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TO

Transcript of Proceedings ACRST-3176

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Title: Advisory Committee on Reactor Safeguards and Advisory Committee on Nuclear Waste Joint Subcommittee Meeting

Date: Wednesday, November 14, 2001

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NUCLEAR REGULATORY COMMISSION

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Integrated Safety Analysis

ACRS/ACNW Briefing - November 14, 2001

Yawar Faraz
Sr. Project Manager, NMSS/FCSS

Why revise 10 CFR Part 70

Subpart H

- Integrate radiological, criticality, fire, chemical and environmental safety disciplines
- Use systematic methods to (1) identify accidents, (2) determine likelihoods, and (3) estimate consequences
- Identify items relied on for safety (IROFS)

Who is required to meet Subpart H

Nuclear fuel fabrication facilities and new enrichment facilities

- Uranium fuel fabrication facilities
  1. Framatome (west)
  2. Framatome (east)
  3. Westinghouse
  4. Global
  5. NFS
  6. BWXT
- MOX
- Future uranium enrichment facilities

Subpart H ISA Requirements

The Licensees are required to

- Perform an integrated safety analysis (ISA)
- Comply with performance requirements of 10 CFR 70.61
- Identify items relied on for safety
- Establish management measures

Subpart H - performance requirements

- Accident sequence must be 'highly unlikely' if

\- worker
(1) 100 rem or more
(2) chemical-caused fatality

\- public (outside 'controlled area')
(1) 25 rem or more
(2) greater than 30 mg soluble uranium intake
(3) irreversible chemical injury

Subpart H - performance requirements

- Accident sequence must be 'unlikely' if

- worker
(1) more than 25 rem but less than 100 rem
(2) irreversible chemical injury

- public (outside 'controlled area')
(1) greater than 5 rem but less than 25 rem
(2) chemically-induced transient illnesses

- environment (outside 'restricted area')
(1) air concentration greater than 5000 times 10 CFR 20 App B Table 2 value

Management Measures

- Measures to assure that IROFS are available and reliable when needed
  - configuration management, training, QA, audits, procurement, problem identification/control, corrective actions, etc.
  - maintenance (corrective/preventive), functional testing, surveillance, calibration, etc.
  - written policies and procedures, large safety margins, signs, tags, etc.
  - material handling, shipping, storage, etc.
  - human factors, work environment, workload, etc.

Submittals Made

- April 18, 2001 - Licensees submitted, for NRC approval, an ISA Plan describing

- ISA approach
- processes to be analyzed
- schedule for completing the analyses for each process

- BWXT ISA Plan approved in July 2001
- NFS ISA Plan approved in October 2001

Submittals Required

- October 18, 2004 - In accordance with the ISA Plan, licensees are required to
  - complete a site-wide ISA
  - correct all unacceptable performance deficiencies
  - submit a site-wide ISA Summary for NRC approval

Challenges

- Issue 10 CFR Part 70 SRP
- Work with the Part 70 stakeholders to develop failure rate guidance
- Conduct site-wide ISA Summary and onsite ISA reviews starting in April 2002
- Use ISA to risk-inform NRC's licensing reviews and inspection/enforcement actions after approval of site-wide ISA

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
ADVISORY COMMITTEE ON NUCLEAR WASTE
MEETING OF THE ACRS/ACNW JOINT SUBCOMMITTEE
ROOM T-2B3, 11545 ROCKVILLE PIKE, ROCKVILLE, MD

NOVEMBER 14, 2001

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NUCLEAR ENERGY INSTITUTE

Comments on Proposed Final Version of SRP Chapter 3

- History of the Rulemaking
- Future Actions
- Integration of the Safety Programs
- Specific Chapter 3 Issues

History of the Rulemaking

- January 1986 – Sequoyah Fuels Event
- May 1991 – General Electric Event
- February 1992 - NUREG 1324
- September 1996 – NEI Petition for Rulemaking for an ISA
- October 2000 – NRC Issues revised Part 70 requiring an ISA (without SRP)
- April 2001 – Licensees Plans for submitting an ISA provided to NRC

Future Actions

- March 2002 – NRC approves ISA Plans submitted by licensees
- ???? – NRC issues guidance documents on Facility Change Process (70.72) and Backfit (70.76)
- October 2004 – All existing licensees must have completed ISAs and submitted ISAs Summaries to NRC
- October 2004 – Licensees must submit a plan to correct any identified unacceptable performance deficiencies

Integration of Safety Programs

- Chapter 3 – Integrated Safety Analysis
- Chapter 4 – Radiation Safety
- Chapter 5 – Nuclear Criticality Safety
- Chapter 6 – Chemical Process Safety
- Chapter 7 – Fire Safety
- Chapter 8 – Emergency Management
- Chapter 9 – Environmental Protection
- Chapter 10 – Decommissioning
- Chapter 11 – Management Measures

Specific Chapter 3 Issues

- Implementation
  - What is acceptable (learning curve)?
  - How detailed is the ISA Summary?
  - How quantitative does it need to be?
  - How do all of the safety programs work together?

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Standard Review Plan
Chap. 3: Integrated Safety Analysis

PRESENTATION TO THE ACRS/ACNW JOINT SUBCOMMITTEE
November 14, 2001

§70.62 Mandates ISA Tasks

..shall perform an ISA that..

- Identifies radiological and chemical hazards
- Identifies accident sequences
- Identifies consequence and likelihood
- Identifies Items Relied on for Safety
- Evaluates compliance with performance requirements of section 70.61

§70.61 - performance requirements

- 'High Consequence' Events:
  - Worker: 100 rem or more, chemical-caused fatality
  - Person offsite: >25 rem, or >30 mg Uranium intake, or irreversible chemical injury
- ...must be 'highly unlikely'.
- 'Intermediate Consequence' Events:
  - worker: more than 25 rem but less than 100 rem, or irreversible chemical injury
  - Person offsite: >5 rem (but <25 rem), or chemically-induced transient illnesses, or contamination 5000 times environmental effluent standard
- ...must be 'unlikely'.

§70.61 performance requirements

- continued -

- Chemical standards are only for
  - licensed material e.g., UO_2F_2
  - chemicals produced from licensed material (defined term) e.g., HF from UF_6
  - Defer to OSHA - general worker chemical safety issues
  - Defer to EPA - general public chemical safety issues

- Part 70 ISA term, 'item relied on for safety':
  - Structures, systems, equipment, components and <u>activities of personnel</u> that are relied on to prevent or mitigate potential accidents that could exceed the performance requirements

NRC review of ISA Summary

Acceptance Criteria for Compliance with 70.61

- Criteria for applicant's evaluation of potential accidents against performance requirements
  - Completeness ..of accident identification
  - Correctness .. of consequence evaluations
  - Adequacy .. of likelihood evaluations
- SRP Chapter 3 provides ISA review guidance
- Appendix A of Chap. 3 describes an example ISA analysis method

What does an ISA look like?

ISA TASKS

- 1. Identify hazards
- 2. Identify accidents
- 3. Estimate consequences
- 4. Identify items relied on for safety (IROFS)
- 5. Specify accident sequences
- 6. Evaluate likelihoods of accident sequences
- 7. Define ‘highly unlikely’ and ‘unlikely’
- 8. Compare accident likelihoods to definitions

Hazard and Accident Identification

NUREG-1513, ISA Guidance Document

- NUREG-1513: How to do an ISA
- Describes several hazard and accident identification methods
- Flow chart for selection of method appropriate to complexity of process
- Methods: fault trees, event trees, HAZOP, What If-Checklist

Consequence Estimation

- 'High Consequences' is defined quantitatively
- So ISA must estimate consequences quantitatively
- SRP guidance for calculations: NUREG/CR-6410
- Purpose of consequence evaluation is to determine gross level of prevention or mitigation required, not to assess risk.

Accident Sequence Specification

- SRP ISA Chap. 3 Appendix A gives one example of a method for displaying accident sequences
- App. A method lists each accident sequence as a row in a table
- Other methods are acceptable
- Other good methods: fault trees or event trees

App. A Likelihood Evaluation Method

Appendix A gives an example of one acceptable method for likelihood evaluation.

Other methods may be acceptable.

App. A Likelihood Evaluation Method

- Based on the equation for the frequency of the accident sequence as a function of event rates, probabilities, outage or mission times
- Uses integer indices representing logarithms of event rates, probabilities, and times
- Example tables relating control qualities to indices
- Intent was that applicants develop such tables of qualities relatable to failure rates

Likelihood Evaluation

- Double Contingency - ANSI/ANS 8.1 standard: a qualitative criterion
- Process designs should incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible.

App. A Likelihood Evaluation Method

Based on equation for accident frequency

Examples of different accident sequence equations:

1. system of 2 active redundant contols:

accident frequency $f = \lambda_2 u_1 + \lambda_1 u_2$

Where: λ_2 is failure rate of control 2

u_2 is unavailability of control 2

App. A Likelihood Evaluation Method

freq. of sequence 1: $f_1 = \lambda_1 u_2 \approx \lambda_1 \lambda_2 T_2$

Where: λ's are failure rates

T_2 is down-time for control 2

That is, T_2 is the duration that the system is vulnerable to failure of the other control.

App. A Likelihood Evaluation Method

freq. of sequence 1: $f_1 = \lambda_1 u_2 \approx \lambda_1 \lambda_2 T_2$

$$\log(f_1) \approx \log(\lambda_1) + \log(\lambda_2) + \log(T_2)$$

App. A Likelihood Evaluation Method

For example, if:

$\lambda_1 = 10^{-1}$ $\quad$ $Log(\lambda_1) = -1$

$\lambda_2 = 10^{-2}$ $\quad$ $Log(\lambda_2) = -2$

$T_2 = 10^{-3}$ $\quad$ $Log(T_2) = -3$

Then: $Log(f_1) = -1-2-3 = -6$

App. A Likelihood Evaluation Method

Based on equation for accident frequency

2. operator performs task subject to a safety procedure to avoid a failure limit.

f_a = frequency of accident

λ_1 = frequency of task (e.g. 365 times per year)

p_1 = probability operator exceeds failure limit per task

$f_a = \lambda_1 \, p_1$

App. A Likelihood Evaluation Method

Basing likelihood evaluation method on underlying frequency equation helps assure that failure rates and down-times of all relevant items relied on for safety are:

1) considered in the evaluation, and

2) subject to management measures

App. A Likelihood Evaluation Method

In the Appendix A method, assignments of index values to failure rates and times are to be based on pre-defined tabulated qualitative or quantitative criteria. (See tables A-3,4,5)

The bases underlying these criteria should be explained in the documentation of the applicant's ISA methodology. Over-arching goals are objectivity, validity, and consistency.

Example 1:
Double toxic chemical line

The system is a line for adding an aqueous toxic chemical to a U process. The accident is a leak with potential for exposure of workers to the chemical. Protection against leaks in the line is provided by an outer containment pipe. Presence of chemical in the space between the two lines is checked by weekly surveillance of a sight glass. Outer line leak tightness is tested every 2 years.

Example 1: Double Chemical Line

Failure rate of inner line: $\lambda_1 = 10^{-2}$ per year

$\text{Log}(\lambda_1) = \text{frq1} = -2$

Average outage time of line 1 is ½ week

$T_1 = ½\ \text{week} = 10^{-2}$ year

$\text{Log}(T_1) = \text{dur1} = -2$

Example 1: Double Chemical Line

Failure rate of outer line: $\lambda_1 = 10^{-2}$ per year

$Log(\lambda_2)$ = frq2 = -2

Average outage time of outer line is 1 year

T_2 = 1 year = 10^0

$Log(T_2)$ = dur2 = 0

Example 1: Double Chemical Line

f_1 = frequency of accident sequence 1

$f_1 \approx \lambda_1 \lambda_2 T_2$

$\log(f_1) \approx \log(\lambda_1) + \log(\lambda_2) + \log(T_2)$

See Example Table A-1

Summary of Appendix A Method

- A table of accident sequences, one event per column
- A set of parameters taken from the equation for the frequency of the accident sequence
- Integer indices assigned to parameters and summed as a likelihood (frequency) index
- Assignments of index values based on pre-defined tables of criteria

Example 2: Overloading a Transfer Cart

The system is a mobile cart used to transfer uranium compounds between processes. The accident consists of overloading the cart to the point where a nuclear criticality occurs. The protection against this consists of two administrative controls and one passive engineered control. Cart is used less than 100 times a year.

Example 2: Overloading a Transfer Cart

CONTROLS

- Admin control: procedure requires loading of cans by independent operator and measurement to assure moderator content of storage cans is within limits
- Admin control: procedure and sign on cart limits number of storage cans on cart
- Passive Engineered Control: Cart has only a limited size and space to hold storage cans

Example 2: Overloading a Transfer Cart

EQUATION FOR ACCIDENT FREQUENCY:

Frq1 = frequency of uses of cart = 2 (100 /year)
See Table A-4:
Pr2 = prob. that moderator limit on cans is violated = -3
Pr3 = prob. that operator loads too many cans = -3
Pr4 = prob.that overload is sufficient to cause criticality
=-4 (passive structure limits overload)

Example 2: Overloading a Transfer Cart

Likelihood index = frq1+pr2+pr3+pr4

= 2 -3 -3 -4

= -8

Guideline: index < -5 should be acceptable

Example 3: Criticality due to excess U mass

System is a liquid chemistry process involving addition of U compound. Protection consists of an admin control with a passive engineered control. The administrative control limits total U-235 mass, implemented by documented weight measurement with mass limit of 350 grams U-235 in single batch sized containers. The passive control is the geometry of the process vessel, which is such that criticality would require 70 Kg U-235 of the most reactive compound available before criticality is possible.

Example 3: Criticality due to excess U mass

Accident is a criticality caused by failure to observe the mass limit by an amount exceeding 70 Kg U-235.

Example 3: Criticality due to excess U mass

Three "events" in accident sequence:

Loading process with U: frq1 = 2 (100 times/yr)

Not observing 350 gm limit: pr2 = -3

Loading 70 kg, given mass limit not observed:

Why unlikely? Safety factor of 200.

Difficult to standardize quantification.

70 Kg error is qualitatively different.

Pr3 = -4 ?? Likelihood index = 2 -3 -4 = -5 ??

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Risk Informing the Nuclear Materials and Waste Arenas

Risk Task Group

Office of Nuclear Materials Safety and Safeguards

11/13/01

Risk-Informing Activities in Three Parallel Paths

- Support Risk-Related Activities and Initiatives of NMSS Divisions
- Develop Three Tier Training Program
- Implement Framework for Risk-Informed Regulation in Materials and Waste Arenas
  - Conduct Case Studies

Assistance and Peer Review

- Coordinate NMSS RIRIP input
- Assist in ISA reviews and related activities
- Assist in implementing Phase II Working Group recommendations
- Assist in resolving irradiator petition
- Assist in resolving radiography petition
- Assist in implementing NUREG-1717
- Assist in decommissioning guidance consolidation
- Peer review other risk related initiatives as needed

Training

- Introduction to Risk Assessment in NMSS
- Quantitative Frequency Analysis (Fuel Cycle)
- Use of Byproduct Material Risk Study (training and handbook being developed)
- Assessing other Tier III Training needs with TTC

Implement Framework for Risk-Informed Regulation

- SECY-99-100 and SRM provide guidance
- First phase involves conducting case studies

SECY-99-100

- Proposed framework for risk-informed regulation
- Process for moving forward
  - <u>Identify candidate applications</u>
  - Decide how to modify current approaches
  - Change the approaches
  - Implement risk-informed approaches
  - Develop or adapt risk-informed tools

SRM to SECY-99-100

- Commission approved propose framework
- Develop materials and waste safety goals analogous to reactor safety goal
  - Should guide NRC staff and define "safety"
  - Consider property damage
  - Consider whether critical group can be defined
  - Give due consideration to 10 CFR 20

Objectives of the Case Studies

- Test draft screening criteria and produce a final version
- Examine feasibility of developing safety goals
- Gain insights on risk-informing processes
- Identify tools, data and guidance needed

Case Study Areas

- Gas Chromatographs
- Static Eliminators
- Fixed Gauges
- Uranium Recovery
- Site Decommissioning of Trojan Nuclear Plant
- Transportation of Trojan Reactor Vessel
- Dry Cask Storage of TMI-2 Fuel Debris at DOE/INEEL (Seismic Exemption)
- Paducah Gaseous Diffusion Plant Seismic Upgrades

Insights From Case Studies
Screening Criteria/Considerations

- Encompass relevant considerations
- Should be ***considerations*** instead of criteria
- Can be a useful decision-making tool
- Ready to be finalized
- Application can be subjective, guidance needed

Insights From Case Studies
Screening Considerations

1. Maintain or improve safety
2. Improve efficiency or effectiveness
3. Reduce unnecessary regulatory burden
4. Help communicate a decision/situation
5. Availability of sufficient information
6. Implementation at a reasonable cost
7. Existence of other precluding factors

Screening Considerations

1) Could a risk-informed regulatory approach help to resolve a question with respect to maintaining or improving the activity's safety?

2) Could a risk-informed regulatory approach improve the efficiency or the effectiveness of the NRC regulatory process?

3) Could a risk-informed regulatory approach reduce unnecessary regulatory burden for the applicant or licensee?

4) Would a risk-informed approach help to effectively communicate a regulatory decision?

↳ *If the answer to any of the above is yes, proceed to additional considerations; if not, the activity is considered to be screened out*

5) Do information (data) and/or analytical models exist that are of sufficient quality or could they be reasonably developed to support risk-informing a regulatory activity?

↳ *If the answer to criterion 5 is yes, proceed to additional considerations; if not, the activity is considered to be screened out.)*

6) Can startup and implementation of a risk-informed approach be realized at a reasonable cost to the NRC, applicant or licensee, and/or the public, and provide a net benefit?

↳ *If the answer to criterion 6 is yes, proceed to additional consideration; if not, the activity is considered to be screened out.)*

7) Do other factors exist which would limit the utility of implementing a risk-informed approach?

↳ *If the answer to criterion 7 is no, a risk-informed approach may be implemented; if the answer is yes, the activity may be given additional consideration or be screened out.)*

Insights From Case Studies
Safety Goals

- Development of safety goals is feasible
- Multi-tiered structure, similar to reactors
- Subsidiary objectives for each program area
- Decision-making could be facilitated if clear set of safety goals existed
- *More on safety goals later*

Insights From Case Studies
Value of Using Risk-Information

- Helped to make decisions that were consistent with agency's current strategic goals
- Can be useful in identifying shortcomings in our regulations or regulatory processes

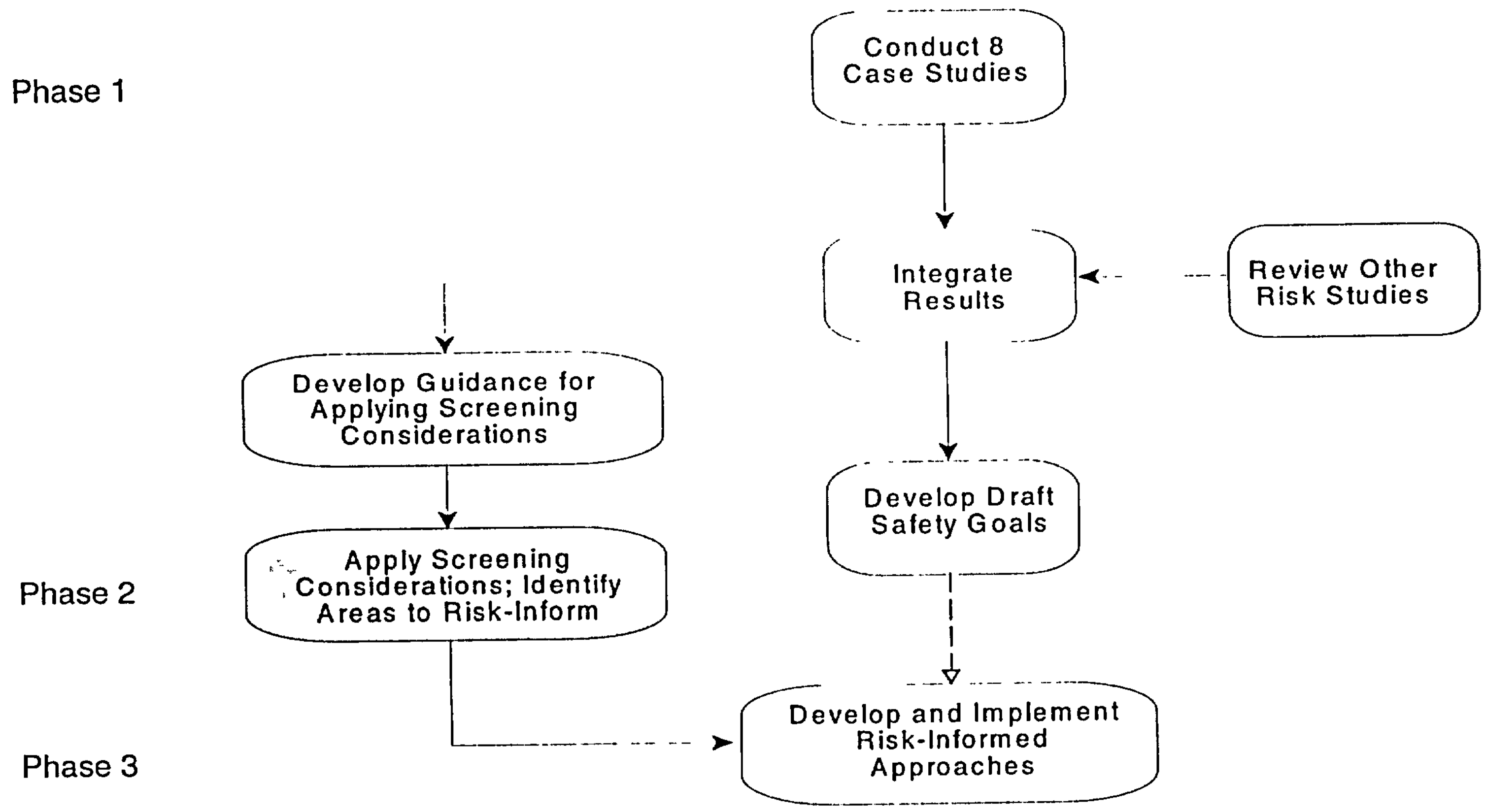
Insights From Case Studies
Value of Using Risk-Information

- To realize benefits of risk-informed approach:
  - Continue with staff training
  - Introduce risk-informed guidance on rulemaking, licensing, inspection and enforcement
  - Develop safety goals
  - Recognize zero is impossible in the real world
  - Address human reliability in a consistent and credible approach

Insights From Case Studies
Information, Tools, Methods, Guidance

- Exist in varying degrees
- Sufficient in some areas to support risk-informed decision making
- Could use NRR data/models for consistency in some generic case
- Models of processes provide consistent set of assumptions for generic cases
- Share weakness of the human factor

Where We Go from Here



Safety Goals

- The case studies have shown that safety goals, and quantitative measures of what is safe enough, could be useful in risk-informing specific situations within the materials and waste arenas.

Purpose of Safety Goals

- To articulate safety philosophy;
- To address "how safe is safe enough";
- To define a level of risk that is low enough without explicit consideration of whether it is possible or economic to achieve it.
- To facilitate risk management.
- They are not ***requirements***; they are ***aspirations.***

Purpose of Safety Goals

- To make safety objectives explicit
- To identify risk metrics to manage
- To specify quantitative values of risk metrics that act as criteria or guidelines for regulatory decision-making.

Safety Goals not Limits

- Safety goals are aspirations
- Risk-based regulations: dose with likelihood
- For example: 10 CFR 70.61, 32.23-24
- "unlikely", "negligible"
- ALARA: conditional requirement
- 3 separate criteria: limits, conditional limits, goals

Safety Goals Implied in Case Studies

- Transportation: accident probability of 1E-6 for vessel shipment acceptable to NRC
- Site Decommissioning: unrestricted release of site if annual dose is < public dose limit
- Uranium Recovery: prevent significant adverse impact to health and environment (GEIS)
- Gaseous Diffusion Plant: health risk (injury) to public determined to be sufficiently small to allow continued operation during seismic upgrade

Safety Goals Implied in Case Studies

- Gas Chromatographs: accident doses must meet criteria in 10 CFR 32.23, .24, .26, .27
- Fixed Gauges: manufacturer's design dose criteria in 10 CFR 32.51 are elements of safety goals
- Static Eliminators: zero release from sealed source
- Storage: 10 CFR part 72 statements of consideration recognized that dry cask risk < nuclear power plant risk

10 CFR 32 Safety Limits

Use:	Normal use and disposal	Normal storage 1 loc.	1 unit .. 1 loc.	1 unit .. 1 loc.
Group at risk:	Most highly exposed (user)	Most highly exposed (distributor)	A person	A person
Whole body:	.001 rem	.01 rem	.5 rem	15 rem
Hands, etc:	.015 rem	.15 rem	7.5 rem	200 rem
Likelihood:	Unlikely in 1 year	Unlikely in 1 year	Prob. is low	Prob. negligible

10 CFR 32.23

"Negligible – not more than one such failure per year for each 1 million units distributed."

Where Safety Goals Might Have Helped

- Certification of gaseous diffusion plants
- Exemption for Trojan reactor vessel shipment
- Exemption for TMI-2 fuel debris storage at DOE/INEEL

Where Safety Goals Might Help

- Site Decommissioning: realistic long-term scenarios
- Uranium Recovery: remediation alternatives; nonradiological risk
- Transportation: worker and public risk
- Dry Cask Storage: risk perspective
- Byproduct Material: consistent basis for licensing

Issues to Consider

- Individual and societal goals
- Voluntary and involuntary risks
- Worker and public risks
- Some of the risk to public and workers involve nonradiological hazards
- Operational phase risk and long-term risk

➢ Recognize that material use and waste areas present qualitatively different issues than reactors

Three-Tier Safety Goal Structure

Early First Draft

- Qualitative Goals (Tier I)
  - Risk to Individual (Public and Worker)
  - Risk to Society
  - Environmental and Property Damage Risk
- Quantitative Objectives (Tier II)
  - Quantitative Health Objectives (5)
  - Quantitative Environmental Objective
  - Quantitative Patient Objective
- Subsidiary Objectives (Tier III)
  - Chronic
  - Episodic

Three-Tier Safety Goal Structure

	Reactor Operations	**Materials & Waste**	
Tier I Qualitative Goals	•Risk to individuals •Societal risk	•Risk to individual/society, including public and workers •Environmental and property damage risk	
Tier II Quantitative Goals	•Prompt fatality risk •Cancer fatality risk	•Quantitative health objectives •Quantitative environmental objective (QEO)	
Tier III Subsidiary Objectives	•Core damage frequency •Large early release frequency	Chronic	Episodic
		Dose Rate	Various

Qualitative Goals

Early First Draft

- Individual: Nuclear materials use and disposal do not pose significant additional risks to the life and health of individual members of the public, and to workers associated with these activities.

- Society: Societal risks to life and health from nuclear materials use and disposal are not significant additions to other societal risks, and the benefits of the use greatly outweigh the risks.

- Environment and Property: Nuclear materials use and disposal do not result in environmental or property damage in excess of other means of achieving a similar end objective that is deemed beneficial to society.

Quantitative Objectives

Early First Draft

- Quantitative Health Objectives (QHO)
  - Individual Public Acute (QHO 1): The risk to an individual member of the public, in the vicinity of a facility or site, of prompt fatality due to acute radiation exposure that might result from accidents involving nuclear materials use and disposal activities does not exceed one-tenth of one percent (0.1 percent) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. public are generally exposed.
  - Individual Public Latent (QHO 2): The risk to the population, in the vicinity of a facility or site, of cancer fatalities that might result from nuclear materials use and disposal does not exceed one-tenth of one percent (0.1 percent) of the sum of cancer fatality risks resulting from all other causes.
  - Individual Worker Acute (QHO 3): The risk of prompt fatality to any worker arising from a nuclear materials use or disposal activity does not exceed one percent (1 percent) of the sum of prompt occupational fatality risks that U.S. workers are generally exposed.
  - Individual Worker Latent (QHO 4): The risk of latent cancer to workers from nuclear materials use and disposal activities does not exceed a small fraction of the risk of cancer of workers in other hazardous material industries.
  - Societal Public (QHO5): The cumulative risk (expected value) of acute plus latent fatalities for a nuclear materials application is much less than (1%) the benefit of that application.

Quantitative Objectives

Early First Draft

- Quantitative Environmental Objective (QEO)
  - The risk of environmental or property damage that is implied by a particular materials use or disposal activity are clearly less than the sum of the risks from all other activities aimed at achieving a comparable societal benefit.

Subsidiary Objectives

Early First Draft

- Chronic risk goal
  - Various dose values have been proposed: 1, 2, 4, 40 mrem/yr? Relative?

- Episodic
  - Expressed in terms of engineering or process failures and corresponding likelihoods (see table)

Example Subsidiary (Episodic) Objectives for Various Uses

Use or Facility	Subsidiary Objective – Likelihood of ...
Uranium Milling	Yellowcake and chemical release
In Situ Leaching	Yellowcake and chemical release/groundwater excursion
Fuel Conversion	Yellowcake release/UF6 and other chemical release
Fuel Enrichment	UF6 and other chemical release
Fuel Fabrication	Large radiological and chemical release/criticality
Industrial Uses	Radiation dose to workers/public
High Level Waste	Defined in new 10 CFR Part 63
Low Level Waste	Release from waste disposal unit
Mill Tailings	Release from impoundment area
Decommissioning	Dose
Spent Fuel (Pool)	Fuel Damage/release
Spent Fuel (Dry Storage)	Loss of confinement, shielding, criticality control, and/or fuel retrievability
Transportation	Loss of containment, shielding, and/or criticality control
Reactor Operation	Core damage/large early release

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United States
Nuclear Regulatory Commission

Probabilistic Risk Assessment for Dry Cask Storage

Jack Guttmann, Section Chief
Technical Review Section B
Spent Fuel Project Office
Nuclear Materials Safety and Safeguards

Presentation to ACRS/ACNW Joint Subcommittee
November 14, 2001

DRY CASK STORAGE PRA

BACKGROUND:

- SFPO ISSUED USER NEED LETTER TO RES FOR DRY STORAGE PRA
- RES - SFPO ESTABLISHED TASK GROUP
- GENERIC PRA USING CERTIFIED CASK ON GENERIC SITE
- PRA PERFORMED IN-HOUSE WITH LIMITED CONTRACTOR ASSISTANCE (E.G., HUMAN FACTORS)

United States
Nuclear Regulatory Commission

DRY CASK STORAGE PRA

PURPOSE:

- PROVIDE TOOLS FOR RISK-INFORMING 10 CFR 72
- PROVIDE TOOLS IN SUPPORT OF NMSS's RISK TASK GROUP ACTIVITIES (E.G., SAFETY GOALS DEVELOPMENT)
- PROVIDE TOOLS FOR RISK-INFORMING INSPECTION PROGRAMS
- MAINTAIN SAFETY
- ENHANCE PUBLIC CONFIDENCE
- REDUCE UNNECESSARY BURDEN

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DRY CASK STORAGE PRA

TASK FORCE EXPERTISE:

- ✓ PROJECT MANAGEMENT
- ✓ PRA
- ✓ STRUCTURAL DYNAMICS
- ✓ MATERIAL SCIENCES (PROBABILITY OF FAULTY WELDS)
- ✓ SEISMIC
- ✓ CRITICALITY
- ✓ THERMAL
- ✓ CONSEQUENCE ANALYSIS
- ✓ STATISTICS
- ✓ HUMAN FACTORS (CONTRACTOR)

United States
Nuclear Regulatory Commission

Probabilistic Risk Assessment for Dry Cask Storage: Introduction

Alan Rubin, Section Chief
Probabilistic Risk Analysis Branch
Office of Nuclear Regulatory Research

Presentation to ACRS/ACNW Joint Subcommittee

November 14, 2001

Overview

- Introduction
- Overall modeling approach/SAPHIRE PRA model
- External initiating events frequencies
- Fire analysis
- Thermal loads
- Mechanical loads
- Cask response to thermal & mechanical loads
- Consequences
- Additional Analyses/Next Steps

Objectives of the Dry Cask PRA

- Develop methodology for performing PRA for dry cask storage systems

- Perform a pilot PRA for a specific cask design (Holtec HI-STORM) at a BWR site

  - Assess potential risk to public
  - Identify dominant risk contributors

Dry Cask PRA Team Members

- **DRAA/PRAB**

[Project mgt., SAPHIRE PRA model, initiating events, fire analysis]

  - Alan Rubin, Section Chief
  - Edward Rodrick/Lee Abramson, Project Manager
  - Christopher Ryder
  - Brad Hardin
  - Moni Dey

- **DET/ERAB**

[Mechanical loads analyses]

  - Khalid Shaukat

- **DET/MEB**

[Failure analyses for thermal and mechanical loads]

  - Cayetano Santos
  - Douglas Kalinousky

- **DSARE/SMSAB**

[Thermal loads, consequence analyses, criticality]

  - Jason Schaperow
  - Carlos Navarro
  - Anthony Ulses

Scope of the Study

- ❑ Handling

  - Loading fuel into multi-purpose canister (MPC)
  - Drying/inerting/sealing MPC
  - Inserting MCP into overpack

- ❑ Transfer (moving cask to storage pad)

- ❑ Storage

- ❑ Beyond scope

  - Fabrication of cask
  - Off-site transportation
  - Sabotage

A Risk Analysis of Dry Cask Storage:
Discussion of Methods

ACRS/ACNW Subcommittee

Christopher Ryder, RES/DRAA/PRAB

November 14, 2001

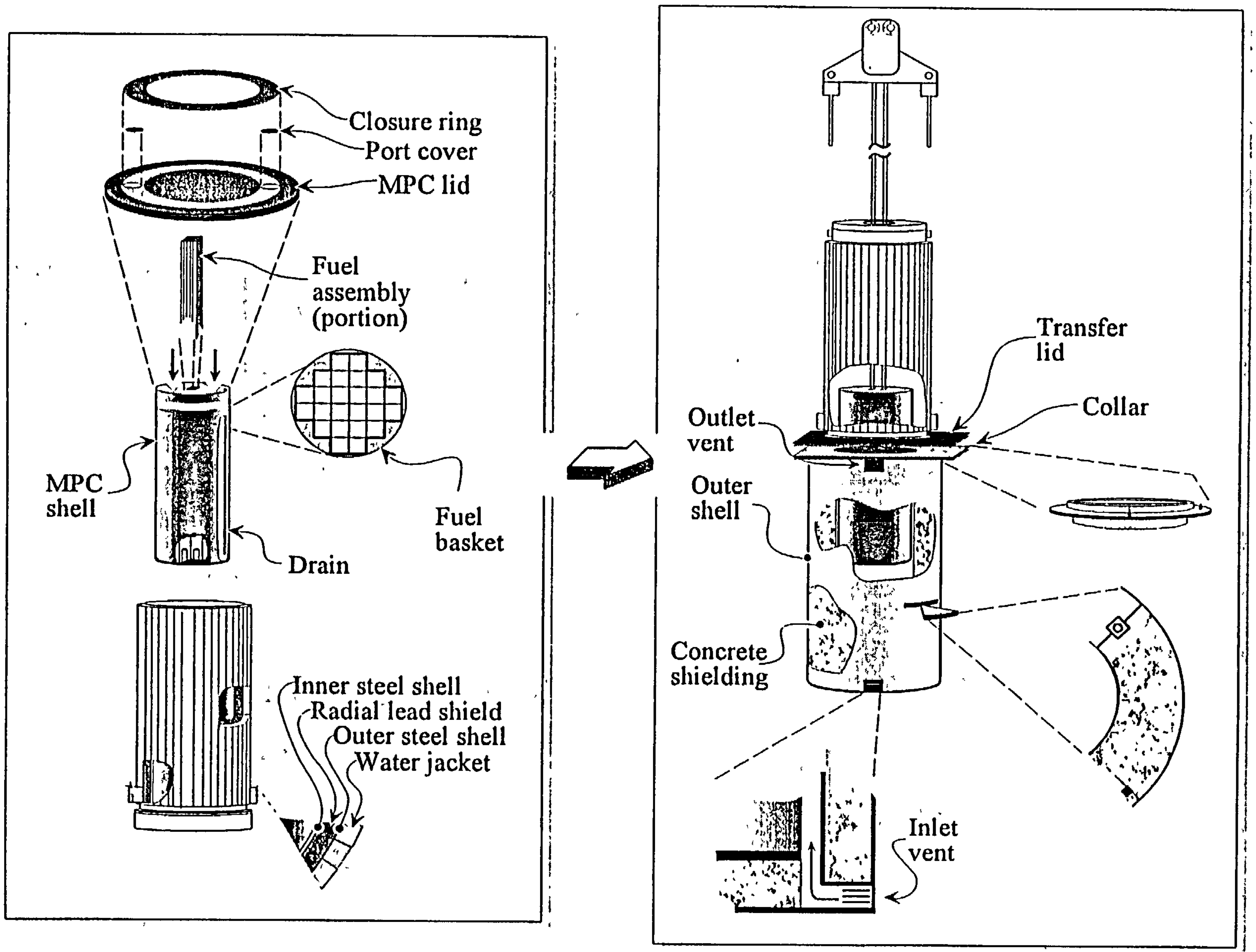
Dry Cask PRA

- Holtec International HI-STORM cask
  - Multipurpose canister (MPC) contains fuel
  - Transfer cask (TRAC) shields MPC in reactor building
  - Overpack shields MPC outside and in storage

- Major dimensions ...

	Outer Diameter (feet)	Height (feet)	Shell Thickness (feet)
MPC	5.7	15.9	½ inch
TRAC	6.7	16.3 to 16.7	1.0
Overpack	11.2	19.3	2.5

Weight of loaded overpack — 180 tons


Closure ring
Port cover
MPC lid
Fuel assembly (portion)
MPC shell
Drain
Fuel basket
Inner steel shell
Radial lead shield
Outer steel shell
Water jacket
Transfer lid
Collar
Outlet vent
Outer shell
Concrete shielding
Inlet vent

Phases of Dry Cask Storage

- Loading Fuel
- Lifting MPC/TRAC from spent fuel pool
- Moving MPC/TRAC to the preparation area
- Preparation
  - Drying
  - Inerting
  - Sealing
- Moving MPC/TRAC to the overpack
- Inserting MPC into overpack

} **Handling**

- Moving the MPC/overpack to the storage pad } **Transfer**
- Storing for 20 years } **Storage**

Dry Cask PRA

- Two possible approaches to analyzing initiating events
  - Retain all initiating events to calculate risk, no matter how low their frequency
  - Perform a screening analysis
- Screening analysis done to use resources effectively

List of Initiating Events

- Enumerate events based on ...
  - "PRA Procedures Guide," NUREG/CR-2300
  - Study of cask design
  - Observe plant operations
  - Review plant procedures
  - Discussions with NMSS staff

- Screen out events based on ...
  - Irrelevant to the subject site
  - Engineering analyses revealed events that did not affect the cask
  - Low risk
    - Frequency of initiating event
    - Probability of MPC failure

Initiating Events

- Handling Phase
  - Mechanical Events
    - Drop when open
    - Drop when sealed
- Transfer Phase
  - Mechanical Events
    - Drop
    - Tip over
  - Thermal Events
    - Fire from transfer vehicle fuel

Initiating Events (continued)

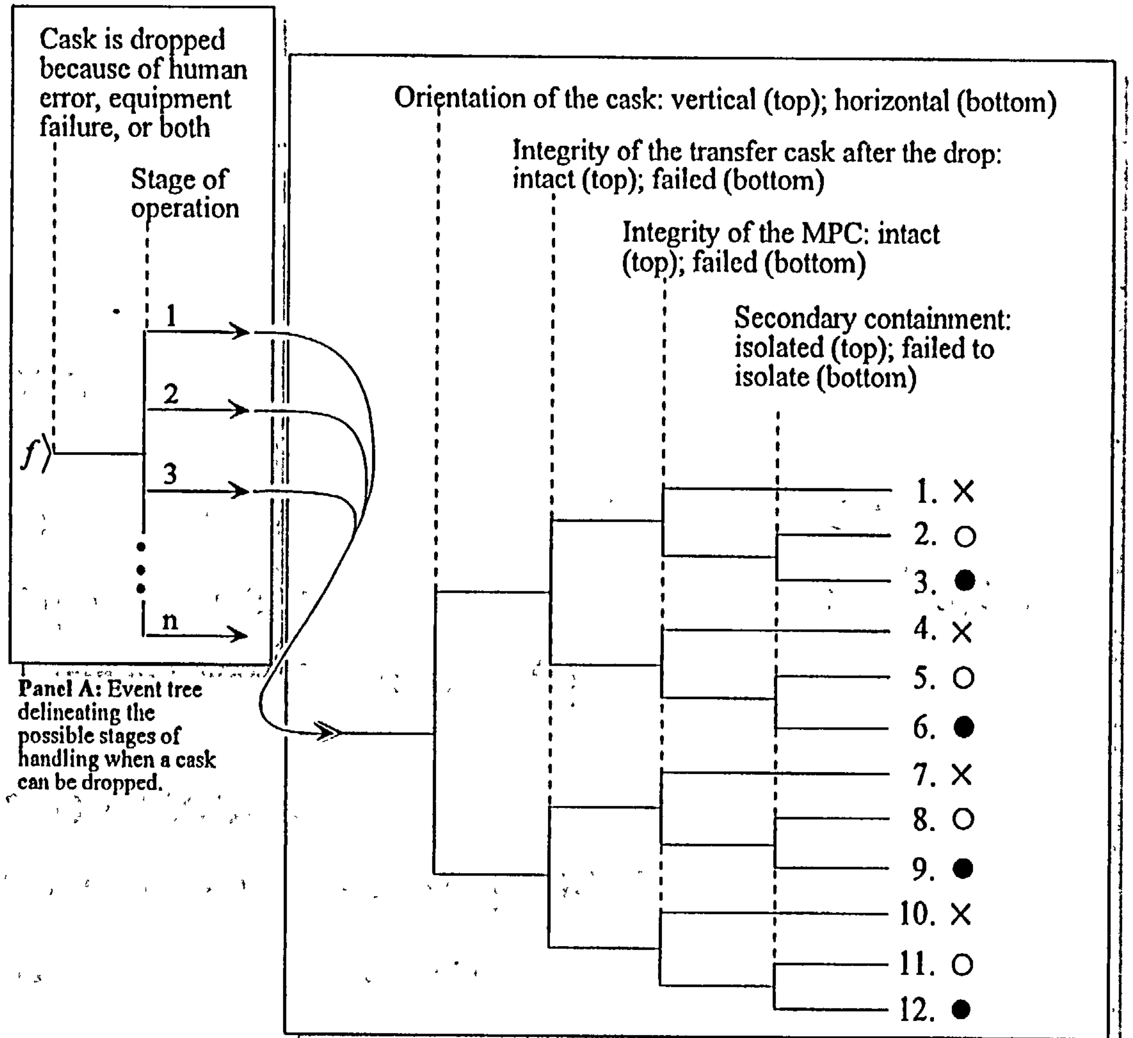
- Storage Phase
  - Mechanical Events
    - Tip over (earthquakes, high winds)
    - Strike from heavy object (tornado-generated missile)
    - Explosion (gas main, barge, truck)
  - Thermal Events
    - Vent blockage (flood water, debris)
  - Mechanical-Thermal Events
    - Accidental strike from aircraft
  - Other
    - Lightning

Method of Analysis

- Event trees model response of cask to initiating events

- Fault trees determine the probability of accident sequences caused by human error and equipment failure

- Stylized illustration of an event tree
  - Dropping a cask
  - MPC sealed
  - MPC inside transfer cask
  - Cask is inside reactor building



Panel A: Event tree delineating the possible stages of handling when a cask can be dropped.

Panel B: Event tree modeling the responses of a cask and secondary containment isolation to an initiating event of dropping a cask

Legend: ×denotes sequences with no consequences. ○ denotes sequences with smaller consequences. ● denotes larger consequences.

Inputs to the PRA

- Initiating event frequencies
- Probability of MPC failure
  - Mechanical and thermal loads
  - Fracture mechanics
- For events in the reactor building ...
  - Probability of secondary containment system isolation
  - Decontamination factors with & without isolation
- Consequences

Dry Cask Storage PRA

External Initiating Event Frequencies

Briefing to ACRS/ACNW

Brad Hardin, RES/DRAA/PRAB

November 14, 2001

External Events Evaluated

- Accidental aircraft crashes
- Tornadoes
  - cask sliding and tip over
  - wind-generated missiles
- Flooding
- Lightning

Accidental Aircraft Crashes

- Annual frequency of aircraft crashes into the storage site during takeoffs and landings estimated

$$F_a = \sum(C_a x\ N_a)\ x\ A_{eq}$$

Where:

F_a = Number of crashes per year into the storage site
C_a = Empirical constant for number of crashes/year/mile^2
N_a = Total number of takeoffs and landings per year
A_{eq} = Equivalent cask target area for aircraft crash (mile^2)

- Estimate that frequency of accidental air crashes during takeoffs and landings ~1E-9 events/year.

Tornadoes - Sliding and Tip Over

- Tornado wind speeds
  - Cask sliding - 400 mph or greater required
  - Cask tip over - 600 mph or greater
  - Highest recorded tornado in U.S. ~ 300 mph.
- Performed regression analysis
  - Resulting expression extrapolated out to 400 mph
  - Estimated probability of exceedance for 400 mph ~ 1E-5
- Historical data for annual number of tornadoes in site area
- Estimate frequency of tornado-related cask sliding~1E-9 /year
- Estimate frequency of tornado-related cask tipping <<1E-9/year
  (No attempt to extrapolate the data out to 600 mph)

Tornado-Generated Missiles

- Analysis of missiles generated by design basis tornado with wind speed 360 mph (utility pole, 12" Sch 40 pipe, steel rod, automobile)
  - No penetration of concrete shell and no MPC failure

- Conclude frequency of occurrence of tornado-driven missiles failing cask << 1E-9 events/year.

Flooding

- Flooding at storage site screened out:
  - Topography precludes flooding during heavy rainfall
  - Site elevation precludes river-related flooding (including dam break)

Lightning

- Lightning activity in U.S. monitored by National Lightning Detection Network
  - Operated, and data disseminated, by Global Atmospherics, Inc.
  - Over 100 detection sites spread over the country
  - Data provided ground flash density (lightning strikes/year/mile^2)

- Estimated frequency lightning strikes ~ 1E-2 strikes/year

Fire Analysis for Dry Cask PRA

Moni Dey, Probabilistic Risk Analysis Branch, DRAA/RES

Briefing for ACRS/ACNW

November 14, 2001

Statement of Problem

- Fuel spillage from Lear Jet 45 aircraft
- Dry cask remains upright and is engulfed in fire
- Fire analysis of 1 dry cask
- Dry cask OD=3.37 m, and height = 5.87 m
- 6080 lb of Jet A fuel spilled

Objective of Analysis

Determine:

- **Duration of fire assuming all the fuel leaks out**
- **Vertical temperature distribution of hot gas from fire around dry cask**
- **Temperature near inlet and outlet vents**

Analysis – Duration of Fire

- Manner of spillage needs to be postulated
- Duration of fire will be less if all the fuel spills at once
- Minimum spill rate chosen so that dry cask will be engulfed in fire
- Worst case scenario analyzed

Analysis – Duration of Fire

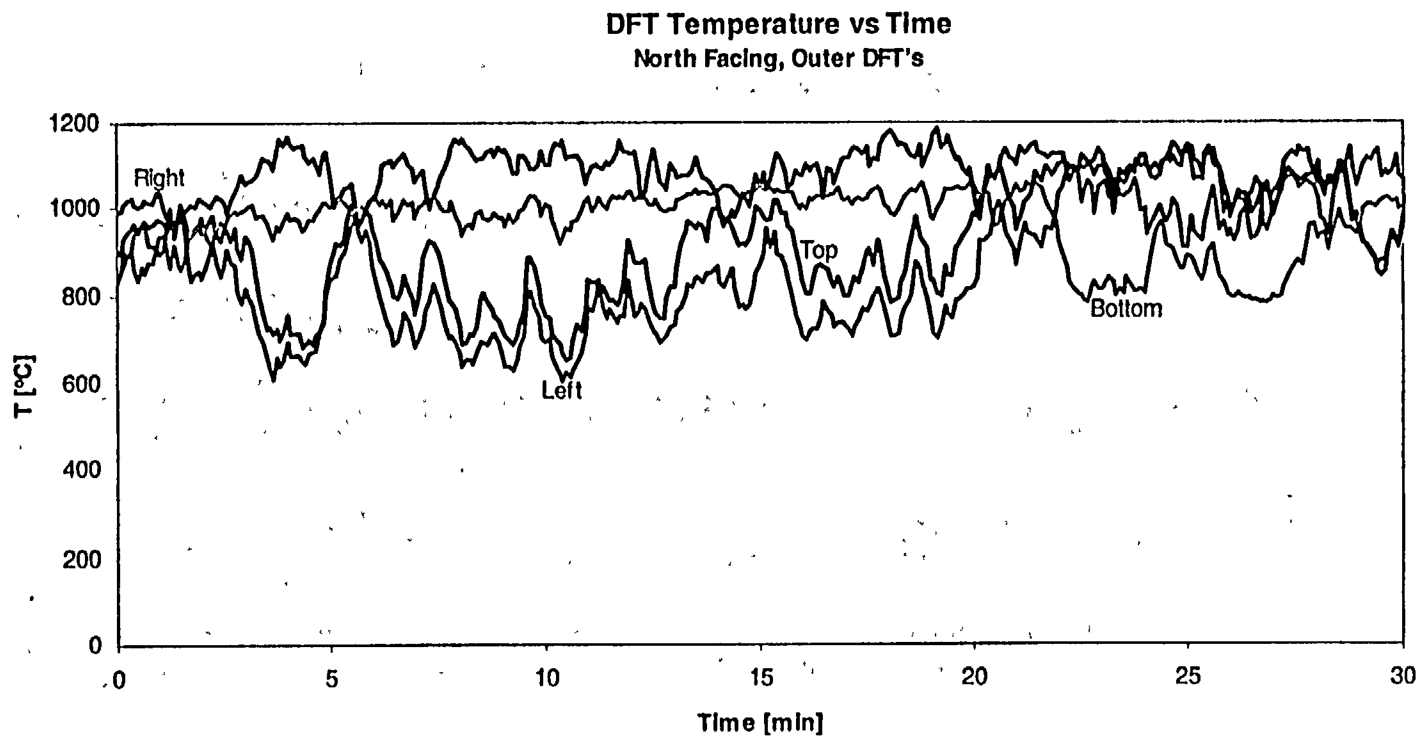
- Equilibrium diameter of fuel pool related to fuel spill rate and burning rate
- Burning rate = 4 mm/min (see data in attachment)
- Assumed fuel pool size needed to engulf fire is twice diameter of dry cask
- Duration of fire estimated to be 24 minutes

Analysis – Temperature of Hot Gas

Two sources of information used:

- **Plume Models**
- **Recent SNL tests**
  - **Horizontal transportation cask**
  - **Temperatures measured near cask near ground level was ~ 1800 F**

SNL Test Data



Plume Models

- Several plume correlations developed in last two decades
- Temperature and velocity in plume measured
- Plume divided into
  - Consistent flame region
  - Intermittent flame region
  - Plume with no flame

Plume Models

- Based on correlation:
  - entire dry cask projected to be in consistent flame region
  - Temperature of hot gas around dry cask estimated to be 1500 F
  - Recommend using 1000 C (1832 F) for hazard analysis

(see attachment for details)

Conclusion of Fire Analysis

For conservative fire scenario postulated:

- **Duration of fire estimated to be ~ 24 minutes**
- **Inlet and outlet vents of cask will be exposed to hot gases at ~ 1830 F**

Table 4.2 Summary of centre line data for a buoyant methane diffusion flame on 0.3 m square porous burner (McCaffrey, 1979) (Figure 4.8)

Centreline velocity: $\dfrac{u_0}{Q^{1/5}} = k\left(\dfrac{z}{Q^{2/5}}\right)^{\eta}$

Centreline temperature: $\dfrac{2g\Delta T_0}{T_0} = \left(\dfrac{k}{C}\right)^2 \cdot \left(\dfrac{z}{Q^{2/5}}\right)^{2\eta-1}$

Region[a]	k	η	$z/\dot{Q}^{2/5}$ (m/kW$^{2/5}$)	C
Flame	6.8 m$^{1/2}$/s	1/2	< 0.08	0.9
Intermittent	1.9 m/kW$^{1/5}$.s	0	0.08–0.2	0.9
Plume	1.1 m$^{4/3}$/kW$^{1/3}$.s	−1/3	> 0.2	0.9

Figure 4.17 Variation of centre-line temperature rise with height in a buoyant methane diffusion flame. Scales as $z/\dot{Q}_c^{2/5}$ (Table 4.2) (McCaffrey, 1979, by permission.)

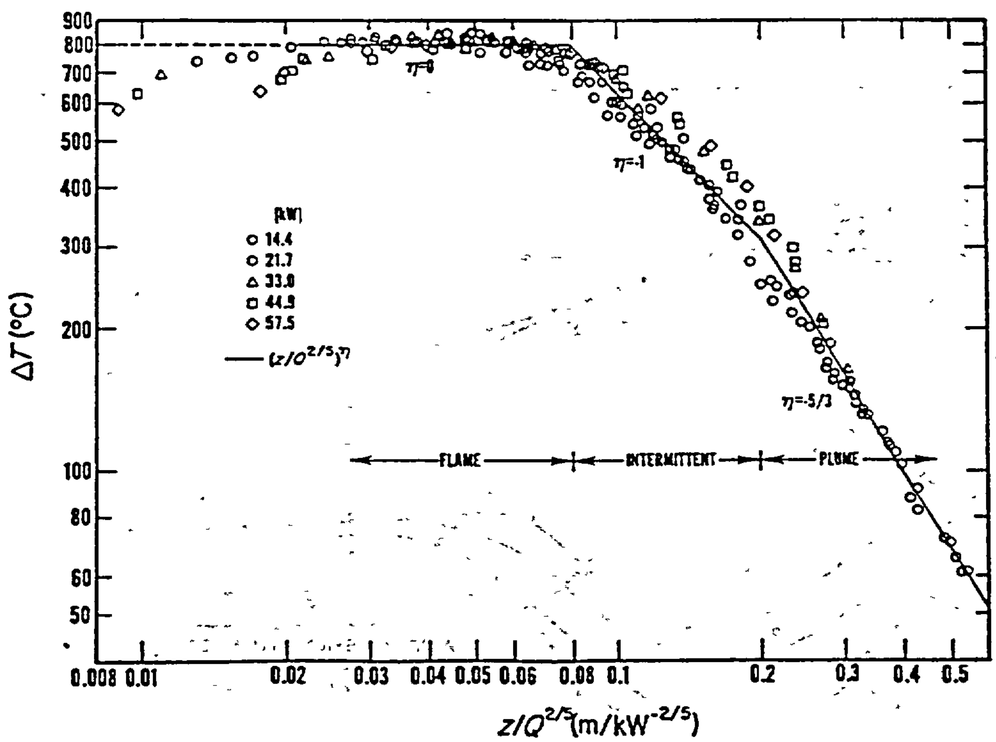


TABLE 3-11.1 *Physical Properties and Burning Rates for Hydrocarbon Pool Fires on Land*

Normal Paraffins	Net Heat Combustion (J/kg)	Heat of Vaporization (J/kg)	Boiling Point (°K)	Liq. Specific Heat (J/kg °K)	Burning Rate* (m/s)
Methane	500.2×10^5	5.1×10^5	111.7	—	2.08×10^{-4}
Ethane	472.0×10^5	4.9×10^5	264.6	—	1.22×10^{-4}
Propane	460.1×10^5	4.3×10^5	231.1	2.4×10^3	1.37×10^{-4}
Butane	453.9×10^5	3.9×10^5	272.7	2.3×10^3	1.32×10^{-4}
Pentane	450.1×10^5	3.6×10^5	309.7	—	1.43×10^{-4}
Hexane	447.7×10^5	3.4×10^5	341.9	2.5×10^3	1.22×10^{-4}
Heptane	445.9×10^5	3.2×10^5	371.9	2.1×10^3	1.13×10^{-4}
Octane	444.3×10^5	3.0×10^5	398.9	—	1.05×10^{-4}
Nonane	443.2×10^5	3.0×10^5	424.0	—	9.67×10^{-5}
Other Paraffins					
Isobutane	452.6×10^5	3.7×10^5	261.4	2.3×10^3	1.55×10^{-4}
Isohexane	445.4×10^5	3.2×10^5	333.5	—	1.37×10^{-4}
Isopentane	449.2×10^5	3.4×10^5	301.1	—	1.23×10^{-4}
Alkenes					
Ethylene	471.9×10^5	4.8×10^5	169.5	—	1.23×10^{-4}
Propylene	458.0×10^5	3.4×10^5	225.5	—	1.33×10^{-4}
Butylene	453.3×10^5	3.9×10^5	266.9	—	1.47×20^{-4}
Napthenes					
Cyclohexane	434.6×10^5	3.6×10^5	353.9	—	1.15×10^{-4}
Cyclopentane	465×10^5	3.9×10^5	322.5	—	1.32×10^{-4}
Methylcyclopentane	440×10^5	3.8×10^5	345.0	—	1.18×10^{-4}
Aromatics					
Benzene	406.0×10^5	3.9×10^5	353.3	1.4×10^3	1.00×10^{-4}
Toluene	405.5×10^5	3.6×10^5	383.8	1.5×10^3	9.5×10^{-5}
Xylene (o)	408.4×10^5	3.5×10^5	417.6	—	9.67×10^{-5}
Ethylbenzene	413.5×10^5	3.4×10^5	409.4	1.6×10^3	9.67×10^{-5}

*Note: Burning rates listed for C_1 to C_4 hydrocarbons are appropriate only for spills onto land, since their boiling points are typically below ambient temperatures and heat transfer from a body of water may be appreciable. All burning rates are estimated from property data and are not actual measurements.

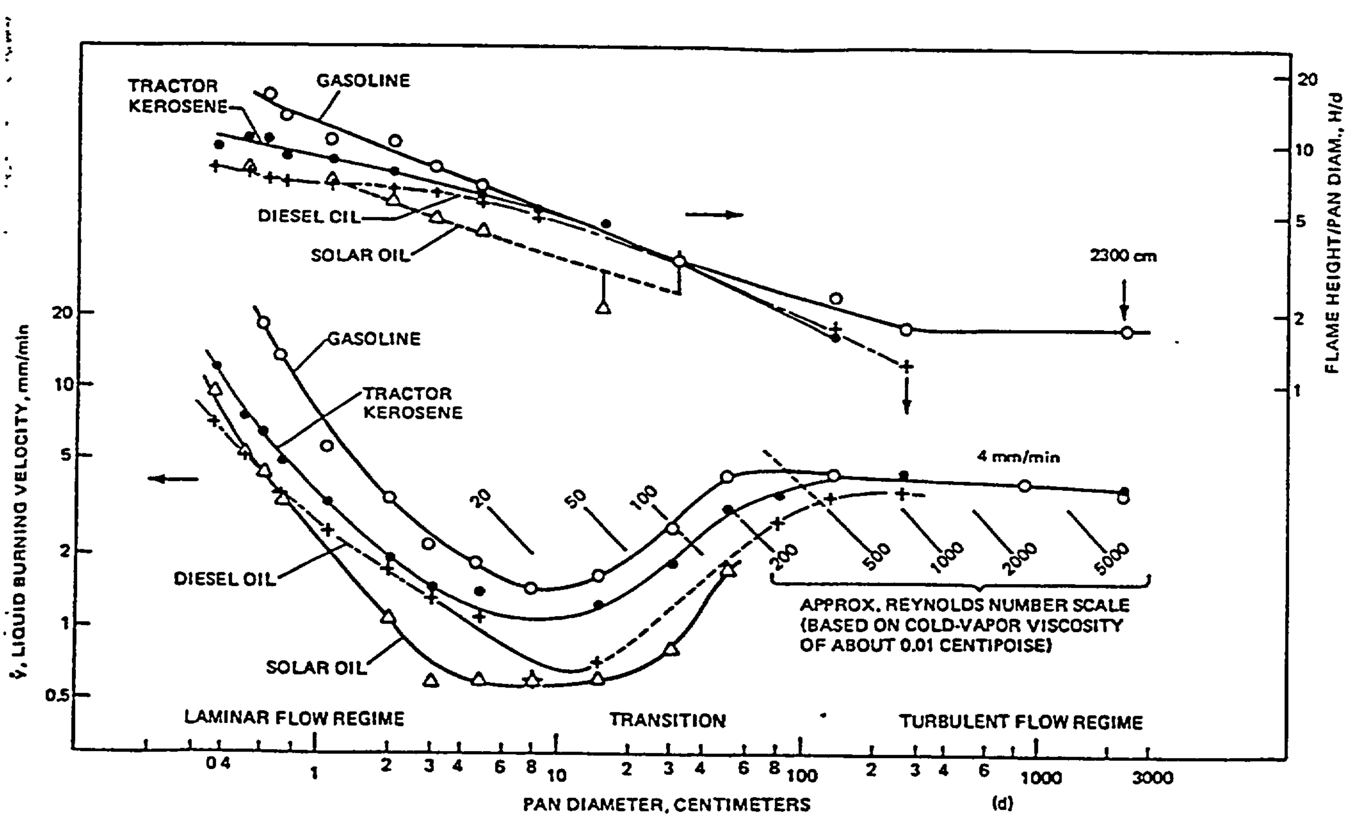


Fig. 3-11.2. Burning rates and flame heights for various hydrocarbon pool fires.[3]

United States
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Thermal Loads for Evaluating the Failure Probability of the HI-STORM 100 Cask Under Severe Accident Conditions

Briefing for the ACRS/ACNW Joint Subcommittee

Jason H. Schaperow
Safety Margins and Systems Analysis Branch
Division of Systems Analysis and Regulatory Effectiveness
Office of Nuclear Regulatory Research

November 14, 2001

Overview

Objective of Analysis

Assess cask heatup to allow evaluation of cask failure probability

Approach

Assess three scenarios for the HI-STORM 100 cask: blocked vents, buried cask, and external fire

Conclusions

Slow heatup for blocked vents and buried cask, due to low decay power

For external fire, temperature rise limited by fire duration.

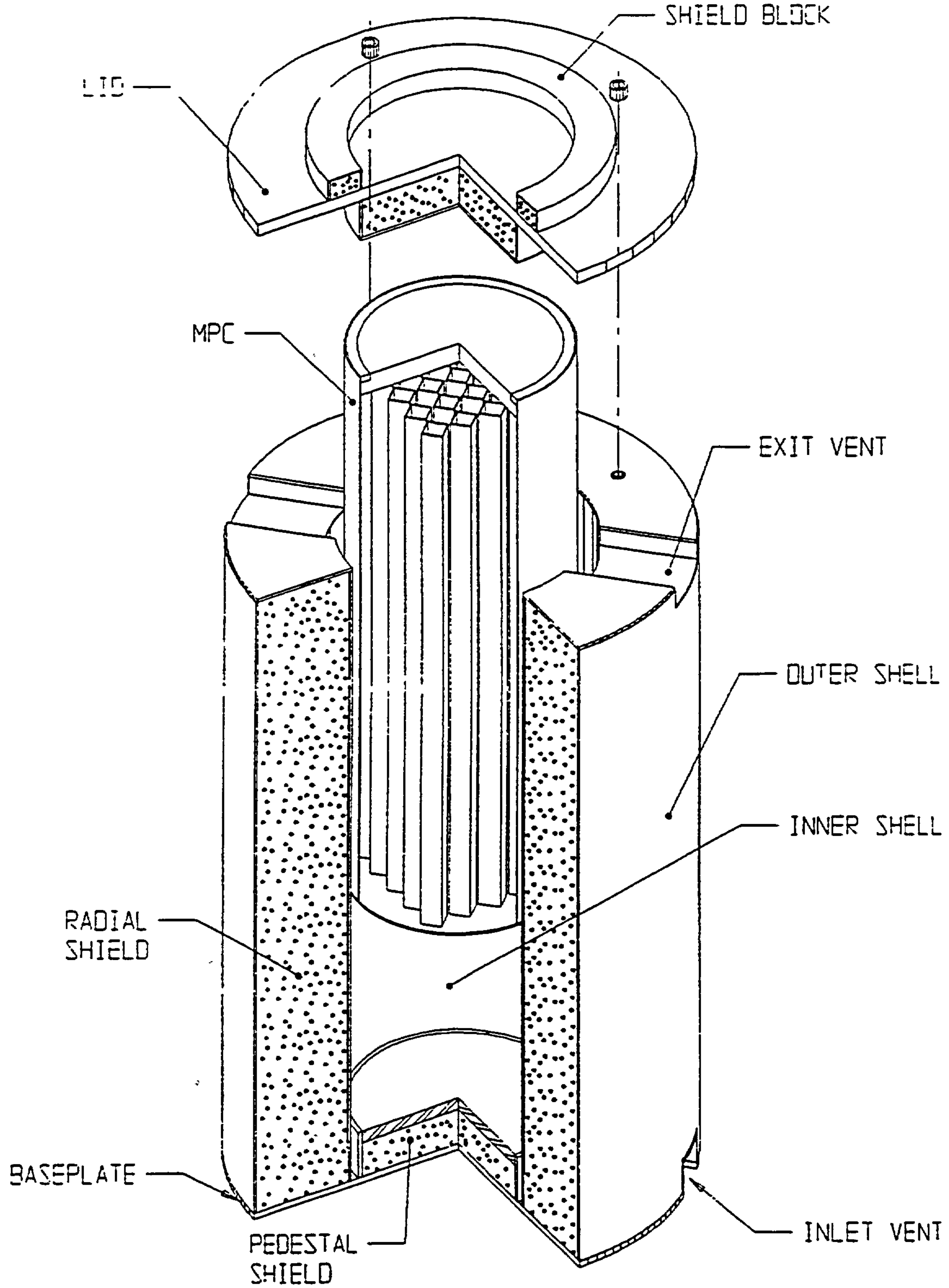


FIGURE 1.1.1; HI-STORM 100 OVERPACK WITH MPC PARTIALLY INSERTED

HI-STORM 100 Cask

HI-STORM 100 cask consists of a sealed metallic canister (called MPC) inside an overpack.

MPC is the confinement boundary for storage of spent fuel assemblies.

Overpack, which is constructed from steel and concrete, provides mechanical protection and radiological shielding.

Overpack has air ducts to allow passive natural convection cooling of the contained MPC.

Approach

Assessed three scenarios to develop a range of conditions that can be used to evaluate cask failure probability: blocked vents, buried cask, and external fire.

Case	Object of Case
Blocked Vents	Estimate heatup resulting from blocking all four intake vents
Buried Cask	Estimate heatup resulting from burial of cask under debris (no heat removal from exterior of cask)
External Fire	Estimate heatup resulting from external fire

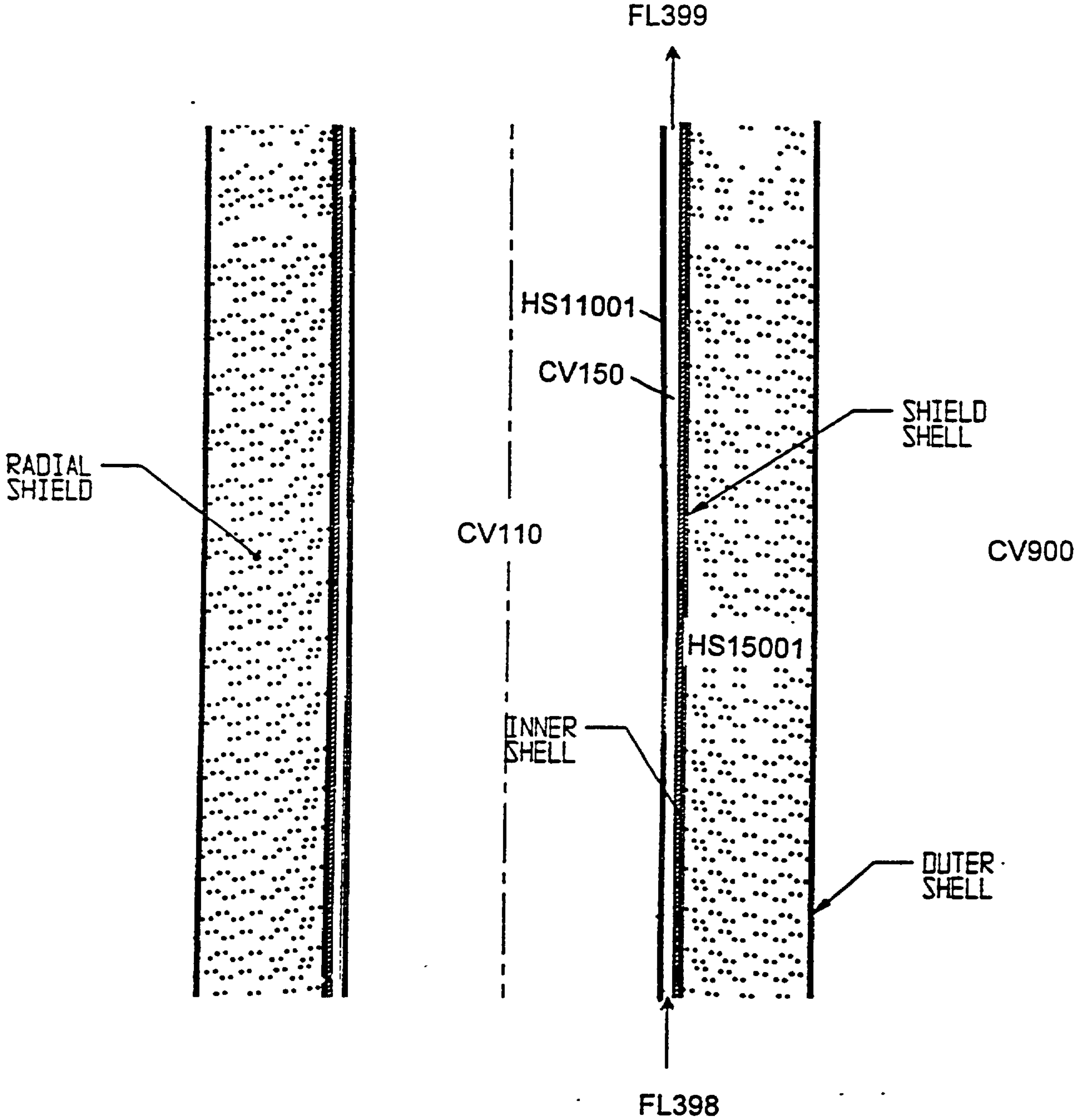
MELCOR Code

Integrated accident analysis code developed to simulate severe reactor accidents.

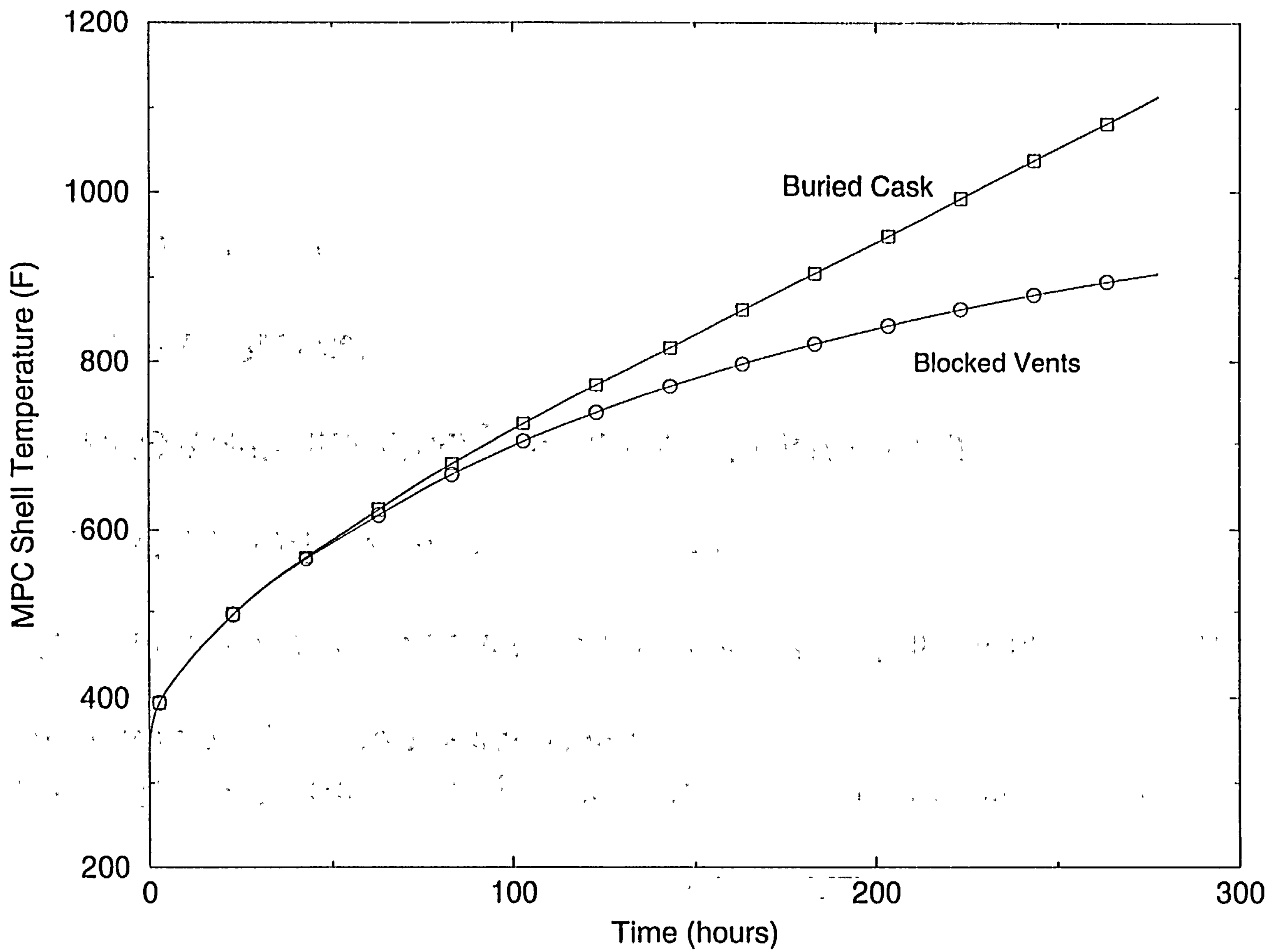
Used to calculate thermal hydraulics, core melt progression, and fission product source term.

Major inputs include

- **control volumes**
- **flow paths**
- **heat structures**
- **decay power** (each assembly has maximum of 315 watts, which is .007% of its operating power)


FL399
HS11001
CV150
SHIELD SHELL
RADIAL SHIELD
CV110
CV900
HS15001
INNER SHELL
OUTER SHELL
FL398

Results for Blocked Vents and Buried Cask Scenarios



External Fire Scenario

Ran MELCOR using a temperature of 1830°F for the environment to simulate a fully engulfing external fire

Maximum fire duration for Lear Jet 45 crash estimated to be .4 hours

Sensitivity analysis with assumed 4-hour fire

MELCOR estimate of temperature rise for MPC shell

- .4-hour fire: 80°F
- 4-hour fire: 260°F

Mechanical Loads on HI-TRAC and HI-STORM Casks and Stresses on MPC

Briefing for the ACRS/ACNW Joint Committee

S. Khalid Shaukat
Engineering Research Applications Branch
Division of Engineering Technology
Office of Nuclear Regulatory Research

November 14, 2001

OBJECTIVES

- To estimate the mechanical loads on the cask system for scenarios during handling, transfer, and storage of the Dry Cask System (HI-TRAC and HI-STORM).

- To determine the stresses in the Multi-Purpose Canister (MPC) that are used for estimating its probability of failure or consequences to public.

HANDLING EVENTS (MPC in HI-TRAC)

Drop from crane:

- Drop of HI-TRAC containing MPC was analyzed.
  - A drop of < 28" from the floor will not tip over.
- A drop of 62 ft on Rx Bldg floor or on top of overpack, could cause 64,000 psi axial stress in the MPC shell. Circumferential stress is small (<1,000 psi).

MPC falling from HI-TRAK into Overpack:

- 20 ft drop of MPC into the overpack could cause 11,000 psi axial stress in the MPC shell.

TRANSFER EVENTS (MPC IN OVERPACK)

Move to Storage Pad

- If crawler vehicle traveling at 0.4 mph (max. speed) carrying the cask may drop it on the asphalt or gravel. 11" drop would not tip over the cask.

- If the cask fell on the ground and crawler operator fails to stop the vehicle, the cask (360,000 lbs) will not move. Crawler (158,000 lbs) tracks will slip.

- If the crawler carrying the cask hits another cask on the pad, it may slide but not tip over the "struck" cask. The stresses in the base plate, lid, and the shell will be very small (< 340 psi).

STORAGE EVENTS (MPC IN OVERPACK)

Seismic Event:

- Sliding:
  - Almost no sliding (<0.1") for DE of 0.15g.
  - Sensitivity analyses show that it would take 10 x DE (1.5g) to move the casks up to half the separation distance between the casks.
- Tip over: No tip over for E.Q. of 10 x DE.

Aircraft Impact: (LearJet 45, 20,500 lbs, Max Vel 527mph)

- Speed > 235 mph could slide/tip-over the cask.

STORAGE EVENTS (CONTINUED)

Tornado:

- Tornado velocity of 400 mph could slide the cask.

- Tornado velocity of 600 mph could tip over the cask.

- 360 mph tornado generated missiles (Utility pole, 12" Sch 40 pipe, steel rod, automobile) won't penetrate cask.

- An automobile, as tornado missile, will not slide or tip over the cask.

STORAGE EVENTS (CONTINUED)

Shock waves:

Caused by explosions from natural gas pipeline at 4.5 miles will not affect the structural integrity of the cask.

Flood:

- Flood velocity of 25 fps (17 mph) or less will not slide or tip over the cask.

MPC Failure Analysis: Thermal & Mechanical Loads

Briefing for the ACRS/ACNW Joint Subcommittee

Ed Hackett, Tanny Santos, Doug Kalinousky

Materials Engineering Branch

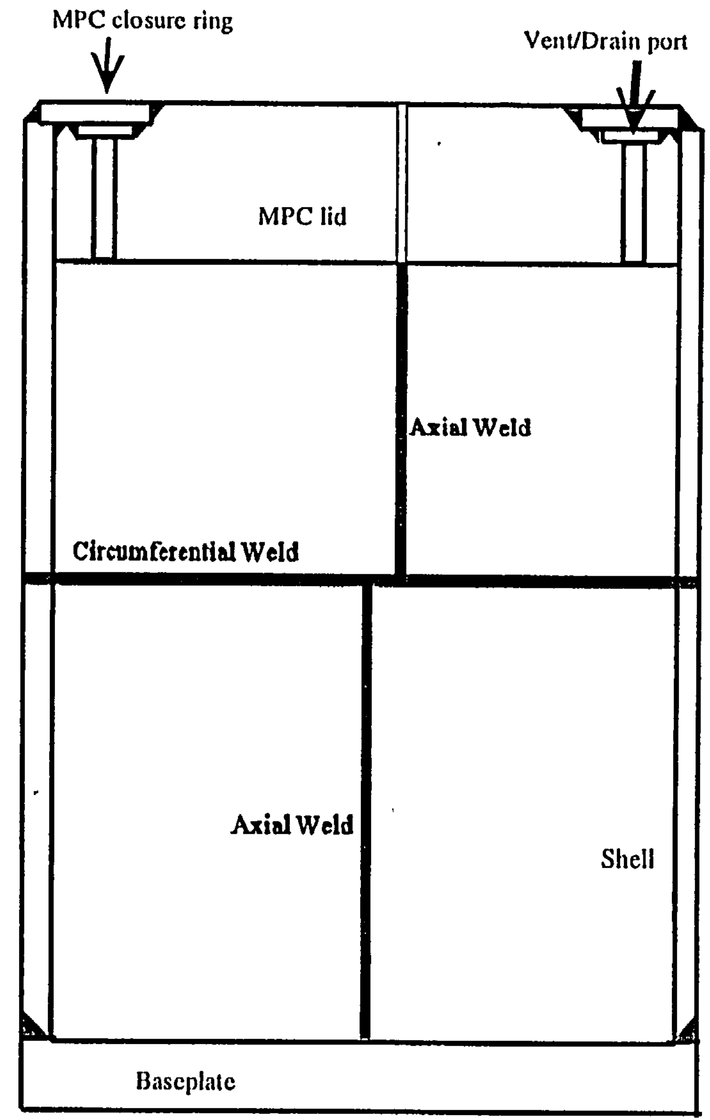
Division of Engineering Technology

Office of Nuclear Regulatory Research

November 14, 2001

Multi-Purpose Canister

- 3 Failure Mechanisms
  - Fracture
  - Limit Load
  - Creep Rupture
- Failure models created in Excel with @RISK add on module
- Monte-Carlo simulations



General Information

- Mechanical Accidents
  - HI-TRAC Vertical Drop (handling)
  - MPC Drop (handling)
  - HI-STORM Tipover (storage)
- 2 Failure Mechanisms
  - Fracture
  - Limit Load
- Thermal Accidents
  - Blocked Vents
  - Buried Cask
  - External Fire
- Stress from internal pressurization
- 3 Failure Mechanisms
  - Fracture
  - Limit Load
  - Creep Rupture

Fracture Mechanics

- Failure Analysis Diagram (FAD) Methodology
  - Structures with flaws
  - Flaw parameters from PRODIGAL analysis
  - Assume all flaws surface breaking (conservative)
  - Toughness and strength properties from literature

Limit Load

- Structures without flaws
- Failure criteria
  - applied stress exceeds flow stress
  - membrane stress: $\sigma_f = ½\,(\sigma_y + \sigma_u)$
  - bending and membrane stress: 150% σ_f

$$\therefore\ \sigma_{fb} = ¾(\sigma_y + \sigma_u)$$

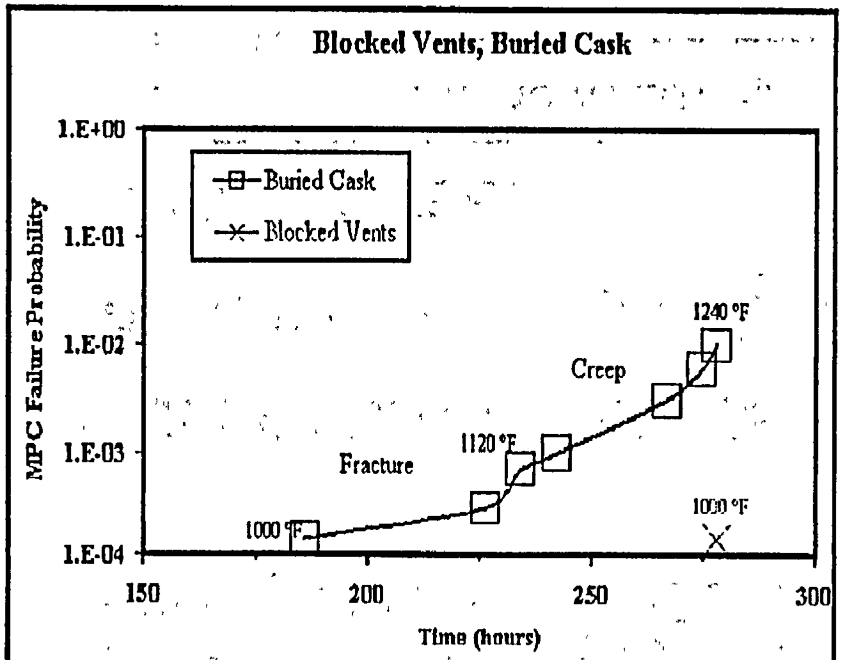
- Sampled σ_y and σ_u

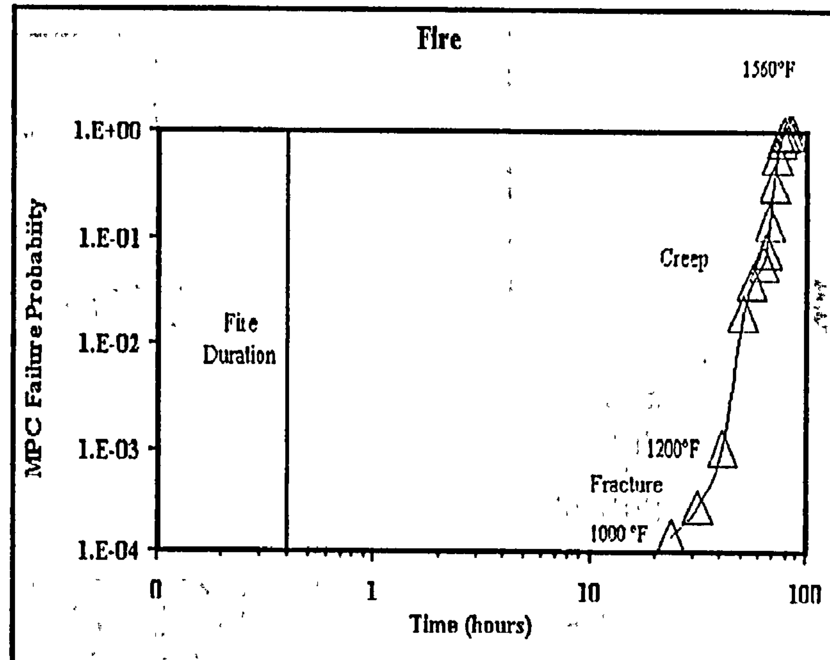
Creep Rupture

- Damage accumulation model
  - Stress, temperature, time
- Used for flawed and unflawed material
  - Flaw adds a stress magnification
- Creep rupture strengths obtained from literature
  - Time/temperature conditions converted to a Larson-Miller (L-M) parameter
- Evaluation procedure
  - For a given stress, sample L-M
  - Calculate creep damage fraction
  - Sum all damage fractions
  - If sum $\geq$ 1, failure
- Assumed initial steady state temp for 40 years

Results: Thermal Loads

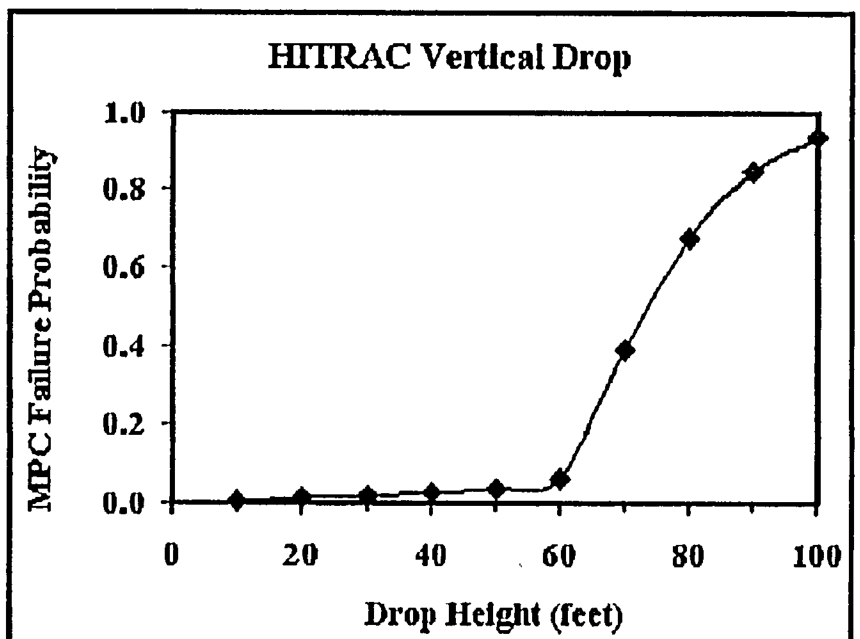
- Failure probability as a function of time and temperature for thermal scenarios
- Fire duration (~25 min) is NOT long enough to cause MPC failure

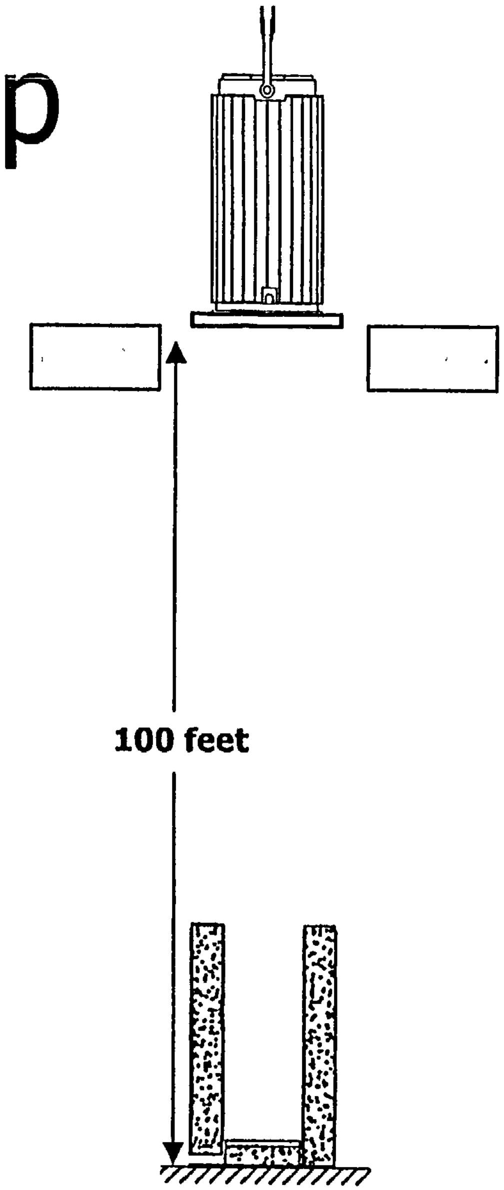




TRAC/MPC Vertical Drop

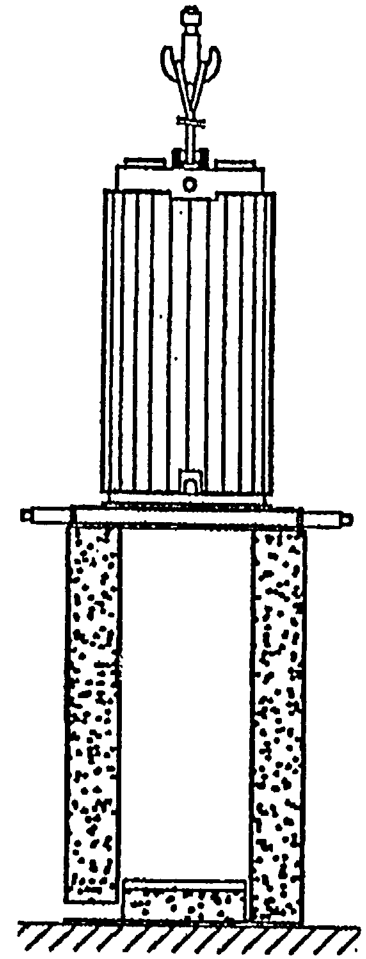
- Failure probability as a function of drop height from 0 to 100 feet





MPC Drop

- 20 foot vertical drop
  - Into HI-STORM
  - Maximum applied stress = 11 ksi
  - All failures from fracture
  - Failure probability = $2x10^{-4}$



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Consequence Evaluation for the HI-STORM 100 Cask Under Severe Accident Conditions

Briefing for the ACRS/ACNW Joint Subcommittee

Jason H. Schaperow
Safety Margins and Systems Analysis Branch
Division of Systems Analysis and Regulatory Effectiveness
Office of Nuclear Regulatory Research

November 14, 2001

Overview

Objective

Assess consequences of dry cask storage accidents

Approach

Use the MACCS reactor accident consequence code with input representative of dry cask storage accidents

Examine effect of important parameters on consequences

MACCS Code

Consequence code for accidental radioactive release into the atmosphere

Atmospheric transport

Dose accumulation

Exposure mitigating actions

Health effects

Parameters Being Examined

Examine effect of...

- **Radionuclide inventory**
- **Release fractions**
- **Release start time**
- **Release duration**
- **Initial plume dimensions**
- **Plume heat content**
- **Population density**
- **Site-specific weather**

Inventory

Cask has a lower inventory than a reactor

Fewer assemblies in a cask than in a reactor core

	Number of Assemblies	
	HI-STORM cask	reactor core
PWR	24	157 (2400 MWt)
BWR	68	560 (2600 MWt)

Fuel in cask has been out of reactor for at least five years

Out of 60 isotopes used for MACCS analysis for reactor accident consequences, only 16 have non-zero inventories.

Source Term

Factors being evaluated

- **Fraction of rods failing**
- **Release from failed rod**
- **Deposition in cask**

United States
Nuclear Regulatory Commission

Probabilistic Risk Assessment for Dry Cask Storage: Next Steps

Alan Rubin, Section Chief
Probabilistic Risk Analysis Branch
Office of Nuclear Regulatory Research

Presentation to ACRS/ACNW Joint Subcommittee

November 14, 2001

Next Steps - Complete Additional Analyses

- ❑ Human reliability analysis
- ❑ Probability of cask drop (human error/equipment failure)
- ❑ Mechanical loads
  - Higher crane drop heights (> 60 ft.)
  - Drop from crawler on to yielding surface
- ❑ Thermal loads
  - More detailed nodalization
  - Higher decay heat (misloading fuel)
  - Effects of improper drying/inerting of MPC

Next Steps - Complete Additional Analyses (cont.)

- Fuel failure models
- Probability of failure of secondary containment isolation
- Source term/consequences
- Revise and run integrated PRA model
- Estimate overall risk and identify dominant risk contributors

Next Steps (cont.)

- Issue draft report to NMSS - June 2002
- Peer review
- Need for additional detailed analyses - TBD
- Issue final report