NOV 14 1989

MEMORANDUM FOR: The Files

FROM: Nancy L. Osgood
Transportation Branch, NMSS

SUBJECT: MEETING SUMMARY CONCERNING GENERAL ATOMICS LEGAL WEIGHT TRUCK CASKS

Attendees	NRC	EG&G, Idaho
GA	Ross Chappell	Mel Jensen
	Earl Easton	
Rich Boonstra	George Gardes	Weston
Jack Boshoven	Daniel Huang	
Maria Koploy	Henry Lee	Meraj Rahimi
Richard Meyer	Curt Lindner	
Larry Pickering	Nancy Osgood	DOE, Idaho
Shiaw-Der Su	Carl Withee	
Al Zimmer	Li Yang	Walt Mings

Introduction

A meeting was held at the request of General Atomics (GA) at Rockville, Maryland, on October 18, 1989, to discuss the GA-4 and GA-9 spent fuel shipping casks. The GA-4 (4 PWR assemblies) and the GA-9 (9 BWR assemblies) are being developed for the Department of Energy for spent fuel shipment by truck under the Nuclear Waste Policy Act. The meeting marked the end of the preliminary design stage.

Discussion

The discussion followed the meeting handout, which is enclosed. Additional points are described below.

1. Fuel Basket. The basket has been redesigned, and now incorporates B4C cores for neutron poison. The structural response of the basket will be discussed in detail in a future meeting. It was suggested that testing of the basket be considered.

2. Fuel Burnup. Burnup credit is taken for the GA-4 cask. Credit for fuel depletion and fission product poisions will be used. It was stated that any request for burnup credit must include physical measurements of fuel burnup and must address potentially unburned fuel in fuel assembly ends.

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GA

FILE MEMO

3. Poison Credit. Criticality analyses use a 5% reduction in boron in B4C poison cores to allow for uncertainties. Chemical assay data will be used to confirm this allowance.

4. Radiation Shielding. Radiation dose rates are shown to meet all regulatory limits. Accident dose rates are calculated assuming no neutron shield and no impact limiters.

5. Schedule. An application for the GA-4 and GA-9 casks is expected to be submitted to NRC in 1992.

Original Signed by

Nancy L. Osgood
Transportation Branch, NMSS

Enclosure: Meeting Handout

Distribution: w/o enclosure
NRC File Center NRC PDR NMSS r/f SGTB r/f RChappell
NLOsgood CEMacDonald Meeting Attendees Meeting Notebook

OFC :SGTB	:SGTB	:SGTB	:	:	:
NAME:NLOsgood:kds	:CRChappell	:CEMacDonald	:	:	:
DATE:11/14/89	:11/14/89	:11/ /89	:	:	:

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FILE MEMO

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

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Jack Boshoven	Earl Easton	**Weston:** Meraj Rahimi
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Transportation Branch, NMSS

Enclosure: Meeting Handout

GA-4 AND GA-9 CASK DEVELOPMENT PROJECT

PRESENTATION TO

NRC TRANSPORTATION BRANCH
ROCKVILLE, MD

OCTOBER 18, 1989

GENERAL ATOMICS

J-059(1)
10-12-89

GENERAL ATOMICS

GA-4 AND GA-9 CASK SHIELDING DESIGNS ARE COMPATIBLE

- OPTIMIZED FOR MAXIMUM PAYLOADS
- SIMILAR SHIELDING CONFIGURATIONS
- SAME SHIELDING MATERIALS
- IDENTICAL ANALYTICAL APPROACH
- SIMILAR RADIATION DOSE LEVELS EXTERNAL TO CASKS

J-217(45)
10-11-89

GENERAL ATOMICS

NEUTRON SOURCE DATA BASED ON DOE/RW–0184

DESCRIPTION	GA-4 (PWR)	GA-9 (BWR)
ENRICHMENT (% U-235)	3.2	2.75
BURNUP (MWD/MTU)	35,000	30,000
COOLING TIME (YR)	10	10
FUEL LOADING (MTU/ASSEMBLY)	0.469	0.197
NEUTRON SOURCE (N/S-ASSEMBLY)	1.2×10^8	4.0×10^7
TOTAL NEUTRON SOURCE PER CASK (N/S)	4.8×10^8	3.6×10^8
NEUTRON SPECTRUM	Cf-252	Cf-252

J-217(46)
10-11-89

GENERAL ATOMICS

GAMMA SOURCE DATA BASED ON DOE/RW–0814

- INCLUDING FUEL AND HARDWARE
- DEPENDENT UPON BURNUP AND COOLING TIME
- INSENSITIVE TO FUEL ENRICHMENT
- SAME DESIGN BASIS AS FOR NEUTRON SOURCE DATA

J-217(47)
10-11-89

1.25 MEV GAMMAS ARE THE PRINCIPAL CONTRIBUTORS TO EXTERNAL DOSE RATES

COMPONENT	1.25 MEV GAMMAS/S-ASSEMBLY	
	PWR	BWR
ACTIVE FUEL	1.1×10^{14}	2.3×10^{13}
TOP HARDWARE	1.1×10^{12}	2.7×10^{11}
BOTTOM HARDWARE	2.0×10^{12}	1.0×10^{12}

GENERAL ATOMICS

DOSE CALCULATIONS INCLUDE ALL SOURCE COMPONENTS

- PRIMARY NEUTRONS FROM SPENT FUEL
- SECONDARY NEUTRONS FROM ADDITIONAL FISSION IN FUEL AND DEPLETED URANIUM
- PRIMARY GAMMAS FROM FUEL AND HARDWARE
- SECONDARY GAMMAS FROM NEUTRON INTERACTIONS
- SCATTERING OF NEUTRONS AND GAMMAS FROM AIR AND GROUND

GENERAL ATOMICS

SHIELDING ANALYSES USE STANDARD MATERIAL DENSITIES WITH NEGLIGIBLE HYDROGEN DEPLETION FOR NEUTRON SHIELDING MATERIAL

COMPONENT	MATERIAL	DENSITY g/cm^3
GAMMA SHIELD	DEPLETED URANIUM	19.05
NEUTRON SHIELD	RX–201–1 (1.0 WT % B)	0.90
STRUCTURE	XM-19 AND SS-304L	7.92
IMPACT LIMITER	AL HONEYCOMB	0.0

J-217(50)
10-11-89

GENERAL ATOMICS

WE USED 3-D MCNP MONTE CARLO CODE TO SIZE SHIELDING CONFIGURATIONS

- RECOMMENDED BY ORNL AS A STANDARD MONTE CARLO CODE
- EXPLICIT 3-D MODEL OF CASK GEOMETRY
- BUILT-IN POINTWISE CROSS SECTIONS
- TREATMENT OF ALL SOURCE COMPONENTS
- NO CORRECTIONS REQUIRED TO DOSE RESULTS

GENERAL ATOMICS

WE USED PATH AND TWODANT CODES FOR DOSE MAPPING*

DESCRIPTION	PATH	TWODANT
METHOD	POINT KERNEL INTEGRATION	MULTIGROUP DISCRETE ORDINATES
GEOMETRY	XYZ (3-D)	RZ CYLINDRICAL (2-D)
PRIMARY GAMMAS	YES	NO
NEUTRONS + (n,γ)	NO	YES
AIR SCATTERING	YES	YES
GROUND SCATTERING	NO	NO

J-217(53)
10-11-89

*RESULTS NORMALIZED TO MCNP TO ACCOUNT FOR APPROXIMATIONS

GENERAL ATOMICS

SHIELD ANALYSIS CONSIDERS NORMAL AND HYPOTHETICAL ACCIDENT CONDITIONS

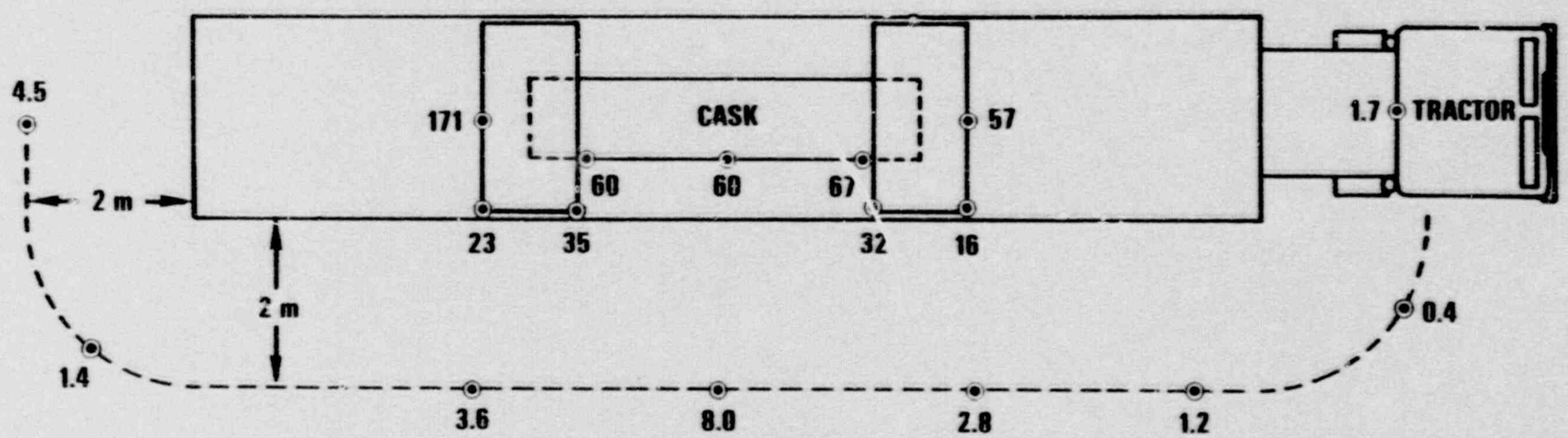
DESCRIPTION	NORMAL TRANSPORT	HYPOTHETICAL ACCIDENT
NEUTRON SHIELD	INTACT	REMOVED
STEEL SKIN	INTACT	REMOVED
IMPACT LIMITER	VOID	REMOVED
DOSE POINTS	CASK SURFACE 2 m FROM TRAILER BACK OF CAB	1 m FROM DAMAGED CASK SURFACE

J-217(52)
10-11-89

GENERAL ATOMICS

NORMAL TRANSPORT RADIATION LEVELS MEET REGULATORY LIMITS

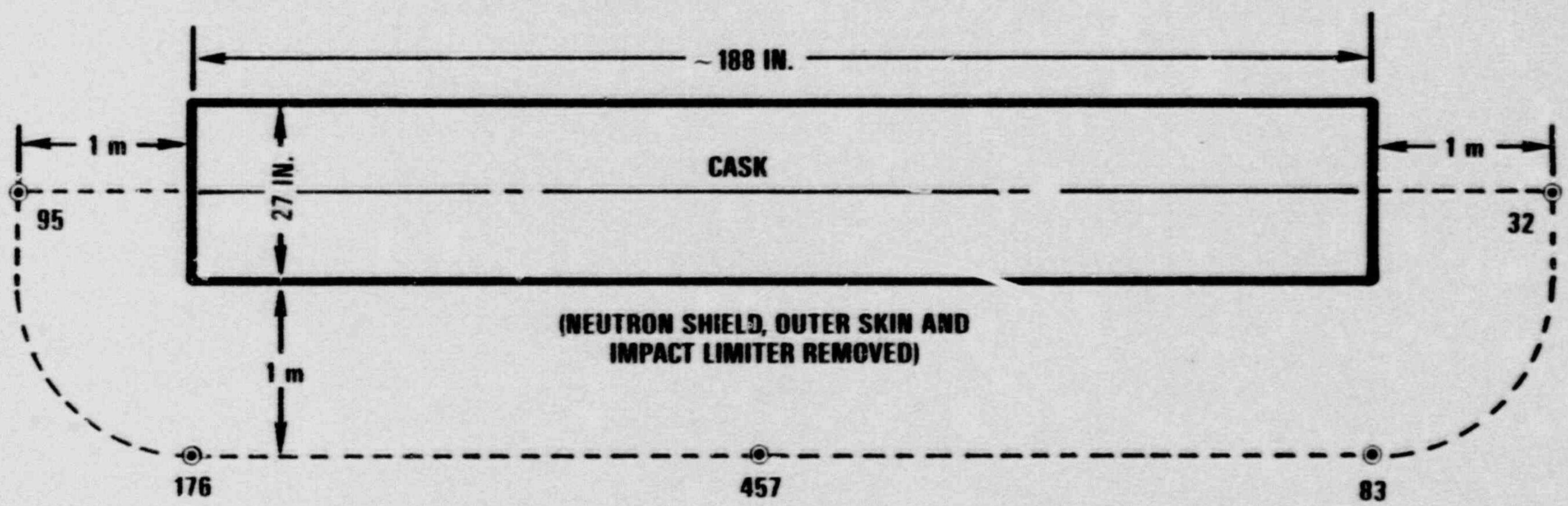
- DOSE RATES IN MREM/H FOR GA-4 CASK
- SIMILAR DOSE LEVELS FOR GA-9 CASK



J-217(84)
10-11-89

ACCIDENT DOSE RATES ARE KEPT BELOW 1000 MREM/H

- DOSE RATES IN MREM/H ILLUSTRATED BELOW FOR GA-4 CASK WITHOUT DU CRACK
- ABOUT 500 MREM/H AVAILABLE TO ALLOW FOR DU CRACK



J-217(54)
10-11-89

GA-4 AND GA-9 CASK SHIELDING DESIGNS COMPLY WITH REGULATIONS

- MOST EFFECTIVE SHIELDING MATERIALS USED
- OPTIMUM DISTRIBUTION OF NEUTRON AND GAMMA DOSES ($\sim$20% n AND 80% γ SPLIT)
- SHIELDING ADEQUACY DEMONSTRATED BY 3-D MCNP
- TRANSPORTATION DOSE LIMITS MET FOR NORMAL TRANSPORT AND HYPOTHETICAL ACCIDENT CONDITIONS

GENERAL ATOMICS

CRITICALITY EVALUATION

JACK BOSHOVEN

J-217(21)
10-11-89

GENERAL ATOMICS

CRITICALITY DESIGN AND ANALYSIS INCORPORATES NRC RECOMMENDATIONS

- MOST REACTIVE FUEL TYPE TO BE DETERMINED IN FINAL DESIGN
- 5% MARGIN FOR BORON CONTENT IN B_4C IN ADDITION TO 2% MANUFACTURING UNCERTAINTY
- NO NEUTRON SHIELDING FOR ACCIDENT CONDITONS
- ADDITIONAL BENCHMARK CALCULATIONS FOR CRITICAL EXPERIMENTS WITH DU REFLECTOR
- IMPLEMENTATION OF PHYSICAL MEASUREMENTS OF FUEL REACTIVITY FOR GA-4 CASK

GENERAL ATOMICS

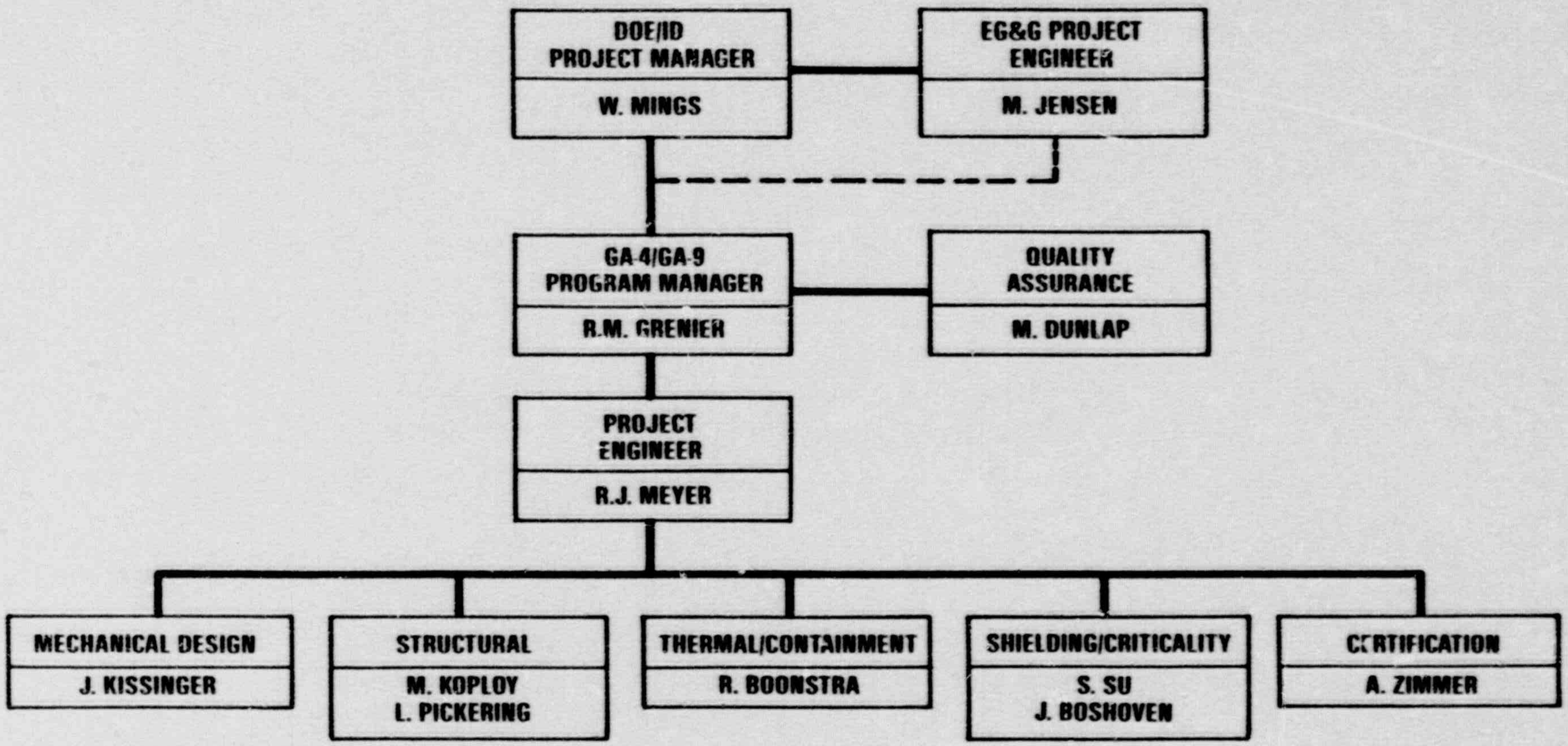
WE HAVE COMPLETED OUR PRELIMINARY DESIGN

• INTRODUCTION	
– AGENDA REVIEW	AL ZIMMER
– PROJECT ORGANIZATION	
– PROGRAM STATUS	
• DESIGN UPDATE	DICK MEYER
• SHIELDING EVALUATION	SHIAW-DER SU
• CRITICALITY EVALUATION	JACK BOSHOVEN
• THERMAL EVALUATION	RICH BOONSTRA
– ANALYSIS	
– TESTING	
• STRUCTURAL EVALUATION	MARIA KOPLOY/LARRY PICKERING
– ANALYSIS	
– TESTING	

J-217(41)
10-11-89

GENERAL ATOMICS

PROJECT ORGANIZATIONAL CHANGES MADE SINCE LAST MEETING



GENERAL ATOMICS

PRELIMINARY DESIGN REVIEW IS IN PROGRESS

- PRELIMINARY DESIGN PACKAGE COMPLETED
- DESIGN REVIEW COMMITTEE REVIEWING PRELIMINARY DESIGN PACKAGE
- REVIEW MEETING SCHEDULED FOR NOVEMBER 6, 1989
- ADDITIONAL IMPACT LIMITER TESTING PLANNED
- PLANNING FOR HALF-SCALE MODEL

GENERAL ATOMICS

DESIGN UPDATE

RICHARD MEYER

J-217(56)
10-11-89

GENERAL ATOMICS

PROJECT STATUS
GENERAL ATOMICS GA-4/9 LEGAL WEIGHT TRUCK CASK DESIGN

- PRELIMINARY DESIGN PACKAGE SUBMITTED TO DOE – 9/30/89
- MATERIAL SELECTION COMPLETE
- MAJOR STRUCTURAL, THERMAL AND NUCLEAR CALCULATIONS COMPLETE
- ENGINEERING TESTS OF NEUTRON SHIELD MATERIALS COMPLETE
- PHASE ONE OF IMPACT LIMITER TESTING COMPLETE
- PRELIMINARY DESIGN OF TRAILER COMPLETE

J-217(58)
10-11-89

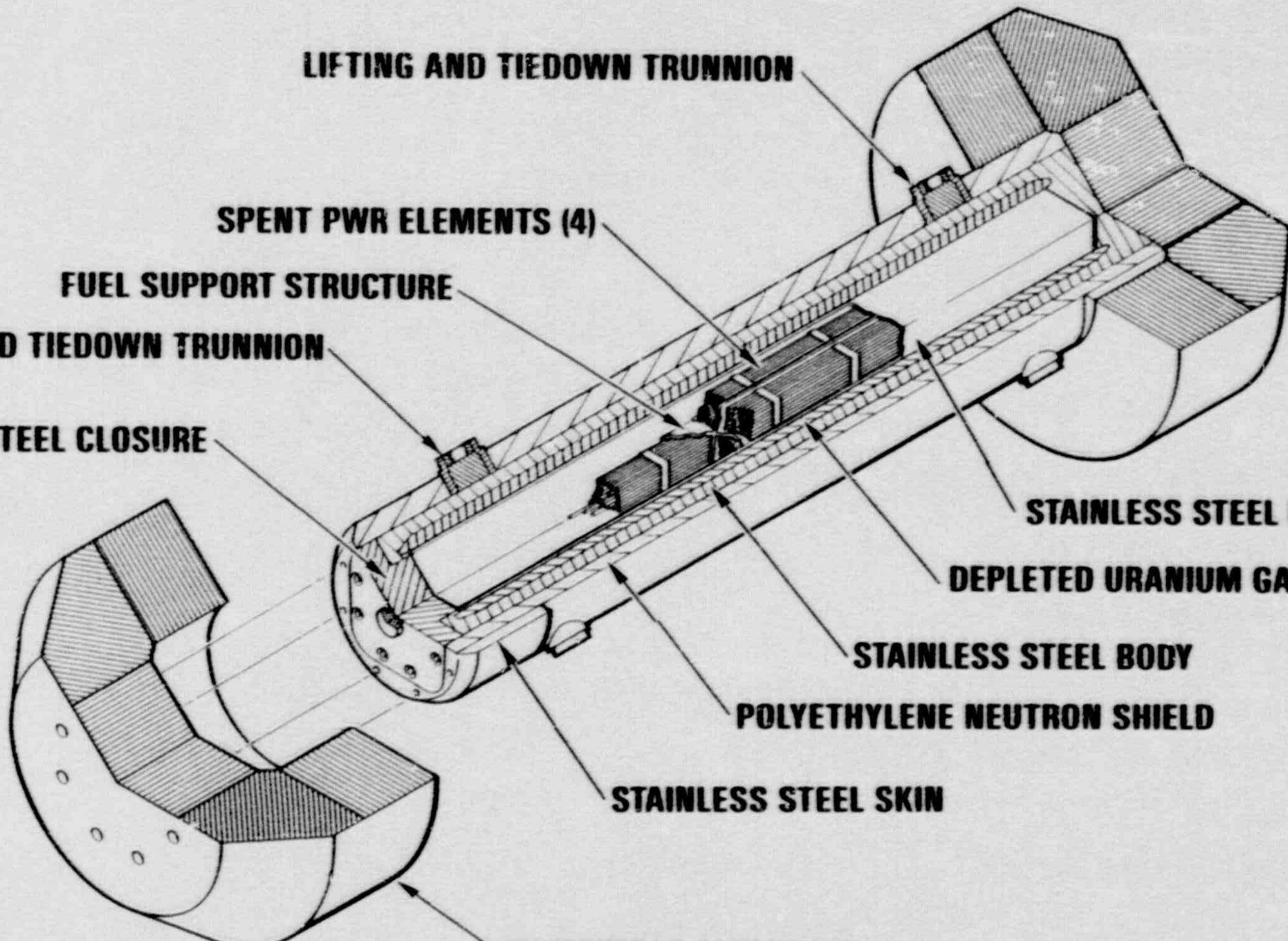
GENERAL ATOMICS

WE HAVE MADE SIGNIFICANT DESIGN IMPROVEMENTS TO THE GA-4/9 CASK DESIGNS

- IMPACT LIMITER REDESIGN BASED ON ENGINEERING TESTS
- SUPPORT STRUCTURE UNDER IMPACT LIMITERS IS ROUND
- TRUNNIONS MOVED TO CORNERS FROM FLATS
- REMOVABLE FUEL SUPPORT STRUCTURE WITH B_4C RODS
- 304 SST TO XM-19 SST
- ADDITIONAL BOLTS ADDED FOR IMPACT LIMITER ATTACHMENT
- ADDED PROTECTION AROUND CLOSURE

GENERAL ATOMICS

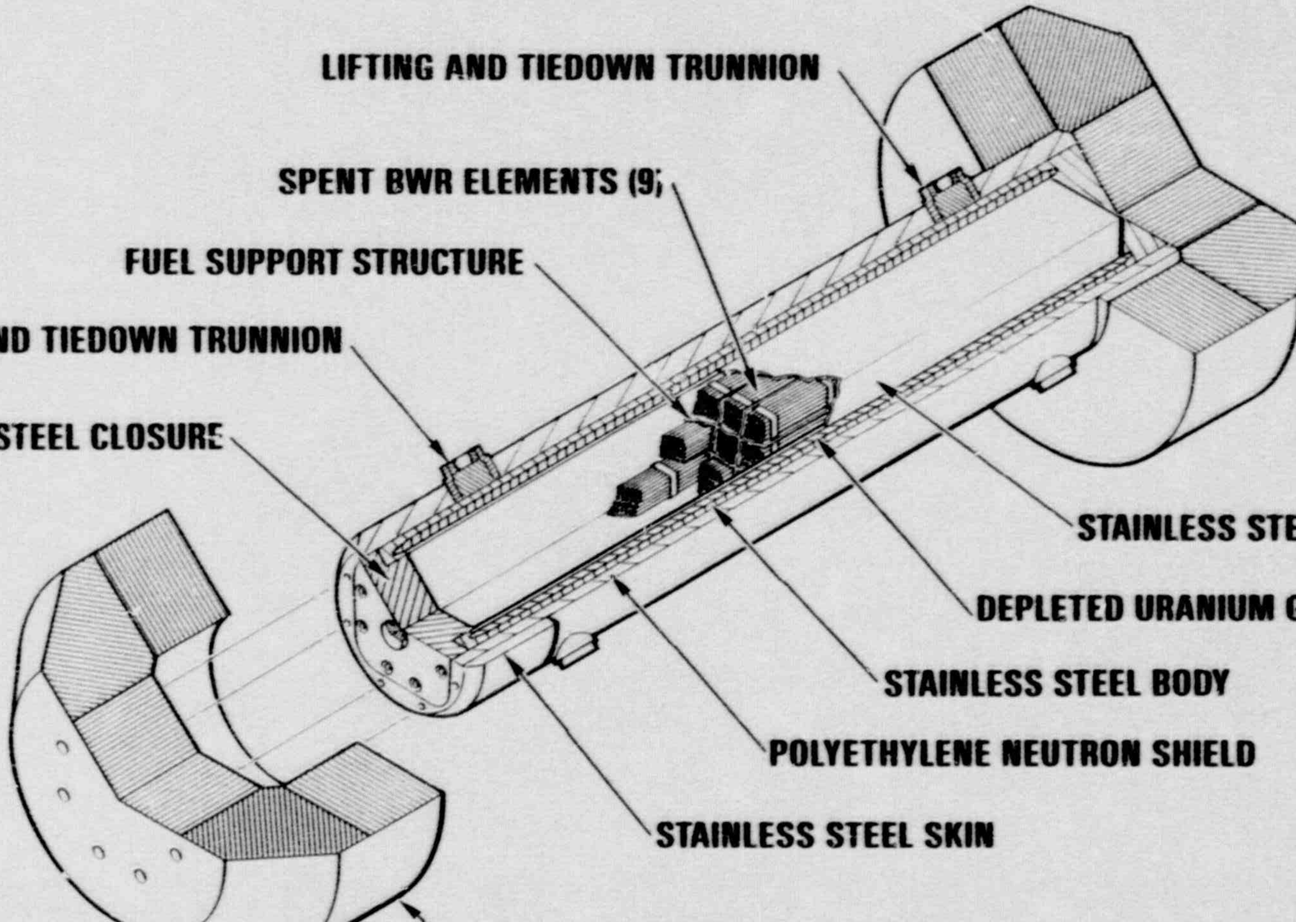
GA-4 LEGAL WEIGHT TRUCK SHIPPING CASK



J-215(1)
10-9-89

GENERAL ATOMICS

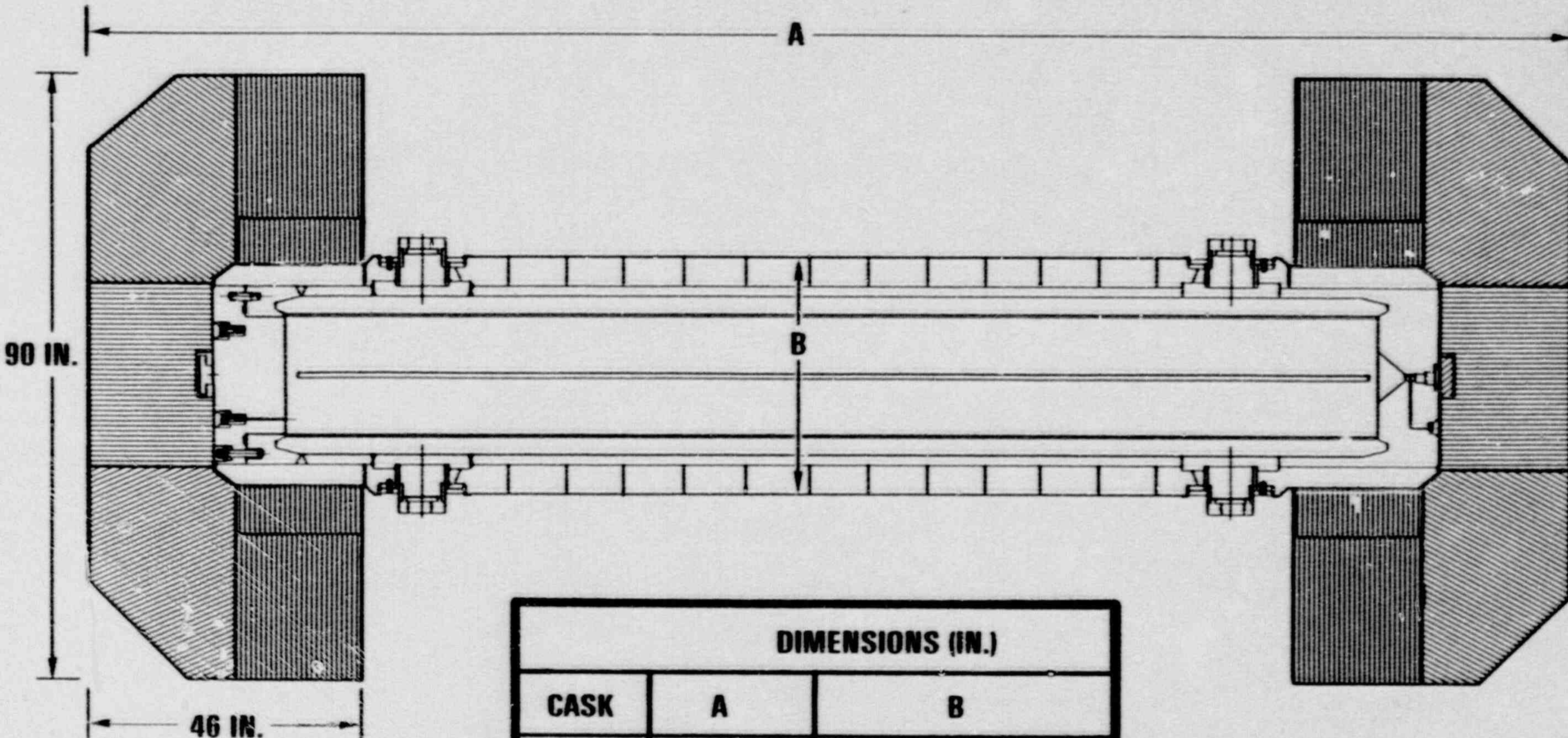
GA-9 LEGAL WEIGHT TRUCK SHIPPING CASK



J-215(1)
10-9-89

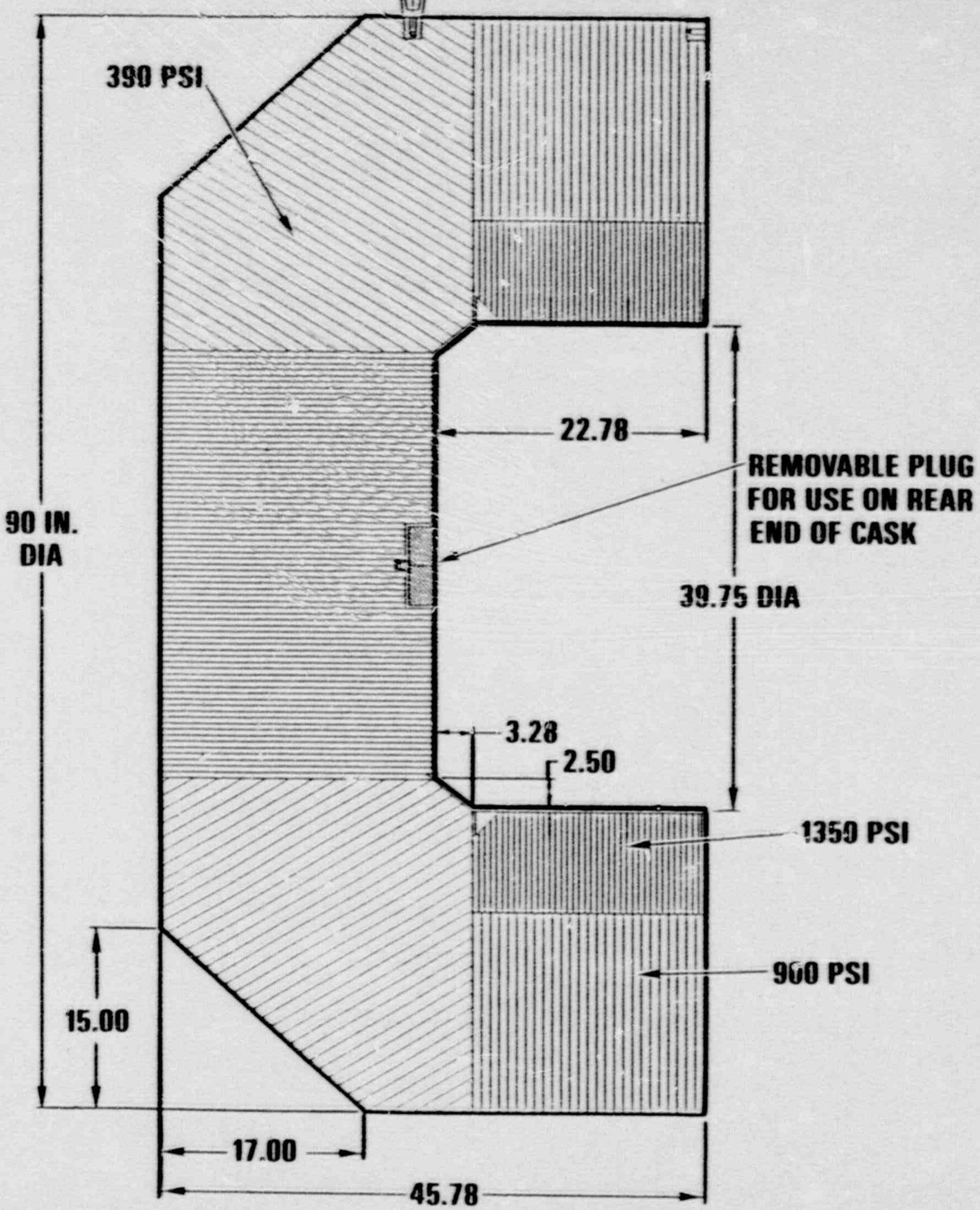
GENERAL ATOMICS

INTERCHANGEABLE IMPACT LIMITERS ARE BOLTED TO THE ENDS OF THE CASK



DIMENSIONS (IN.)			
CASK	A	B	
		CORNERS	FLATS
GA-4	233.75	40.9	36.4
GA-9	244.00	39.5	34.4

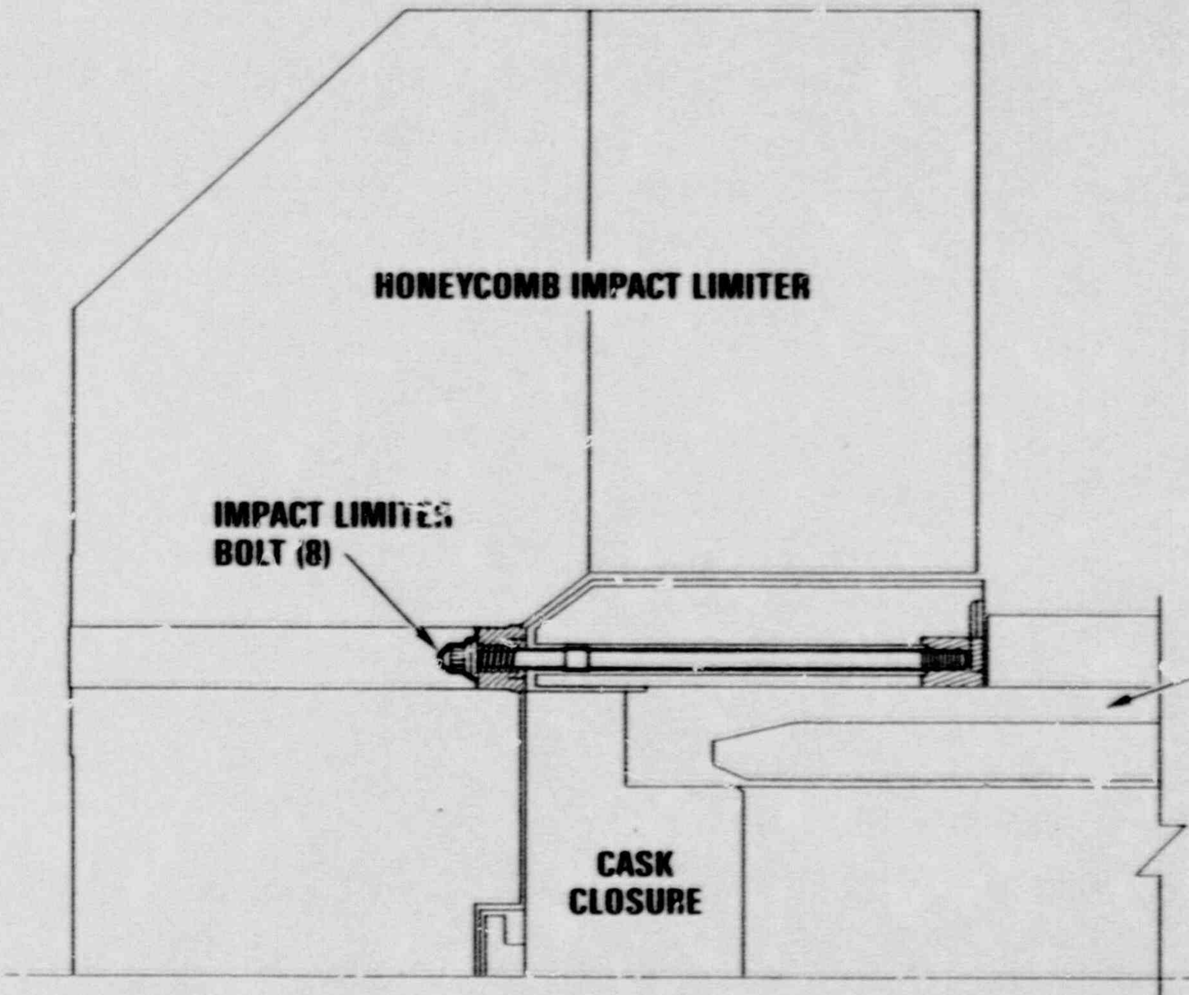
J-032(4)
10-12-89



GENERAL ATOMICS

GENERAL ATOMICS

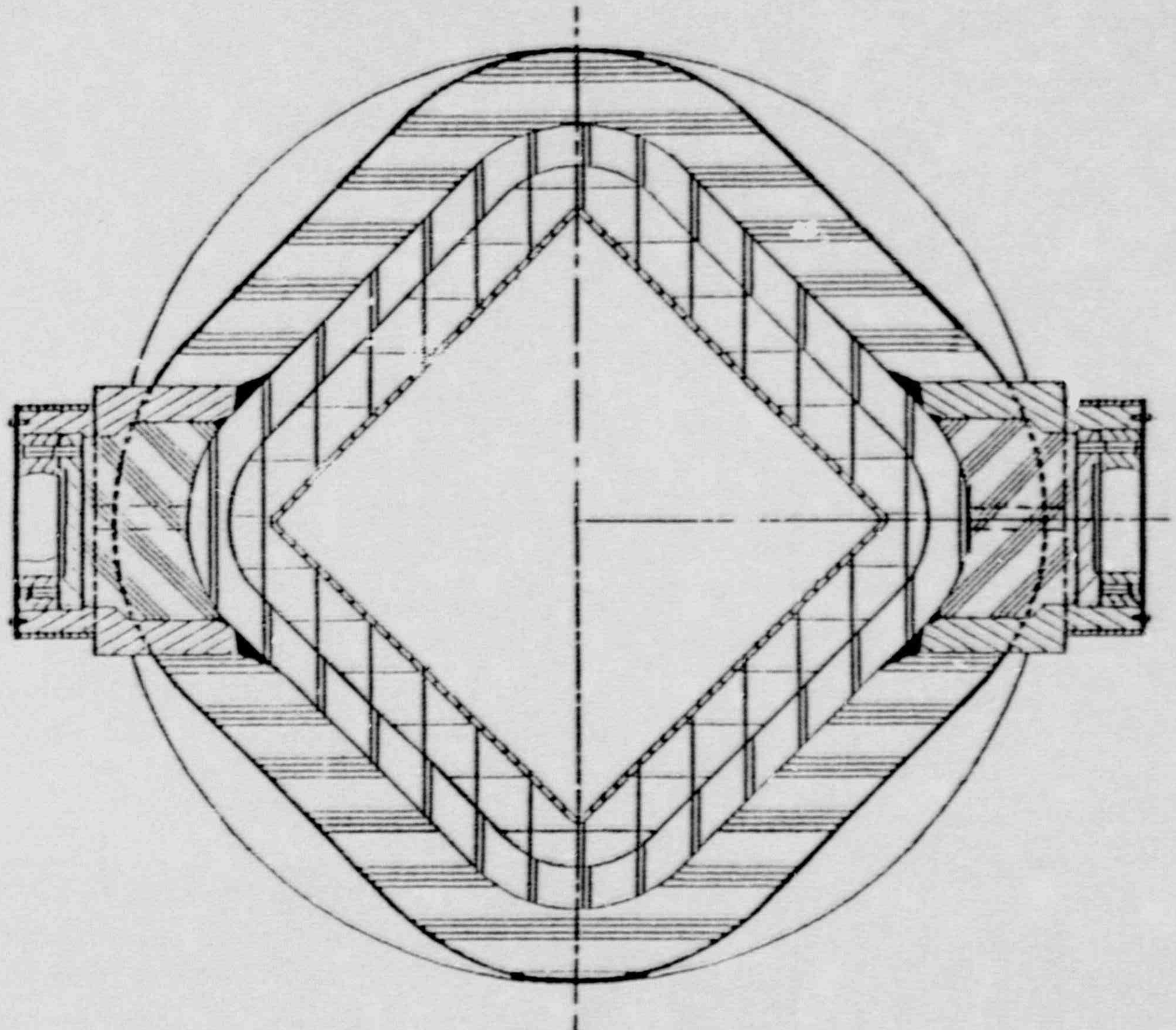
8 BOLTS ATTACH IMPACT LIMITERS TO CASK BODY



J-217(60)
10-11-89

GENERAL ATOMICS

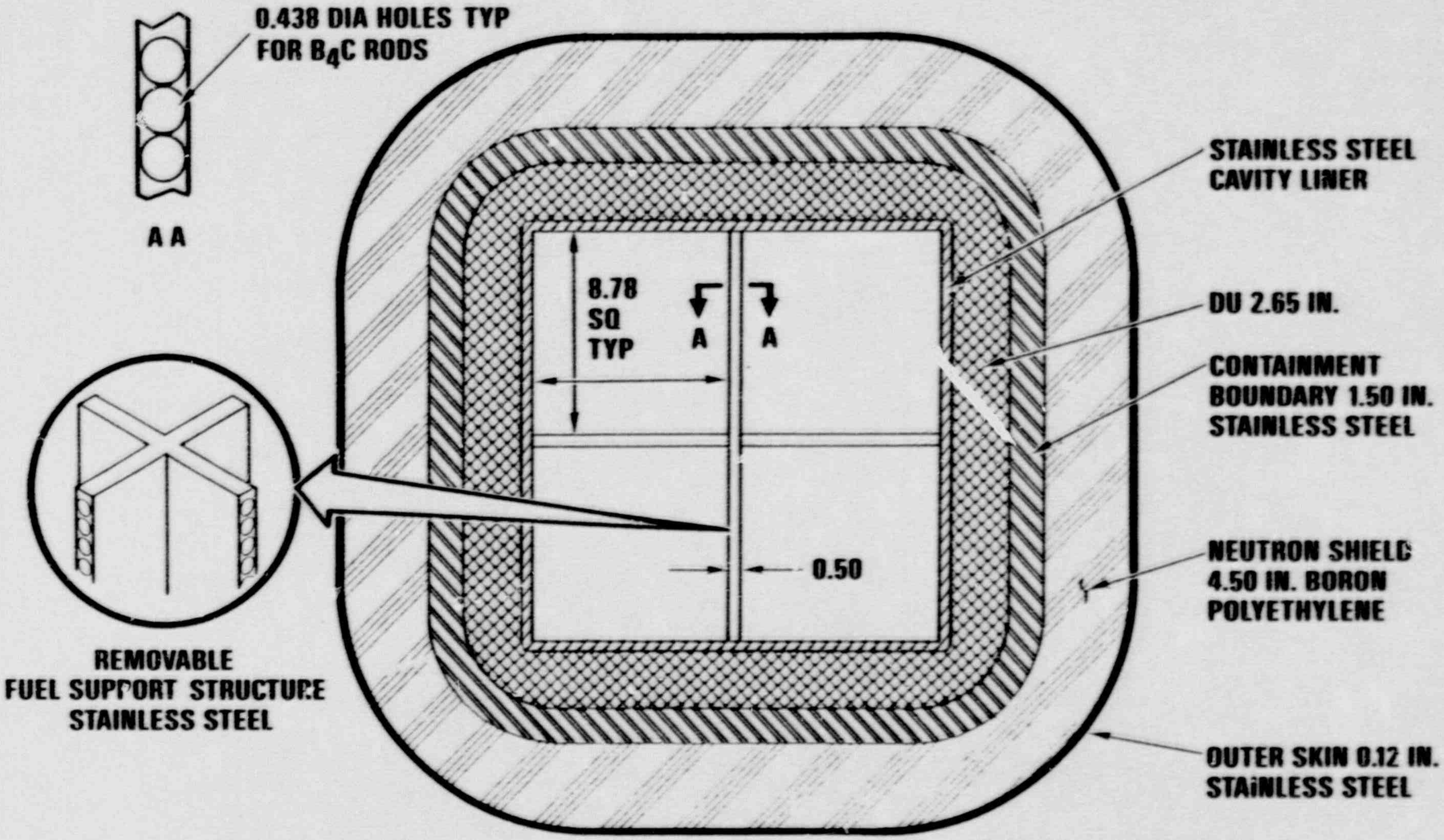
FRONT TWO TRUNNIONS ARE USED FOR PRIMARY LIFTING



J-217(57)
10-11-89

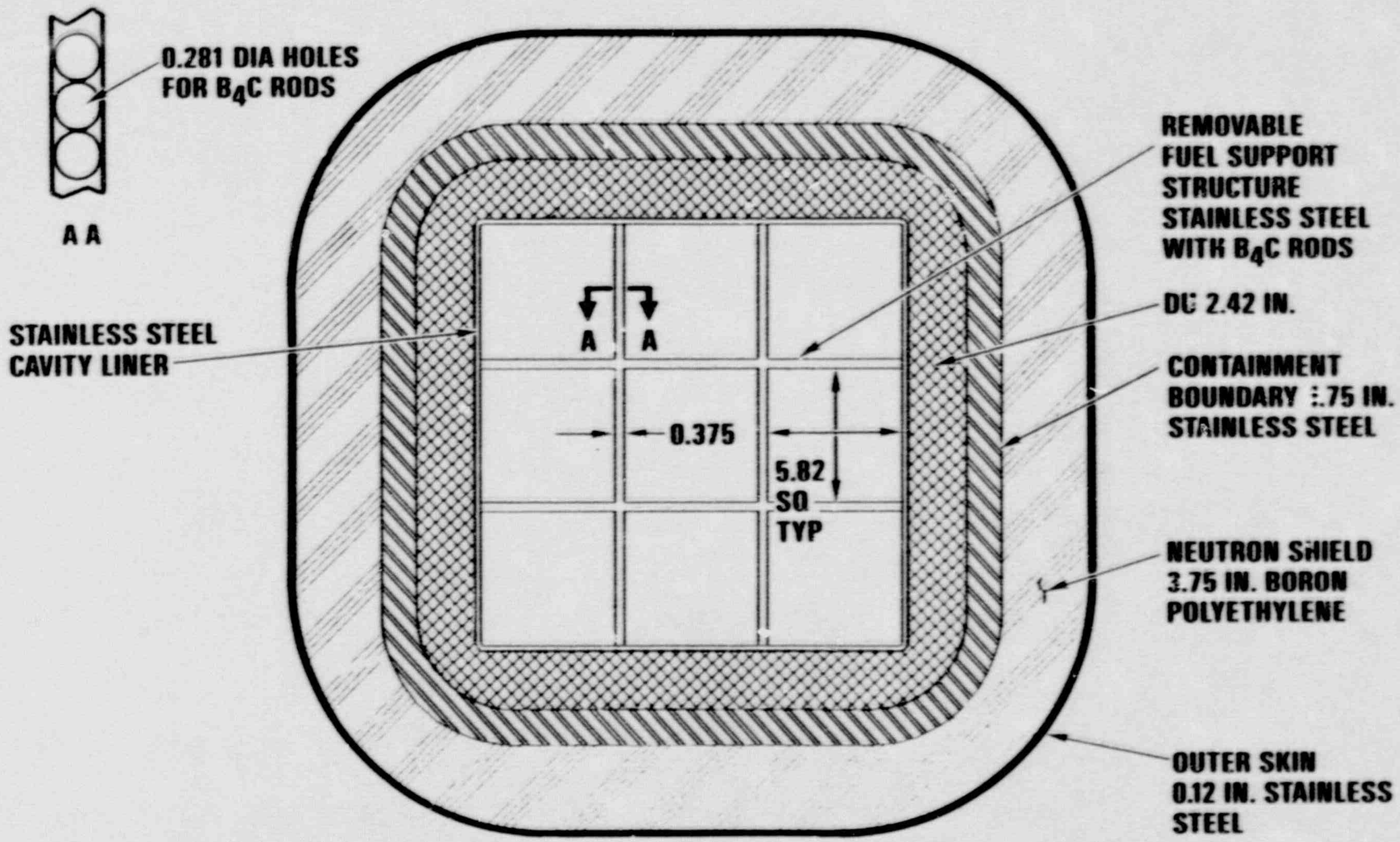
GENERAL ATOMICS

GA-4 CASK CARRIES 4 PWR SPENT FUEL ELEMENTS



J-032(6)
10-12-89

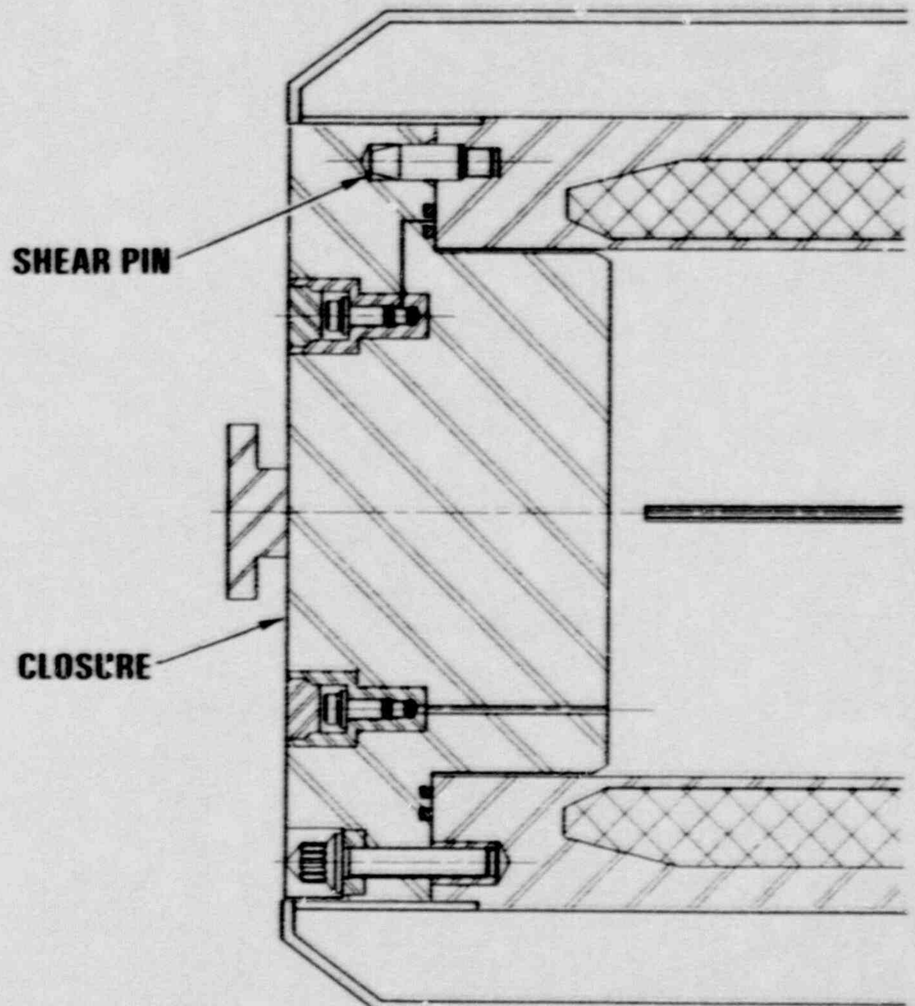
GA-9 CASK CARRIES 9 BWR SPENT FUEL ELEMENTS



J-032(7)
10-12-89

GENERAL ATOMICS

BOLTS AND SHEAR PINS RETAIN CLOSURE



J-032(8)
10-12-89

GENERAL ATOMICS

SHIELDING EVALUATION

SHIAW-DER SU

J-217(43)
10-11-89

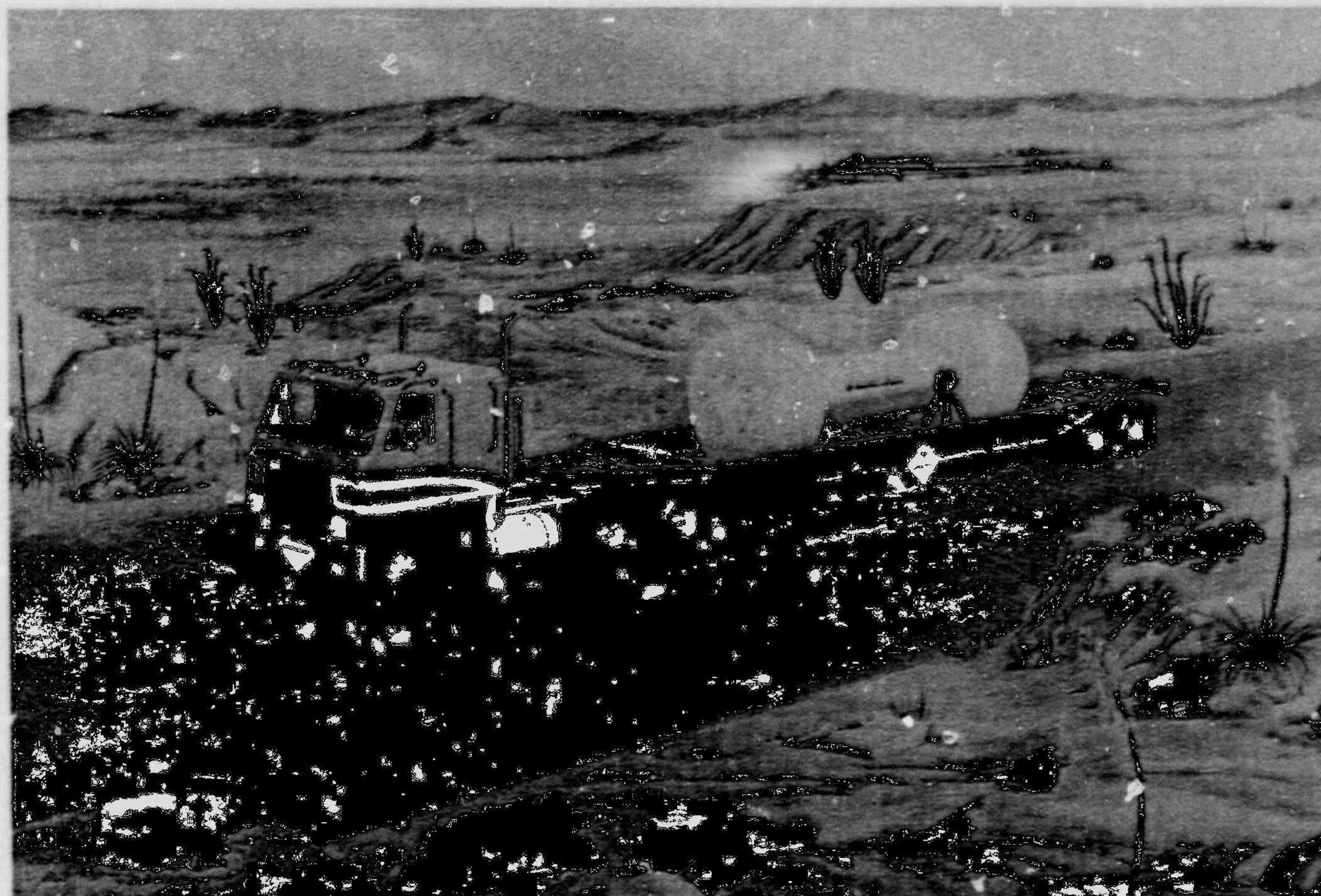
GENERAL ATOMICS

OPTIMIZED SHIELD CONFIGURATIONS MEET DOSE LIMITS

- MOST EFFECTIVE GAMMA SHIELDING MATERIAL
  - DEPLETED URANIUIM
- MOST EFFECTIVE NEUTRON SHIELDING MATERIAL
  - BORATED POLYETHYLENE
- SHAPED CORNERS
- REDUCED NEUTRON SHIELDING FOR UPPER AND LOWER SIDEWALL
- ALL-STEEL TOP AND BOTTOM ENDS

GENERAL ATOMICS

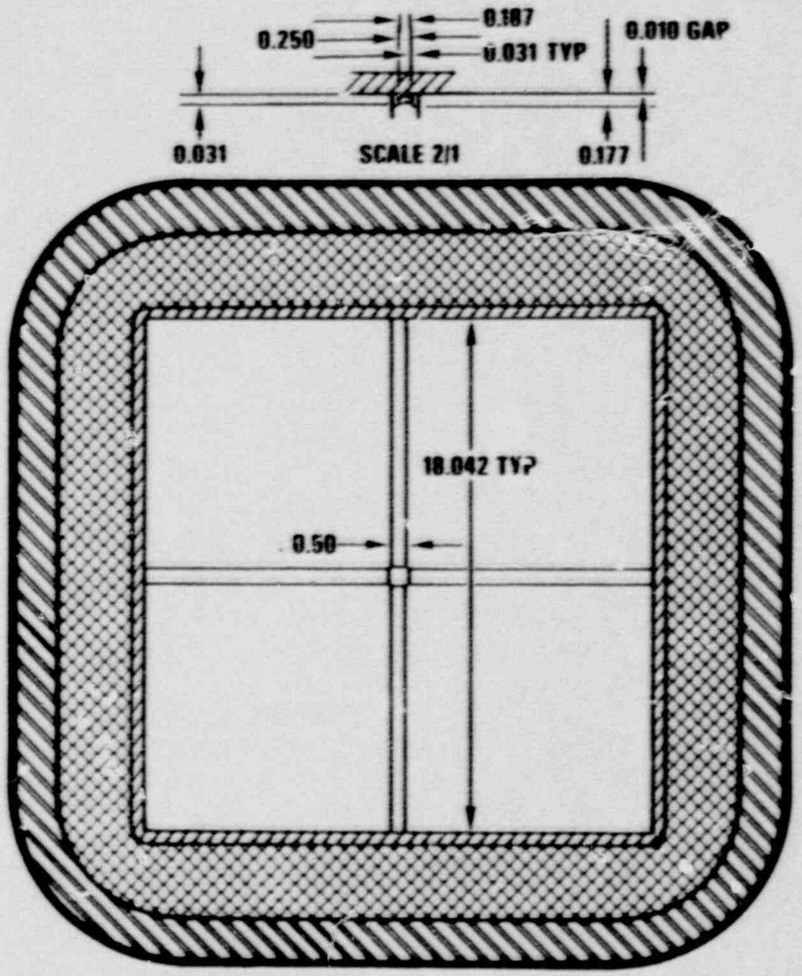
GA LEGAL WEIGHT CASK AND TRANSPORTER

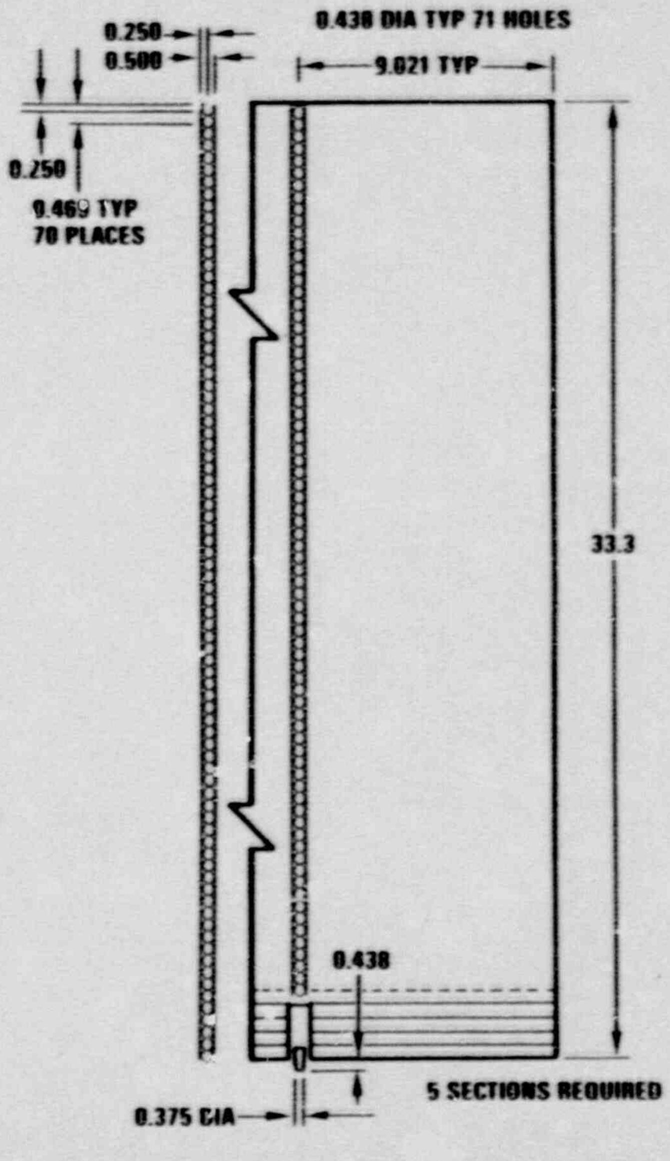


J-217(83)
10-11-89

GENERAL ATOMICS

GA-4 CASK COMBINES B_4C POISON AND BURNUP CREDIT FOR CRITICALITY CONTROL

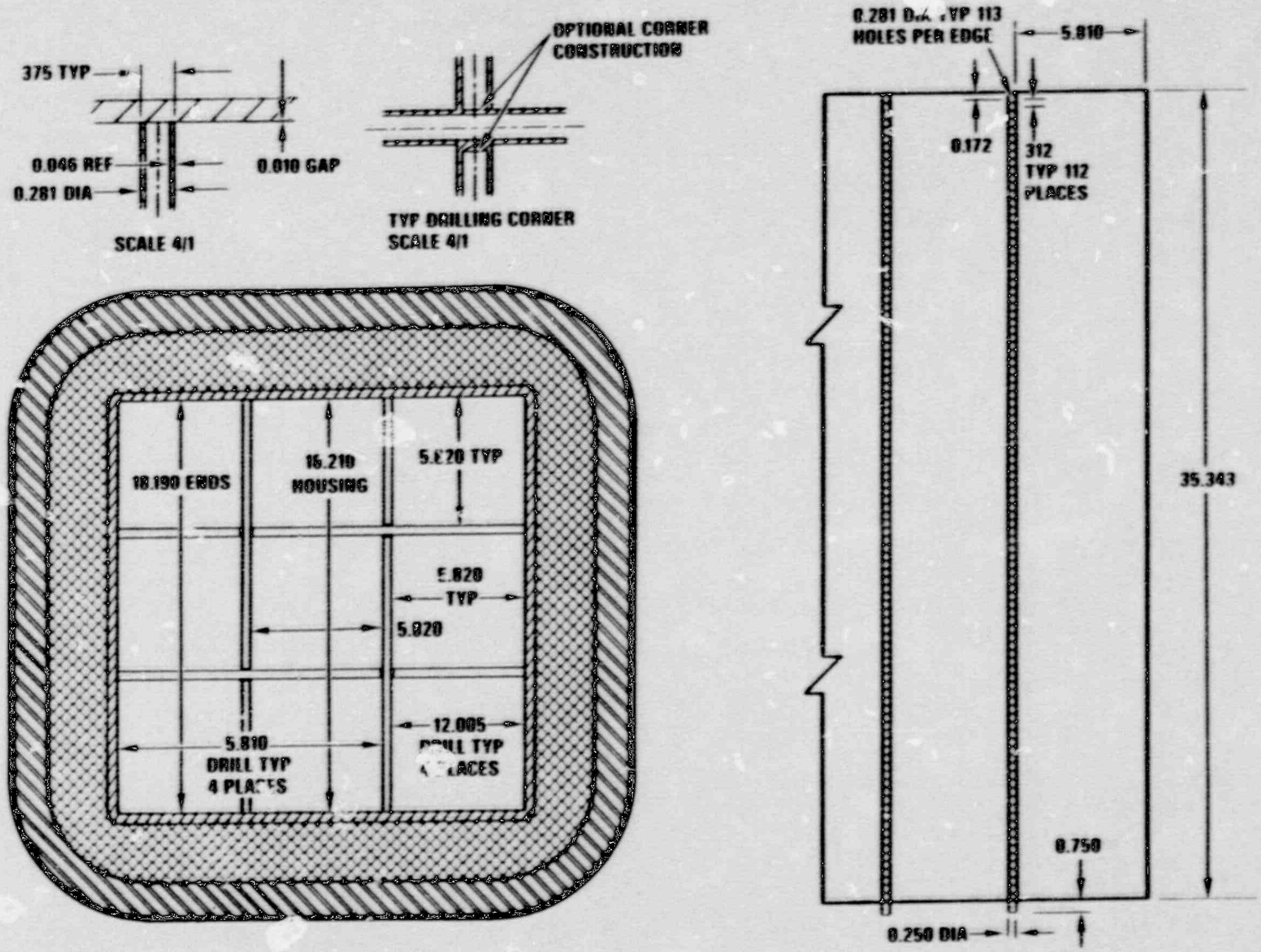




J-217(25)
10-11-89

GENERAL ATOMICS

GA-9 CASK DEPENDS ON B_4C POISON ONLY FOR CRITICALITY CONTROL



J-217(26)
10-11-89

GENERAL ATOMICS

GA-4 AND GA-9 CASKS MEET CRITICALITY SAFETY

DESCRIPTION	GA-4	GA-9
BURNUP CREDIT	YES	NO
MAXIMUM ENRICHMENT	4.5%	4.5%
AXIAL BURNUP DISTRIBUTION	UNIFORM	NA
MAXIMUM K–EFF	0.93	0.86

J-217(27)
10-11-89

GENERAL ATOMICS

GA-4 CASK REQUIRES MINIMAL BURNUP CREDIT FOR CRITICALITY CONTROL

ENRICHMENT (WT % U-235)	BURNUP (GWD/MTU)
<2.2	0.0
3.0	8.0
3.5	12.0
4.0	18.0
4.5	20.0

J-217(28)
10-11-89

GENERAL ATOMICS

BURNUP CREDIT SUPPLEMENTS CRITICALITY CONTROL FOR GA-4

K-INF FOR INFINITE ARRAY OF W 17 x 17 ASSEMBLIES (4 WT %)	1.43
DELTA-K DUE TO FINITE CASK	−0.20
DELTA-K DUE TO FIXED B_4C POISON AND ASSOCIATED STEEL	−0.20
DELTA-K DUE TO BURNUP	−0.10
FINAL K-EFF	0..93

J-217(30)
10-11-89

GENERAL ATOMICS

k_{eff} MUST BE $\leq$ 0.95

$$k_{eff} = k_{keno} + B + 2\,(\sigma_B^2 + \sigma_k^2)^{1/2}$$

k_{keno} = KENO RESULT FOR WORST-CASE CONFIGURATION WITH CONSERVATIVE CONSTRUCTION AND MATERIAL THICKNESS TOLERANCES

B = ANALYTICAL BIAS DETERMINED FROM BENCHMARK CRITICAL EXPERIMENTS

σ_B = ONE SIGMA STATISTICAL UNCERTAINTY ASSOCIATED WITH BIAS

σ_k = ONE SIGMA STATISTICAL UNCERTAINTY ASSOCIATED WITH KENO CALCULATION

*NOTE: THIS EQUATION ASSUMES MOST REACTIVE FUEL AND CONFIGURATION

J-217(31)
10-11-89

GENERAL ATOMICS

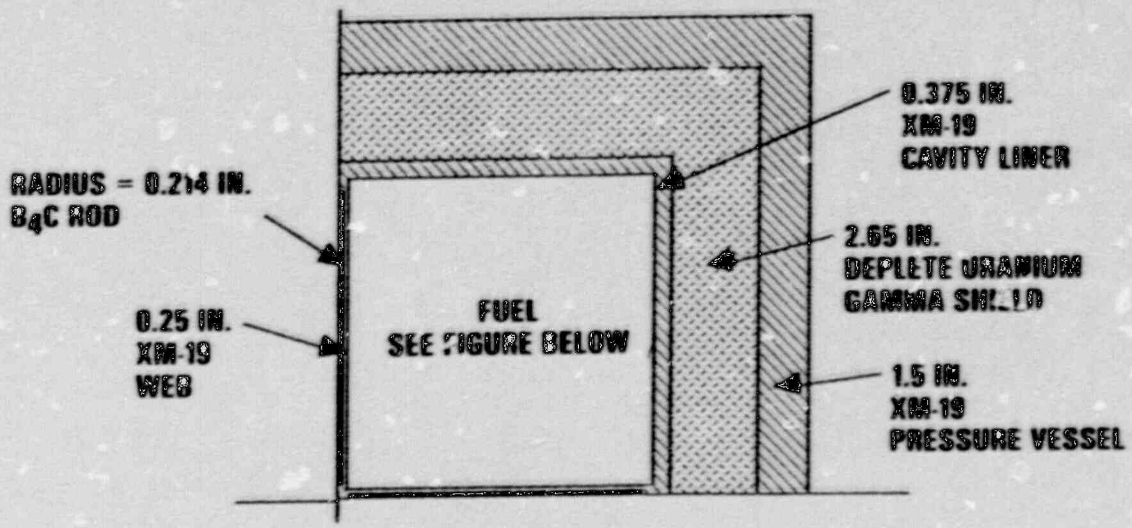
PRELIMINARY CRITICALITY ANALYSIS CONSIDERS TYPICAL FUEL ASSEMBLIES

DESCRIPTION	GA-4	GA-9
FUEL TYPE	W 17 x 17 STD	GE 7 x 7 STD
NO. OF FUEL RODS	264	49
NO. OF WATER HOLES	25	0
UO_2 DENSITY (% TD)	94	94

J-217(32)
10-11-89

GENERAL ATOMICS

GA-4 CASK MODEL SIMULATES EXACT GEOMETRY



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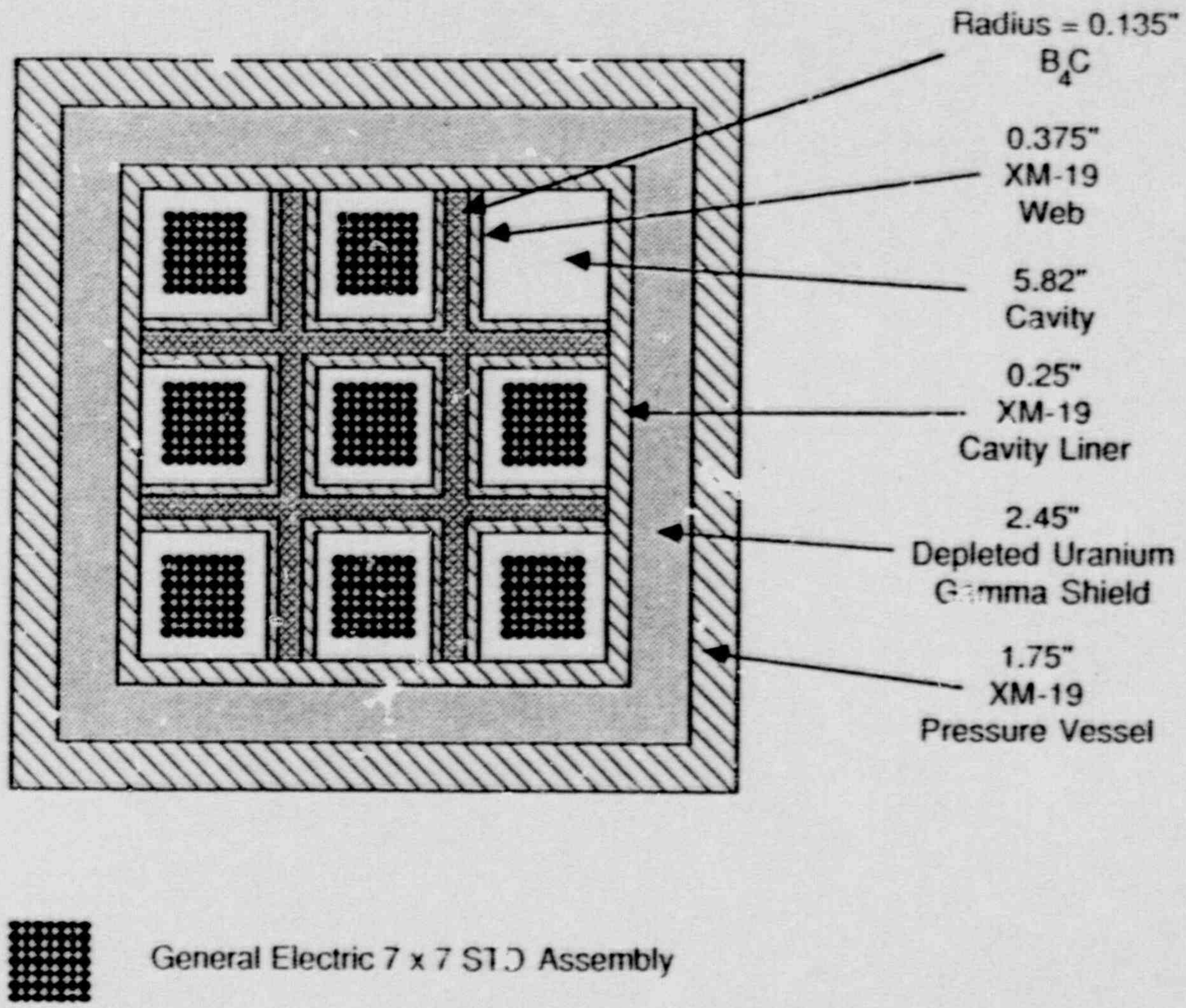
1 = FUEL ROD
2 = WATER HOLE

J-217(33)
10-11-89

GENERAL ATOMICS

GA-9 CASK MODEL IS ALSO EXPLICIT



J-217(34)
10-11-89

GENERAL ATOMICS

CRITICALITY ANALYSIS USES CONSERVATIVE ASSUMPTIONS

- INFINITE ARRAY OF CASKS (FISSILE CLASS I)
- COMPLETE LOSS OF NEUTRON SHIELDING FOLLOWING THERMAL EVENT
- FULL WATER FLOODING
- OMISSION OF GRID PLATES, SPACERS AND HARDWARE IN FUEL ASSEMBLY
- NO BURNABLE POISONS
- WATER DENSITY AT 1.0 G/CC
- TEMPERATURE AT 20°C (293 K)

J-217(35)
10-11-89

GENERAL ATOMICS

BOTH 27-GROUP AND 123-GROUP CROSS SECTION DATA ARE ACCEPTABLE FOR CRITICALITY ANALYSIS

DESCRIPTION	27-GROUP	123-GROUP
CASK TYPE	GA-4	GA-9
FUEL ASSUMPTION	BURNED	FRESH
FISSION PRODUCT DATA	COMPLETE	LIMITED
ANALYTICAL BIAS IN K-EFF*	−0.0145	−0.0004

*FOR FRESH FUEL (NEGATIVE VALUE UNDERPREDICTION)

J-217(36)
10-11-89

GENERAL ATOMICS

GA WILL PERFORM FURTHER CRITICALITY ANALYSIS DURING FINAL DESIGN

- DETERMINATION OF MOST REACTIVE FUEL
  - BURNED FUEL FOR GA-4 CASK
  - FRESH FUEL FOR GA-9 CASK
- EVALUATION OF NON-UINIFORM AXIAL BURNUP DISTRIBUTION

J-217(37)
10-11-89

GENERAL ATOMICS

K_{∞} FOR INDIVIDUAL ASSEMBLIES DETERMINES MOST REACTIVE FUEL

- INFINITE PLANE ARRAY OF FUEL ASSEMBLIES
- FINITE FUEL HEIGHT WITH WATER REFLECTORS
- INCLUSION OF FISSION PRODUCT AND ACTINIDE ABSORBERS FOR BURNED FUEL
- CALCULATIONS OF K_{∞} FOR VARIOUS FUEL ASSEMBLIES
- SELECTION OF FUEL WITH HIGHEST K_{∞} FOR CASK CRITICALITY ANALYSIS

J-217(38)
10-11-89

GENERAL ATOMICS

PHYSICAL MEASUREMENTS WILL VERIFY CRITICALITY SAFETY

- PART OF PRESHIPMENT INSPECTIONS
- BURNUP METER
  - IN-POOL MEASUREMENTS OF NEUTRONS FROM SPENT FUEL USING FISSION CHAMBER
  - NEUTRON COUNTING RATE CORRELATED TO BURNUP, ENRICHMENT AND COOLING TIME
- REACTIVITY METER
  - CONSISTING OF A NEUTRON SOURCE AND A FLUX DETECTOR PLACED IN ASSEMBLY WATER HOLES
  - CALIBRATION AGAINST A PRESELECTED FUEL ASSEMBLY
  - MEASUREMENT OF K-EFF VS COUNT RATE (CPS)

GENERAL ATOMICS

PRELIMINARY CRITICALITY CONTROL DESIGN IS COMPLETE

- USE OF PROVEN AND MOST EFFECTIVE POISON MATERIAL (B_4C)
- ESTABLISHMENT OF BURNUP CREDIT REQUIREMENT FOR GA-4 CASK
- SPECIFICATION OF FIXED ABSORBER (B_4C) REQUIREMENTS FOR GA-4 AND GA-9 CASKS TO MEET K-EFF $<$0.95 FOR FISSILE CLASS I
- COMPLETION OF BENCHMARK CALCULATIONS AGAINST CRITICAL EXPERIMENTS FOR FRESH FUEL USING 27-GROUP AND 123-GROUP CROSS SECTIONS
- ADDITIONAL CRITICALITY ANALYSIS TO BE PERFORMED IN FINAL DESIGN FOR INCLUSION IN SARP

GENERAL ATOMICS

THERMAL EVALUATION

RICH BOONSTRA

J-217(62)
10-11-89

GENERAL ATOMICS

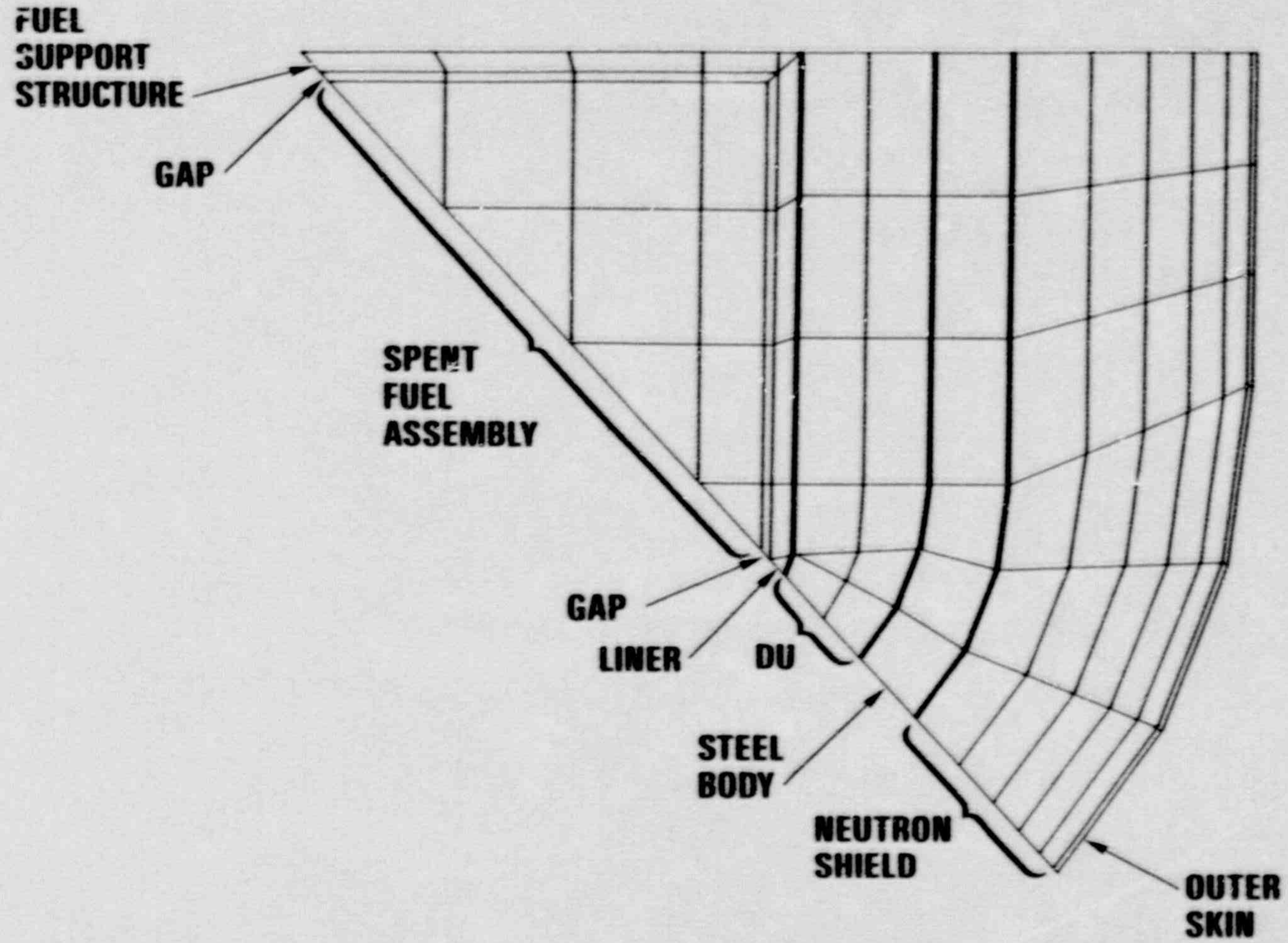
THERMAL EVALUATION COVERS ANALYSIS AND TESTING

- NORMAL CONDITIONS OF TRANSPORT
  - PATRAN/ANSYS
  - 2-D GA-4 AND GA-9
  - 3-D GA-4
- HYPOTHETICAL ACCIDENT CONDITIONS
  - PATRAN/ANSYS
  - 3-D GA-4
  - DAMAGE AT CLOSURE END
- TESTING OF NEUTRON SHIELD
  - SMALL-SCALE SCREENING TESTS
  - FULL-SCALE SECTION FIRE TESTS

J-217(63)
10-11-89

GENERAL ATOMICS

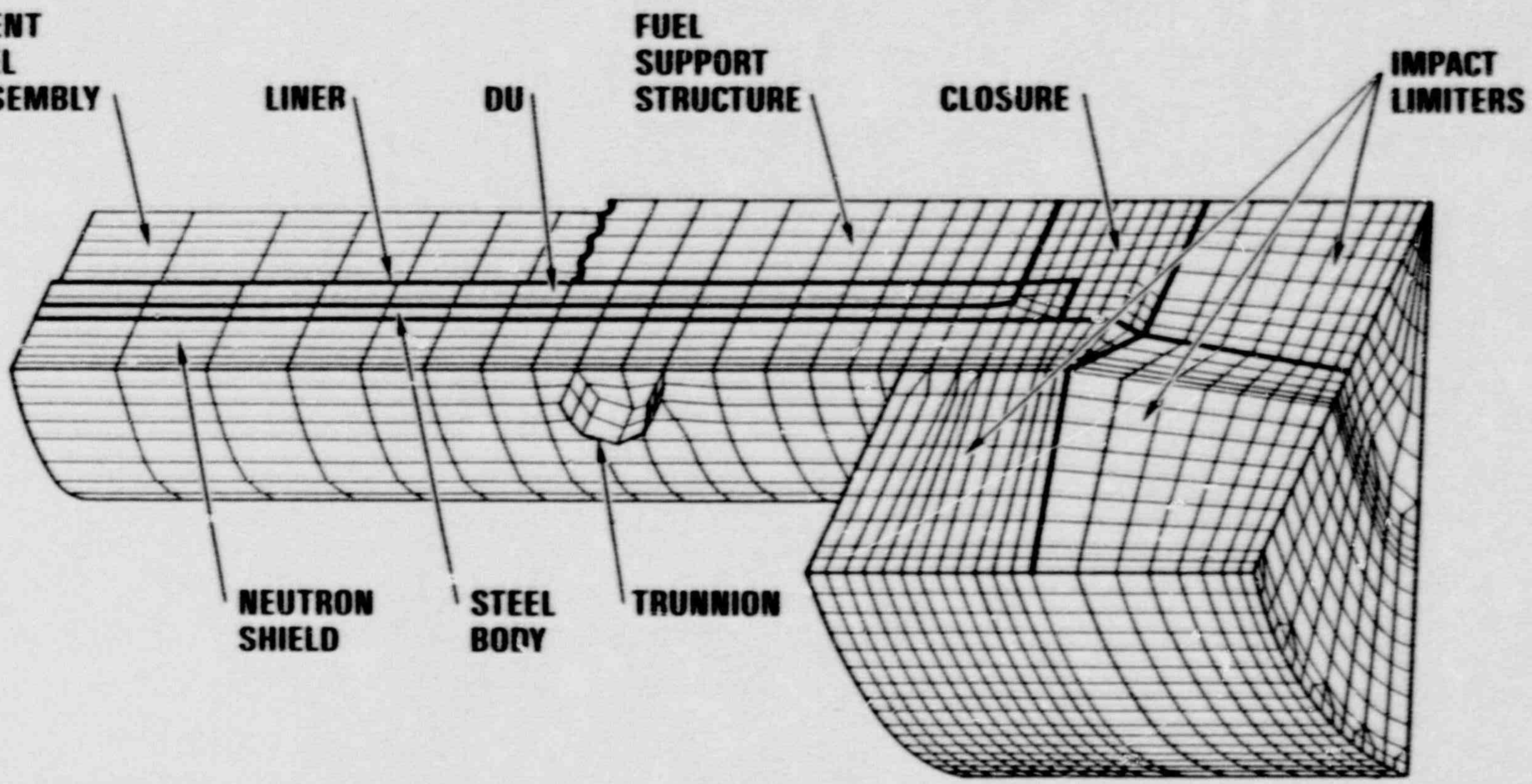
2-D NORMAL MODEL TREATS 1/8TH CROSS SECTION AT MID-LENGTH



J-217(2)
10-10-89

GENERAL ATOMICS

3-D NORMAL MODEL EXTENDS THRU CLOSURE END



J-217(3)
10-10-89

GENERAL ATOMICS

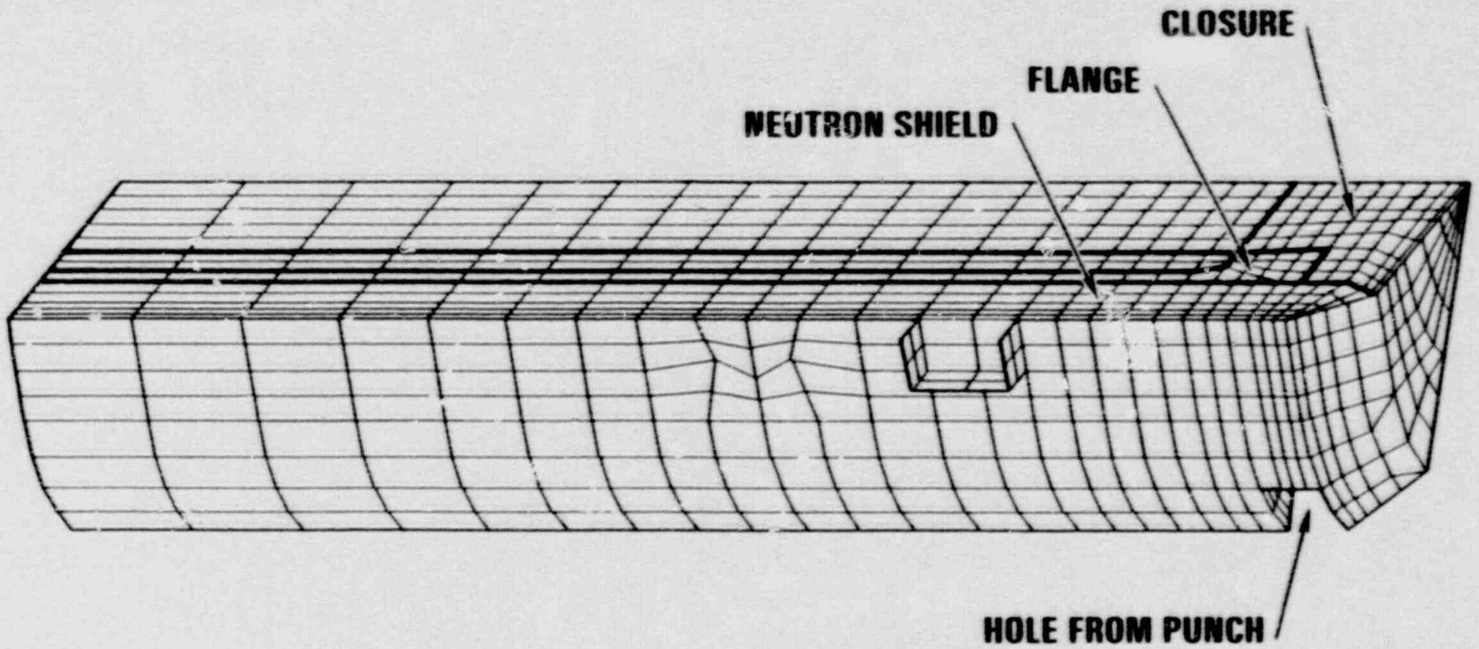
ALL CRITERIA FOR NORMAL CONDITIONS ARE MET

COMPONENT	MAX TEMP (°F)	CRITERION (°F)
FUEL CLADDING	368	716
NEUTRON SHIELD	167	180
SEALS	135	400
SURFACE	142	180

J-217(64)
10-11-89

GENERAL ATOMICS

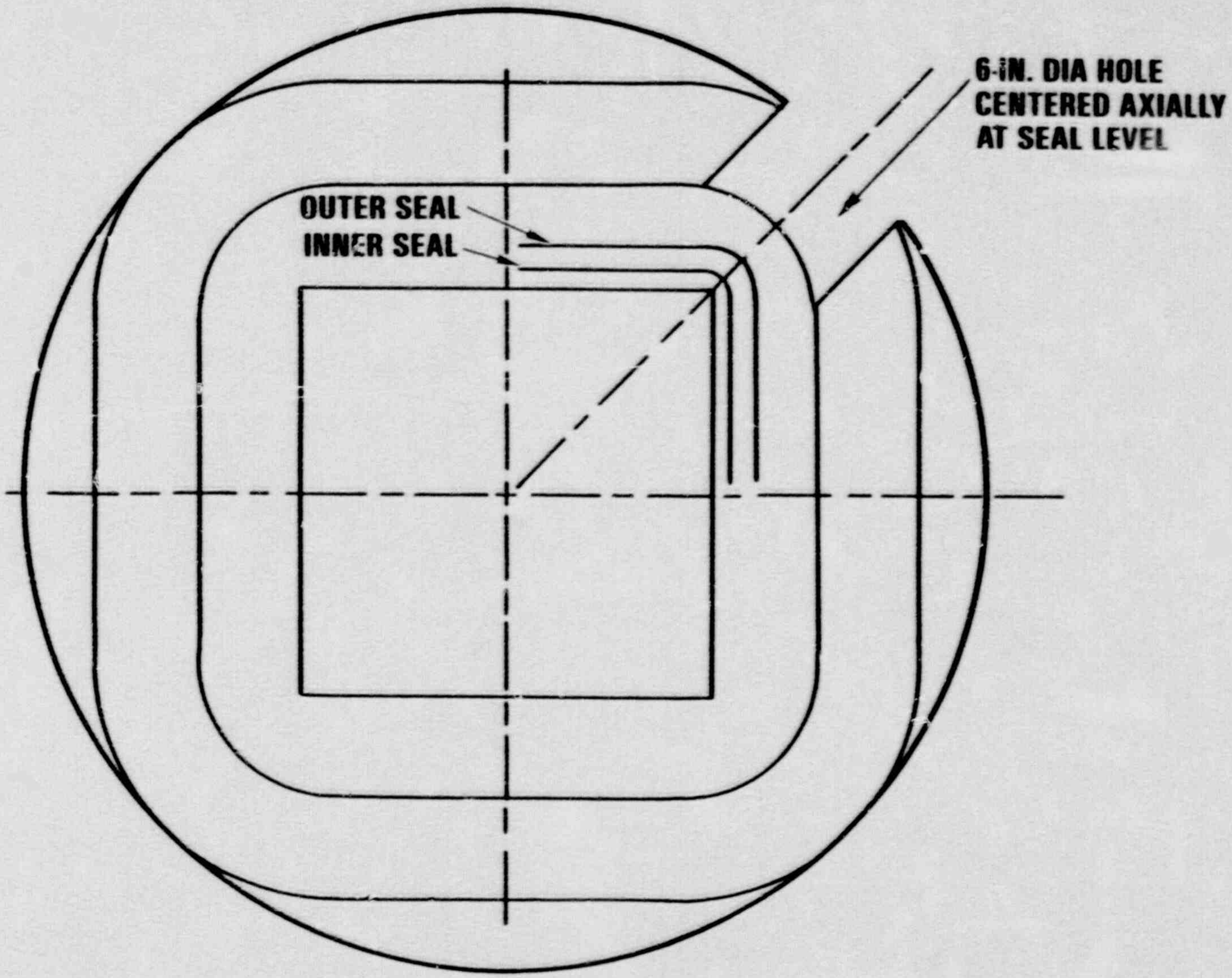
THERMAL ACCIDENT MODEL #1 ASSUMES SEVERE DAMAGE



J-217(4)
10-10-89

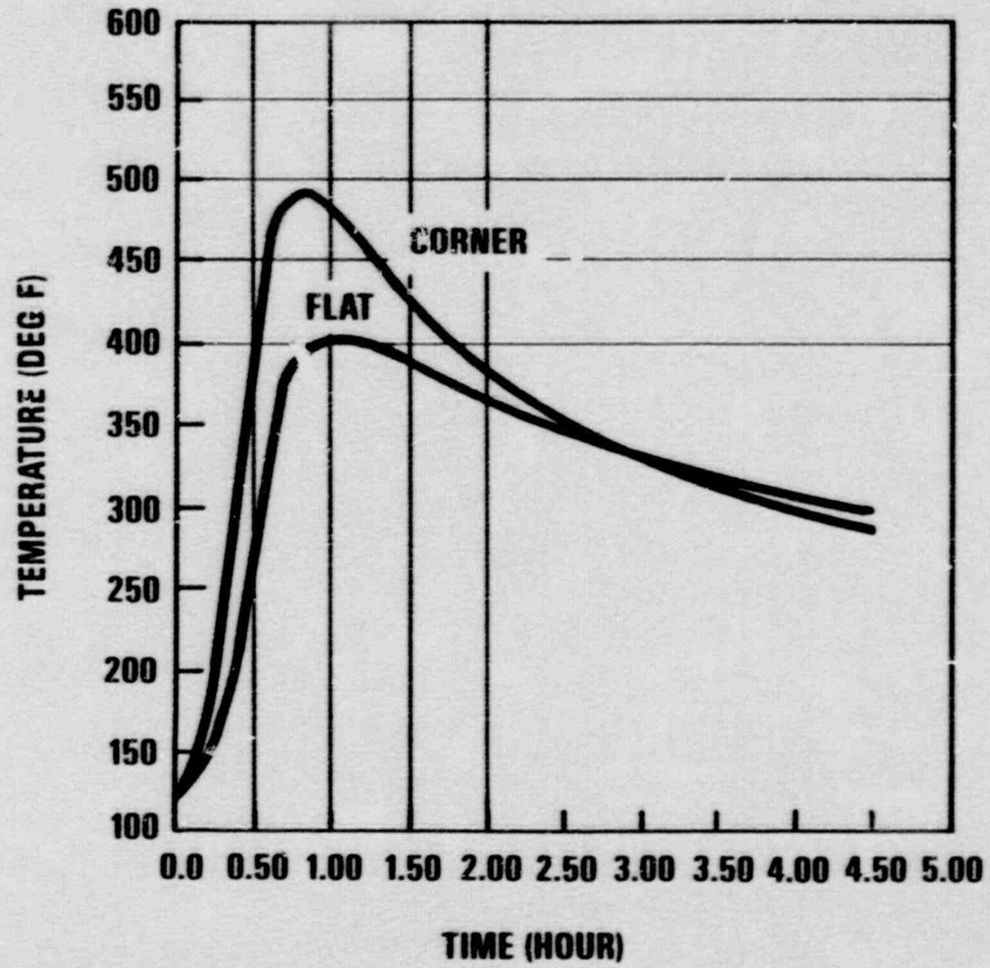
GENERAL ATOMICS

PUNCH IMPACTS CLOSURE END NEAR SEALS



J-217(5)
10-10-89

INNER CLOSURE SEAL REMAINS BELOW 500°F



GENERAL ATOMICS

SEAL PERFORMANCE IS ACCEPTABLE FOR PRELIMINARY DESIGN

- SEAL TYPE IS FLUOROELASTOMER (PARKER V835–75)
- NORMAL CONDITIONS
  - MAX INNER SEAL TEMPERATURE IS 135°F << 400°F (CONTINUOUS USE LIMIT)
  - PARKER HANDBOOK INDICATES OK AT −40°F
- ACCIDENT CONDITIONS
  - LOCALIZED INNER SEAL TEMPERATURE IS 450–500°F FOR 0.75 HR
  - PARKER HANDBOOK INDICATES OK FOR 2-3 HR

J-217(65)
10-11-89

GENERAL ATOMICS

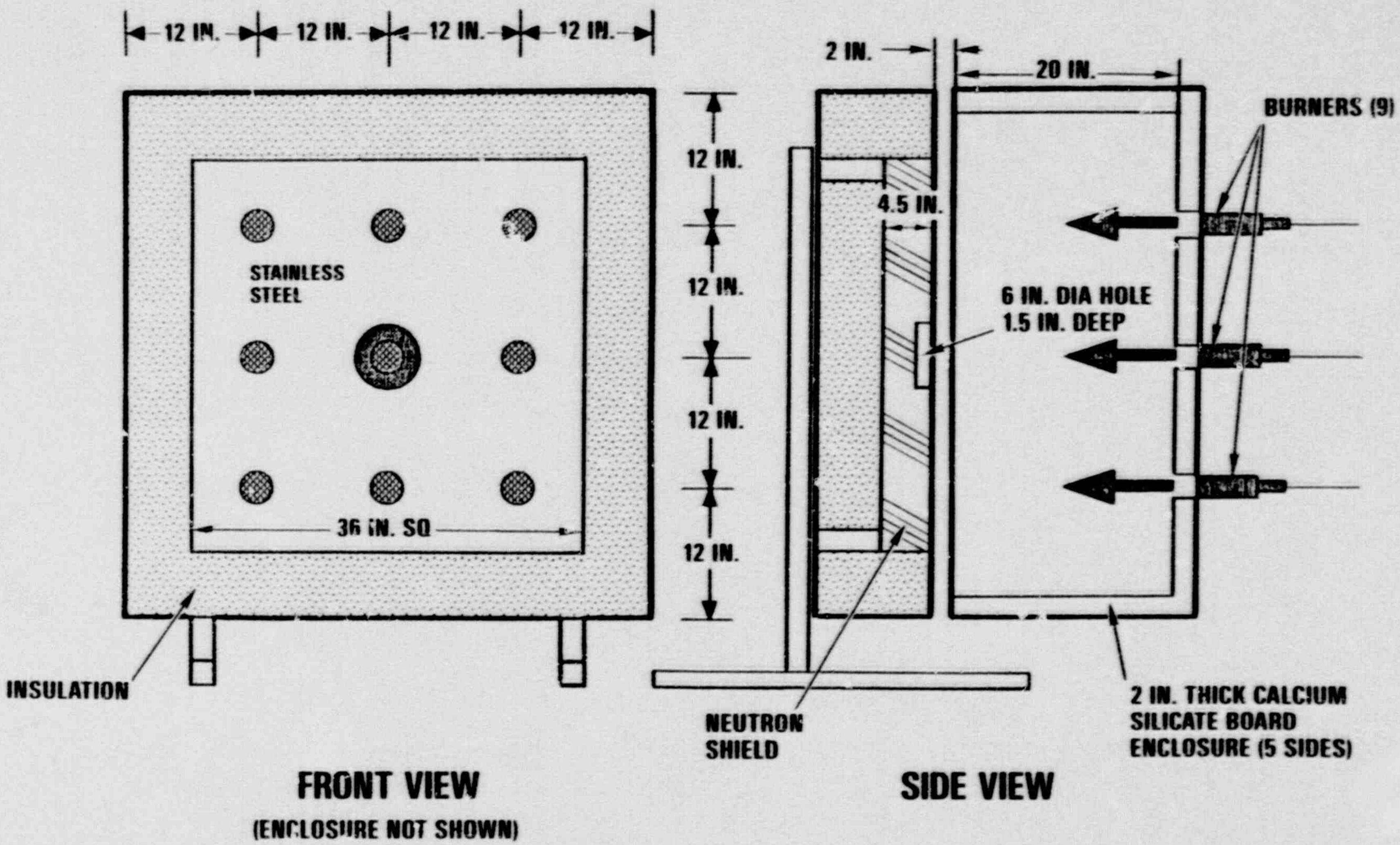
TESTING OF NEUTRON SHIELD USED TWO PHASES

- SMALL-SCALE TESTS
  - ASTM OR MODIFIED PROCEDURE
  - SCREEN FOR THERMAL/STRUCTURAL PERFORMANCE
  - 9 CANDIDATE MATERIALS
    - RX–237, –201–1, –207, –277
    - BISCO NS–1, NS–3, NS–4–FR
    - KOBE TYPE I, TYPE II
- FULL-SCALE SECTION FIRE TEST ON SELECTED MATERIALS
  - BISCO NS–4–FR, RX–201–1, RX–207
  - SUBJECT TO REGULATORY THERMAL ACCIDENT

J-217(66)
10-11-89

GENERAL ATOMICS

TEST ASSEMBLY MODELS FULL-SCALE SECTION OF NEUTRON SHIELD WITH DAMAGE



J-217(7)
10-10-89

GENERAL ATOMICS

FULL SCALE TESTING SHOWS ALL THREE MATERIALS ACCEPTABLE

- NO PROLONGED FLAMING AFTER 0.5 HR
- NO T/C EXCURSIONS INDICATING EXOTHERMIC REACTION AFTER 0.5 HR

J-217(67)
10-11-89

GENERAL ATOMICS

STRUCTURAL DESIGN STATUS

MARIA KOPLOY

LARRY PICKERING

RICHARD BOONSTRA

J-217(73)
10-11-89

GENERAL ATOMICS

STRUCTURAL DISCUSSION WILL FOCUS ON ANALYTICAL AND TEST RESULTS

- IMPACT LIMITER PHASE I TEST RESULTS
- CLOSURE BOLT
- FREE DROP ANALYSIS
- CAVITY LINER + FUEL SUPPORT STRUCTURE ANALYSIS
- THERMAL ACCIDENT STRESS ANALYSIS

GENERAL ATOMICS

PHASE I IMPACT LIMITER TESTS PROVIDED IMPORTANT DESIGN INFORMATION

HONEYCOMB BEHAVIOR TESTS

- CRUSH ANGLE TESTS
- DYNAMIC EFFECT TESTS
- TEMPERATURE TESTS
- BACKING AND SCALING TESTS

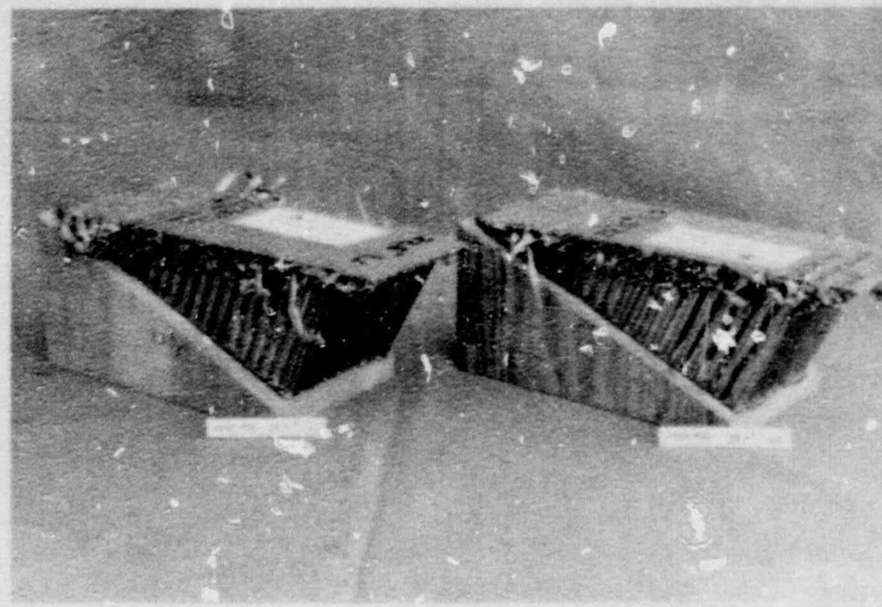
IMPACT LIMITER BEHAVIOR TESTS

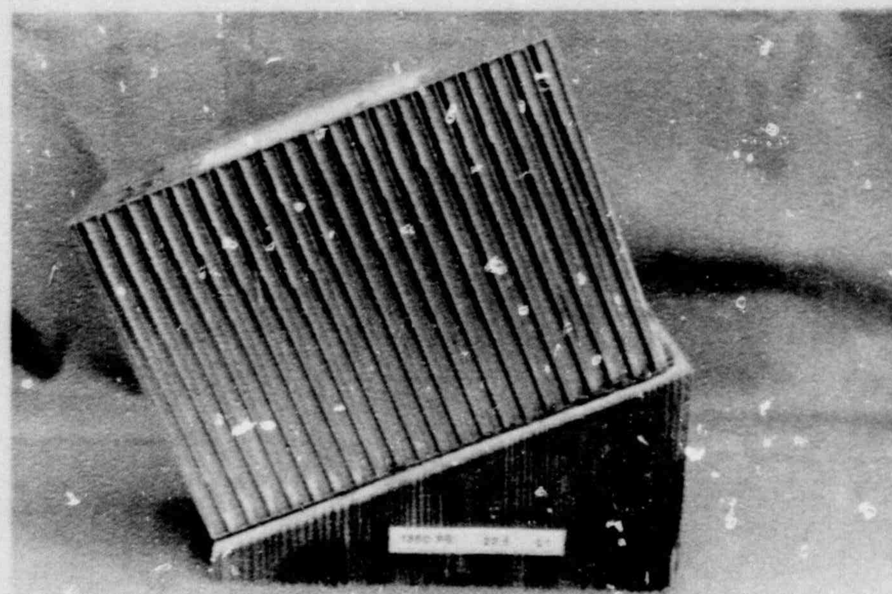
- 30° CRUSH TEST
- 90° (SIDE) CRUSH TEST

J-217(75)
10-11-89

GENERAL ATOMICS

CRUSH ANGLE TESTS WERE PERFORMED ON SMALL SAMPLES





J-217(76)
10-11-89

GENERAL ATOMICS

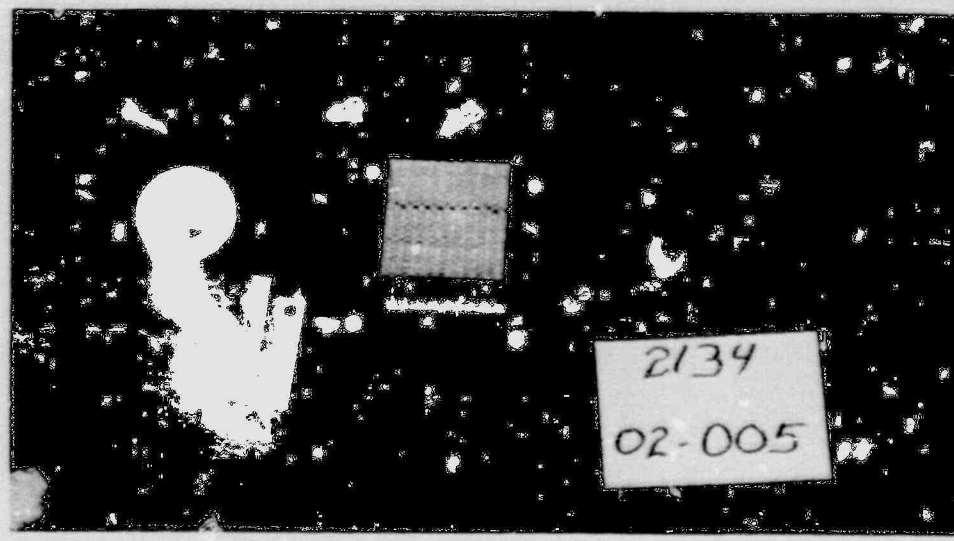
CRUSH ANGLE TESTS DEMONSTRATED HONEYCOMB ENERGY ABSORBTION CAPABILITIES UP TO 37-1/2°

CRUSH ANGLE	L DIRECTION % CRUSH STRENGTH RETENTION	W DIRECTION % CRUSH STRENGTH RETENTION
	1350 PSI	
0	100	
7-1/2	90	94
15	87	88
22-1/2	86	83
30	80	78
37-1/2	79	72
45	74	48
	2350 PSI	
0	100	
7-1/2	100	103
15	93	84
22-1/2	94	93
30	92	78
37-1/2	81	65
45	PEELED OFF FACESHEET	PEELED OFF FACESHEET

J-217(77)
10-11-89

GENERAL ATOMICS

DYNAMIC TESTS WERE
PERFORMED AT 44 FT/SEC



1350 PSI CRUSH STRENGTH INCREASED BY 10%

2350 PSI CRUSH STRENGTH DID NOT CHANGE

J-217(78)
10-11-89

GENERAL ATOMICS

HONEYCOMB STRENGTH DOES NOT CHANGE MUCH WITH TEMPERATURE

CORE TYPE	TEST TEMP	CRUSH STRENGTH RETENTION (%)	STROKE BEFORE BOTTOMING OUT (%)
1350 PSI	R.T.	100	72
	200°F	95	73
	−20°F	102	75
2350 PSI	R.T.	100	71
	200°F	95	78
	−20°F	106	78

J-217(79)
10-11-89

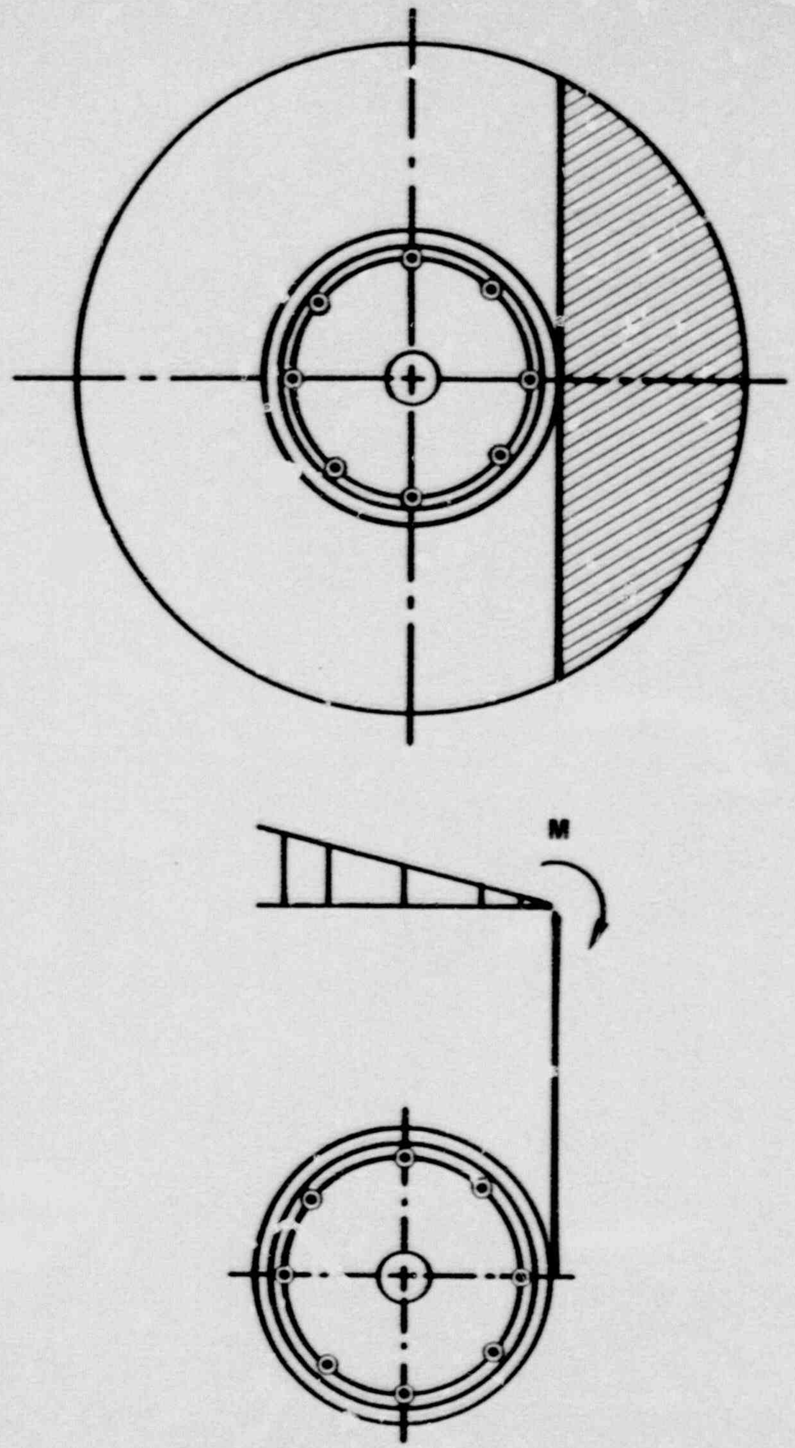
GENERAL ATOMICS

THE IMPACT LIMITER DESIGN USES PHASE I TEST EXPERIENCE

- UNBACKED HONEYCOMB ABSORBS ENERGY
  - END AND SIDE HONEYCOMBS PROVIDE SUPPORT FOR THE CORNER HONEYCOMB TO CRUSH
  - HONEYCOMB ORIENTED UP TO 37-1/2° FROM THE IMPACT POINT ABSORBS ENERGY
- HONEYCOMB CRUSHING SCALES FOR IMPACT LIMITER
- IMPACT LIMITER ATTACHMENTS REACT MOMENTS DUE TO CRUSH OF UNBACKED AREA

GENERAL ATOMICS

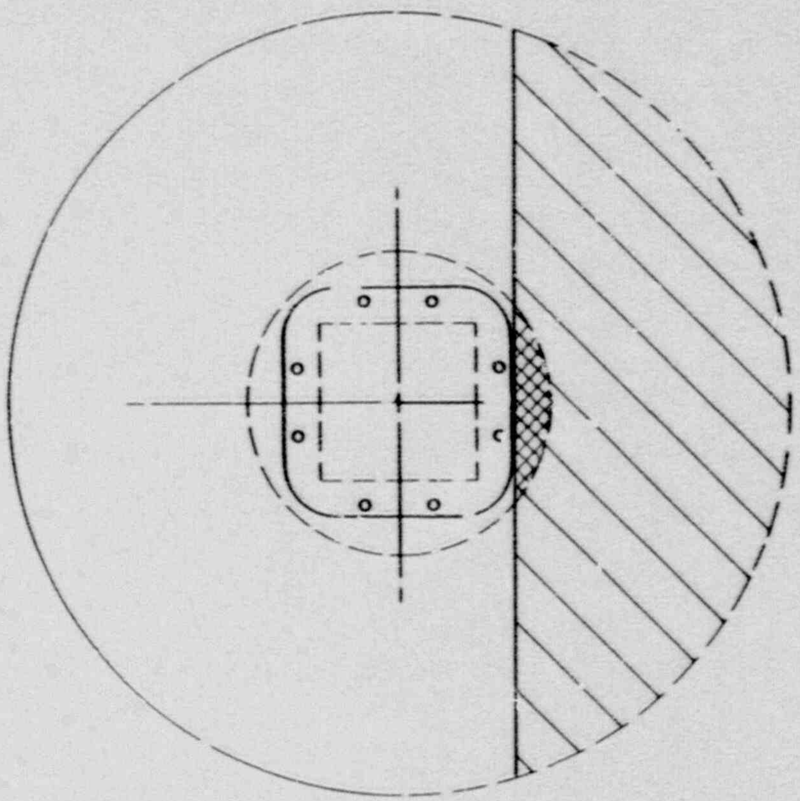
IMPACT LIMITER ATTACHMENT BOLTS ARE DESIGNED TO TAKE MOMENTS DUE TO CRUSH OF UNBACKED AREA

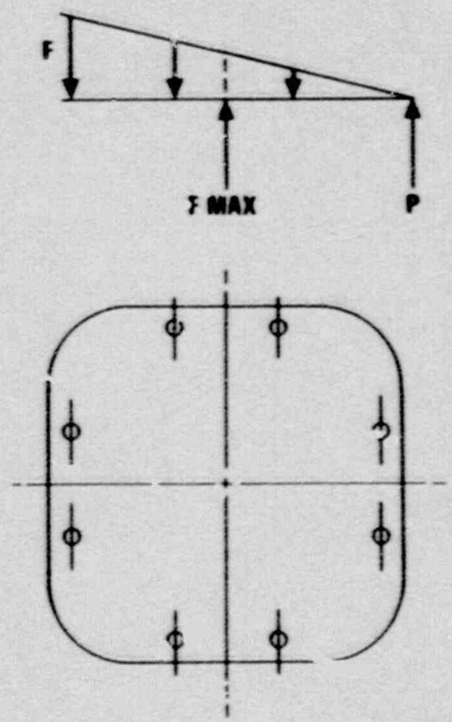


J-217(13)
10-11-89

GENERAL ATOMICS

THE MAXIMUM AXIAL LOAD ON THE CLOSURE BOLTS DUE TO THE CONTENTS ACCELERATION WAS CONSERVATIVELY CALCULATED





$F_{MAX} = W \times g's$

W = CLOSURE WT
2 x FUEL WT
2 x FSS WT

$\sigma_{MEMBRANE}$ =

82.5 KSI < 123.2 KSI

J-217(12)
10 11-89

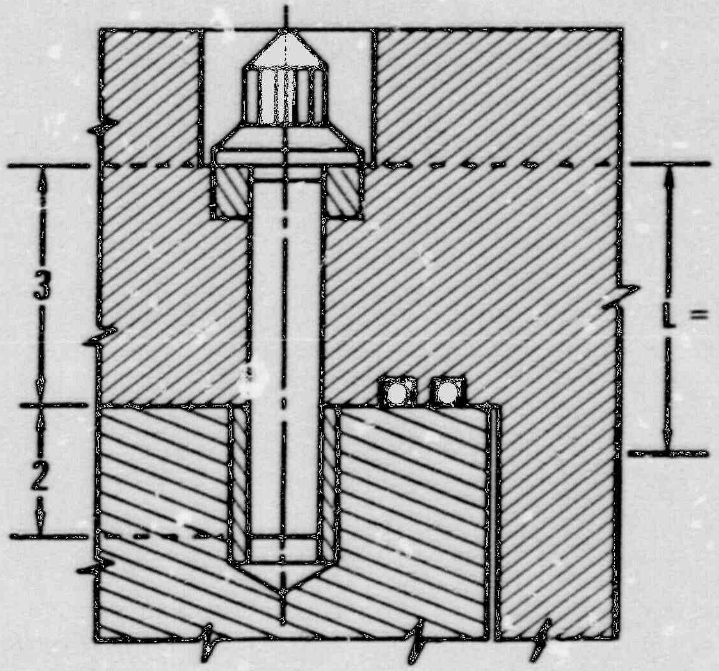
GENERAL ATOMICS

CLOSURE BOLTS ARE DESIGNED TO WITHSTAND THE MAXIMUM CLOSURE MOVEMENT AND AXIAL FORCE SIMULTANEOUSLY

$$M = \frac{5.25\ E\ I\ \Delta}{L^2}$$

$$\Delta_{MAX} = 0.01\ IN.$$

$$\sigma_{BENDING} = \frac{Mc}{I} = 49.6\ KSI$$



$$\sigma_{MEMBRANE} + \sigma_{BENDING} = 82.5 + 49.6 = 132.1\ KSI < 144\ KSI$$

J-217(14)
10-11-89

SHEAR PINS ARE SIZED FOR PUNCTURE ON SIDE OF CLOSURE

SHEAR

68.7 KSI $<$ 73.9 KSI ALLOWABLE AT 200°F

GENERAL ATOMICS

GACAP SHOWS GA-4 STRESSES ARE BELOW ALLOWABLES DURING 30-FT FREE DROP

	RIGID		FLEXIBLE		
DROP ANGLE	STRESS INTENSITY (KSI)	MARGIN OF SAFETY[a]	STRESS INTENSITY (KSI)	MARGIN OF SAFETY[a]	DYNAMIC AMPLIFICATION FACTOR
0°	36.84	0.89	58.58	0.19	1.58
	37.45[b]	0.86	53.22	0.31	1.42
15°	40.18	0.73	41.27	0.69	1.02
30°	35.32	0.97	48.42	0.44	1.36
45°	21.89	2.18	46.05	0.51	2.13
60°	22.57	2.09	26.22	1.66	1.10
75°	45.47	0.53	45.84	0.52	1.01
78°	45.54	0.53	50.39	0.38	1.11
90°	18.46	2.78	23.00	2.03	NA
	17.55[b]	2.97	26.37	1.64	NA

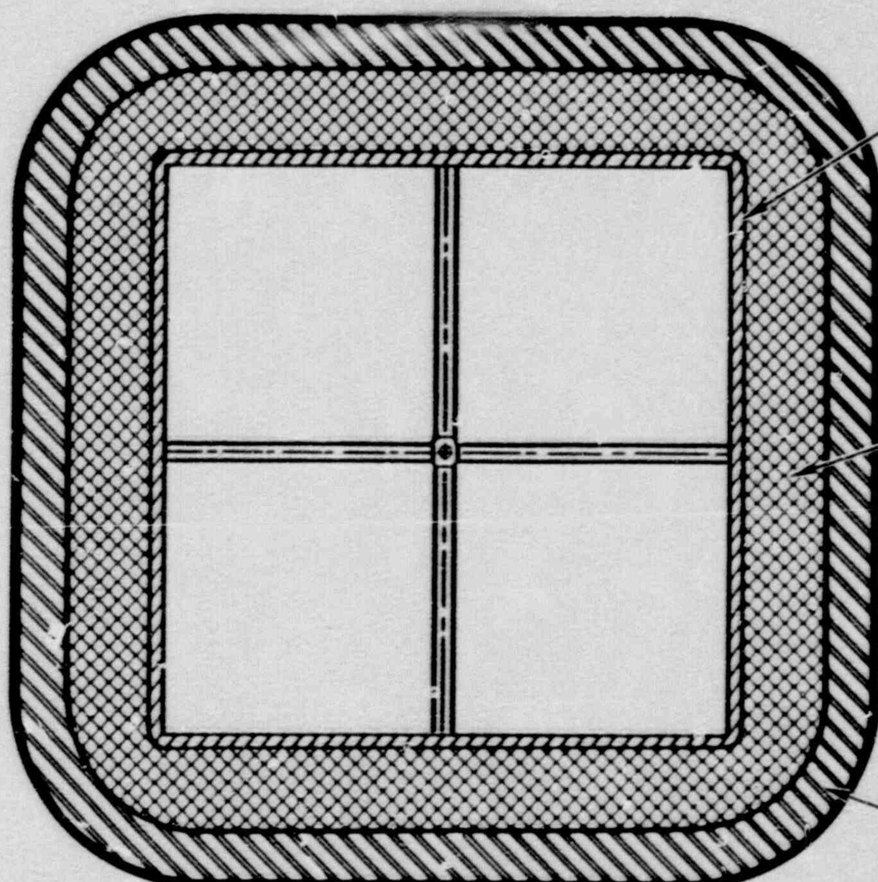
(a) MARGIN OF SAFETY IS CALCULATED AGAINST PRIMARY MEMBRANE STRESS ALLOWABLE EQUAL TO 69.7 KSI

(b) NEW IMPACT LIMITER DESIGN

J-217(81)
10-11-89

GENERAL ATOMICS

ANSYS MODELS WERE USED TO ENVELOP THE WORST CASE IN THE GA-4 CAVITY LINER

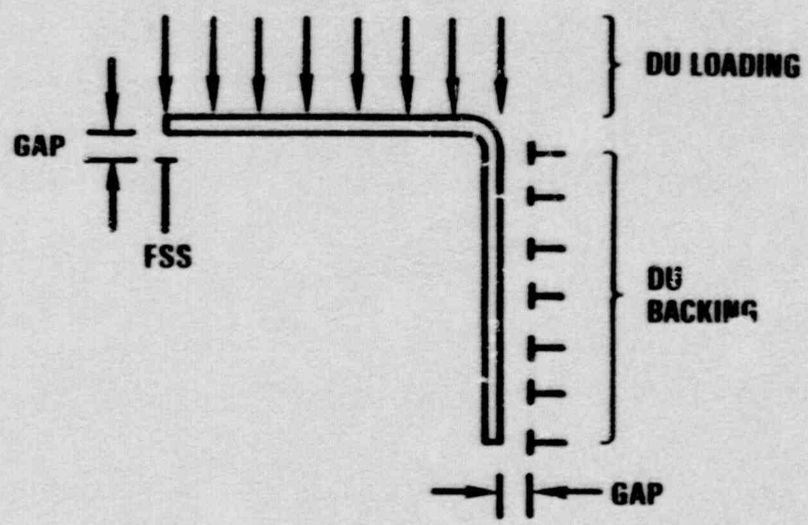


J-217(91)
10-11-89

GENERAL ATOMICS

ANSYS MODELS WERE USED TO ENVELOP THE WORST CASE IN THE GA-4 CAVITY LINER

- SIDE DROP FLAT ORIENTATION



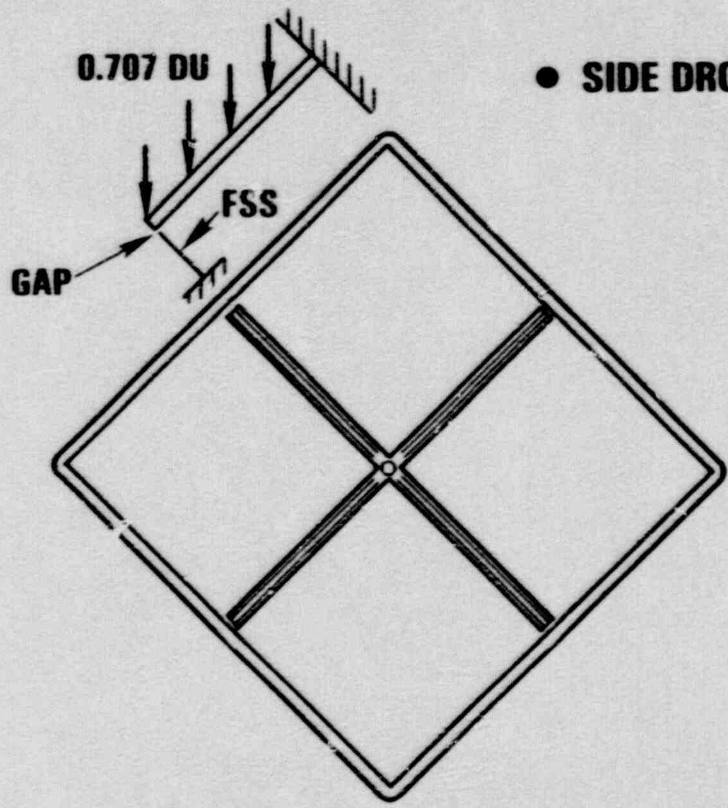
	$P_m + P_b$* SI, KSI	ALLOWABLE KSI	MARGIN OF SAFETY
NORMAL	35.2	49.8	+0.41
ACCIDENT	72.0	99.5	+0.38

*INCLUDES OUT-OF-PLANE BENDING

-217(90)
10-11-89

GENERAL ATOMICS

ANSYS MODELS WERE USED TO ENVELOP THE WORST CASE IN THE GA-4 CAVITY LINER



- SIDE DROP CORNER ORIENTATION

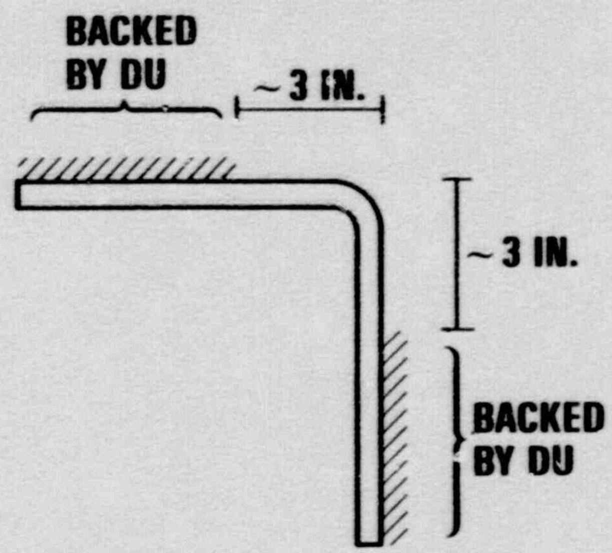
	$P_m + P_b$* SI, KSI	ALLOWABLE	MARGIN OF SAFETY
NORMAL	40.6	49.8	+0.23
ACCIDENT	88.3	99.5	+0.13

*INCLUDES OUT-OF-PLANE BENDING

J-217(93)
10-11-89

ANSYS MODELS WERE USED TO ENVELOP THE WORST CASE IN THE GA-4 CAVITY LINER

- INTERNAL PRESSURE



$P_m + P_b$

NORMAL 2 KSI << 49.8 KSI ALLOWABLE

MARGIN OF SAFETY + HIGH

1

IMAGE EVALUATION TEST TARGET (MT-3)

1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

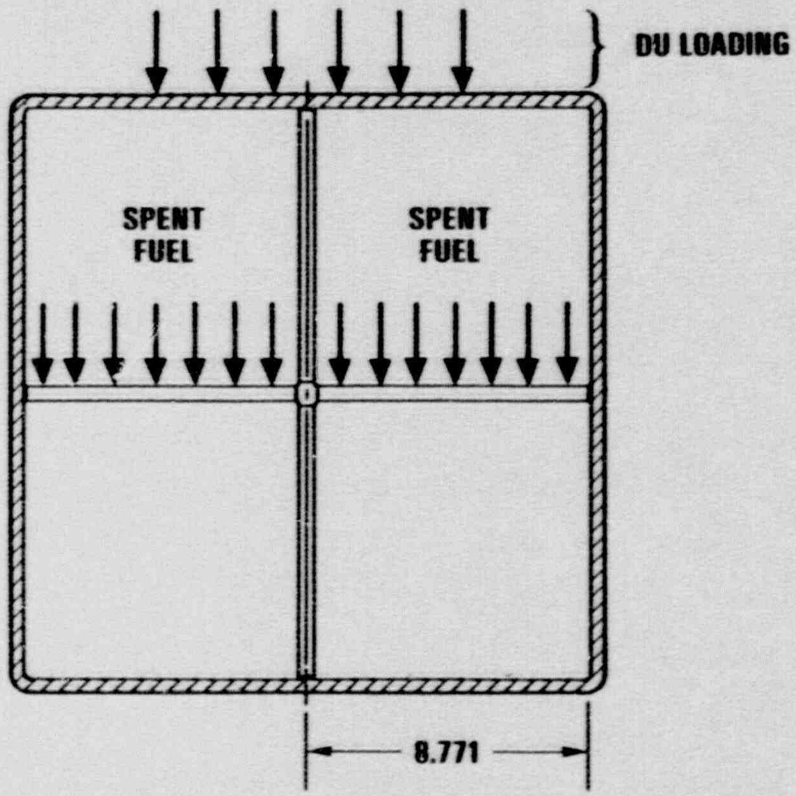
IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6″

GENERAL ATOMICS

THE FUEL SUPPORT STRUCTURE DOES NOT BUCKLE – GA-4 CASK



LOADING	APPLIED LOAD, LB	BUCKLE[a] LOAD, LB
NORMAL	599	1432[b]
ACCIDENT	1422	2153[c]

[a] CONSIDERING INITIAL CROOKEDNESS OF 0.03 IN. AND PINNED-PINNED END CONDITIONS

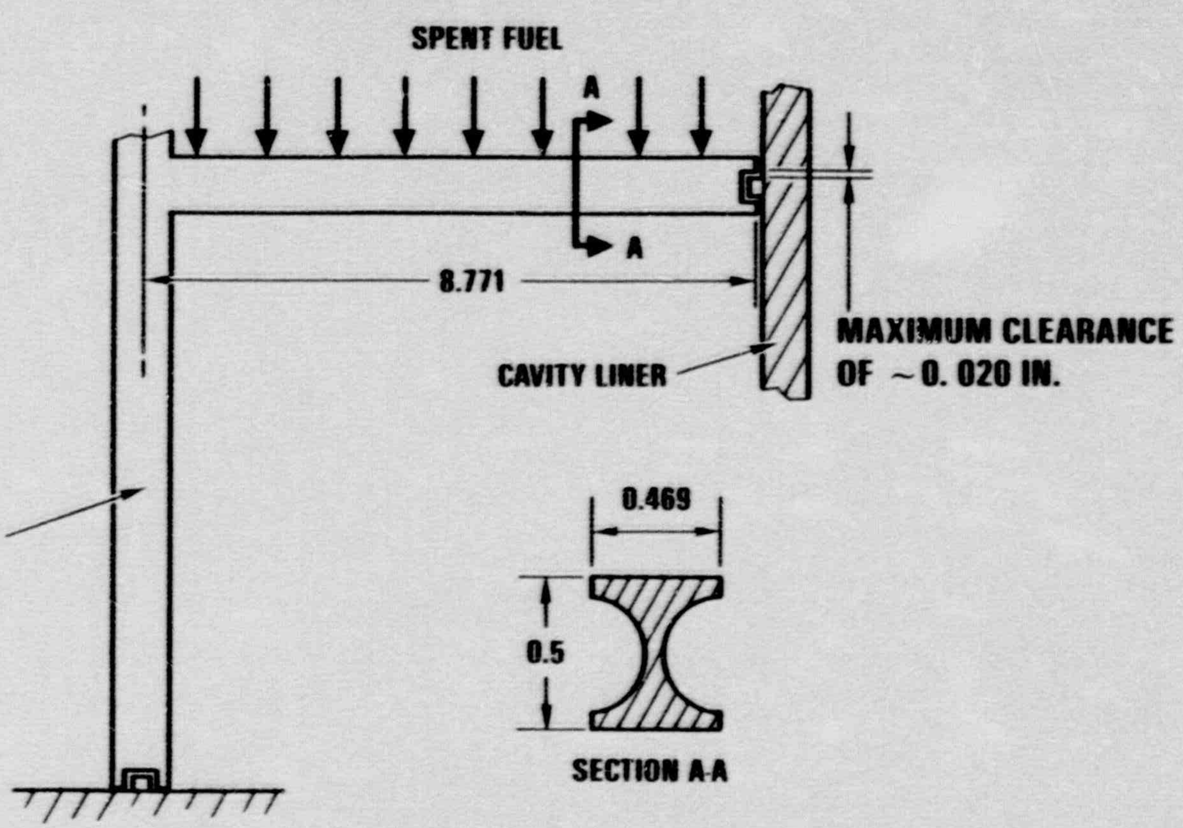
[b] INCLUDES FS = 2

[c] INCLUDES FS = 1.34

J-217(17)
10-11-89

GENERAL ATOMICS

THE BENDING STRESS IN THE FUEL SUPPORT STRUCTURE IS BELOW ALLOWABLES

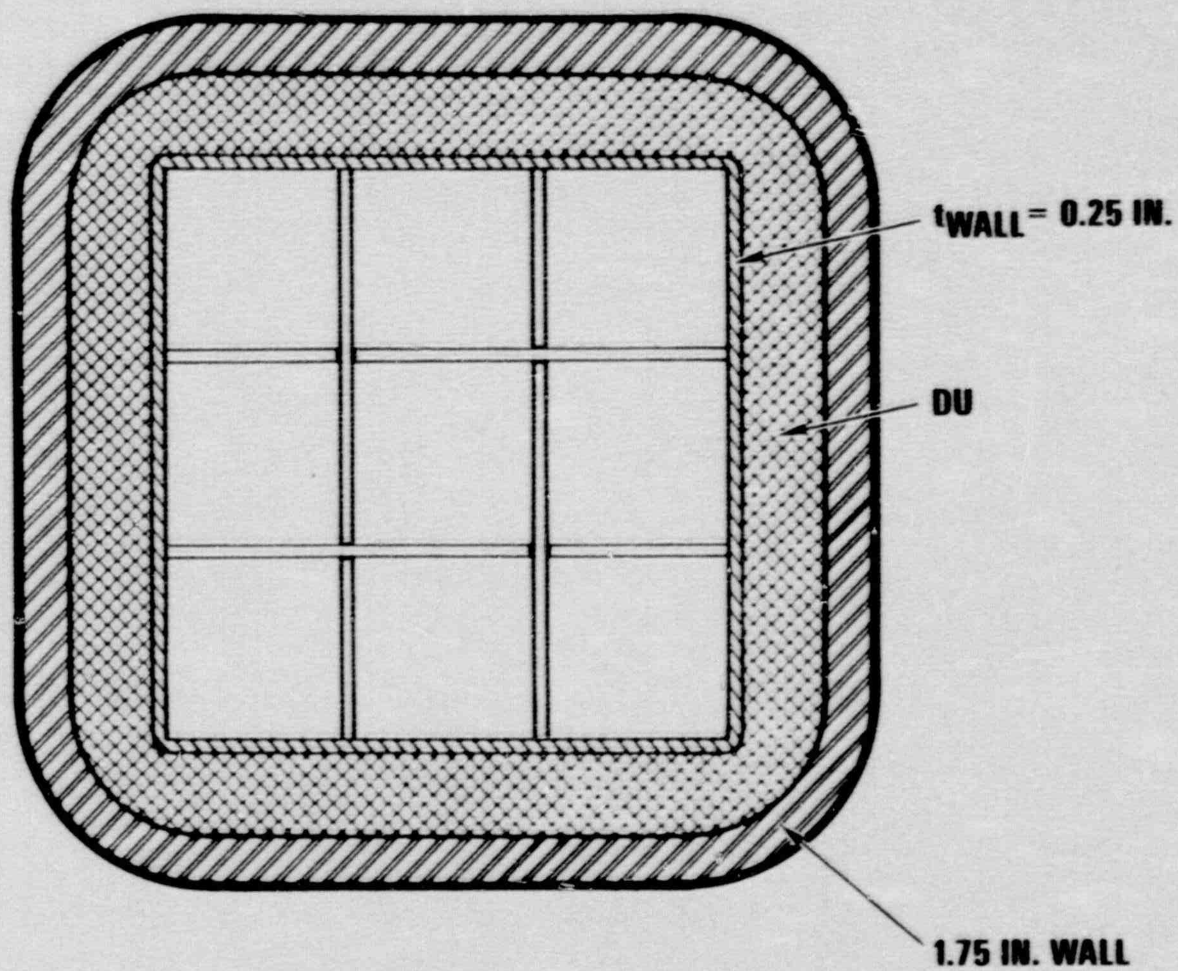


	P_b SI, KSI	ALLOWABLE KSi	MARGIN OF SAFETY
ACCIDENT	32.9	95.1 (AT 300°F)	+1.89

J-217(18)
10-11-89

GENERAL ATOMICS

ANSYS MODELS WERE USED TO ENVELOP THE WORST CASE IN THE GA-9 CAVITY LINER



J-217(97)
10-11-89

GENERAL ATOMICS

ANSYS MODELS WERE USED TO ENVELOPE THE WORST CASE IN THE CAVITY LINER – GA-9 CASK

- CAVITY LILNER – DU LOADING

  SIDE DROP

	$P_m + P_b$* SI, KSI	ALLOWABLE PSI	MARGIN OF SAFETY
FLAT ORIENTATION			
NORMAL	39.6	49.8	+0.26
ACCIDENT	95.2	99.5	+0.05
CORNER ORIENTATION			
NORMAL	38.3	49.8	+0.30
ACCIDENT	80.4	99.5	+0.24

*INCLUDES OUT-OF-PLANE BENDING

J-217(19)
10-11-89

GENERAL ATOMICS

THE FUEL SUPPORT STRUCTURE DOES NOT BUCKLE – GA-9 CASK

LOADING	APPLIED LOAD, LB	BUCKLE[a] LOAD, LB
NORMAL	256	884[b]
ACCIDENT	645	1329[c]

(a) CONSIDERING INITIAL CROOKEDNESS OF 0.03 IN. AND PINNED-PINNED END CONDITIONS

(b) INCLUDES FS = 2

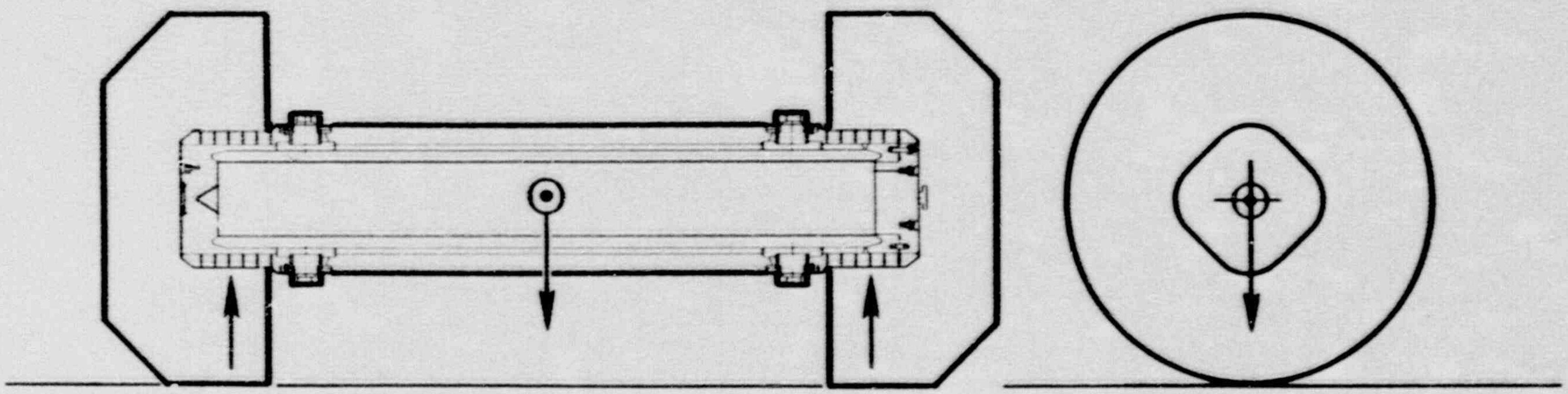
(c) INCLUDES FS = 1.34

J-217(20)
10-11-89

GENERAL ATOMICS

THE HIGHEST STRESS CONDITION IN THE CONTAINMENT OCCURS DURING THE 30 FT SIDE DROP

30 FT SIDE DROP



J-217(94)
10-11-89

GENERAL ATOMICS

ANSYS RESULTS ARE USED TO STUDY CRITICAL SIDE DROP EVENTS

- ANSYS ANALYSIS – 10 g

- INCLUDE CAVITY LINER (CL) EFFECT AT MIDLENGTH

$$S_Z = \left\{ \begin{matrix} \text{ANSYS} \\ \text{RESULTS} \end{matrix} \right\} - \frac{Mc}{I} \text{ WITHOUT CL} + \frac{Mc}{I} \text{ WITH CL}$$

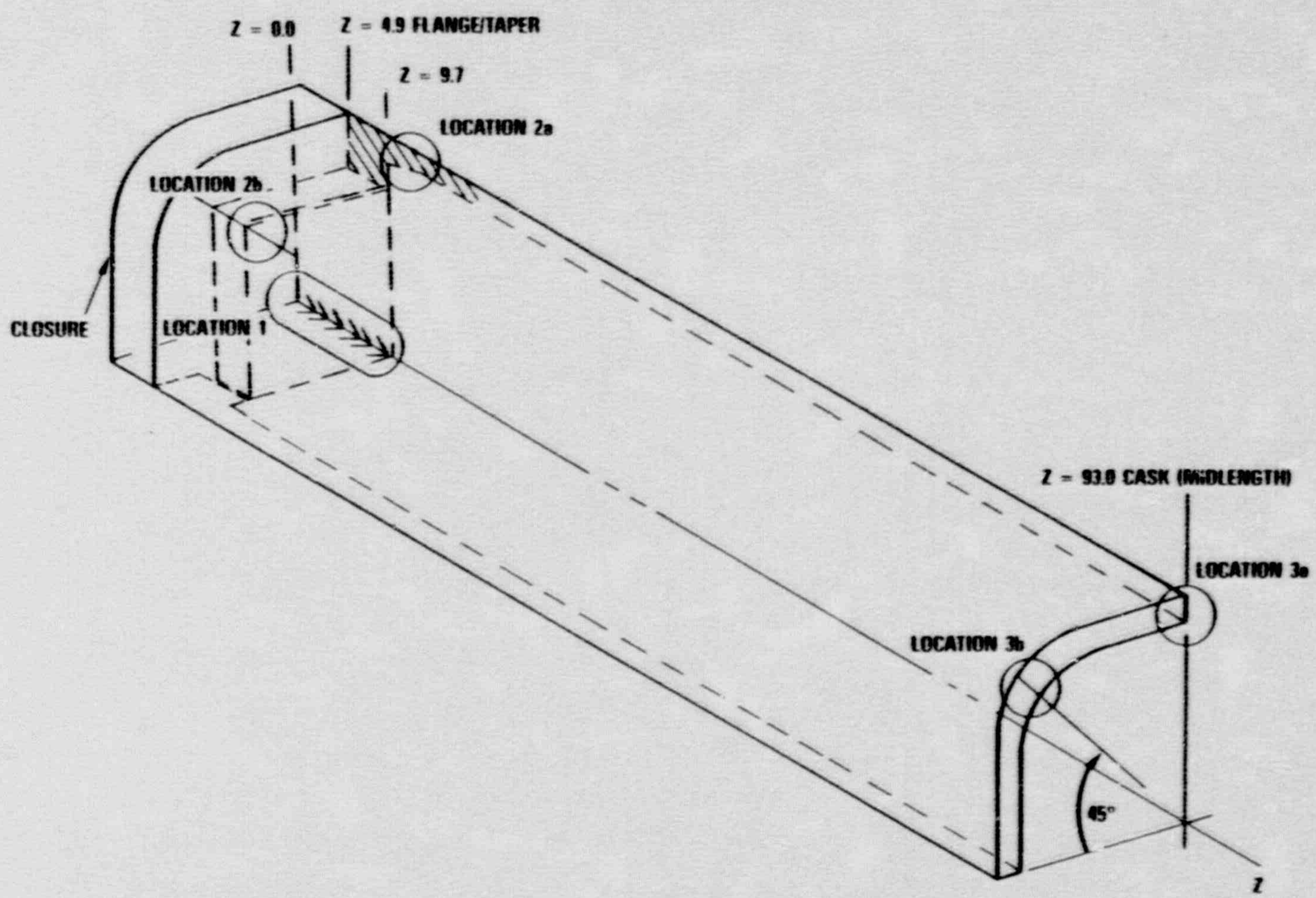
- SCALE ANSYS RESULTS TO RIGID BODY G-LEVEL

- MULTIPLY BY DYNAMIC AMPLIFICATION FACTOR TO OBTAIN FLEXIBLE BODY RESULTS

J-217(96)
10-11-89

GENERAL ATOMICS

CRITICAL POINTS ON THE CONTAINMENT BOUNDARY



GENERAL ATOMICS

MAXIMUM STRES INTENSITY VALUES OCCURRED AT CASK MIDLENGTH – 9 m (29.5 FT) DROP RESULTS – GA-4

		FLAT ORIENTATION		CORNER ORIENTATION	
		RIGID	FLEXIBLE	RIGID	FLEXIBLE
LOCATION	TYPE	SI, KSI	SI, KSI	SI, KSI	SI, KSI
1 CENTER OF CLOSURE	P_b	2.16	3.08	4.76	6.76
2a FLANGE/TAPER, X=0, LOWER	P_m	9.00	12.82	17.78	25.28
	$P_m + P_b$	38.72	55.27	24.03	34.86
2b FLANGE/TAPER, CORNER, LOWER	P_m	19.75	28.04	5.22	7.45
	$P_m + P_b$	31.46	45.23	18.97	28.07
3a MIDLENGTH Z=94, MIDWALL	P_m	30.51	43.24	20.99	35.54
	$P_m + P_b$	50.90	71.63	26.44	37.24
3b MIDLENGTH Z=94, CORNER	P_m	31.60	44.87	42.48	60.30
	$P_m + P_b$	36.01	50.74	44.73	63.83

ALLOWABLES:

$P_{m\ (200°F)}$ = 69.7 KSI

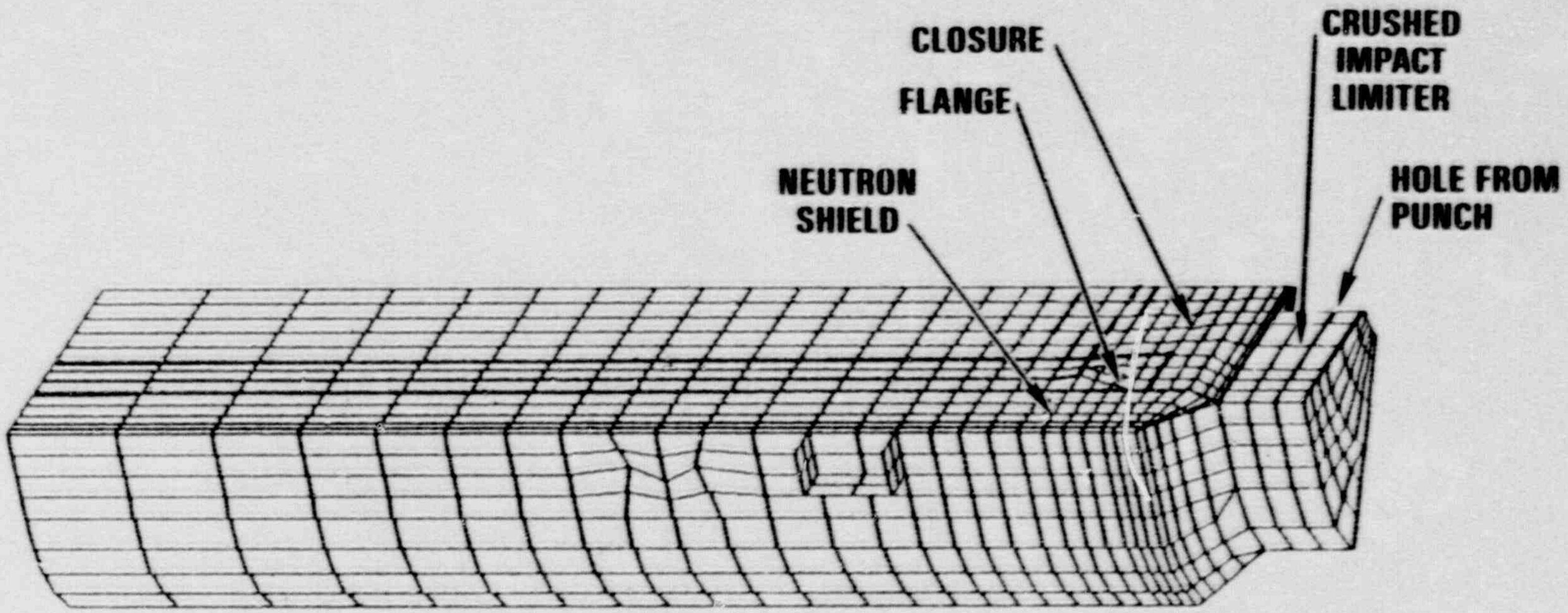
$P_m + P_{b\ (200°F)}$ = 99.5 KSI

MINIMUM MARGIN OF SAFETY	RIGID	FLEXIBLE
P_m	+0.64	+0.16
$P_m + P_b$	+0.95	+0.39

J-217(95)
10-11-89

GENERAL ATOMICS

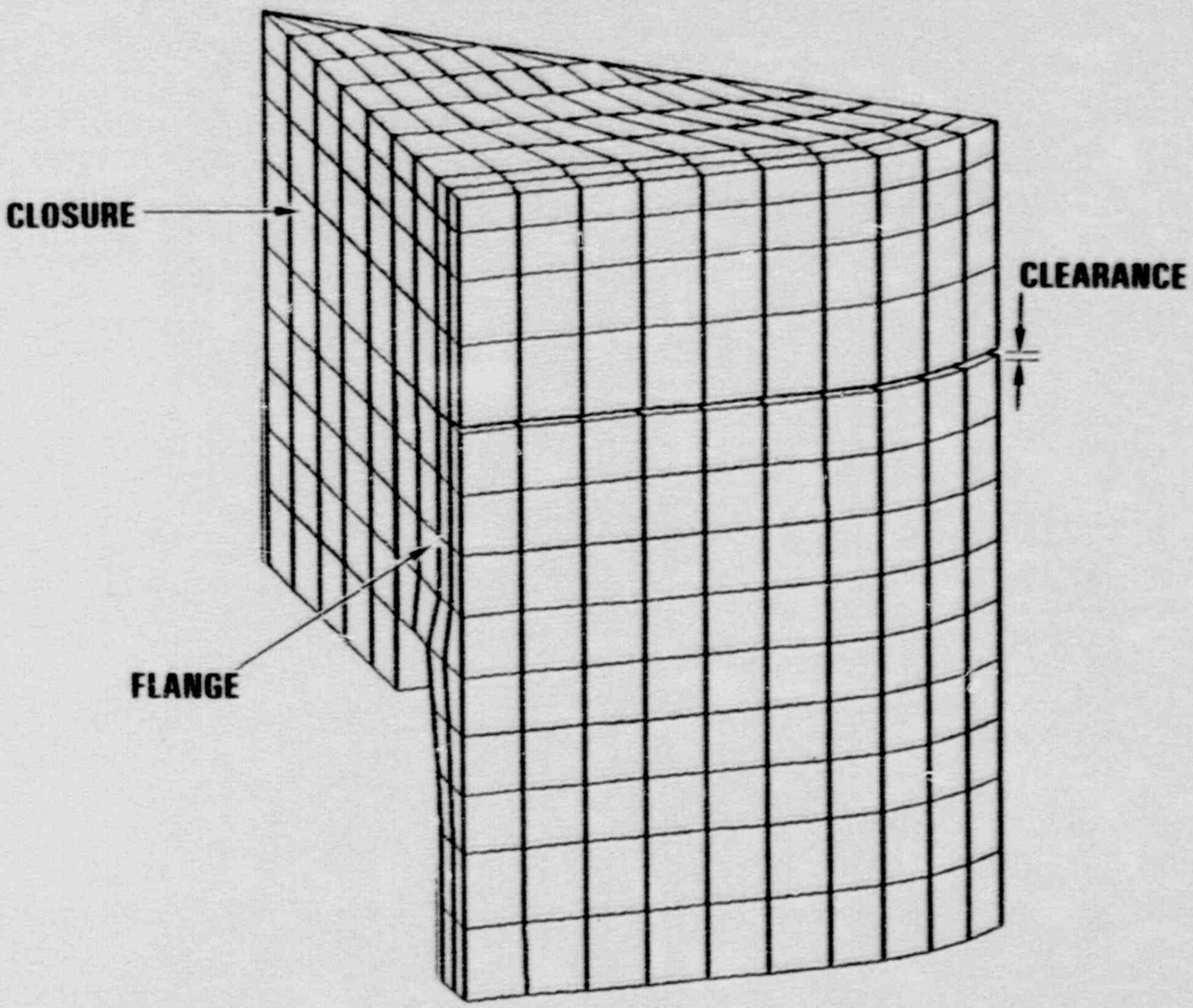
THERMAL ACCIDENT MODEL #2 RETAINS CRUSHED TOP IMPACT LIMITER



J-217(10)
10-10-89

GENERAL ATOMICS

STRUCTURAL MODEL PREDICTS THERMAL STRESSES AND DISPLACEMENTS



J-217(11)
10-10-89

STRESSES/DISPLACEMENTS ARE ACCEPTABLE

- MAXIMUM THERMAL GRADIENTS OCCUR AT 0.5 HR
- CRITICAL AREAS ARE BELOW MINIMUM YIELD (Sy)
  - CLOSURE BOLT (129 KSI VS 138 AT 400°F)
  - SURFACE NEAR SEAL (<35 KSI VS 40.8 AT 400°F)
  - SIDEWALL (<22 KSI VS 43.4 AT 300°F)
- YIELDING CONFINED TO TOP AND CORNER OF CLOSURE
- SEAL INTERFACE OPENS TO 0.044 IN. MAXIMUM

GENERAL ATOMICS

SUMMARY OF DISCUSSIONS

- PHASE I IMPACT LIMITER TEST RESULTS WERE USED TO IMPROVE IMPACT LIMITERS
- CLOSURE BOLTS ARE DESIGNED TO WITHSTAND ALL CLOSURE LOADS AND MOVEMENTS
- ANALYSES SHOW SIDE DROP IS MOST CRITICAL FREE DROP FOR CASK BODY
- FUEL CAVITY LINER AND SUPPORT STRUCTURE WILL MAINTAIN GEOMETRY AFTER HYPOTHETICAL ACCIDENT EVENTS

GENERAL ATOMICS
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