Multi-Canister Overpack Fragility Analysis – Background and Status

Presentation for Nuclear Waste Technical Review Board

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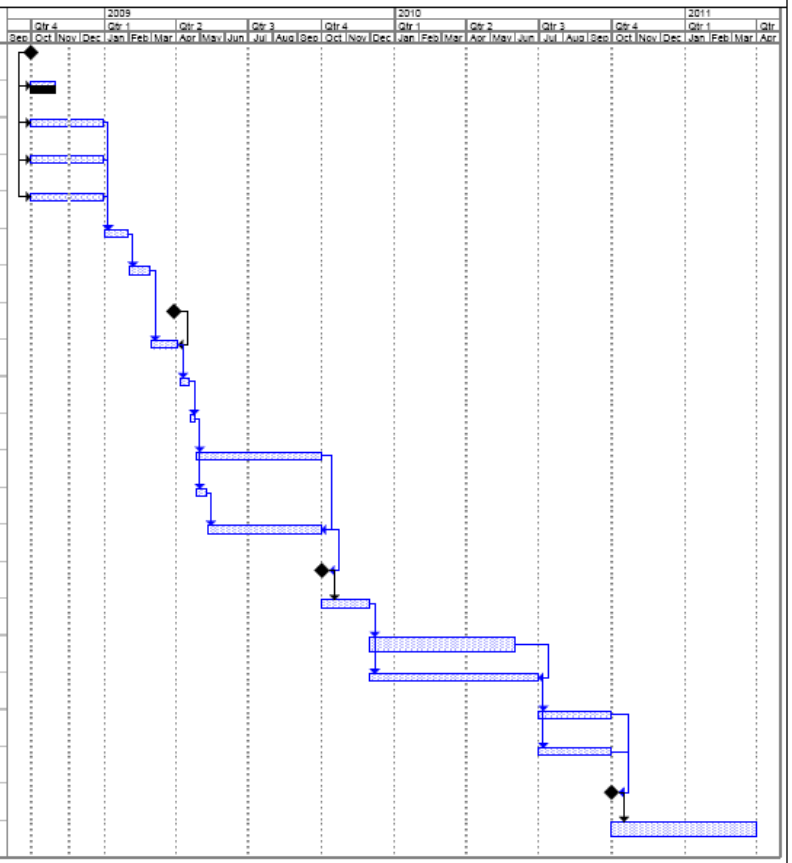
Background

- Deterministic analyses, supported by drop tests, indicated MCO would meet specified pre-closure safety requirements.
- Probabilistic analyses completed by LLNL in early 2008 did not confirm acceptable MCO performance for pre-closure for off-angle drops.
- LA was submitted in June 2008 with MCOs excluded, pending completion of analyses for pre-closure handling scenarios.
- A meeting was held with the YMP in August 2008 to identify a path forward.
  - The MCO upper head was identified as an additional area of concern based on YMP-specific handling operations.
  - The NSNFP identified several analytical and, if needed, design solutions for ensuring the MCO breach probability would be sufficiently low.
  - A path forward for remedying the situation was agreed upon.

MCO Task Plan

MCO Tasks

ID	ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	1	Start	0 days	Wed 10/1/08	Wed 10/1/08		
2	2	Provide MCO potential structural challenge scenarios to INL (does not include transportation cask scenarios)	22 days	Wed 10/1/08	Thu 10/30/08	1SS	PCSA
3	3	Review MCO threaded region for determination of confinement	65 days	Wed 10/1/08	Tue 12/30/08	1SS	INL
4	4	MCO Material Property comparison with LLNL Analysis	65 days	Wed 10/1/08	Tue 12/30/08	1SS	INL
5	5	Review Application of Triaxiality factor to MCOs	65 days	Wed 10/1/08	Tue 12/30/08	1SS	INL
6	6	Document evaluation in a report and deliver to BSC	21 days	Fri 1/2/09	Fri 1/30/09	3,4,5	INL
7	7	Review INL's report	20 days	Mon 2/2/09	Fri 2/27/09	6	PCSA
8	8	Complete NNPP analysis methodology	0 days	Mon 3/30/09	Mon 3/30/09		PCSA
9	9	Adapt insights from NNPP methodology applicable to MCOs	25 days?	Mon 3/2/09	Fri 4/3/09	7,8FF	PCSA
10	10	Prepare for structural analysis workshop	10 days	Mon 4/6/09	Fri 4/17/09	9	INL,PCSA
11	11	Conduct structural analysis workshop	5 days	Mon 4/20/09	Fri 4/24/09	10	INL,PCSA,RPM
12	12	Issue simple design modifications of MCOs or CRCF, if any, as concluded in the workshop	113 days	Mon 4/27/09	Wed 9/30/09	11	RPM,INL
13	13	Update and provide updated structural challenges to INL based on design modifications, if any	10 days	Mon 4/27/09	Fri 5/8/09	11	PCSA
14	14	Conduct MCO structural analyses	103 days	Mon 5/11/09	Wed 9/30/09	13,12FF	INL
15	15	Deliver documented structural analyses to BSC	0 days	Thu 10/1/09	Thu 10/1/09	14FF	INL
16	16	Review INL structural analysis	42 days	Fri 10/2/09	Mon 11/30/09	15	PCSA
17	17	Perform waste package structural analysis	130 days	Tue 12/1/09	Mon 5/31/10	16	RPM
18	18	Update CRCF Event Sequence Categorization Analysis	152 days	Tue 12/1/09	Wed 6/30/10	16,17FF	PCSA
19	19	Update Preclosure Nuclear Safety Design Basis Document	66 days	Thu 7/1/10	Thu 9/30/10	18	PCSA
20	20	Update Preclosure Safety Controls Document	66 days	Thu 7/1/10	Thu 9/30/10	18	PCSA
21	21	Complete effort and provide conclusions	0 days	Thu 9/30/10	Thu 9/30/10	20FF,19FF	PCSA
22	22	Update Integrated Interface Control Document (IICD)	130 days	Fri 10/1/10	Thu 3/31/11	21	RW



Project: MCOs Schedule
Date: Tue 11/18/08

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Page 1

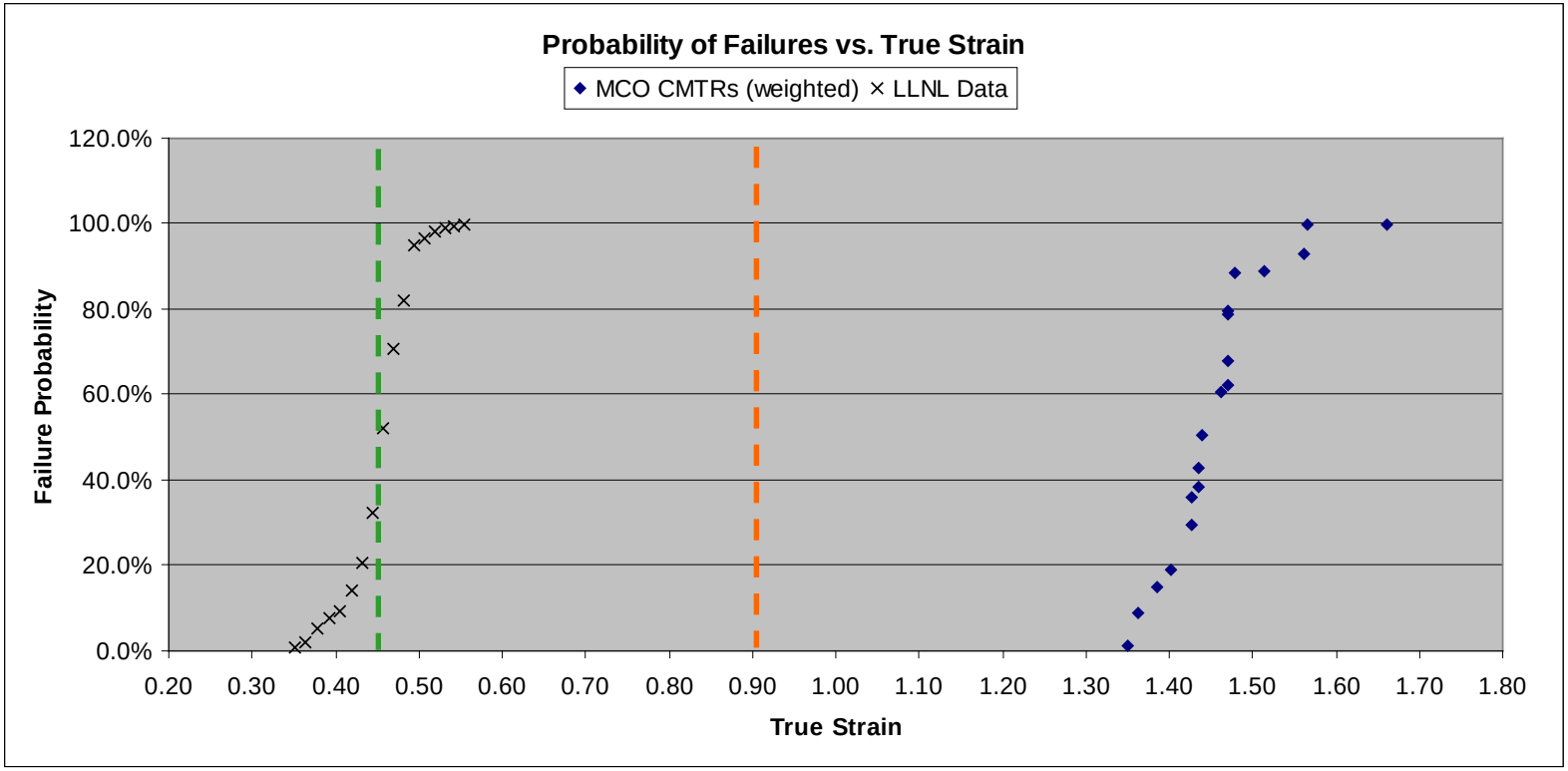
Initial NSNFP Actions

- Develop recommendations for establishing an acceptance criteria for MCO performance relative to pre-closure scenarios
  - Evaluate implication of breach in upper head space above the primary seal
  - Evaluate triaxiality effects and the applicability of the recommended triaxiality factor to specified MCO scenarios
  - Review material properties used in LLNL fragility analysis and evaluate their applicability to the MCO
- These evaluations were completed in early 2009.
  - *MCO Evaluation for Dropped Object Impacts*, EDF-NSNF-091, R.K. Blandford
  - Key findings and recommendations include …….

Key Findings and Recommendations

- An MCO-specific fragility curve should be developed.
  - This shifts the mean strain at failure significantly upward and also narrows the standard deviation associated with that mean.
  - Additionally, the 8.3% correction to account for variation in material properties is no longer necessary.
- Triaxiality factors of 1 and 2 are conservative for regions dominated by compressive and tensile states, respectively.
  - Highest equivalent plastic strains appear in compression-dominated inner surfaces but tension-dominated outer surfaces are more likely to result in crack initiation.
- If additional margin is needed, an approach based on average through-wall plastic equivalent strains should be given consideration.
  - As of the 2013 Edition, ASME Boiler & Pressure Vessel Code, Section III, Division 3, provides a strain-based acceptance criteria for containments (transportation and storage) for energy limited events such as accidental drops

Data used in LLNL Fragility Analysis vs. MCO CMTR Data



Case 13: Peak equivalent plastic strain

Case 13: Peak equivalent through-wall average strain

The Last Word

From the March 2009 NSNFP Monthly Report:

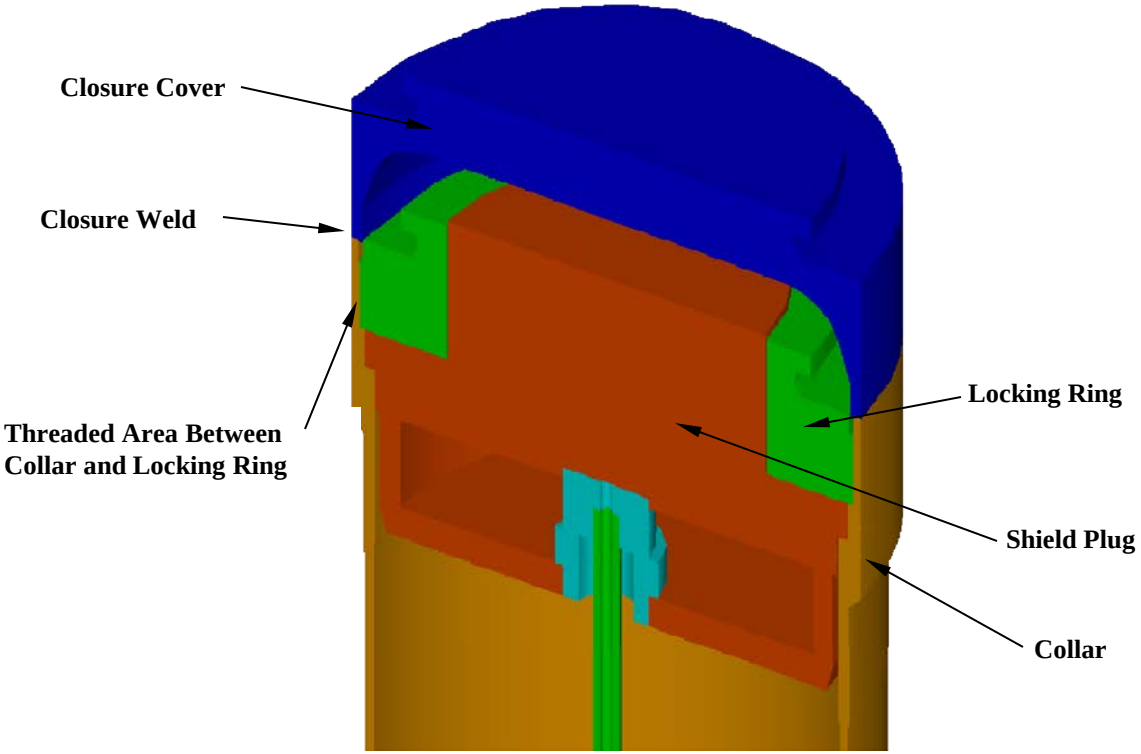
> *Workshop scheduled for April with the Yucca Mountain Project and the Naval Nuclear Propulsion Program has been put on hold due to staff reductions and changes at the YMP. The purpose of the workshop was to review and discuss probabilistic assessments of canister breach in pre-closure safety analyses.*

Additional Supporting Material

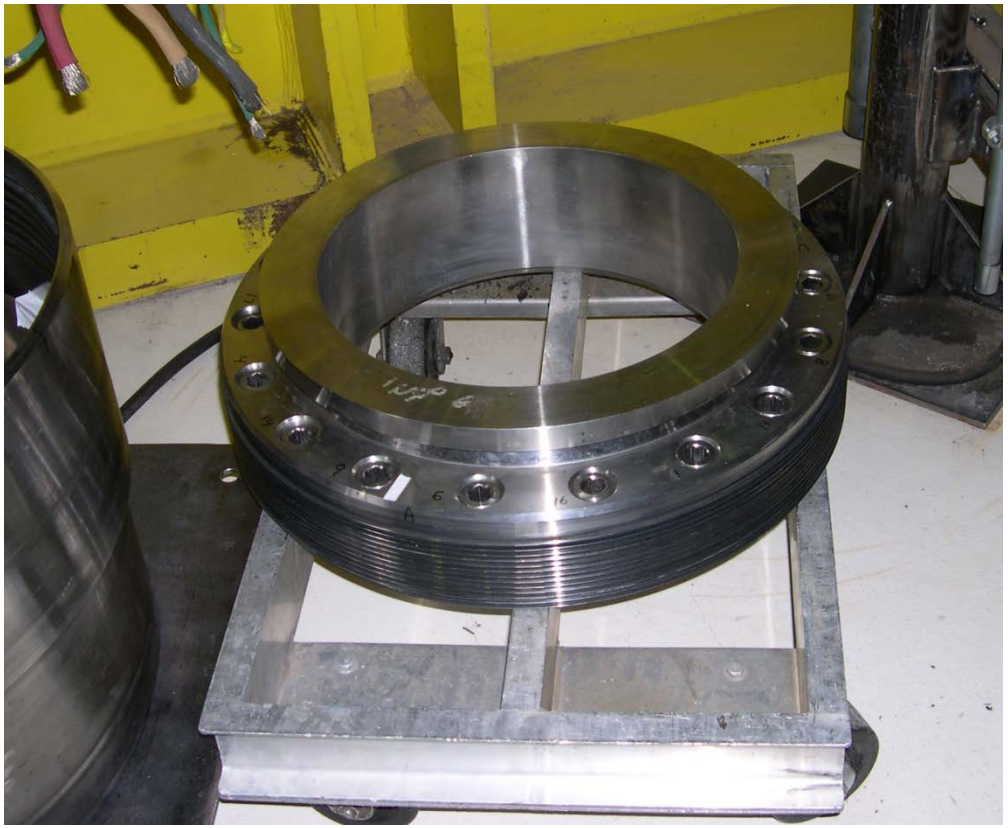
LLNL Fragility Analyses

- Failure probability based on equivalent plastic strain from MCO model to a cumulative distribution function representing the failure distribution of 204 uni-axial pull tests of annealed 304L tubing
- Significant conservatisms are embedded in the LLNL analyses
  - Tubing typically fails at lower elongation values than bar and plate
  - LLNL source data was corrected to true strain using an expression that assumes uniform strain and thus does not account for reduction in area due to necking
  - CDF is based solely on data from tensile testing
  - CDF is shifted 8.3% to account for material variability
  - A factor of 2 was imposed throughout to adjust for potential effects of triaxiality
  - Failure likelihood is based on the single most highly strained ‘finite element brick’
- Not clear how probability of other events in the limiting event sequence(s) were factored in to develop the allowable failure probability

MCO Closure Assembly

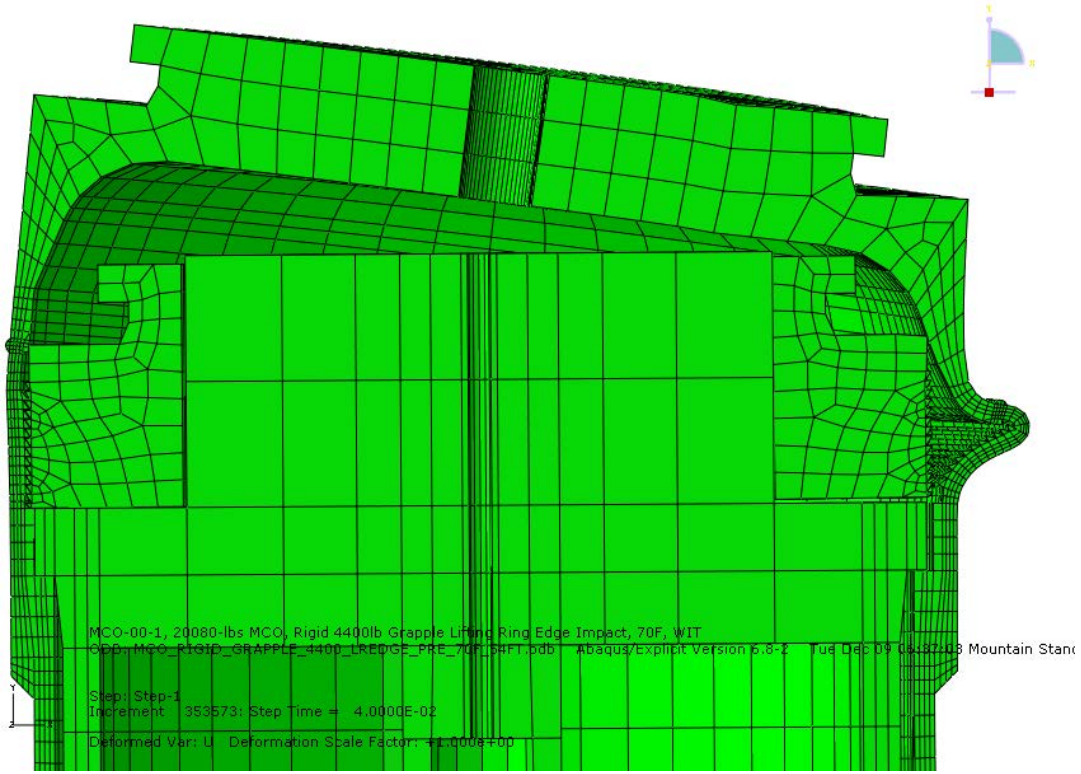


MCO Locking Ring



- Eighteen jacking setscrews maintain preload on shield plug which compresses the primary seal.

Case 13: 4400 lbs from 54 feet and MCO at 70F, (most severe case evaluated)



Deformation for evaluated upper head impact scenarios is in the threaded portion of the upper collar, above the primary seal.

- After applying triaxial factor, equivalent plastic strains are .6219, .8954, and .4583, at inner, outer, and average through-wall, respectively.