

QUALIFYING THE AL-STAR 180 IMPACT LIMITER USING LS-DYNA BENCHMARKED ON SCALE MODEL TESTS ON HI-STAR 100

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CHARACTERISTICS OF THE AL- STAR IMPACT LIMITER

- **AL-STAR IMPACT LIMITER IS USED ON ALL "HI-STAR" SERIES OF TRANSPORT CASKS. ESSENTIAL CHARACTERISTICS ARE:**
 - **A SNUGLY FITTING SKIRT AROUND THE MACHINED FORGINGS TO PROVIDE LATERAL STABILITY DURING DROP EVENTS.**
 - **A RIGID "BACKBONE" CONNECTED TO THE SKIRT TO SERVE AS THE MOUNTING SURFACE FOR THE CRUSH MATERIAL.**
 - **CRUSH MATERIAL SELECTED TO BE INSENSITIVE TO TEMPERATURE AND HUMIDITY.**
 - **RIGID "BACKBONE" CORE ALLOWS THE DEFORMATION PROFILE OF THE CRUSH MATERIAL TO BE WELL-DEFINED DURING DROP EVENTS**

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APPLICATION OF LS-DYNA TO CASK DROP ANALYSES

- MANY TECHNICAL INVESTIGATIONS BY DIFFERENT ORGANIZATIONS IN 2000-2007 USING LS-DYNA WITH DIFFERENT IMPACT LIMITER MATERIALS (e.g. PATRAM 2004).
- RECENT EXAMPLE OF AN ANALYSIS OF HI-STAR 100 DROP TESTING PROVIDED IN NEXT SLIDE

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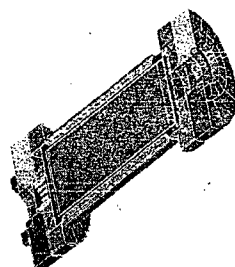
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Paper Published in "Packaging, Transport, Storage & Security of Radioactive Materials"

HI-STAR 100 spent fuel transport cask analytical evaluation for drop events

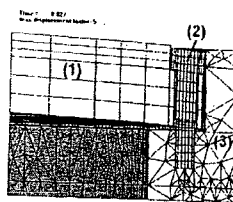
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The US Nuclear Regulatory Commission (NRC) is responsible for licensing commercial reactors.



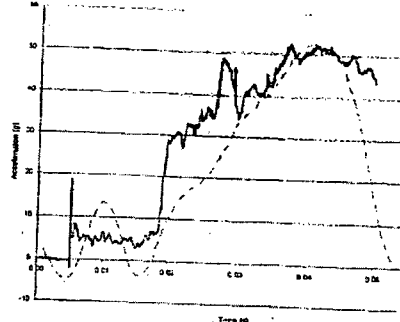
2. Finite element analysis model geometry

with the NRC containing spent fuel and contaminated with



(1) - impact limiter plate, (2) - closure plate bolt, (3) - up flange geometry shown at peak deflection with +5 scaling.
3. Finite element analysis mesh

that surrounds the neutron shield. Shell elements are also used in the impact limiter to represent the skin, honeycomb septums, disks and stiffening cylinders. The joining of shells to solids is accomplished via tied shell



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LS-DYNA

- THE MATURATION OF THE DYNAMIC SIMULATION FINITE ELEMENT ANALYSIS CODE LS-DYNA AS A RELIABLE IMPACT ANALYSIS TOOL ENABLED HOLTEC TO DEVELOP AN LS-DYNA MODEL FOR THE AL-STAR IMPACT LIMITER.
- LS-DYNA MODEL BENCHMARKED USING HI-STAR 100 TEST DATA; SUBMITTED TO USNRC AS PART OF LICENSING SUBMITTAL FOR THE HI-STAR HB AND THE HI-STAR 180.

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ADVANTAGES OF USING LS-DYNA IN LIEU OF SCALE MODEL TESTING

- CAN ASSESS SAFETY MARGIN
- SIMULATE SEAL PERFORMANCE
- PERFORM SENSITIVITY STUDY
- PERFORM PARAMETER STUDIES
- DIRECTLY REPRODUCE FULL-SCALE BEHAVIOR

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LICENSING OF HI-STAR 100

- 1/4 SCALE MODEL OF HI-STAR 100 WITH AL-STAR IMPACT LIMITER PREPARED USING *THE PRINCIPLE OF SIMILARITY*
- SIMILARITY PRINCIPLE HOLDS THAT THE 1/4-SCALE MODEL WILL YIELD ACCELERATIONS THAT ARE 4-TIMES THOSE EXPERIENCED BY THE FULL-SIZE HI-STAR 100 CASK.
- 1/4-SCALE DROP TESTS (TWO SERIES) FOR END DROP, SIDE DROP, C.G. OVER CORNER, AND SLAPDOWN DOCUMENTED IN HI-STAR 100 SAR.
- A SIMPLIFIED PREDICTION MODEL DEVELOPED TO PREDICT THE DYNAMIC RESPONSE OF THE PACKAGE. GOOD CORRELATION ACHIEVED;
- PREDICTION MODEL CAN BE USED TO EXAMINE OTHER DROP SCENARIOS

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LICENSING OF HI-STAR HB

- LS-DYNA MODEL OF AL-STAR FIRST USED TO LICENSE HI-STAR HB
- SHORTER AND LIGHTER CASK WITH DIFFERENT MPC AND FUEL BASKET
- PRE-SUBMITTAL MEETINGS CONCLUSIONS:
 - BENCHMARKING OF LS-DYNA USING HI-STAR 100 TEST RESULTS SHOULD EXAMINE PEAK DECELERATIONS, MAXIMUM CRUSH, TIME DURATION AND SHAPE OF RESPONSE.

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BENCHMARK RESULTS USING LS-DYNA COMPLY WITH PRE-SUBMITTAL CONCLUSIONS AND SHOW EXCELLENT AGREEMENT WITH TEST DATA

Table 1. Comparison of Test Results and LS-DYNA Simulation Results

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Drop Case		Deceleration (g's) ^A		Crush Depth (in)		Impact Duration (ms)	
		Measured	Predicted	Measured	Predicted	Measured	Predicted
1. End Drop		53.9	56.65	10.6	10.35	37.2/40.7 ^B	44
2. C.G. Over Corner		38.8	38.96	9.82/15.25 ^C	18.46	61	62.8
3. Side Drop		45.7	48.62	12.5	12.86	53.1	50
4. Slap-Down	Primary	49.0	49.48	10.7	10.64	44.4	45
	Secondary	59.0	63.84	13.5	13.51	41.2	42

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BENCHMARK RESULTS

- IN ADDITION TO EXCELLENT AGREEMENT FOR PEAK G'S, CRUSH DEPTH, DURATION, THE SHAPE OF THE DECELERATION-TIME CURVE IS ALSO IN GOOD AGREEMENT.
- BENCHMARK REPORT SUBMITTED "HB" DOCKET (9261) AND ON CURRENT "180" DOCKET.

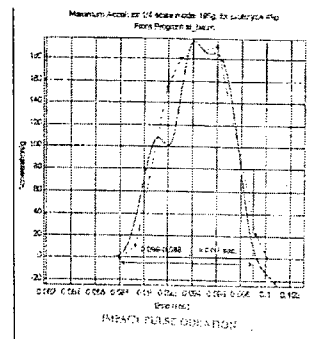


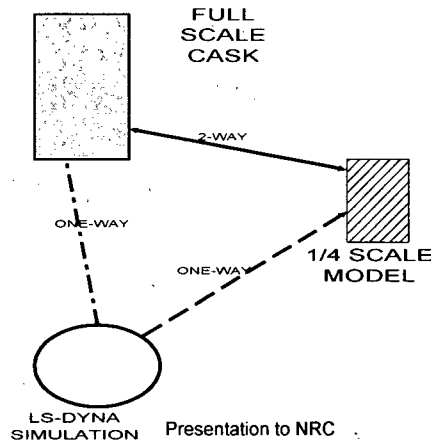
Figure 42. Predicted Deceleration Time History (Comparison - Slap-down (Primary Impact))
 --- Deceleration in LS-DYNA (crush data in test) (solid line)
 ---- Deceleration in test (crush data in test) (dashed line)

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PRINCIPLE OF SIMILARITY GUARANTEES CORRECT COMPUTER SIMULATION OF FULL-SIZE OR MODEL

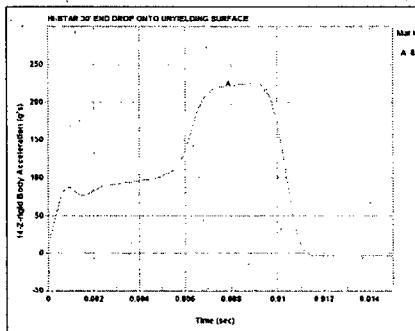


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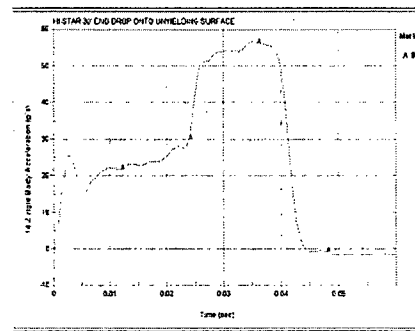
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Comparison - End Drop (1/4-scale vs. full scale FEA Model)



Maximum Filtered Deceleration (224.4 g's @ 450 Hz) –
1/4 Scale End Drop (Top)



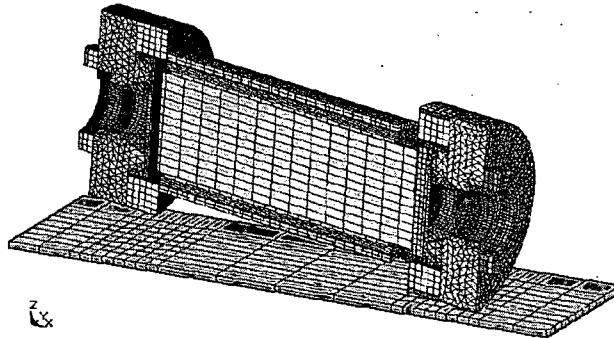
Maximum Filtered Deceleration (56.576 g's @ 450 Hz) –
Full Scale End Drop (Top)

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BENCHMARK HI-STAR 100 MODEL USES MESH DENSITY AND
DETAIL SIMILAR TO MODELS BY OTHER RESEARCHERS

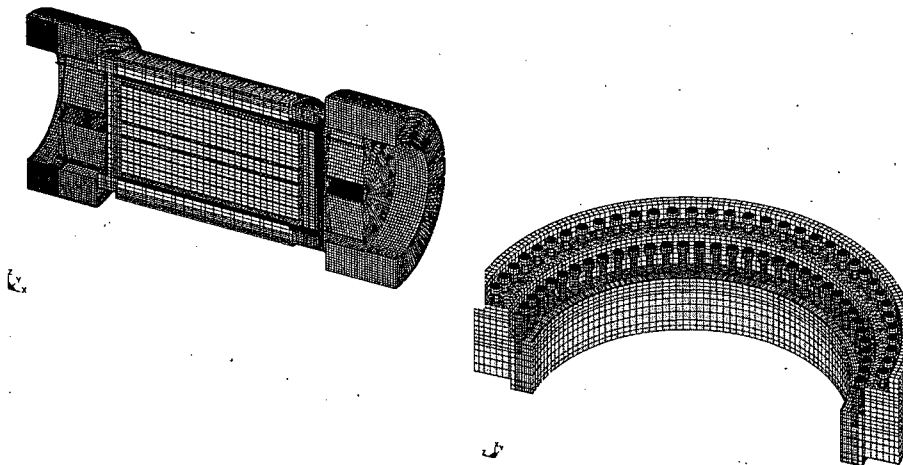


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HI-STAR 180 FEM USED FOR SATISFACTION OF
10CFR71 REQUIREMENTS



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CONCLUSIONS

- 1/4-SCALE MODEL SATISFIES PRINCIPLES OF SIMILARITY
- SIMILARITY PRINCIPLES INDEPENDENT OF ANALYTICAL PREDICTION METHOD
- FEA ANALYSIS OF FULL-SCALE CASK AND 1/4 SCALE CASK LEAD TO THE SAME CONCLUSION
- HOLTEC HAS SUCCESSFULLY BENCHMARKED LS-DYNA FOR USE WITH AL-STAR FAMILY OF IMPACT LIMITERS

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