix of programmatic and technical design criteria (mostly qualitative)

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Design Bases Functions and Values

- Adherence to the DCP
- Required for new facilities
- Long a cornerstone of the U.S. approach to nuclear safety
- Similar to single-failure criterion:
  - Two or more failures needed for criticality accident
  - "Unlikely" (discussed in detail later)
  - Independent (statistically, $P_{AB} = P_A P_{A|B} = P_B P_{A|B}$)
  - Concurrent (not simultaneous occurrence; simultaneous failed state)

Design Bases Functions and Values

- Maximum k-effective, methodology for determining Upper Subcritical Limits
- Methodology for determining bias and uncertainty (validation)
- Choice of administrative margin
- USLs for normal and credible abnormal conditions

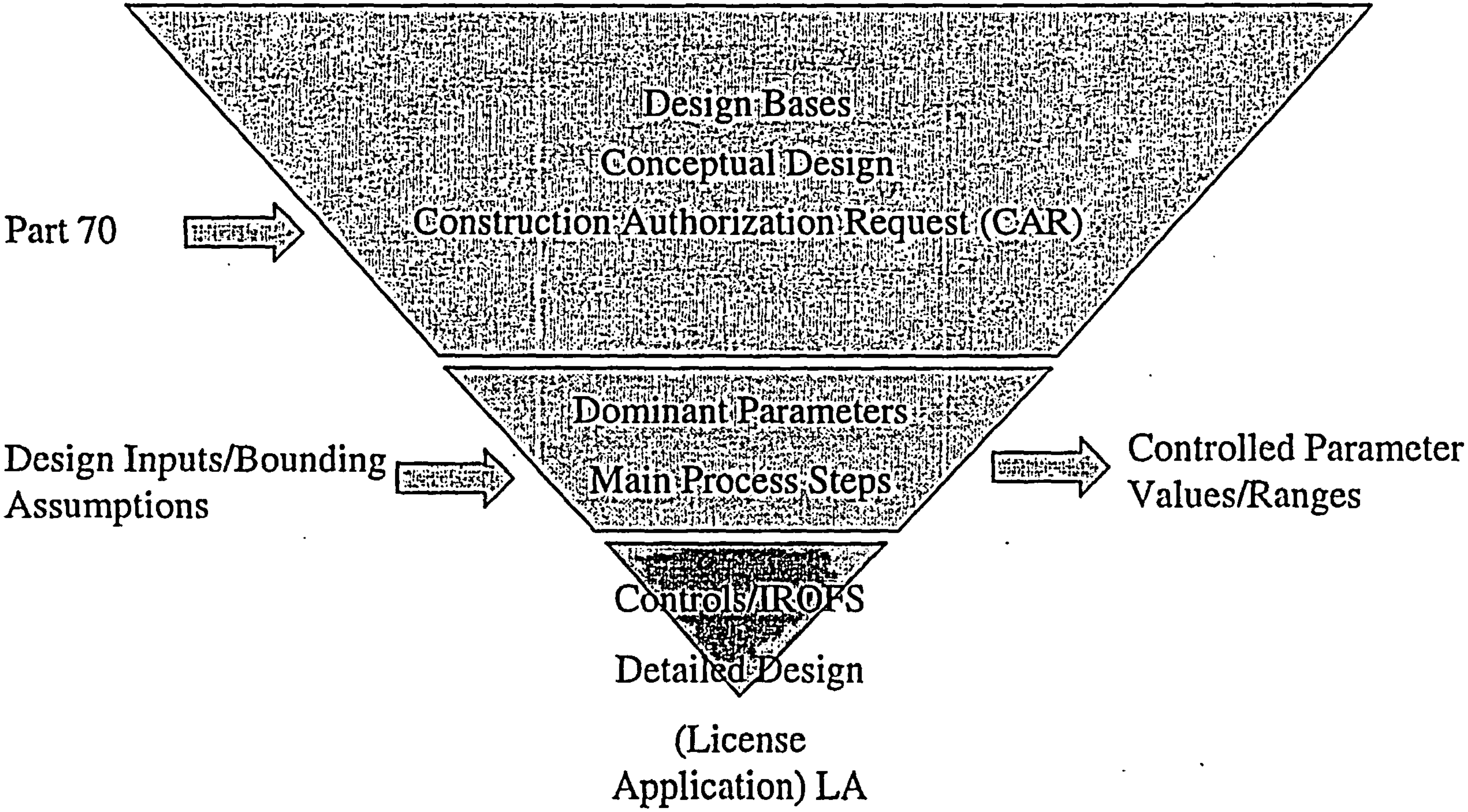
Design Bases Functions and Values

- Subcritical under normal and credible abnormal conditions
- Tied to specification of USLs
- Tied to DCP: “credible abnormal” = 1 contingency/control failure in accordance with DCP
- Requires worst-case upsets considered, shown subcritical

	Controlled Parameters	Uncontrolled Parameters
Normal	At safety limits	Worst-case
Abnormal	One parameter as worst-case at a time Rest at safety limits	Worst-case

Design Bases Functions and Values

- Dominant controlled parameters for each major process step



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Design Bases Functions and Values

- Dominant controlled parameters for each major process step
- Parameter Information contained in Tables 6-1 (AP) and 6-2 (MP)
- Reviewed to confirm that an appropriate design strategy used
- Bounding/input assumptions reviewed in CAR
- Subcritical limits derived during design reviewed in LA

Design Bases Functions and Values

- Preferred* design approach/control hierarchy
- Passive engineered (PEC)
- Active engineered (AEC)
- Enhanced administrative (EA)
- Simple administrative (SA)

---

* Expected in a majority of cases — deviations should be the exception, not the rule.

Design Bases Functions and Values

- Controlled parameter
  - Geometry/volume (with or without neutron absorber)
  - Mass
  - Moderation
  - Other controlled parameters...
- Double contingency implementation
  - Multi-parameter control (two or more changes in system parameters)
  - Single-parameter control (two or more changes in one system parameter)

Design Bases Functions and Values

- Criticality accident alarm system (CAAS)
- Management measures/safety grades
- Organization and administration of NCS Program:
- Roles and responsibilities during design phase
- Education/experience for NCS positions
- Key elements/functions of program

Design Bases Functions and Values

- Technical practices, related to:
- Deriving subcritical limits
- Factors to be considered for different control modes
- Compliance with ANSI/ANS-8 Series standards
- Documentation of criticality evaluations

Design Bases Functions and Values

- Approach to balancing fire and nuclear safety risks:
- Fire impact on nuclear safety
- Nuclear safety impacts on fire
- ISA will consider cross-discipline safety risks; overall risk to workers must be minimized.
- Moderating fire suppression agents will not be used in moderation-control areas

Chronology of NRC Review

- Determination of design bases in each safety discipline – Jan 2000
- Review of CAR against acceptance criteria in the SRP – Feb 2001
- Formulation of questions (screened for relevance to design basis)
- Issuance of request for additional information (RAI) – June 2001
- Receipt of RAI responses – August 2001

Chronology of NRC Review (continued)

- Formulation of additional questions based on responses
- Communication of additional questions by telephone calls and meetings
- Receipt and review of subsequent responses in “clarification letters” – Nov. 2001 – March 2002
- Writing/issuing the draft safety evaluation report (SER), including categorizing remaining questions into a discrete list of open issues - Apr 2002

Chronology of NRC Review (continued)

- Telephone calls and meetings to resolve open issues
- Review of validation report
- Review of revised CAR – Oct 2002
- Telephone calls and meetings to resolve open issues
- Revised validation reports submitted – Jan 2003
- Writing and issuing revised draft SER – Apr 2003

NCS Review of the CAR

- CAR submitted February 2001
- Followed SRP format (August 2000)
- Organization and Administration
    - Location of Nuclear Safety organization in corporate structure
    - Roles and responsibilities
    - Education and experience levels for NCS positions

NCS Review of the CAR

- Main issues with Organization/administration:
  - ➢ Roles and responsibilities originally only defined for the operations phase
  - ➢ Little justification given for experience levels of NCS positions
  - ➢ No mention of specific MOX/Pu experience (NCS-1)

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NCS Review of the CAR

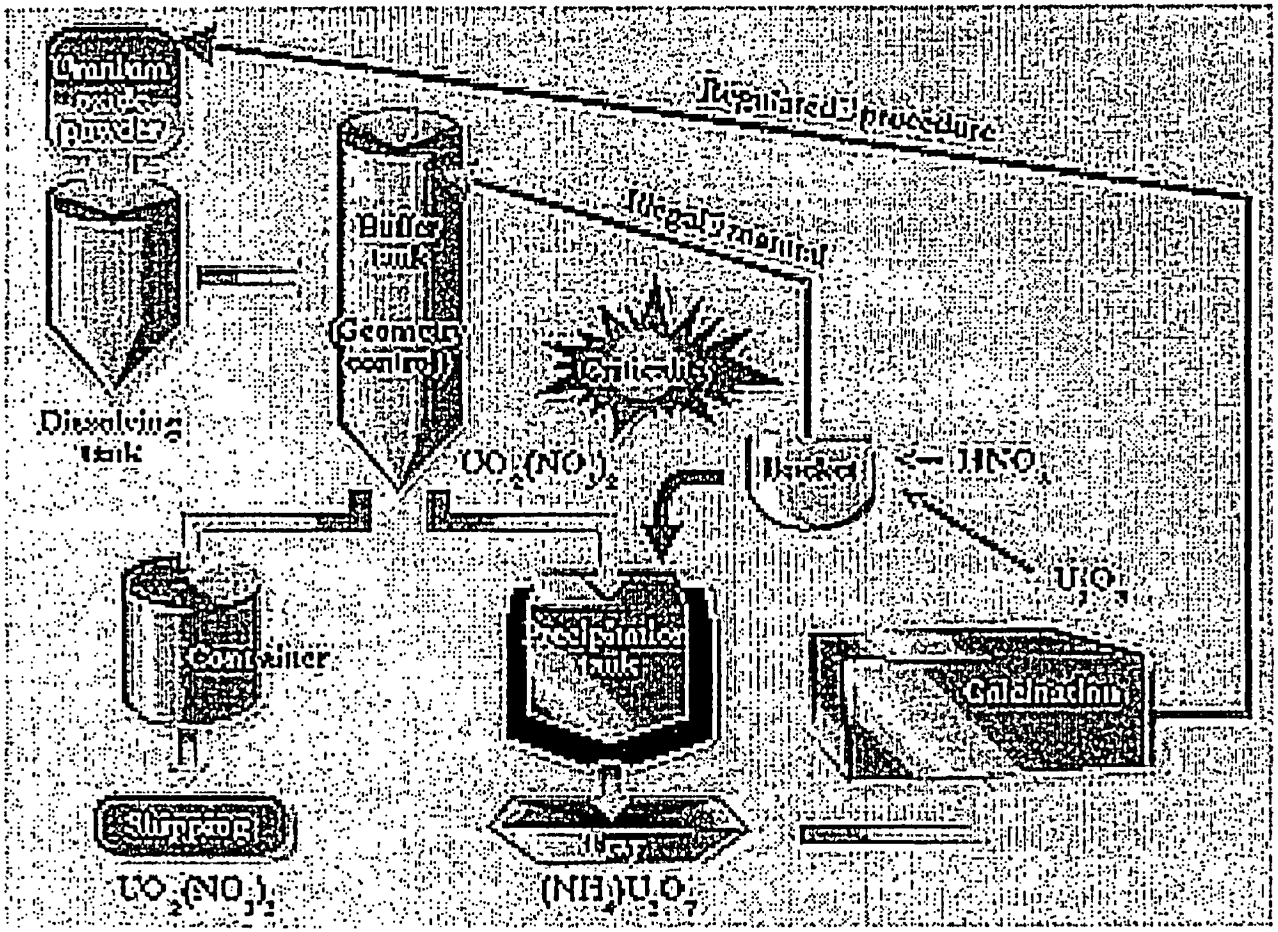
- Management Measures for the MFFF (Chapter 14)
  - Configuration Management
  - Maintenance
  - Training
  - Procedures
  - Audits/Assessments
  - Incident Investigation
  - Records Management

NCS Review of the CAR

- Configuration Control
  - ➢ Control of safety basis documents
  - ➢ Control of process equipment
  - ➢ Control of safety controls
  - ➢ Includes <u>change control</u> ensures changes are not made that invalidate safety basis; compliance of "as-built" process with safety basis

Importance of Maintaining Configuration Control

Ex: 1999 Tokai-mura criticality accident



Regulatory Role of Validation Reports

- SRP Section 6.4.3.3.1: "As part of providing reasonable assurance that an adequate margin of subcriticality has been provided...the applicant has, at the facility, a documented, reviewed, and approved validation report...The validation report should contain the following..."
    - ➢ Description of the theory of the methodology
    - ➢ Description of the area(s) of applicability (AOA)
    - ➢ Description of benchmark experiments
    - ➢ Bias and uncertainty in: bias, methodology, data, and margin of subcriticality

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Regulatory Role of Validation Reports (continued)

- Validation report submitted separately from CAR. Schedule:
    - Part I: June 2001
    - Revised Part I and Initial Part II: Dec 2001
    - Revised Parts I and II, Initial Part III: Jan 2003
- Plant is divided into 5 different AOAs
    - AOA(1): Pu nitrate solutions
    - AOA(2): MOX fuel pellets, rods, and assemblies
    - AOA(3): PuO2 powder
    - AOA(4): MOX powder
    - AOA(5): Pu solution compounds (oxalates, fluorides, etc.)

Content of Validation Reports

- AOA addressed by the report
- Description of the calculational method:
  - Computer code and version (code, cross section libraries)
  - Cross-section libraries to be used
  - Hardware platform
- Description of the code validation methodology
- Description of anticipated MOX design applications covered by the report

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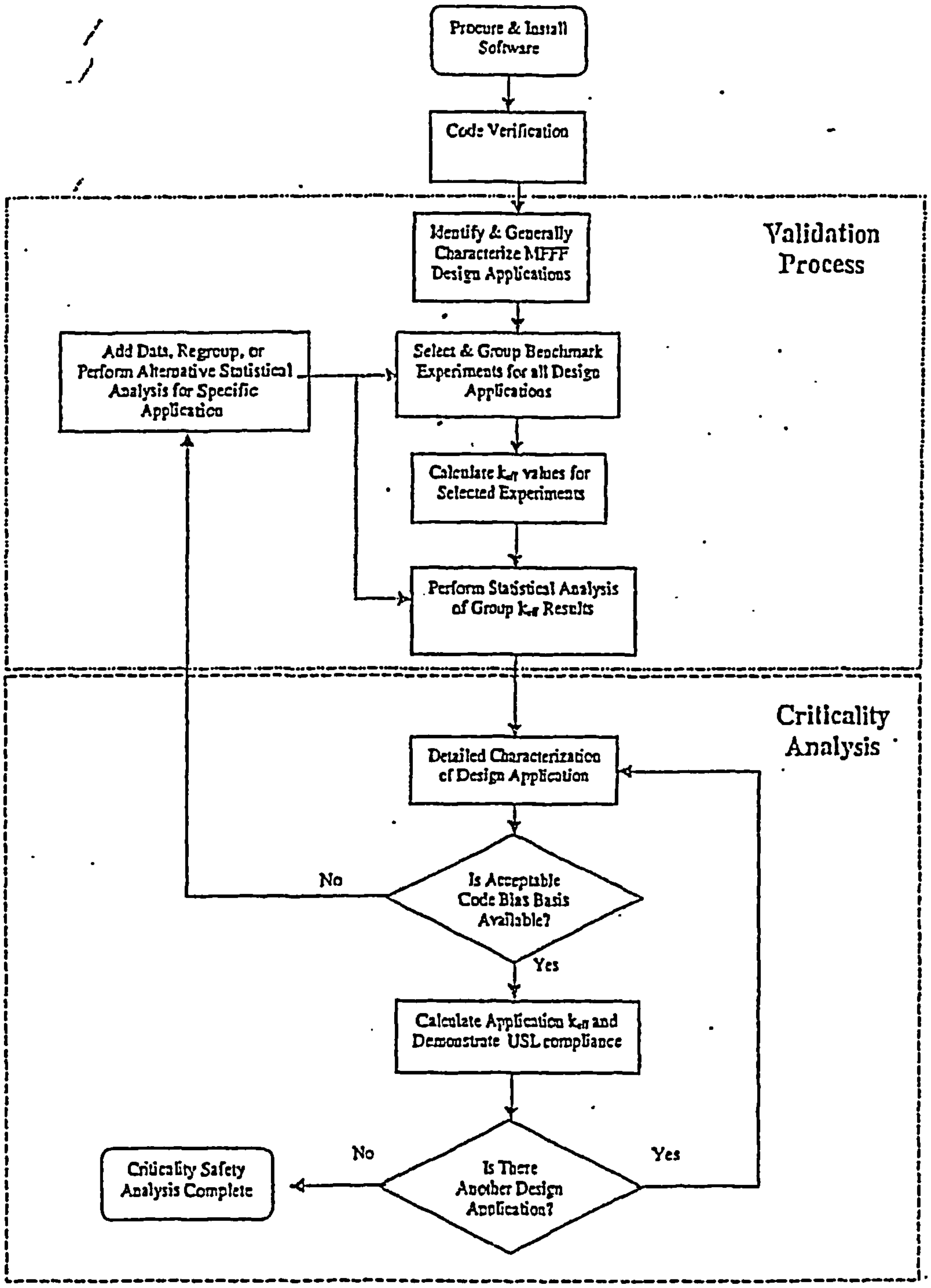
Content of Validation Reports

- Description of benchmark experiments
- Analysis of the validation results:
  - Calculated k-eff and standard deviations
  - Results of the statistical methodology
  - Result of trends to determine larges bias/uncertainty across the AOA
  - Determination of the USL
- Justification of the chosen “administrative margin”

Content of Validation Reports



Procure & Install Software

Code Verification

Validation Process

Identify & Generally Characterize MFFF Design Applications

Add Data, Regroup, or Perform Alternative Statistical Analysis for Specific Application

Select & Group Benchmark Experiments for all Design Applications

Calculate k_{eff} values for Selected Experiments

Perform Statistical Analysis of Group k_{eff} Results

Criticality Analysis

Detailed Characterization of Design Application

Is Acceptable Code Bias Basis Available?

No

Yes

Calculate Application k_{eff} and Demonstrate USL compliance

Is There Another Design Application?

No

Yes

Criticality Safety Analysis Complete

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Content of Validation Reports

- Identify and Characterize Design Applications
  - Described chemical form, reflection, moderation, isotopic range, density, geometric shape, neutron energy by process area
  - Described for anticipated normal and abnormal conditions
- Select and Group Benchmark Experiments
  - Generally from the International Handbook of Criticality Safety Benchmark Experiments (ICSBEP) Handbook
  - Choose systems with similar physical and neutronic characteristics

Content of Validation Reports

- Code Validation Methodology
  - NUREG/CR-6361 contains two statistical methods
  - Statistical analysis—ORNL code USLSTATS
  - Both methods require normally distributed data
  - If <25 benchmarks, statistical techniques cannot be used

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Content of Validation Reports

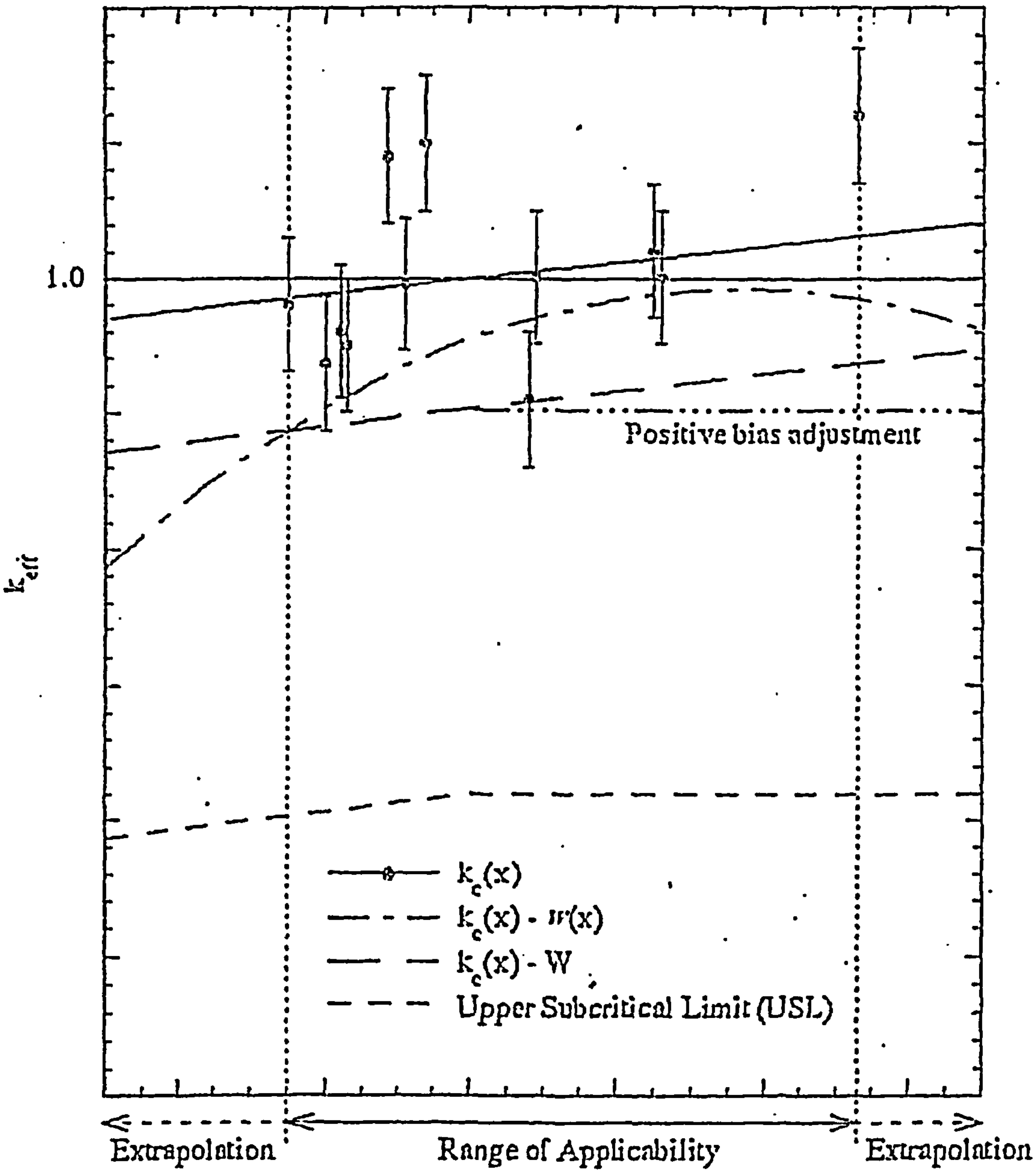
- Method 1: “Confidence Band with Administrative Margin”
  - Linear least-squares approach to calculate bias
  - Constant width confidence band at 95% confidence level
  - Arbitrary administrative margin ?k_m

$$w(x) = t_{1-\gamma} S_P \sqrt{1 + \frac{1}{n} + \frac{(x - \bar{x})^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2}}$$

$$W = \max(w(x) \mid x_A \leq x \leq x_B)$$

$$USL_1 = 1 + \beta(x) - \Delta k_M - W$$

Content of Validation Reports



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Content of Validation Reports

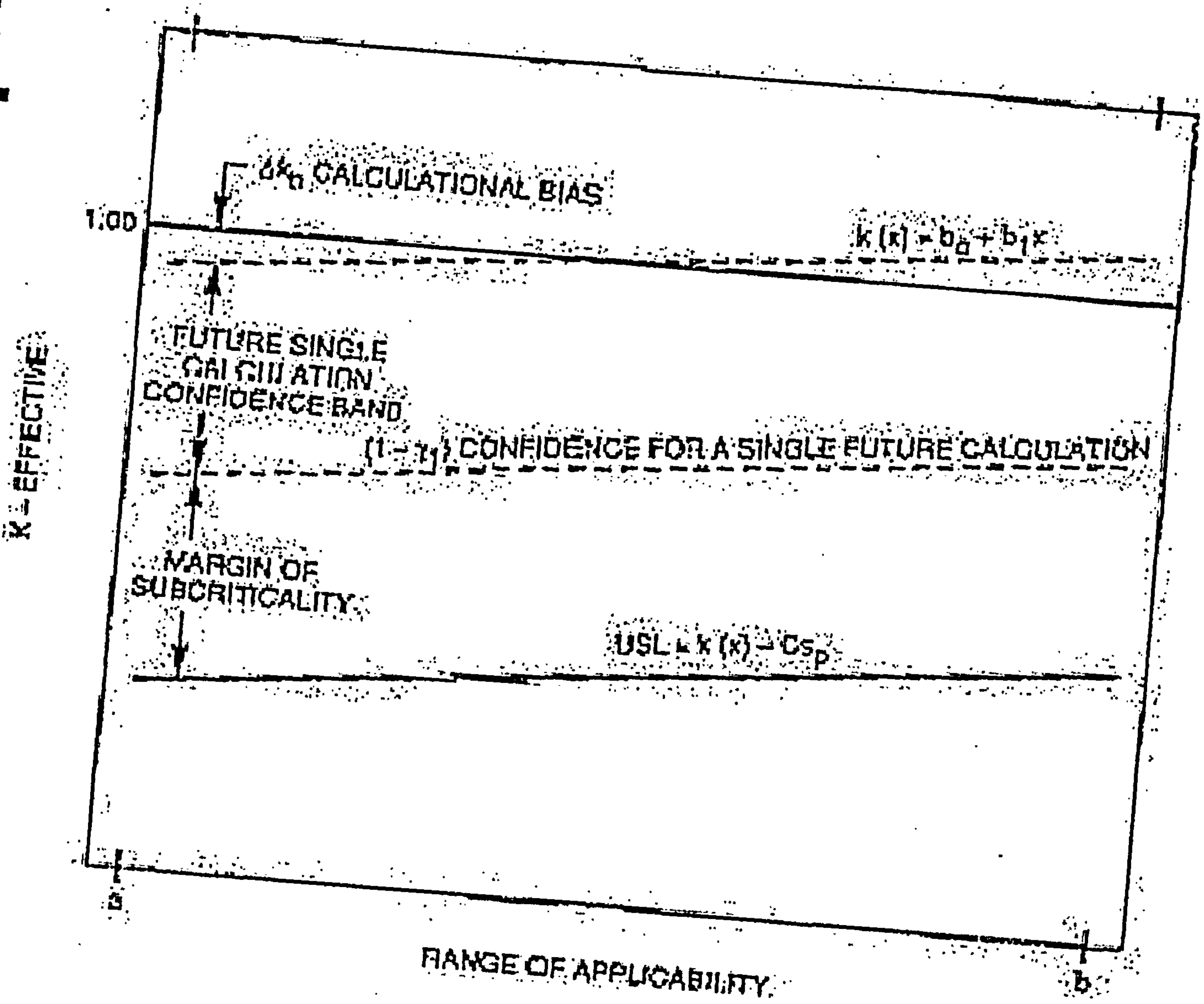
- Method 2: "Single-Sided Uniform Width Closed Interval Approach/Lower Tolerance Band"
  - Combined lower tolerance band with subcritical margin
  - Determines tolerance band

$$USL_2 = 1 + \beta(x) - C_{\alpha/P} S_P$$

$$S_P^2 = S_{k(x)}^2 + \frac{1}{n}\sum_{i=1}^{n} \sigma_i^2$$

S_k^2 = variance of regression fit (without variance)
σ_i^2 = variance of individual data point (within variance)
P = proportion of all future critical calculations (99.5%)
α = confidence (95%)
$C_{\alpha/P}$ = statistical multiplier

Content of Validation Reports



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Content of Validation Reports

- Upper Safety Limit USL-2 normally significantly lower than USL-1 without additional margin ?k_m
- USLSTATS allows user to select administrative margin (Method 1)
- Necessary but not sufficient test for acceptability of ?k_m:

USL-1 (with margin) < USL-2

Content of Validation Reports

- Non-normally distributed data: Non-Parametric Margin (NPM)
  - Confidence β that a fraction q of critical systems above limit:

    $\beta = 1 - q^N$ (N data points)
  - Lowest k-effective in data set used, with margin based on β
- If k-eff of experiment is not exactly 1, calculated value of k-eff is normalized to k=1
- Positive corrections to the bias not allowed

Content of Validation Reports

- Bias:
  - ➢ Determined as function of most important parameters of the system
  - ➢ Includes:
    - » Neutron energy (Energy of Average Lethargy Causing Fission, EALF)
    - » Moderation (H/X or v^m/v^f)
    - » ^{240}Pu content
    - » Pu/(U+Pu) content

Contents of Validation Reports

- Justification of administrative margin used:
  - $?k_m=0.05$ assumed for all cases
  - Fuel cycle and nuclear industry practice (comparison of licensing basis across NRC licensees and DOE facilities)
  - Comparison of statistical methods. USL-1 (with 0.05) < USL-2

Issues with Validation Reports

- <u>Choice of the minimum subcritical margin</u> ?k_m
  - ➢ **Wide variation in industry, little guidance**
  - ➢ **Compared MOX plant to HEU facilities**
    - » HEU & Pu plants show high sensitivity of k-eff to changes in underlying data, system parameters
    - » Unknown or unquantified uncertainties can have large impact on bias
    - » MOX-portion of plant (i.e. <6.3wt% Pu) was more similar to LEU plants

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Issues with Validation Reports

Licensee/Certificate Holder	Normal Conditions	Credible Abnormal Conditions
High Enriched Uranium Facilities		
BWXT Lynchburg, VA	$K \leq 0.94$ ($\leq$ 10wt% U-235); ≤ 0.92 (> 10wt% U-235)	$K \leq 0.97$ ($\leq$10wt% U-235); ≤ 0.95 (>10wt% U-235)
NFS Erwin, TN	$K + 2\sigma - \text{bias} \leq 0.90$	$K + 2\sigma - \text{bias} \leq 0.95$
Gaseous Diffusion Plant Facilities		
USEC Paducah, OH	$K \leq 0.9634$ (includes bias, uncertainty, Δk_m)	Same as normal
USEC Portsmouth, OH	$K \leq 0.9605$ (includes bias, uncertainty, Δk_m)	Same as normal
Low Enriched Uranium Facilities		
Framatome ANP Lynchbrug, VA	$K + 2\sigma - \text{bias} \leq 0.87$	$K + 2\sigma - \text{bias} \leq 0.95$
Framatome ANP Richland, WA	$K = K_{calc} - 2\sigma - \text{bias} - 0.05$	$K = K_{calc} - 2\sigma - \text{bias} - 0.03$
Global Nuclear Fuels Wilmington, NC	$K + 3\sigma - \text{bias} \leq 0.97$	Same as normal
Westinghouse Columbia, SC	$K + 2\sigma + \text{bias} + \text{uncertainty} \leq 0.95$	$K + 2\sigma + \text{bias} + \text{uncertainty} \leq 0.98$
Westinghouse Hematite, MO	$K \leq 0.95$ (includes bias and uncertainty)	Same as normal

Issues with Validation Reports

- ?k_m = 0.05 acceptable for finished MOX (AOA(2)):
  - Low ^{239}Pu content (lower sensitivity)
  - MOX fuel neutronically well-characterized for use in reactors
  - Material inherently low-risk due to fixed configuration
  - Chosen benchmarks unusually close in terms of configuration to anticipated applications (fuel rod lattices)
  - Most of these benchmarks are well-moderated
- ?k_m = 0.05 accepted for abnormal case
- Lower normal case limit deemed appropriate, margin depends on sensitivity of system changes in k-eff

Issues with Validation Reports

- Why arguments for choosing subcritical margin not accepted by NRC:
  - Historical practice HEU facilities, most similar to most of MOX (lower limit in normal case)
  - Comparison of USL-1 and USL-2 Method-2 contains additional statistical uncertainties not included in Method-1, but...
    - » USL-1 (with ?k_m) < USL-2 necessary, but not sufficient, to show ?k_m acceptable
    - » Possibly other systematic (non-statistical) uncertainties that cannot be determined by comparing two statistical techniques

Issues with Validation Reports

- Insufficient benchmark data to apply statistical techniques
- <25 benchmarks in some cases applicability of Methods 1 and 2 was questionable
    - ➢ In original validation, only 14 benchmarks for AOA(4) (MOX powders)
    - ➢ AOA(1) had 182 and AOA(3) had 46, but these two did not pass the chi-squared test for normality

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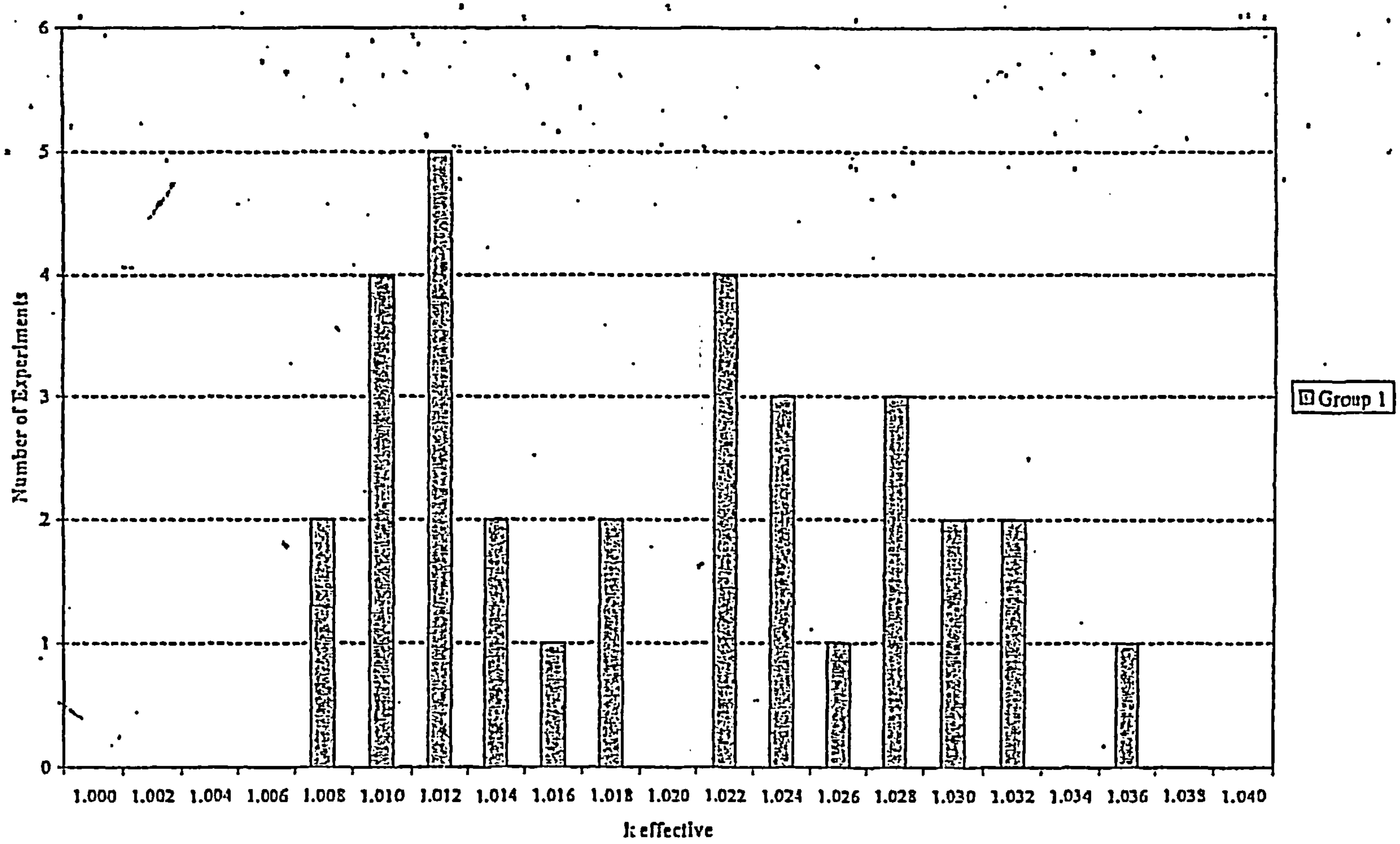
Issues with Validation Reports



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Issues with Validation Reports

- Several changes made to the validation:
  - Significantly more benchmarks (66 instead of 14 for AOA(4))
  - Use of NPM in computing results for AOA(1),(3), and (4)
  - Use of Sensitivity/Uncertainty (S/U) codes from ORNL to identify additional benchmarks in AOA(3) and (4)

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Issues with Validation Reports

- **Area of applicability compared to range covered by benchmarks**
  - **AOA consisted of identifying range of parameters over which code was valid:**
    - Fissile form (chemical composition, physical form, densities, etc.)
    - Materials of composition (including strong absorbers, reflectors, moderators)
    - Neutron energy range
    - Neutron moderation (strongly correlated to neutron energy)
    - Isotopic nature (^{240}Pu, Pu/(U+Pu))

Issues with Validation Reports

- Should also include code options:
  - Number of neutron generations, neutrons per generation required for convergence
  - Variance reduction techniques
  - Cross-section treatments (albedos, biasing/variance reduction, etc.)
- Definition of AOA in Part III not clear (range of neutron energy and moderation, material forms)

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Issues with Validation Reports

- <u>AOA exceeded range of parameters covered by benchmarks</u> (significantly in some cases):
  - ➢ <u>AOA(2)</u>: benchmarks up to 0.91eV EALF; design applications up to 1eV
  - ➢ <u>AOA(3)</u>: benchmarks down to 1eV; design applications down to 0.05eV
  - ➢ <u>AOA(4)</u>: benchmarks up to 210 H/Pu; design applications up to 1900 H/Pu

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Issues with Validation Reports

- AOA(4): benchmarks up to 210 H/Pu; design applications up to 291 H/Pu
- AOA(5): benchmarks down to 0.135eV; design applications down to 0.1eV*
- AOA(5): benchmarks up to 858 H/Pu (and none in range of 49.6 to 78); design applications up to 83000 H/Pu*

---

* Based on worst-case comparison of several tables; some internal disagreement

Issues with Validation Reports

- Shortcomings with respect to materials included in benchmarks:
  - AOA(1), (3), and (5): No cases with Cadmium or Borated Concrete
  - AOA(2): No cases with Borated Shield (composition unknown) or Concrete
  - AOA(4): No cases with Water or Concrete (benchmarks had plexiglass)

Issues with Validation Reports

Table showing comparison of design applications and benchmarks for different AOAs (**bold** = areas of disagreement)

	AOA	Description	Exp.	H/Pu or vm/vf	EALF (eV)	240Pu wt%	PuO2 wt%	Absorbers/Reflectors
Design	1	Pu nitrate solutions		100-200	.14-.25	4	100	Cd/water, Borated Concrete
Bench.			191	85-1157	.05-.55	.54-4.67	100	Cd/water, Concrete
Design	2	MOX pellets, rods, assemblies		1.9-10	.1-1	4	2-6.3	Water, Concrete, Borated shield
Bench.			36	1.1-10.75	.08-.91	8-22	1.5-6.6	Water
Design	3	PuO2 powder		.3-1900	.05-65keV	4	100	Water, Cd, Borated Concrete
Bench.			90	0-210	1-1MeV	2.2-20.2	100	Water, Plexiglass
Design	4	MOX powder		1.6-291	.8-317	4	6.3-22	Water, Concrete
Bench.			66	0-210	.6-1740	2.2-11.6	1.5-100	Plexiglass
Design	5	Pu compound solutions		5.973-83k	.1-67	4	100	Pu(C2O4)2, PuO2F2 Water, Cd, Borated Concrete
Bench.			119	.04-858	.135-4900	2.2-18.35	100	PuO2, PuN Water, Plexiglass

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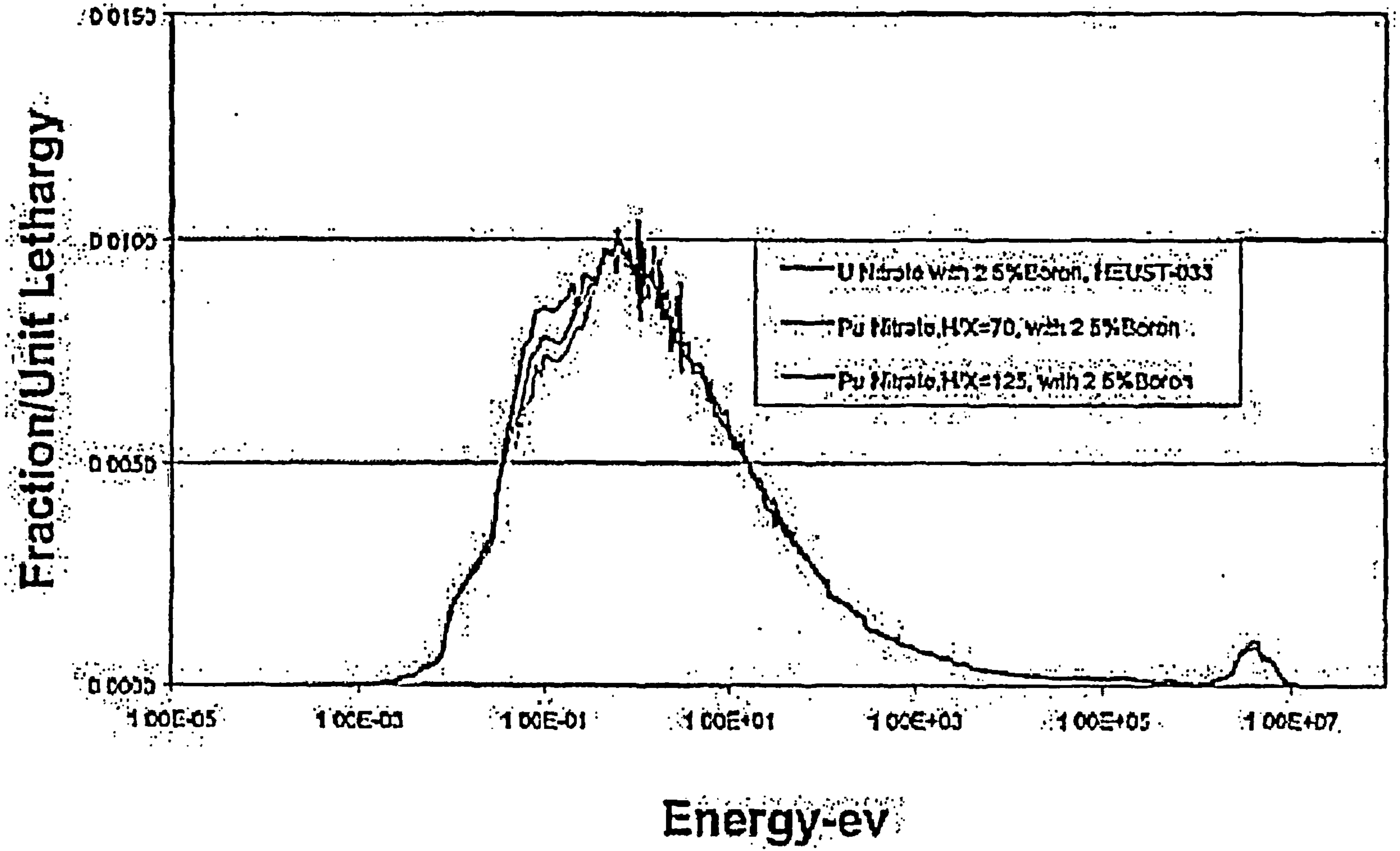
Issues with Validation Reports

- Different approaches to lack of benchmark data in each Part of Validation Report.

<u>Part I:</u>

- Lack of Pu-Nitrate benchmarks with strong absorbers, but...
- U-Nitrate benchmarks with strong absorbers
- Tried to show:
  - ➢ UN systems applicable to PuN systems, because absorbers had similar neutron absorption spectra
  - ➢ Boron and cadmium had little effect on the bias

Issues with Validation Reports



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Issues with Validation Reports

- Not sufficient because:
  - ➢ Comparison of boron absorption spectra only shows part of story, doesn't consider other neutron reactions
  - ➢ Method of substituting of Pu for U not well-described
  - ➢ Study done at very thermal energies, where the source spectrum dependencies largely forgotten
  - ➢ Insufficient benchmarks to demonstrate lack of bias dependency of strong absorbers (boron, cadmium)

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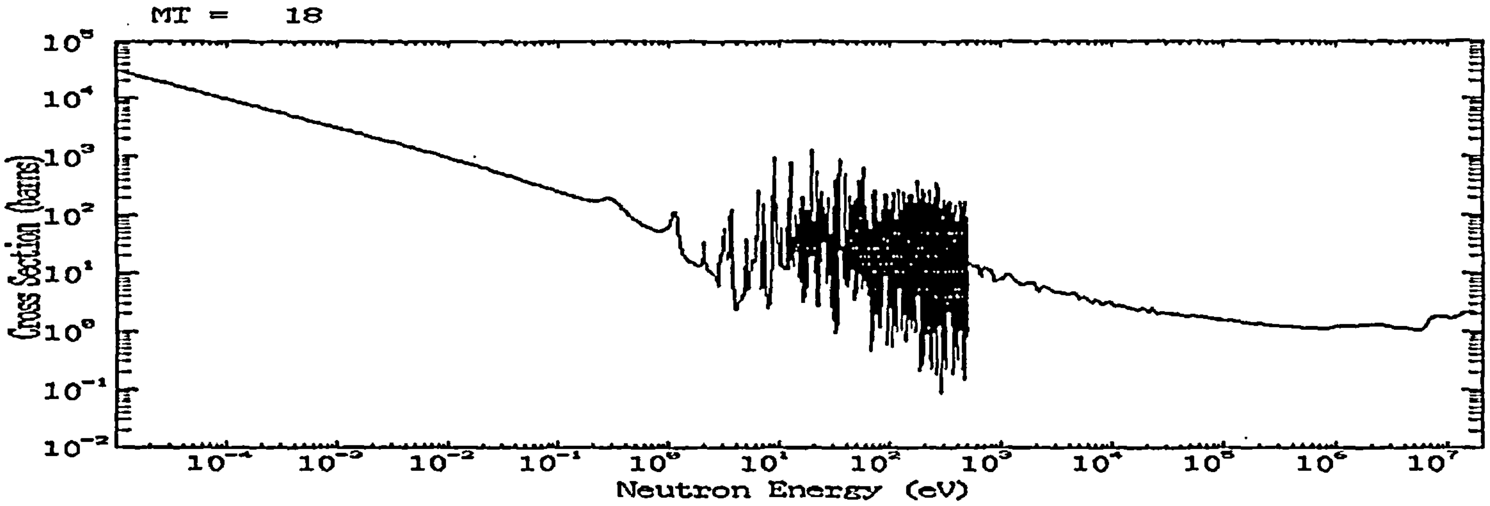
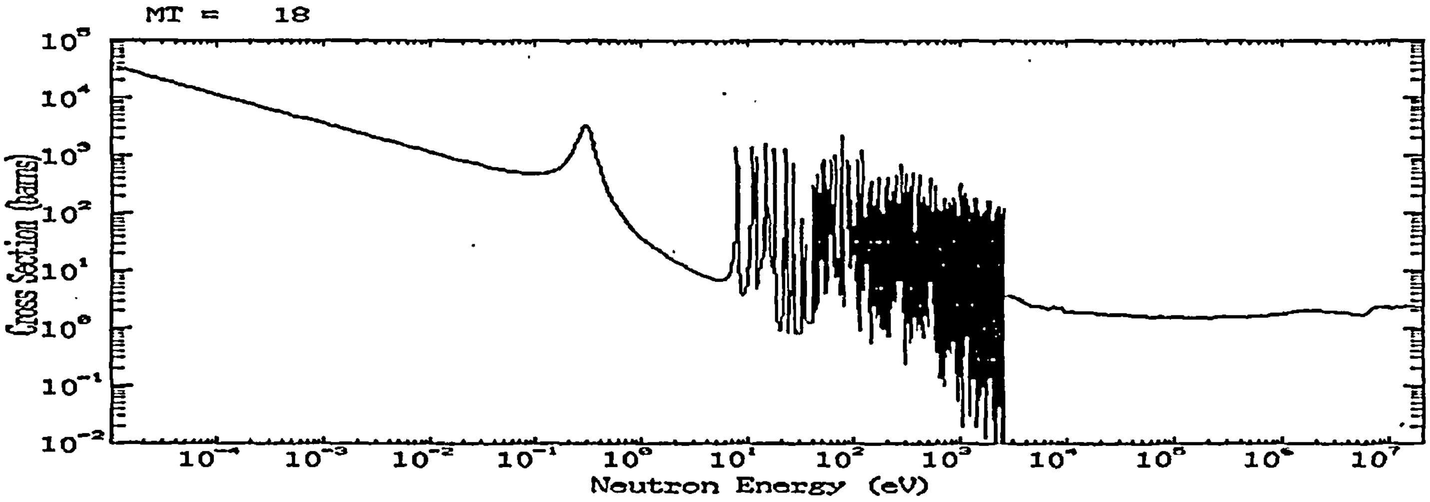
Issues with Validation Reports





Issues with Validation Reports

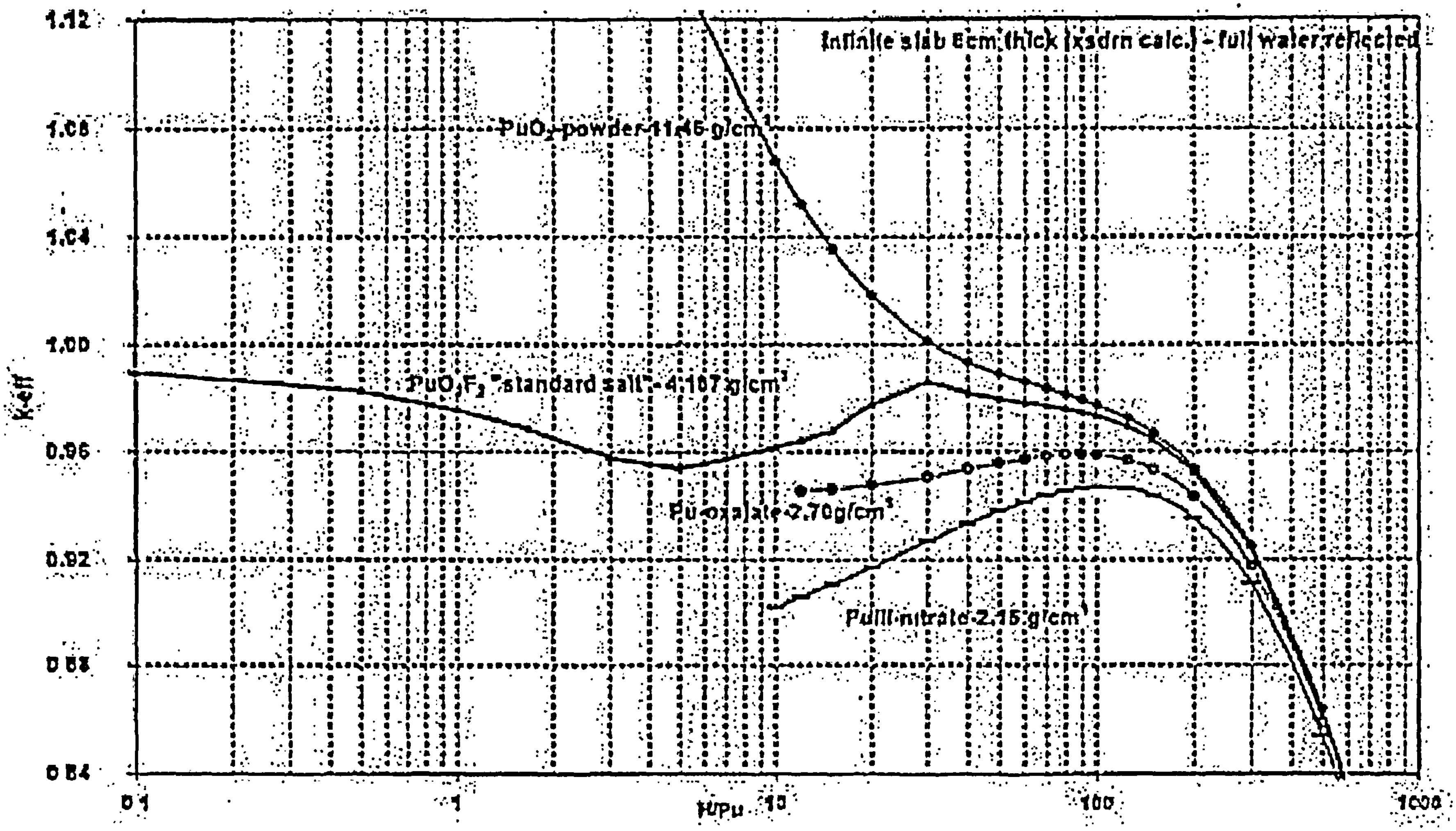
Part III: Basic approach:

(1) Show that reference fissile materials (PuO_2, PuO_2F_2) bound the various aqueous solutions of Pu compounds

(2) Show that the chosen benchmarks (PuO_2-polystyrene and Pu Nitrate) are applicable to validate bounding materials in AOA(5)

- Benchmarks divided into two groups, to cover high and low H/Pu range
  - Group 1 = PuO_2-polystyrene blocks covering 0.685-49000eV (0.04-49.6 H/Pu) range (used in AOA(3))
  - Group 2 = PuN solutions covering 0.135-0.551eV (78-858 H/Pu) range (used in AOA(1))

Issues with Validation Reports



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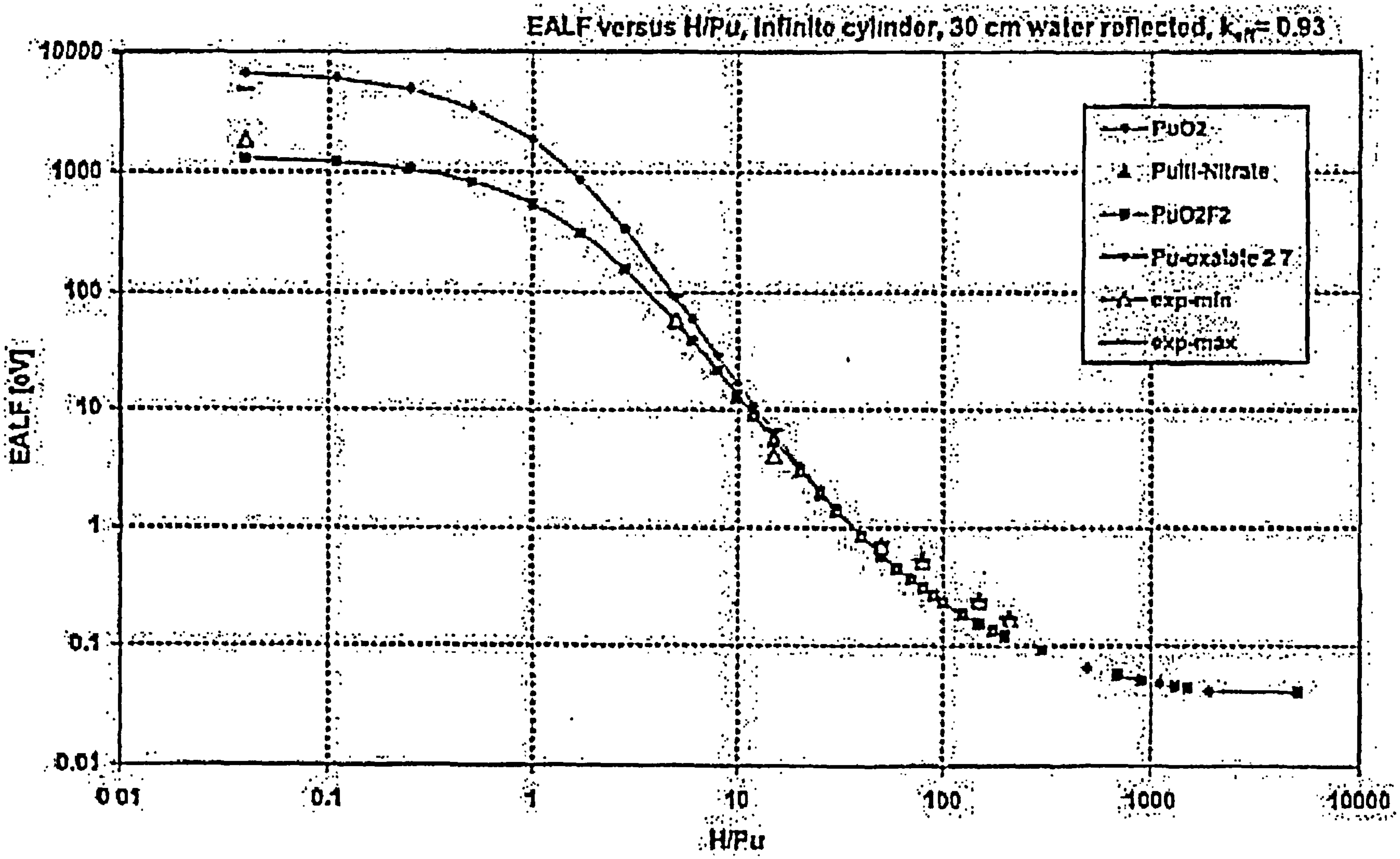
Issues with Validation Reports

- Step (1): Determine bounding fissile materials over range of H/Pu
- Step (2): compare EALF vs. H/Pu for:
  - Different chemical compounds
  - Differing geometrical shapes
  - Differing reflector materials

Issues with Validation Reports



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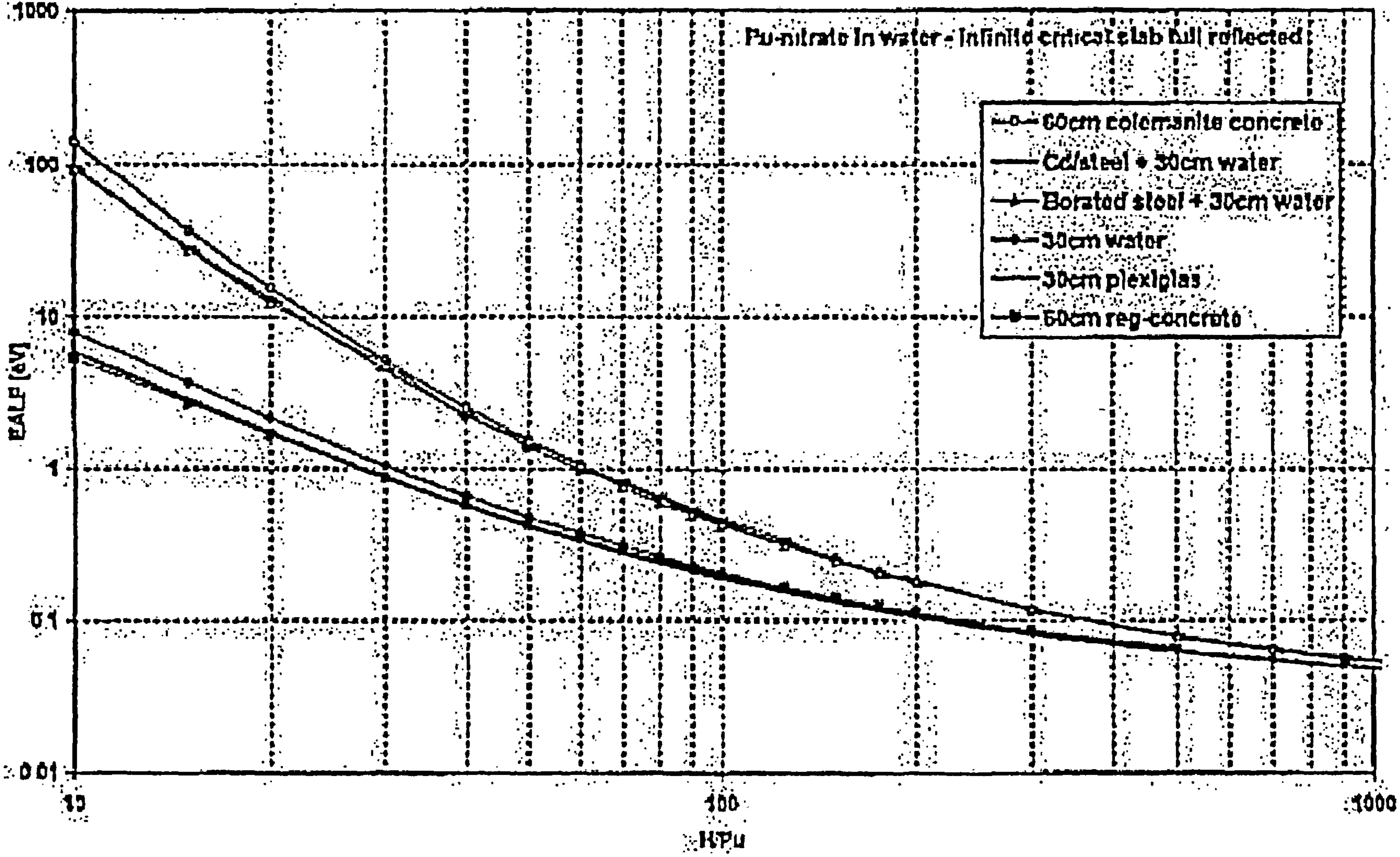
Issues with Validation Reports



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Issues with Validation Reports

- **Differing, seemingly arbitrary, standards for determining applicability of benchmarks to design cases**
- **<u>Part II</u>: A more sophisticated treatment is ORNL's S/U methodology**
  - **Purpose: To determine applicability of benchmark experiments to specified design application**
  - **Determines correlation (between benchmarks and applications) with respect to:**
    - Computed sensitivities
    - Known uncertainties in underlying cross section data

Issues with Validation Reports

$$S_{xi} = \frac{dk_{eff}/k_{eff}}{d\Sigma_{xi}/\Sigma_{xi}} = \left(\frac{\partial k_{eff}}{\partial \Sigma_{xi}}\right)\left(\frac{\Sigma_{xi}}{k_{eff}}\right)$$

x = reaction (fission, absorption, etc.)
i = energy group

$$E \propto \sum_{j=1}^{N}\sum_{i=1}^{g} S_{xij}^{ex} S_{xij}^{ap}$$

S = sensitivity profile
E = integral parameter

Issues with Validation Reports

$$C_{kk} = S_k C_{\alpha\alpha} S_k^T = \begin{pmatrix} \sigma_1^2 & \sigma_{12}^2 & \cdots & \sigma_{1N}^2 \\ \sigma_{21}^2 & \sigma_2^2 & \cdots & \sigma_{2N}^2 \\ \vdots & \vdots & \ddots & \\ \sigma_{N1}^2 & \sigma_{N2}^2 & & \sigma_N^2 \end{pmatrix}$$

S_k = Sensitivity Vector (reactions × energy groups)
$C_{\alpha\alpha}$ = Cross section uncertainty data (diagonal)
C_{kk} = Uncertainty matrix

$$c_k = \sigma_{ij}^2 / \sigma_i \sigma_j \geq 0.8$$

Issues with Validation Reports

- **Use of S/U codes in AOA(3) and (4):**
  - **Approach**
    - Choose pool of benchmark data, based on traditional techniques (physical similarity, neutronic parameters)
    - Choose design applications to compare with
    - Employ S/U techniques to “screen” out benchmarks that are applicable
    - Analyze bias/uncertainties
  - **Originally 14 benchmarks for AOA(4).**
  - **298 candidates considered.**

Issues with Validation Reports

- Summary of 298 candidate benchmarks:
  - 61 Pu benchmarks (fast Pu-metal, PuO_2-polystyrene blocks)
  - 237 mixed Pu/U systems (U/Pu solutions, fuel pin lattices, UO_2-PuO_2 blocks)
- 18 LEU experiments also considered

Issues with Validation Reports

- Design applications: Generic models developed with similar characteristics to anticipated design applications
- These models used in the S/U analysis to screen benchmarks:
  - AOA 4-1: H/Pu = 1.58; EALF = 127eV
  - AOA 4-2: H/Pu = 1.58; EALF = 3751eV
  - AOA 4-3: H/Pu = 1.58; EALF = 27.8eV
  - AOA 4-4: H/Pu = 0.3; EALF = 2355eV
- AOA 4-4 is for a critical mass of dry powder, which exceeds the mass of anything expected at the MFFF
- Additional cases for 4-4 run (163, 40, 8 kg Pu)

Issues with Validation Reports

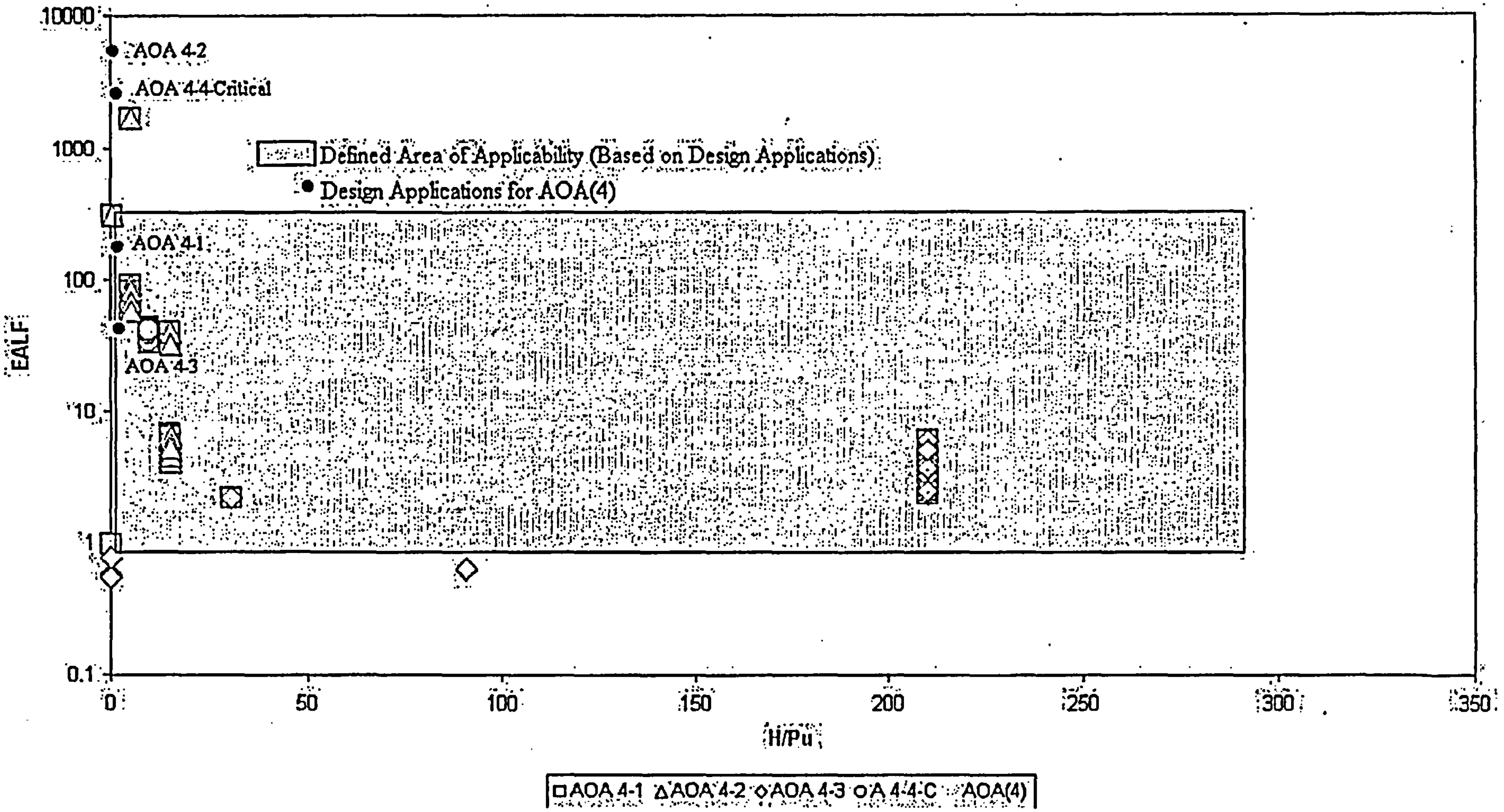
- Benchmarks applicable to each sub-AOA determined:
  - AOA 4-1: 59 benchmarks
  - AOA 4-2: 53 benchmarks
  - AOA 4-3: 44 benchmarks
  - AOA 4-4-Critical: No benchmarks meeting c_k 0.8 criterion, so relaxed to c_k 0.7.
- Concerns with reducing correlation criterion:
  - Adding experiments can reduce USL, because amount of NPM is a function of number of experiments
  - Less applicability is indicated by reduced c_k criterion, but no additional margin applied
  - "Decomposition Problem"

Issues with Validation Reports

- NRC Concerns with application of S/U:
  - Set of "design applications" not representative of the whole AOA
  - Small changes in parameters can make significant differences in set of applicable benchmarks
  - May not be appropriate to lump all benchmarks into a single group for bias calculation
  - Set of benchmarks applicable in differing portions of AOA may be mutually exclusive

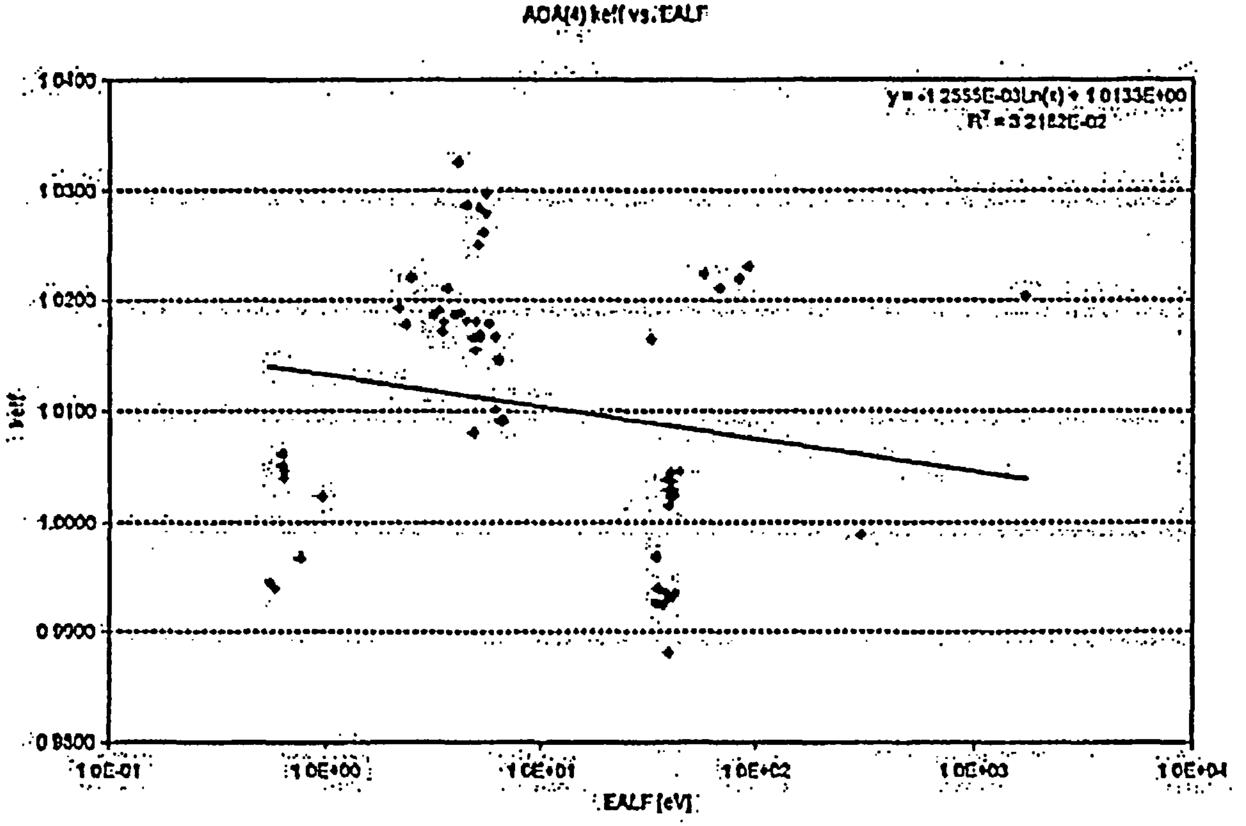
Issues with Validation Reports

H/Pu vs. EALF - Benchmarks Applicable to AOA(4) Using S/U Methodology



Issues with Validation Reports

- <u>Apparent anomalies in calculated results</u>
  - ➢ Statistical techniques require well-behaved data
  - ➢ Benchmarks drawn from small data sets may not display this



Issues from Validation Reports

- ➢ **Scope of review limited to:**
  - » Quality of benchmark data (number and benchmarks, range of important parameters, normality of data)
  - » Description and application of methodology
  - » Comparison of the benchmarks with the required AOA
  - » Reasonableness of results
- ➢ **Did not independently confirm either modeling of benchmarks or statistical calculations**

Issues with Validation Reports

- Major open issues:
  - Range of parameters defining AOA significantly exceeds range covered by benchmarks
  - Questions about application of S/U to AOA(3) and (4)
  - Validity of methods for demonstrating applicability in Parts I & III
  - Apparent anomalies (data clusters, double humps) in k-effective data

Issues with Validation Reports

- NRC will obtain S/U code to do independent confirmation of:
  - Validity of neutron absorption spectrum comparison as sufficiency test for applicability, Part I
  - Correct application of S/U in choosing benchmarks, Part II
  - Validity of neutron energy (EALF) comparison as sufficient test for applicability, Part III

Changes Made to Validation Reports

- Addition of Non-Parametric Techniques (NUREG/CR-6698) to description of methodology
- Use of S/U methodology to define additional benchmarks in Part II, for both AOA(3) and (4)
- Addition of significant amounts of benchmark data to all AOAs
- Addition of Part III, covering miscellaneous Pu-compound solutions

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Changes Made to Validation Reports

- Current Status:
  - ➢ Communicated major issues to DCS in March 2003
  - ➢ Many revolve around range of AOA compared to available benchmarks, methods to validate code where data sparse
  - ➢ DCS stated its actual anticipated calculations often done at optimal conditions – may not need entire range

Changes Made to Validation Reports

- In some cases, boundaries of AOA were somewhat ambiguous from the VR
- DCS agreed to review needed range in parameter space and give more precise definition of AOA
- NRC action - Obtain and apply S/U code to resolve open issues in all parts of VR. Obtain code May 2003

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Subcritical Margin Issue

- Validation reviewed to enable finding regarding subcritical margin
- Includes allowances for bias and uncertainties and minimum subcritical (administrative) margin for unknown uncertainties
- Margin varies from facility to facility
  - ➢ BWTX: 0.92 normal, 0.95 abnormal
  - ➢ NFS: 0.90 normal, 0.95 abnormal
- 0.92 and 0.95 appropriate limits for MFFF provided satisfied with validation effort
- DCS continued to state 0.95 was acceptable for both normal and abnormal conditions

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Subcritical Margin Issue

- Previously stated 0.95 (exclusive of bias and uncertainty) for abnormal conditions is design basis value, 0.95 also accepted for normal case for AOA-2
- Justification for 0.05 margin not found sufficient; little guidance as to what appropriate amount of margin should be
- NUREG-1718 (Section 6.4.3.3.4) has limited guidance:
- Minimum subcritical margin must be justified, but 0.05 generally accepted when bias/uncertainty negligible

Subcritical Margin Issue

- Different limits for normal vs. abnormal can be justified based on:
  - Lower margin for abnormal conditions acceptable because achieving abnormal conditions unlikely
  - Increased risk must be commensurate with risk of achieving abnormal state
  - Abnormal case assumes "worst-case" conditions—greater actual margin

Subcritical Margin Issue

- Approach taken in March meeting
  - ➢ 0.95 acceptable for abnormal limit for all AOAs
  - ➢ 0.95 acceptable for normal case for AOA(2)
  - ➢ Additional normal case margin needed for remaining AOAs – consistent with approach for HEU facilities

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Subcritical Margin Issue

- Rather than specify a specific numerical limit for normal case, allow to be determined on a case-by-case basis
- Because it is determined based on design, cannot be done prior to design
- Recognized that k-eff is not a good measure of safety. Fraction critical (in mass or other parameters) is often a better indicator of available safety margin.

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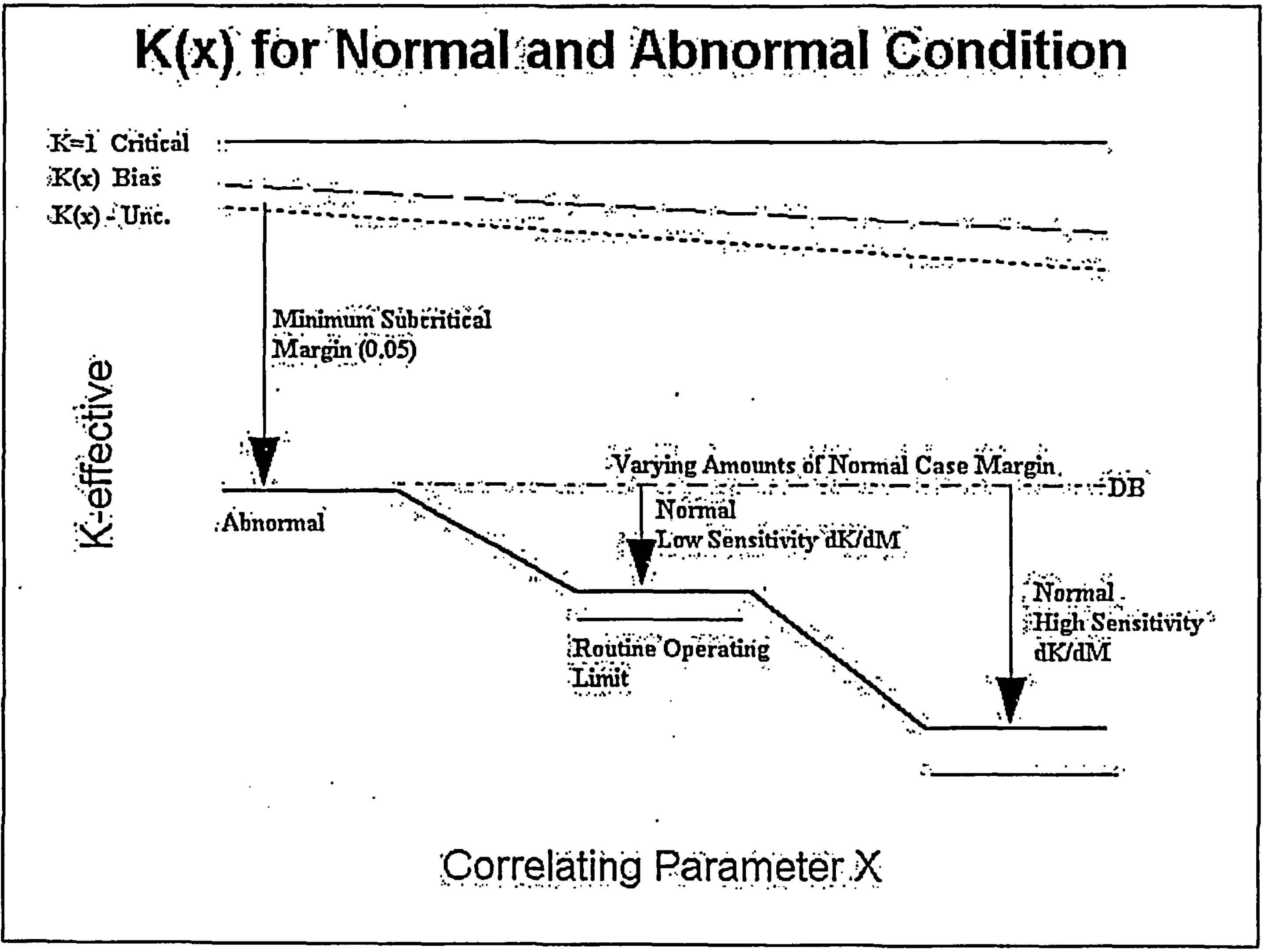
Subcritical Margin Issue



K(x) for Normal and Abnormal Condition

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Subcritical Margin Issue

- Allow margin to be specified as a fraction critical or in terms of k-eff
- Allows greater flexibility/consideration of risk
- Example: SRP Section 6.4.3.3.2.2 on geometry control
    - ➢ 90% minimum critical diameter
    - ➢ 85% minimum critical slab thickness
    - ➢ 75% minimum critical spherical volume
    - ➢ Safe batch 45% minimum critical mass to allow for double batching

End-of-Day 4 Questions-and-Answers Session

NRC FORM 8C
(7-94)
NRCMD 3.57

COVER SHEET FOR CORRESPONDENCE

USE THIS COVER SHEET TO PROTECT ORIGINALS OF MULTI-PAGE CORRESPONDENCE

NRC Review of the Mixed Oxide Fuel Fabrication Facility

Meeting with RF Gosatomnadzor
May 2003

Margaret S. Chatterton and Dr. Christopher S. Tripp
U.S. Nuclear Regulatory Commission

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Day 5 Agenda

- Survey of Draft Safety Evaluation Report
- Status of NCS Open Issues
- Lessons Learned from MOX review
- Anticipated topics for further investigation
- Closeout question-and-answer session

Survey of Draft Safety Evaluation Report (DSER)

- CAR follows SRP
- DSER follows CAR
- First draft April 30, 2002
- Revised to address comments, revised CAR
- Second draft April 30, 2003
- Final draft anticipated September 2003

Survey of DSER: Purpose of SER

- Document staff findings, for:
    - Concurrence chain (NRC management)
    - The applicant
    - The public
    - Other stakeholders (Congress, hearing parties,...)
- Document scope of review
- Survey of DSER

Survey of DSER: Purpose of SER (continued)

- Document conditions of acceptance
- Consolidate basis for approval/denial
- Preserve institutional knowledge for future licensing
- Provide justification for regulatory decisions to the public

Survey of DSER

- Conduct of Review
  - Review objectives
  - Applicable regulations
  - Documents reviewed (Scope)
- Organization and Administration
  - Acceptability of NCS design staff qualifications and experience
  - Acceptability of placement of NCS within design team

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Survey of DSER

- Management measures
  - ➢ Detailed review outside DSER scope
  - ➢ Control classification reviewed as part of MPQAP
- Technical practices review
  - ➢ Commitment to baseline design criteria (70.64(a)(9))
  - ➢ Commitment to follow 70.24, RG-3.71, and ANSI/ANS-8.3 for criticality alarms

Survey of DSER

- **Criticality control design criteria**
  - **Requirement for control modes acceptable (based on SRP)**
  - **Additional clarifications summarized**
    - How geometric tolerances combined
    - Justification of bounding isotopics (based on NRC confirmatory calculations) and density (commitment to measure)
    - Modeling neutron reflection
    - Prohibition on hydrogenous fire suppression agents in moderator controlled areas
    - Only fixed neutron absorbers used

Survey of DSER

- Review of Process Description
  - ➢ Text description in CAR Chapter 11
  - ➢ Criticality Control Units (CAR Tables 6-1, -2)
    - » Overall approach acceptable
    - » Acceptability bounding isotopics, powder density
    - » Exclusion of Pu from auxiliary (non-fissile bearing) systems
    - » Adherence to preferred design approach
    - » Dual vs. single parameter control

Survey of DSER

- **For each AOA:**
  - **Summary of experimental data, code**
  - **Application of method to AOA:**
    - Selection of benchmarks (traditional method, spectral comparison, S/U)
    - Trending parameters chosen for k-eff fit
    - Normality of Data
    - Calculation of Upper Subcritical Limit
  - **Staff continues to review; open issue (NCS-4)**

Survey of DSER

- Subcritical Margins
  - Discusses DCS's justification for $\Delta k_m = 0.05$
  - Acceptability of 0.05 for abnormal conditions
  - Acceptability of 0.05 for AOA(2) normal conditions
  - Need for additional normal condition margin for remaining AOAs
  - Design basis includes:
    - Abnormal case limit for each AOA
    - Methodology for normal condition limit for each AOA

Survey of DSER

- Lack of Principal Systems, Structures, and Components (PSSCs) for NCS
- Commitment to Double Contingency Principle
    - Only DCP portion of baseline design criteria met
    - Acceptable definition of “unlikely” (SRP)
    - Acceptable methodology for demonstrating “highly unlikely” (SRP)
        - Two robust, independent controls
        - Method of determining likelihood
        - Failure detection or additional margin

Survey of DSER

- Commitments to ANSI/ANS-8 standards
  - For each standard:
    - Whether part of design basis
    - Reiterate commitment to which section
    - Acceptability of exceptions/clarification
    - Justification if not part of design basis
- Evaluation findings & Open Items
- References
- Justification for closed open items from first draft (Appendix)

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Status of NCS Open Issues

- Design basis USL for each process type
- Determination of normal condition subcritical margin
- Clarification of commitment to dual vs. single parameter control

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Lessons Learned

- Important to set ground rules up front
- Frequent communication necessary
- Correspondence is inefficient: necessary for documentation
- Telephone conversations streamline process- increases potential for misunderstanding on both sides

Lessons Learned

- Written communication and face-to-face meetings effective
- Important to be involved early in the design process
- Ambiguous responses should be questioned
- Drawbacks to accepting “IOUs” for future commitments (e.g., CAR changes)

Lessons Learned

- Things not always as they seem (e.g., dual-parameter control)
- Precise language important
  - ➢ Inspectable and enforceable
  - ➢ Commitments unambiguous

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Anticipated Topics for Further Investigation

- Demonstration of bounding nature of incoming plutonium isotopics
- Demonstration of bounding powder densities
- Review of normal condition margin
- Applying validation to actual design calculations

Anticipated Topics for Further Investigation

- ISA review
  - Likelihood determination for accident sequences
  - Frequencies for IROFS
  - Management measures to IROFS
- Exemptions from criticality accident alarm coverage

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Anticipated Topics for Further Investigation

- Emergency response procedures for criticality events
- Application of design principles to actual design
- Integration of fire protection and criticality safety concerns

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Anticipated Topics for Further Investigation

- Administrative practices for NCS
  - ➢ NCS program
  - ➢ NCS training
  - ➢ Procedures
  - ➢ Audits
  - ➢ Investigations

Closeout Questions-and-Answers Session

NRC FORM 8C
(7-94)
NRCMD 3.57

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NCS Review of the CAR

- Nuclear Safety Training (for fissile material operators)
  - ➢ Curriculum Contents
  - ➢ Administration
- Audits
  - ➢ NCS Function Audits
  - ➢ Plant Operations Audits
  - ➢ Corrective Actions
- Procedures
  - ➢ Review and approval
  - ➢ Postings

NCS Review of the CAR: Technical Practices for Nuclear Safety

- Design principles include:
  - Preferred control hierarchy
  - Documentation in NCSEs   Flowdown of IROFS to ISA
  - Compliance with DCP demonstrated, defense-in-depth

NCS Review of the CAR

- Criticality Accident Alarm System (CAAS) Specifications:
  - CAAS required in all plant areas as specified in 70.24(a).
  - Specific areas to be exempted identified
  - Exemptions allowed if "will not endanger life or property" and "in the public interest" (10 CFR 70.17)
  - Considered on case-by-case basis (sufficiently low risk/benefit) (NCS-9)
  - Commitment to follow ANSI/ANS-8.3-1997 (as qualified in RG-3.71)

NCS Review of the CAR

- Additional commitments beyond ANSI/ANS-8.3-1997
  - ➢ Operations will be placed into safe shutdown when inoperable
  - ➢ Coverage areas will be determined using shielding codes
  - ➢ Effects of both fixed and transient shielding considered
- Additional Technical Specifications
  - ➢ Each area covered by two gamma or neutron detectors

NCS Review of the CAR

- Control Categories
- Control Modes:
  - Geometry
    - Fixed equipment dimensions
    - “Safe” or “favorable” geometry
    - Safe diameter columns, slab & annular tanks (AP)
    - Most reliable means of control

NCS Review of the CAR

- Mass
  - Limits based on worst-case geometry and material form
  - Subcritical with largest overbatch resulting from a single failure
- Density
  - Conservative assumptions based on process history, handbook data, or standards
  - PuO2 power bounding density of 7 g/cm^3; MOX 3.5 – 5.5 g/cm^3
  - Measured initially, and periodically where form of material changes (NCS-3)

NCS Review of the CAR

- Isotopics
  - Design basis bounding assumptions (96 wt% ^{239}Pu, 4wt% ^{240}Pu, <1wt% ^{241}Pu)
  - Controlled by computer during blending (PuO_2 and UO_2)
  - Master blend 22wt% Pu
  - Final blend 6.3wt% Pu
- Reflection
  - Administratively controlled (one of least reliable means)
  - Analysis uses:
    - 1-inch water for transient reflectors (personnel, temporary materials, water) + any fixed reflection modeled explicitly
    - 12-inches water reflection uncontrolled

NCS Review of the CAR

- Moderation
  - ➢ Used in combination with mass control
  - ➢ Amounts of moderator added to process are strictly limited
  - ➢ Gloveboxes + inert atmosphere primary moderation barrier
  - ➢ Hydrogenous firefighting agents excluded (moderator-control zones)
- Concentration
  - ➢ Limited to systems with low expected quantities of fissile material
  - ➢ Typically only control mode when used => single-parameter limits are established

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NCS Review of the CAR

- Interaction
  - Fixed placement of fissile material equipment, and/or spacing controls
  - Preferred means are passive features such as “birdcages” and array spacers
- Absorber
  - Fixed, removable, or soluble neutron absorbers
  - Only fixed absorbers anticipated
  - One of the most reliable means of control

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NCS Review of the CAR

- Volume
  - ➢ Limits the container volume to less than a spherical critical mass
  - ➢ Considered one of the most reliable means of control
- Heterogeneity
  - ➢ Used for pellets, rods, and assemblies
  - ➢ Homogeneity relied on during/after blending

NCS Review of the CAR

- Process variable control
  - Supports the previous 11 parameters
  - Doesn't directly affect k-eff
  - Affects values of the previous parameters, due to changes in temperature, pressure, etc.
  - Important process variable and could be considered the 12th control mode

NCS Review of the CAR

- Specific information related to control modes is provided in CAR Tables 6-1 and 6-2
- Facility divided into Criticality Control Units (CCUs)
- Physicochemical form specified
- Controlled parameters defined
- Allowed ranges in parameter values determined
- Specific controls identified

Controlled Parameters for Aqueous Polishing

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

Criticality Control Unit	Control Method: 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	Comments
UO2 Dissolution														
Buffer Tank	YES $Pu(NO_3)_3 + H_2O$ [3,6]	NO	NO	NO	NO [1]	NO	NO	YES [7]	TBD [2]	NO	NO	NO	NO	
KDB Dissolution Unit														
Electrolyzer	NO $PuO_2 + H_2O$	NO	YES	NO [1,9] d ≤ 7	NO [1]	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	NO	
Reception tank	NO $PuO_2 + H_2O$	NO	YES slab	NO [1,9] d ≤ 7	NO [1]	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	NO	
PuO_2 filter	NO $PuO_2 + H_2O$	NO	YES Cylinder	NO [1,9] d ≤ 7	NO [1]	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]	NO	YES Slab	NO	NO [1]	NO	NO	NO	TBD [2]	YES Cd coating	NO	NO	PC	
Buffer Tank	YES $Pu(NO_3)_3 + H_2O$ [3,6]	NO	YES Annular	NO	NO [1]	NO	NO	NO	TBD [2]	YES Colemanite concrete	NO	NO	NO	Colemanite concrete is a type of borated concrete.

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Controlled Parameters for MOX Process

Table 6-2. Preliminary Definition of Reference Fissile Medium and Control Methods for MP 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	
Powder Area														
Primary blend ball milling Scrap milling	NO Master blend	YES	NO	YES [1,6] $d \leq 5.5$	YES $^{240}Pu \geq 4\%$[1]; $M_{Pu}/(M_U + M_{Pu}) \leq 22\%$ [5]	NO	YES	NO	NO	NO	NO	NO	M	-U metal balls are present in the ball-mill and are accounted for as reflector in the criticality calculations
	NO Discarded Scrap Powder	YES	NO	YES [1,6] $d \leq 5.5$	YES $^{240}Pu \geq 4\%$[1]; $M_{Pu}/(M_U + M_{Pu}) \leq 22\%$ [5]	NO	YES	NO	NO	NO	NO	YES	M,H	Homogeneity of discarded scrap powder is required by downstream unit.
Final dosing	NO Master blend	YES	NO	YES [1,6] $d \leq 5.5$	YES $^{240}Pu \geq 4\%$[1]; $M_{Pu}/(M_U + M_{Pu}) \leq 22\%$ [5] $M_{Pu}/(M_U + M_{Pu}) \leq 6.3\%$ in jar	NO	YES	NO	NO	NO	NO	NO	M,I	The relative quantity of master blend and UO_2 is controlled; used in downstream units.

NCS Review of the CAR

- Review of CAR Tables 6-1 and 6-2:
    - ➢ Adherence to design principles (preference for passive geometry, etc.)
    - ➢ Reasonableness of design parameters and bounding values
    - ➢ Consistency with process description, industry practice
- Geometry (with absorber) control utilized in AP process.
- Impracticable in much of MP process: mass/moderation used.
- Bounding parameter values: isotopics, powder density, moderation
- Type of absorber, geometric shape specified

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NCS Review of the CAR

- Inconsistencies with Chapter 11 process description
- Criticality evaluation
  - Single and multi-parameter limits (ANSI/ANS-8.1-1983)
  - Handbooks
  - Validated computational methods
- Validation method (NCS-4)
  - Compare measured results for critical benchmarks against calculated results using the code
  - Choose benchmark experiments that are physically and neutronically similar to the systems that will need to be calculated by the code

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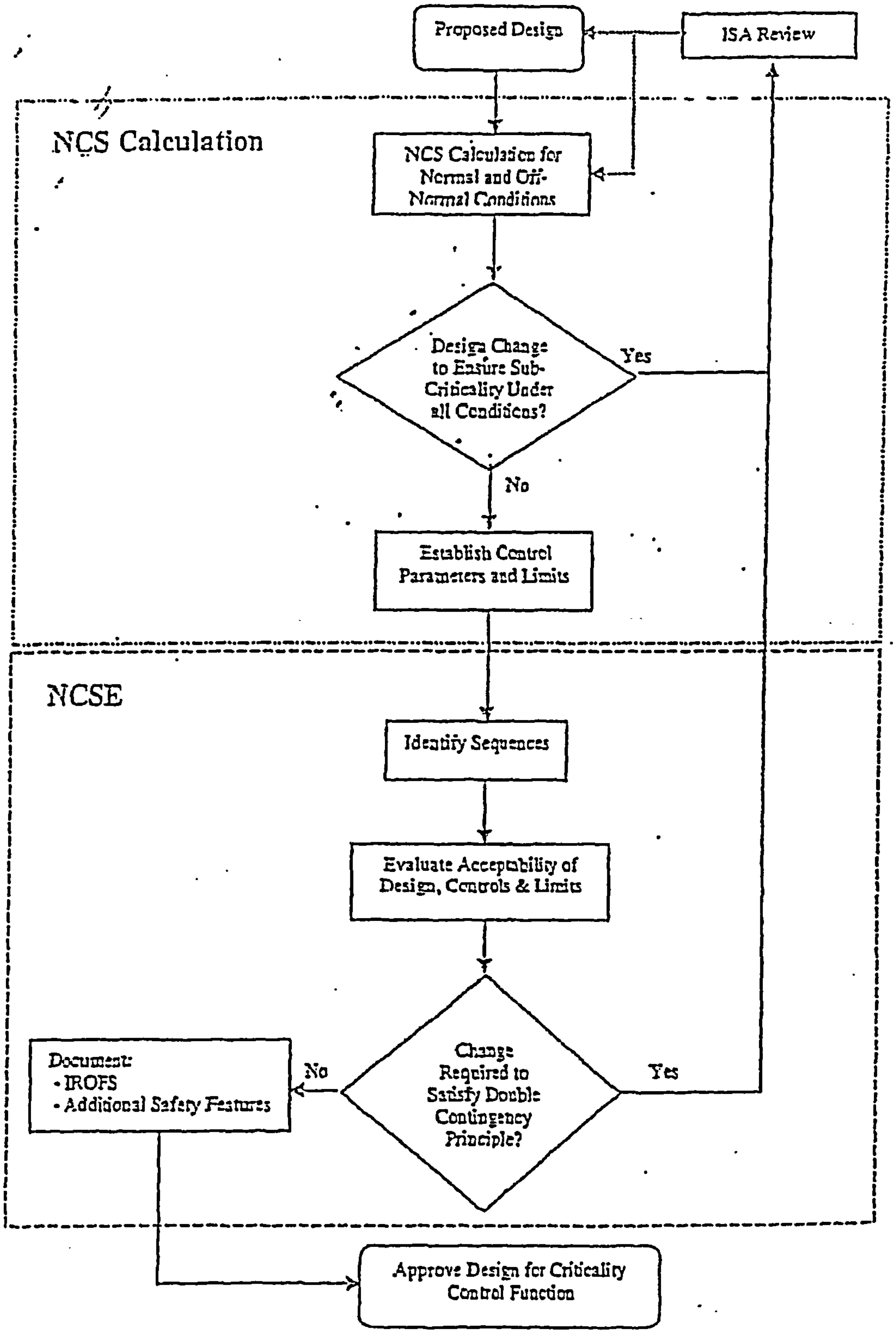
NCS Review of the CAR

- Important characteristics of benchmark experiments:
  - System geometry
  - Fissile material content
  - Moderator-to-fuel ratio
  - Absorber/reflector materials
  - Average neutron energy
- SCALE-5 code under development by ORNL
  - Sensitivity analysis: sensitivity of k-eff to changes in underlying cross sections
  - Uncertainty analysis: combines sensitivity information & cross-section covariance data => correlation coefficient for benchmark comparison

NCS Review of the CAR

- k-eff calculated for each benchmark experiment in area of applicability (AOA)
  - ➢ Trended using a linear regression fit, as a function of the most important parameters
  - ➢ Pu/MOX isotopics (^{240}Pu, Pu/(U+Pu) content)
  - ➢ Energy of average lethargy causing fission (EALF)
  - ➢ H/X or vm/vf ratio
- Benchmarks mostly from the International Handbook of Evaluated Criticality Safety Benchmark Experiments

NCS Review of the CAR



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NCS Review of the CAR

- 15 ANSI/ANS-8 standards endorsed by RG-3.71:
  - Single and multiple-parameter subcritical limits
  - Programmatic commitments:
- Compliance with standard = commitment to all “shall” statements
- NUREG-1718 (SRP):
  - Compliance with “shall” and “should” statements acceptable (subject to limitations)
  - Can propose alternate means of meeting intent of (“should” statements).
  - More specific commitments included in CAR as appropriate. (NCS-10)

NCS Review of the CAR

- ANSI/ANS-8.1 (Design Basis)
- ANSI/ANS-8.3 (Design Basis)
- ANSI/ANS-8.7 (Non-Design Basis)
- ANSI/ANS-8.9 (Non-Design Basis)

NCS Review of the CAR

- ANSI/ANS-8.10 (Non-Design Basis)
- ANSI/ANS-8.12 (Non-Design Basis)
- ANSI/ANS-8.15 (Non-Design Basis)
- ANSI/ANS-8.17 (Design Basis)

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- ANSI/ANS-8.19 (Design Basis)
- ANSI/ANS-8.20 (Design Basis)
- ANSI/ANS-8.21 (Design Basis)
- ANSI/ANS-8.22 (Design Basis)
- ANSI/ANS-8.23 (Non-Design Basis)

RAI Major Issues

- 40 Questions out of 239 on NCS
- RAI-40: Meaning of “unlikely” for meeting DCP
- RAI-41: Sufficiency of DCP in meeting §70.61
  - DCP used to ensure “subcritical under normal and credible abnormal conditions”
  - Deterministic means (DCP/single-failure criterion) to satisfy 70.61(b) and (c)

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RAI Major Issues: Chronology in CAR (NCS-5)

- Aug 2000: SRP Issued with Appendix A (NCS example using index method.) Section 5.4.3.2(B)(viii) also had acceptance criteria for qualitative methods.
- Jan 2001: "Highly Unlikely" methodology as part of NCS design bases.
- Feb 2001: Original CAR took position that DCP + management measures + standards = Highly Unlikely.

RAI Major Issues: Chronology in CAR (NCS-5) (continued)

- July 2001: RAIs 40 & 41 issued
- Aug 2001: RAI response restated CAR position on “Highly Unlikely.” Asked for clarification whether 70.61(d) implies meeting 70.61(b) or are two separate requirements.
- Dec 2001: NRC letter said index method acceptable, summarized existing guidance.
- Mar 2002: DCS letter defined “unlikely” for DCP as qualitatively comparable to 1/100 yrs.

RAI Major Issues: Chronology in CAR (NCS-5) (continued)

- Oct 2002: Revised CAR presented more details on deterministic approach, still in terms of broad programmatic requirements, not specific control characteristics
- Jan 2003: Meeting to address.
- Feb 2003: DCS submitted revised words to Chapter 5
- Mar 2003: NRC proposed revised wording to reference NUREG-1718, make wording more explicit.
  - ➢ DCS revised, and ultimately agreement reached.
  - ➢ DCS moved this to Chapter 6.

NCS-5 Resolution

- Final Resolution
  - ➢ General approach: DCP + QA + industry codes/standards + management measures
  - ➢ Description of accident sequences and IROFS in NCSEs/ISA Summary
  - ➢ "Unlikely" determination for each DCP control based on all "availability and reliability" qualities in NUREG-1718
  - ➢ In addition to DCP, must have
    - » (a) Failure detection on specified frequency
    - » (b) Safety margin such that multiple failures required for criticality, or
    - » (c) Other means, demonstrated comparable to (a),(b)

NCS-1 Resolution

- RAI-68: Description of the qualifications and duties of the NCS staff during the design phase (NCS-1)
  - NCS Function not described for design phase of MFFF
  - DCS clarified that qualifications same as for design phase NRC: No acceptable guidance; compared proposed qualifications to those at other fuel facilities (especially HEU facilities)
  - Need for Pu/MOX processing experience
- Resolution:
  - (a) DCS provided information on experience of staff (COGEMA, SGN); did not commit to MOX/Pu experience requirements
  - (b) DCS committed to provide training on MOX/Pu processing

RAI Major Issues

- RAI-72: Commitment to follow the preferred hierarchy of controls “where practicable”
- RAI-74: Dispositioning of CAAS exemptions. Original CAR stated two cases in which criticality coverage will not be required:
    - ➢ When limited to less than half of a minimum critical mass with no potential for double batching
    - ➢ When used for storage of closed shipping containers
    - ➢ Exemptions historically based on low inherent risk, reviewed on case-by-case basis by NRC. (NCS-9)
- RAI 77: Neutron absorbers for criticality safety (fixed absorbers only)

RAI Major Issues

- <u>RAI-79</u>: Basis for certain technical assumptions/practices:
  - ➢ Isotopic abundance in the CAR bounds the worst case feed material
  - ➢ How reflection (nominal vs. full) used to NCSEs
- <u>RAI-80</u>: No statement two-parameter control preferred to single-parameter control
  - ➢ CAR appeared to imply that dual, independent control is distinct from geometry control (not needed for safe geometry)
  - ➢ NRC agreed that if no identifiable accident sequences leading to criticality, intent of DCP met
  - ➢ DCS committed to evaluate potential failure paths leading to unsafe geometry

RAI Major Issues

- <u>RAI-81</u>: Clarification how DCP implemented when only one control identified in Tables 6-1 and 6-2; revision of Tables 6-1 and 6-2 to clarify control strategy
- <u>RAI-82</u>: Whether physicochemical form receive the same kind of programmatic treatment as other control modes
- <u>RAI-88</u>: Information on methods to be used when there is scarcity of benchmark data

RAI Major Issues

- RAI-90: Commitment to ANSI/ANS-8 Series standards
  - Commitment to Requirements vs. Recommendations (NCS-10)
  - Any exceptions or qualifications (NCS-6,7,8)
  - Additional details specified in SRP
- RAI-91/94: Justification for the use of the administrative margin (NCS-4) Validation Reports
- RAI-98: Clarification that the tables be revised to reflect wherever a parameter was controlled, regardless of whether it was controlled downstream

RAI Major Issues

- RAI-99: Requested a cross-reference between the information in Tables 6-1 and 6-2 with the Process Description in Chapter 11
- RAI-100: Requested CCUs with controlled parameters to be defined for certain process steps not included in the tables
- RAI-103/104: Concerned Tables 6-3 and 6-4 ("permissible" spherical volume, slab thickness, cylinder diameter, spherical mass) for fissile materials in the AP and MP processes

Changes to the CAR

- NCS Function during design phase (Section 6.1.1)
- Identified that specific areas needing CAAS exemptions would be submitted for NRC approval
- Change to technical criteria
    - ➢ 6.3.3.2.4 analysis of bounding nature of isotopics
    - ➢ 6.3.3.2.5 modeling of water reflection

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Changes to the CAR

- Theoretical density for incoming PuO_2 assumed until confirmed.
- Preferred control hierarchy commitment
- Tables 6-3 and 6-4 not to be used as subcritical limits
- Added section discussing each ANSI/ANS-8.1 standard

Changes to the CAR

- Removed reference to specific subcritical margin (0.05) deferred to Validation Reports
- Added summary of design bases
- Significant changes to Tables 6-1 and 6-2

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NCS Open Items

- NCS-1: MOX/Pu experience
- NCS-2: Design bases for auxiliary systems
- NCS-3: Bounding densities
- NCS-4: Validation/Subcritical Margin
- NCS-5: “Highly unlikely” for criticality

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NCS Open Items

- NCS-6,8: Extension of codes AOA beyond experimental benchmark data (ANSI/ANS-8.1, 8.17)
- NCS-7: Commitment to ANSI/ANS-8.15 (special actinides)
- NCS-9: Dispositioning of CAAS exemptions
- NCS-10: Clarification of ANSI standard commitments

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End-of-Day 3 Questions-and-Answers Session

05/20/2003

NRC FORM 8C
(7-94)
NRCMD 3.57

COVER SHEET FOR CORRESPONDENCE

USE THIS COVER SHEET TO PROTECT ORIGINALS OF MULTI-PAGE CORRESPONDENCE

NRC Review of the Mixed Oxide Fuel Fabrication Facility

Meeting with RF Gosatomnadzor
May 2003

Dr. Christopher S. Tripp
U.S. Nuclear Regulatory Commission

Day 4 Agenda

- NRC Review of Validation
- NRC Review of Subcritical Margin
- End-of-day Question-and-Answer Session

Regulatory Role of Validation Reports

- Design basis #2 maximum k-eff for normal and credible abnormal conditions
- Only design basis that fits cleanly into the 10 CFR 50.2 definition.
  - ➢ 70.61(d): "the risk of nuclear criticality accidents must be limited by assuring that under normal and credible abnormal conditions, all nuclear processes are subcritical, including use of an approved margin of subcriticality for safety"
  - ➢ ANSI/ANS-8.1: Requirements for code validation