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HI-STAR 180 STRUCTURAL OPEN TECHNICAL ISSUES

(USNRC Docket No. 71-9325)
A Presentation to the SFST

by
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OTI 2-1

- **OTI**
  - PREDICTIONS FROM 3 TO 5 ACCELEROMETERS SUFFICIENT FOR BENCHMARKING OF LS-DYNA MODEL?
- **PATH FORWARD**
  - STAFF AGREES IT IS SUFFICIENT FOR RIGID BODY DECELERATION AND IMPACT LIMITER CRUSHING
  - FEA USING LS-DYNA WILL BE VALIDATED IF ALL OTHER STRUCTURAL OPEN TECHNICAL ITEMS (OTI) ARE RESOLVED

OTI 2-2

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- **OTI**
  - DIFFERENT RESULT IF ACCELERATION OUTPUT FILTERED RATHER THAN DIFFERENTIATED VELOCITY OUTPUT FILTERED.
- **PATH FORWARD**
  - WITH FLEXIBLE BODIES, ACCELERATION RESPONSE HAS ADDITIONAL HIGH FREQUENCY COMPONENTS FROM THE NUMERICAL SOLUTION. SIMILAR CONCLUSION HAS BEEN REACHED BY OTHERS (www.ohiocae.com/ls-dyna-transport-cask.htm). EXCERPT PROVIDED BELOW:

OTI 2-2 (CONT.)

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- "The displacements and velocities usually do not contain significant noise in the time histories. However, the accelerations usually produce a significant level of noise. Since the accelerations are related to the forces acting on the elements, and the elements have a significant level of oscillations, These oscillations give no indication of the accelerations associated with either deformation of the cask or the rigid body response of the cask ends"

OTI 2-2 (CONT.)

– RATHER THAN FILTERING ACCELERATION RESPONSE AT A LOW ENOUGH VALUE TO REMOVE NUMERICALLY INDUCED HIGH FREQUENCY OSCILLATIONS, HOLTEC USED DIFFERENTIATION OF VELOCITY (WHICH HAD MINIMAL OSCILLATIONS)
– THIS APPROACH SUCCESSFULLY ELIMINATED HIGH FREQUENCY OSCILLATIONS ASSOCIATED WITH ACCELERATION RESPONSE SOLELY DUE TO NUMERICAL ANALYSIS.

OTI 2-3

- **OTI** – ACCURACY OF TETRAHEDRAL ELEMENTS FOR HONEYCOMB
- **PATH FORWARD**
  - HI-STAR 180 CAN BE SIMULATED WITH 100% HEX ELEMENTS, WHILE BENCHMARK IMPACT LIMITER FOR HI-STAR 100 CANNOT BE ENTIRELY MODELED WITH HEX ELEMENTS.
  - HI-STAR 100 MODEL HAS BEEN SUCCESSFULLY BENCHMARKED AGAINST MULTIPLE DROP TESTS. NUMERICAL RESULTS SHOW EXCELLENT AGREEMENT WITH MEASURED ACCELERATIONS AND CRUSH DEPTH IN ALL CASES.
  - MESH CONVERGENCE STUDY WILL BE PERFORMED FOR HI-STAR 180 IMPACT LIMITER MODEL TO DEMONSTRATE ADEQUACY OF HEX MESH (SEE OTI 2-6).

OTI 2-4

- **OTI**
  - EFFECT OF “ADDITIONAL” MATERIAL PROPERTIES OF HEXCEL
- **PATH FORWARD**
  - IN ORDER TO ASSESS THE EFFECT OF INCORPORATING SHEAR STRENGTH INTO HONEYCOMB, MODEL ONE IMPACT LIMITER FOR THE HI-STAR 180. INCLUDE CRUSH MATERIAL, RIBS, RINGS, AND COVER. FEA MODEL DESIGNATED AS **“MODEL 1”**
  - SIMULATE “C.G.-OVER-CORNER” ORIENTATION (100% OF CASK MASS). THIS PRODUCES **“SIMULATION 1.1”.**

OTI 2-5

- **OTI**
  - EFFECT OF MATERIAL ISOTROPY
- **PATH FORWARD**
  - MODIFY **SIMULATION 1.1** TO INCORPORATE TRANSVERSE ISOTROPY (IN CIRCUMFERENTIAL DIRECTION). SEE OTI 2-7.
  - THIS PRODUCES **“SIMULATION 1.2”.**

OTI 2-6

- **OTI**
  - MESH SENSITIVITY OF HONEYCOMB
- **PATH FORWARD**
  - EVALUATE MESH SENSITIVITY BY USING **MODEL 1.**
  - MATERIAL MODEL TO BE DETERMINED BASED ON RESULTS FROM **SIMULATIONS 1.1 AND 1.2.**
  - RESULTS DESIGNATED AS **"SIMULATION 1.3".**

OTI 2-7

- **OTI**
  - USE OF GLOBALLY ORIENTED MATERIAL AXES
- **PATH FORWARD**
  - CURRENT MODEL USES GLOBAL CARTESIAN COORDINATE SYSTEM THAT MOVES WITH THE ELEMENTS (CONFIRMED BY LIVERMORE SOFTWARE)
  - IF EFFECT OF TRANSVERSELY ISOTROPIC PROPERTIES IS NOT SIGNIFICANT (SEE OTI 2-5), THEN ONE GLOBAL SET OF AXES IS SUFFICIENT.
  - OTHERWISE, ORIENTED GLOBAL CARTESIAN SYSTEMS WILL BE DEFINED FOR SEGMENTS AROUND PERIPHERY WITH TRANSVERSELY ISOTROPIC MATERIAL PROPERTIES.
  - USE OF A CYLINDRICAL COORDINATE SYSTEM IS NOT CORRECT SINCE, IN PRACTICE, "WEDGES" ARE CUT FROM A RECTANGULAR BLOCK (SEE SAMPLE BLOCK).
  - SOLUTION RESPONDING TO OTI 2-5 WILL INCORPORATE PROPER AXES AS DISCUSSED ABOVE

OTI 2-8

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- **OTI**
  - DOES PRECRUSH ALTER PROPERTIES?
- **PATH FORWARD**
  - PRECRUSHING IS PERFORMED ONLY FOR A THIN LAYER NEAR TARGET CONTACT SURFACE AND IS PART OF MANUFACTURER'S PRODUCTION PROCESS.
  - NO CHANGE TO GLOBAL RESPONSE OF IMPACT LIMITER. DEMONSTRATED BY 1/8 SCALE TESTS DURING HI-STAR 100 TEST SERIES.
  - ONCE SPIKE IS OVERCOME, RESPONSE IS LIKE ELASTIC-PERFECTLY PLASTIC MATERIAL UNTIL LOCK-UP. THIS IS THE MATERIAL BEHAVIOR THAT HAS BEEN MODELED IN LS-DYNA. THE FOLLOWING FIGURES ARE REPRODUCED FROM THE HI-STAR 100 SAR.

OTI 2-8 (CONT.)

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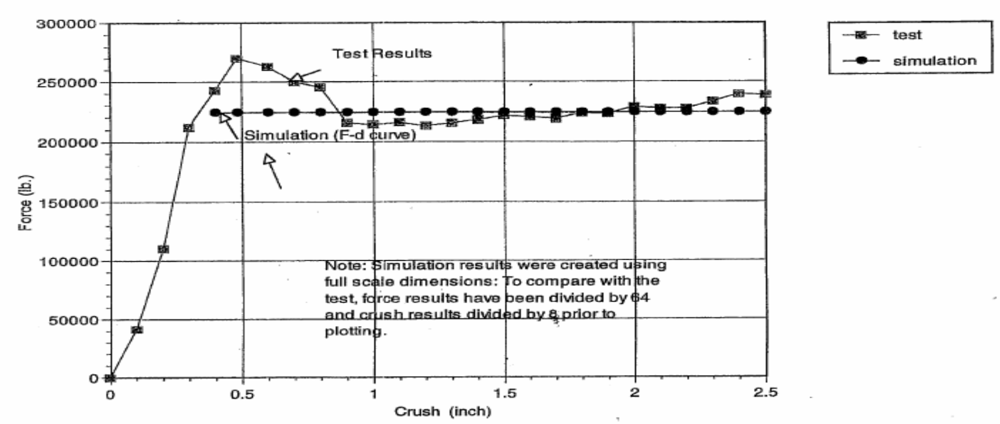

FIGURE 2.A.4.3 : - 1/8th Scale Initial Impact Limiter Configuration - Comparison of Static Force-Crush Data from Test and Simulation - END DROP

HI-951251 REV. 10

OTI 2-8 (CONT.)

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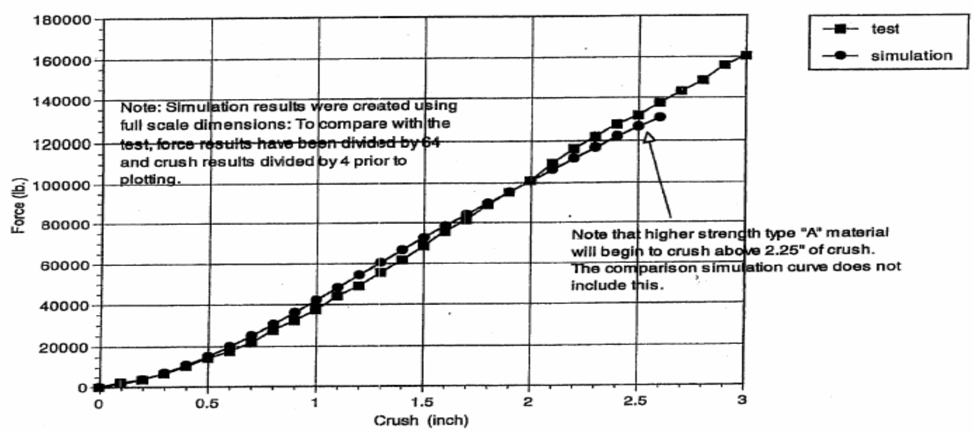

FIGURE 2.A.4.4 : 1/8th Scale Initial Impact Limiter Configuration - Comparison of Static Force-Crush Data from Test and Simulation - 60 DEGREE CRUSH

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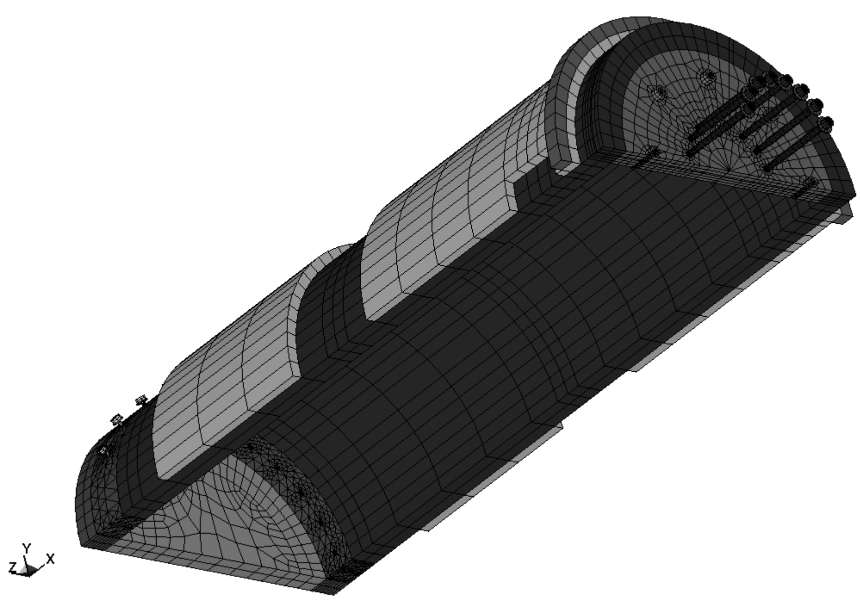
OTI 2-9

- **OTI**
  - IS IMPACT LIMITER MATERIAL MODEL ROBUST ENOUGH TO SIMULATE RANGE OF HONEYCOMB MATERIALS LIKELY TO BE USED?
- **PATH FORWARD**
  - HOLTEC REQUIRES CLARIFICATION OF OTI. THIS ISSUE WAS ADDRESSED DURING HI-STAR 100 TEST PROGRAM AND FOR HI-STAR 180 SUBMITTAL WHERE EFFECT OF % CHANGE IN PROPERTIES IS EVALUATED.
  - ACCEPTABILITY OF MATERIAL REQUIRES THAT IT BE WITHIN THE EVALUATED % BAND (PAGE 2.A-22 OF THE HI-STAR 100 SAR).

OTI 2-10

- **OTI**
  - PROVIDE ADDITIONAL EXPLANATION OF IMPACT LIMITER CONNECTION TO OVERPACK
- **RESPONSE**
  - CONTACT_TIED_SURFACE _TO_SURFACE COMMAND IS USED TO JOIN TWO SEPARATE MESHED REGIONS OF THE OVERPACK. SEE FIGURE BELOW.

OTI 2-10 (CONT.)



OTI 2-11

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- **OTI**
  - MESH SENSITIVITY OF BOLT MODEL. IS THERE A "HARD SPOT" CAUSED BY ABRUPT MESH CHANGE THAT CAUSES PREMATURE FAILURE?
- **PATH FORWARD**
  - MESH SIZE INSIDE OF CASK IS COARSE BECAUSE OF LOWER STRESS GRADIENT; FINER MESH IS USED OUTSIDE OF THE CASK WHERE THE BOLTS ARE SUBJECT TO SHEAR FAILURE
  - DEVELOP **"MODEL 2"**, WHICH IS A SINGLE IMPACT LIMITER ATTACHMENT BOLT
  - USE BOLT AND MESH FROM STAGE 3 BENCHMARK. INCLUDE A TARGET REPRESENTING FLANGE.
  - ALSO USE SAME BOLT BUT WITH UNIFORM FINE MESH ALONG ENTIRE LENGTH
  - SUBJECT BOTH TO A SHEAR PULSE AND EVALUATE DIFFERENCES, IF ANY, IN STRUCTURAL RESPONSE.

OTI 2-12

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- **OTI**
  - JUSTIFY USE OF MINIMUM REDUCTION OF AREA VALUES IN STAGE 3 BENCHMARK FOR IMPACT LIMITER BOLTS
- **PATH FORWARD**
  - IN HI-STAR 100 CONFIGURATION WHERE BOLTS FAILED, BOLTS WERE SUBJECT TO TENSION PLUS SHEAR. IN FINAL SUCCESSFUL CONFIGURATION, AND IN ALL SUBSEQUENT HI-STAR IMPACT LIMITER DESIGN CONFIGURATIONS (INCLUDING HI-STAR 180), ATTACHMENT BOLTS TAKE ONLY TENSION, AND SHEAR IS RESISTED BY IMPACT LIMITER SKIRT.
  - USE OF MINIMUM PROPERTIES IN STAGE 3 BENCHMARK COMPENSATES FOR USE OF UNIAXIAL FAILURE CRITERIA WITHOUT REDUCTION FOR TRI-AXIAL EFFECTS.
  - HOLTEC WILL PROVIDE DETAILED JUSTIFICATION AS PART OF PATH FORWARD FOR BOLT BENCHMARKING REQUEST (OTI 2-13)

OTI 2-13

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- **OTI**
  - JUSTIFY STATEMENT IN SAR OR BENCHMARK BOLT MODEL
- **PATH FORWARD**
  - SAR STATEMENT WILL BE REMOVED AND BOLT BENCHMARK CALCULATION WILL BE ADDED TO CALC PACKAGE
  - HOLTEC WILL BENCHMARK BOLT MODEL AGAINST OPEN LITERATURE USING ONE OF THE CITED REFERENCES
  - BOLT BENCHMARK MODEL IS REFERRED TO AS **"MODEL 3".**

OTI 2-14

HOLTEC INTERNATIONAL

- **OTI**
  - UNVALIDATED BOLT MODEL VS. PHYSICAL TEST
- **PATH FORWARD**
  - CLARIFICATION REQUESTED. DOES SUCCESSFUL BENCHMARK OF BOLTS, PROVIDED BY PATH FORWARD TO OTI 2-13 ALSO RESOLVE OTI 2-14?

OTI 2-15

HOLTEC INTERNATIONAL

- **OTI**
  - PROVIDE CONTROL PROCESSES AND INSPECTION FOR METAMIC
- **PATH FORWARD**
  - COMMITMENT IS MADE TO ACHIEVE CERTAIN CRITICAL CHARACTERISTICS FOR METAMIC (MINIMUM GUARENTEED VALUES).
  - SAR WILL BE UPDATED TO INCLUDE A DESCRIPTION OF THE MANUFACTURING CONTROL PROCESSES AND INSPECTION STEPS

OTI 2-16

HOLTEC INTERNATIONAL

- **OTI**
  - JUSTIFICATION OF METHODOLOGY CHANGE FROM TETRAHEDRAL ELEMENT MESH TO ALL HEXAHEDRAL ELEMENT MESH.
- **PATH FORWARD**
  - HOLTEC DOES NOT VIEW THIS AS A METHODOLOGY CHANGE.
  - CHANGE IN MESH DICTATED BY IMPACT LIMITER CONFIGURATION. ALL HEX ELEMENTS ARE ACHIEVABLE FOR HI-STAR 180 IMPACT LIMITER BUT NOT FOR HI-STAR 100 MODEL.
  - ADD CLARIFICATION TO SAR TO ADDRESS USE OF HEX VERSUS TET ELEMENTS.

OTI 2-17

- **OTI**
  - IMPACT LIMITER ATTACHMENT BOLT MESH CHANGE BETWEEN HI-STAR 100 STAGE III REPORT AND HI-STAR 180.
- **RESPONSE**
  - IMPACT LIMITER ATTACHMENT BOLTS DO NOT TAKE SHEAR IN HI-STAR 180. THEREFORE, MESH DOES NOT HAVE TO BE AS FINE NEAR PENETRATION BECAUSE POSSIBILITY OF LOCAL SHEAR FAILURE DOES NOT EXIST.

OTIS 2-18/2-19

- **OTI**
  - EXPLANATION OF SEVERE LOCAL PANEL DEFORMATIONS AND STRAINS OBSERVED
- **PATH FORWARD**
  - NO FAILURE STRAIN LIMIT IMPOSED ON METAMIC DUE TO PROGRAM LIMITS AT THE TIME ON THICK SHELL ELEMENT. BASED ON RESULTS FROM ANALYSES, CORNER EROSION (OUTSIDE THE ACTIVE FUEL REGION) WILL OCCUR. HOWEVER, ACCEPTEANCE CRITERIA SATISFIED (SEE PATH FORWARD TO OTI 2-33).
  - LATEST LS-DYNA VERSION PERMITS FAILURE LIMIT TO BE APPLIED FOR THICK SHELL ELEMENTS.
  - FUEL BASKET HAS BEEN STRENGTHENED BY ELIMINATING “MOUSE HOLES” AND INCREASING THICKNESS OF EXTERIOR PANELS.

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OTI 2-20

- **OTI**
  - DISCUSSION OF END DROP GAPS
- **PATH FORWARD**
  - END DROP GAPS WERE ANALYZED. HOLTEC WILL REVISE SAR TO CORRECT TABLE ON PAGE 2.7-6 BY INCLUDING GAP VALUES FOR END DROP (SEE TABLE BELOW).
  - ANALYSES WERE BASED ON "REALISTIC" GAPS. SEE PATH FORWARD TO OTI 2-22.

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OTI 2-20 (CONT.)

Case	Values of gap between fuel assembly and support surface, mm (in)	Values of gap between fuel basket and containment surface, mm (in)	Comment
Vertical drop - top down	2.794 (0.11)	2.794 (0.11)	All simulations performed with these assumed gaps.
Vertical drop - bottom down	2.794 (0.11)	2.794 (0.11)	
Side drop	2.794 (0.11)	2.794 (0.11)	Base case run with zero gap; a sensitivity run made with the specified gaps

OTI 2-21

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- **OTI**
  - PROVIDE OUTPUT FILES FOR SIDE DROP SOLUTION WITH MAXIMUM GAPS
- **PATH FORWARD**
  - HOLTEC WILL PROVIDE ALL COMPUTER FILES ASSOCIATED WITH REPORTED SIMULATIONS IN UPDATED SUBMITTAL

OTI 2-22

HOLTEC INTERNATIONAL

- **OTI**
  - INCLUDE ALL MAXIMUM GAPS IN ALL ANALYSES AND MAKE SURE DRAWINGS ARE CONSISTENT
- **PATH FORWARD**
  - NOTE 31 ON DRAWING 4845 SPECIFIES 20 MM AS A MINIMUM CLEARANCE GAP, WHICH IS CONSISTENT WITH SPECIFIED COMPONENT DIMENSIONS.
  - DRAWINGS WILL BE REVISED TO REDUCE MAXIMUM CLEARANCE GAP.
  - ALL GAPS WILL BE INCLUDED BUT SOME CLARIFICATION IS NEEDED FROM STAFF AS WHY GAPS, CONSISTENT WITH REALISTIC INITIAL CONFIGURATIONS, ARE NOT APPROPRIATE FOR DESIGN QUALIFICATION.
  - MAXIMUM GAP ASSUMPTION IS COUNTERFACTUAL
  - INITIAL GAPS AT IMPACT ARE CALCULATED BASED ON DYNAMICS OF PROBLEM

OTI 2-23

- **OTI**
  - JUSTIFY VISUAL EXAMINATION OF CONTOUR PLOTS TO ESTABLISH SAFETY FACTORS
- **PATH FORWARD**
  - REPORTED VALUES ARE BASED ON UPPER BOUND FRINGE LEVEL FOR THE COLOR CONTOURED REGION; THEREFORE, THEY ARE LIKELY TO BE AN OVER-PREDICTION
  - THIS REPORTING PROCEDURE IS SUFFICIENT TO PROVIDE AN ASSESSMENT OF THE SAFETY OF THE CONFIGURATION

OTI 2-24

- **OTI**
  - PROVIDE ADDITIONAL JUSTIFICATION THAT THE NUMERICAL SOLUTIONS ARE CONVERGED
- **PATH FORWARD**
  - MESH CONVERGENCE OF HONEYCOMB ADDRESSED IN OTI 2-6.
  - MESH CONVERGENCE OF IMPACT LIMITER ATTACHMENT BOLTS ADDRESSED IN OTI 2-11.
  - MESH CONVERGENCE OF FUEL BASKET ADDRESSED IN OTIs 2-30 & 2-31
  - MESH CONVERGENCE OF MONOLITHIC SHIELD CYLINDERS ADDRESSED IN OTI 2-25
  - HOLTEC ANTICIPATES THAT PATH FORWARD TO ALL OTIs WILL PROVIDE SUCH JUSTIFICATION OR WILL LEAD TO REVISED LICENSING BASIS SOLUTIONS
  - WITH RESPECT TO ALUMINUM HONEYCOMB, BECAUSE OF REVISED GEOMETRY, THERE ARE NO TETRAHEDRAL ELEMENTS IN HI-STAR 180 MODEL.

OTI 2-25

HOLTEC INTERNATIONAL

- **OTI**
  - REVISE PUNCTURE DROP ANALYSIS. ARE SHIELD CYLINDER LAYERS SEPARATE ENTITIES?
- **PATH FORWARD**
  - PUNCTURE MODEL WILL BE REVISED TO INCORPORATE FINER MESH FOR MONOLITHIC SHIELD CYLINDERS.
  - SHIELD CYLINDER LAYERS ARE SEPARATE ENTITIES, WHICH ARE ONLY JOINED ALONG THEIR OUTSIDE DIAMETER.

OTI 2-26

HOLTEC INTERNATIONAL

- **OTI**
  - DISCUSS DUAL DESIGNATION OF LIDS AS CONTAINMENT BOUNDARY/WATER EXCLUSION LAYER
- **PATH FORWARD**
  - HOLTEC IS AGREEABLE TO DESIGNATING EACH OF THE TWO LIDS INDIVIDUALLY AS A CONTAINMENT BOUNDARY. HOWEVER, FOR A SHORT DURATION PERIOD OF 4 MONTHS IF AN UNEXPECTED LEAK IS INDICATED FROM EITHER LID THE CASK WILL REMAIN TEMPORARILY TRANSPORTABLE BUT ONLY IF THE LEAKING LID REMAINS WITHIN THE “WATER LEAKTIGHT” CRITERION (THE NON-LEAKING LID MUST REMAIN WITHIN “CONTAINMENT LEAKTIGHT” CRITERION).

OTI 2-27

HOLTEC INTERNATIONAL

- **OTI**
  - JUSTIFY DESIGN LIFE OF 40 YEARS
- **PATH FORWARD**
  - HOLTEC IS NOT SEEKING CERTIFICATION OF 40 YEAR DESIGN LIFE. CERTIFICATION IS REQUESTED FOR 5 YEARS.
  - HOLTEC WILL CONTINUE TO DEVELOP SUBSTANTIATING INFORMATION TO SUPPORT RENEWAL OF LICENSE IN THE FUTURE.

OTI 2-28

HOLTEC INTERNATIONAL

- **OTI**
  - JUSTIFY STATEMENT REGARDING USE OF POLYMERIC MATERIAL WITH THE SAME CRUSH PROPERTIES
- **PATH FORWARD**
  - CITED STATEMENT WILL BE REMOVED FROM THE SAR WHEN RESUBMITTED

OTI 2-29

HOLTEC INTERNATIONAL

- **OTI**
  - JUSTIFY 7 DEGREE SLAPDOWN ANGLE
- **RESPONSE**
  - THE 7-DEGREE ANGLE HAS BEEN TREATED AS THE MOST ADVERSE SLAPDOWN ANGLE AND HAS BEEN CUSTOMARILY USED IN THE INDUSTRY SINCE THE MID-80'S.
  - HOLTEC HAS INDEPENDENTLY PERFORMED 2-D ANALYSES OF A RIGID CASK TO CONFIRM THIS WORST-CASE SLAPDOWN ANGLE. THE ANALYSIS METHODOLOGY IS DOCUMENTED IN THE HI-STAR 100 SAR AND WAS USED AS THE DESIGN BASIS FOR THE HI-STAR 100.
  - THE SAME 2-D ANALYSIS HAS BEEN PERFORMED FOR THE HI-STAR 180 TO ESTABLISH THAT THE MOST ADVERSE SLAPDOWN ANGLE IS 7-DEGREES.

OTI 2-30/2-31

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- **OTI**
  - JUSTIFY USE OF SINGLE LAYER THICK SHELLS WITH TWO INTEGRATION POINTS
- **PATH FORWARD**
  - CHARACTERISTIC WIDTH TO PANEL THICKNESS IS 206mm/15mm =13.73, WHICH QUALIFIES THE PANEL AS A THIN PLATE (PER ASME CODE).
  - A COMPARISON WITH A CLASSICAL CLOSED FORM PLATE SOLUTION WILL BE USED TO DEMONSTRATE CONVERGENCE FOR BOTH MESH SIZE AND INTEGRATION POINTS USING THE LS-DYNA THICK SHELL ELEMENT. THIS IS DESIGNATED AS **"MODEL 4".**

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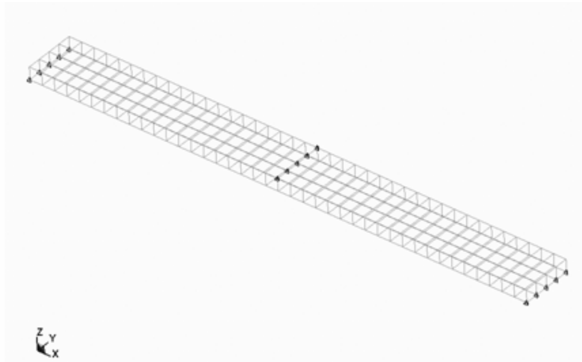
OTI 2-30/2-31 (CONT.)



LS-DYNA Model - Simply Supported Plate with Concentrated Load in the Middle (L=10", w=1", t=0.25")

Comparison of Results for Thick Shell with Different Integration Points					
NIP	2	4	6	8	10
STRESS (ksi)	9.453	11.07	11.38	11.73	11.90
Deflection ($\times 10^{-2}$in)	-2.752	-2.752	-2.752	-2.752	-2.752

Results from Classical Beam Theory: Max. Bending Stress = 12 ksi; deflection = 0.02759"

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OTI 2-32

- **OTI**
  - JUSTIFY 2 THRU-THICKNESS INTEGRATION POINTS IN THIN SHELL ELEMENTS IN LS-DYNA MODELS
- **RESPONSE**
  - THE CONFIGURATIONS WHERE THIN SHELL ELEMENTS HAVE BEEN USED ARE THE IMPACT LIMITER COVER, RIBS, AND BACKBONE STRUCTURE. THE PHYSICS OF THE PROBLEM JUSTIFY THE USE OF 2-POINT INTEGRATION.
  - SAME IMPACT LIMITER SHELL ELEMENT (2-INTEGRATION POINTS) WAS USED FOR BENCHMARK WHERE IMPACT LIMITER PATH RESPONSE GAVE GOOD AGREEMENT WITH TEST RESULTS FOR DECELERATIONS.
  - IF SFST REQUIRES, HOLTEC WILL INTEGRATE A CONSTANT STRAIN ELEMENT EXACTLY TO CLOSE THIS ITEM.

OTI 2-33

- **OTI**
  – WHY NO FAILURE STRAIN LIMIT IMPOSED FOR METAMIC?
- **PATH FORWARD**
  – ENGINEERING FAILURE STRAIN IS 6-8%; TRUE FAILURE STRAIN IS APPROXIMATELY 20%
  – PREVIOUSLY LS-DYNA DID NOT HAVE THE CAPABILITY TO INCLUDE A FAILURE STRAIN LIMIT FOR THICK SHELL ELEMENTS. LATEST VERSION OF LS-DYNA ENABLES USER TO SPECIFY FAILURE STRAIN LIMIT.
  – UPDATED SIMULATIONS WILL USE LATEST PROGRAM VERSION WITH APPROPRIATE FAILURE STRAIN LIMIT.

OTI 2-34

- **OTI**
  – JUSTIFY OMITTING FABRICATION WELDS IN ANALYSES
- **RESPONSE**
  – HOLTEC IS UNAWARE OF ANY CONFIGURATION UNDER MECHANICAL LOADS ONLY, WHERE ADDITION OF MATERIAL (WITH NO LOAD MAGNITUDE CHANGE) WILL LEAD TO A WEAKER STRUCTURE.
  – BASIC THEOREMS OF LIMIT ANALYSIS SUPPORT THE PREVIOUS STATEMENT.
  – STRUCTURAL MODEL WILL BE CONSISTENT WITH DRAWING.

OTI 2-35

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- **OTI**
  - DISCUSSION OF 10CFR 71.43(e), (g), and (h)
- **RESPONSE**
  - SEC. 1.1 ANSWERS 71.43(e) AND 71.43(h).
  - SEC. 1.2.1.1.d AND Table 3.1.1 ANSWERS 71.43(g)

OTI 2-56

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- **OTI**
  - FRACTURE TOUGHNESS REQUIREMENTS FOR LID BOLTS
- **PATH FORWARD**
  - SA 564-630 HAS BEEN CHOSEN AS FINAL MATERIAL FOR BOLTS WITH SB-637-N07718 AS AN OPTION. OTHER BOLT MATERIALS CURRENTLY LISTED IN TABLES, ETC. WILL BE REMOVED.
  - CHARPY TESTS AND DUCTILITY REQUIREMENTS WILL BE ADDED TO THE SAR FOR THE SA 564-630 MATERIAL.

OTI 2-57

- **OTI**
  - JUSTIFY 15 FT.LBS AS CHARPY ENERGY FOR SA 352-LCC
- **PATH FORWARD**
  - HOLTEC HAS WELL ESTABLISHED PROCEDURE
    - USE LS-DYNA TO BENCHMARK MATERIAL MODEL SO THAT FEA MATCHES CHARPY TEST PROCEDURE IN CODES.
    - ORIENT THE SAME CRACK IN THE MOST DAMAGING LOCATION, APPLY THE BOUNDING PUNCTURE LOAD, AND DEMONSTRATE NO CRACK PROPAGATION.

STRUCTURAL CONCLUSIONS

- RESPONSE TO OTIs INVOLVE ADDITIONAL LS-DYNA SIMULATIONS OF SELECTED REGIONS TO EVALUATE MESH SENSITIVITY, BOLT MODELING, INTEGRATION POINTS, ELEMENT TYPE
- AS NECESSARY, LICENSING BASES SOLUTIONS WILL BE RERUN AS PART OF NEXT SUBMITTAL
- FINAL SLIDE SUMMARIZES NEW SUPPORTING ANALYSES

STRUCTURAL CONCLUSIONS (CONT.)

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- MODEL 1 (HONEYCOMB MESH)
  - SIMULATION 1.1 - ADDITIONAL HONEYCOMB PROPERTIES
  - SIMULATION 1.2 - TRANSVERSE ISOTROPY
  - SIMULATION 1.3 – MESH SENSITIVITY
- MODEL 2 (BOLT MESH UNIFORMITY ALONG SHANK)
- MODEL 3 (BOLT BENCHMARK AGAINST OPEN LITERATURE RESULTS)
- MODEL 4 (FUEL BASKET PLATE THICK SHELL ELEMENT - GRID SIZE, NUMBER OF INTEGRATION POINTS, NUMBER OF LAYERS)

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SCHEDULE

- ALL STRUCTURAL ANALYSES WILL BE COMPLETED WITHIN 2 MONTHS.
- HI-STAR 180 SAR WILL BE RESUBMITTED BY SEPTEMBER 25TH.