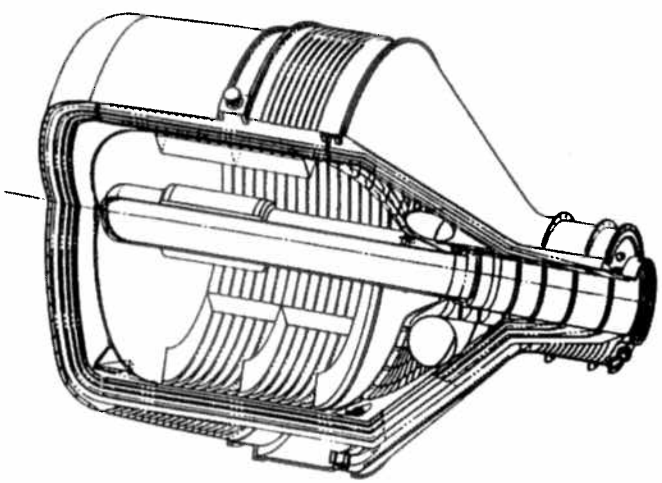
STANFORD

Lockheed

LMSC-P088357
2 MARCH 94

GRAVITY PROBE - B

SCIENCE MISSION DEWAR CRITICAL DESIGN REVIEW



2 MARCH 1994

LMSC B/202 AUDITORIUM

STANFORD

Lockheed

LMSC-P088357
2 MARCH 94

SMD CDR AGENDA

TIME	TOPIC	PRESENTER	CODE
8:00	INTRODUCTION	R. VASSAR	IN
8:10	SMD DESIGN OVERVIEW	W. FOSTER	OV
8:45	SMD REQUIREMENTS	A. NAKASHIMA	RQ
9:10	SMD INTERFACES	A. NAKASHIMA	IF
9:45	RISK AREAS/ NON-COMPLIANCE	A. NAKASHIMA	RI
10:00	DEVELOPMENT TESTS	D. READ	DT
10:30	BREAK		
10:45	DYNAMICS ANALYSIS	L. SOKOLSKY	DY
11:00	STRESS ANALYSIS	L. SOKOLSKY	ST
11:45	THERMAL ANALYSIS	D. READ	TH
12:15	EMERGENCY VENT ANALYSIS	D. READ	EV
12:30	LUNCH		
1:00	HE CM AND SLOSH CONTROL	D. FRANK	CM
1:30	TANKS AND SUBASSEMBLIES	R. PARMLEY	TK
2:00	THERMAL PROTECTION SYSTEM	R. PARMLEY	VS
2:30	PODS SUPPORT SYSTEM	R. PARMLEY	PD
2:45	BREAK		
3:00	CNT ASSEMBLY AND TOP PLATE	D. DONEGAN	CN
3:30	PLUMBING	D. FRANK	PL
4:00	MASS GAUGING	D. FRANK	MG
4:15	INSTRUMENTATION	P. DINEEN	IS
4:45	GROUND SUPPORT EQUIPMENT	D. PICKETT	GS
5:15	FABRICATION AND ASSEMBLY	D. PICKETT	FA
5:45	BREAK		
6:00	MASS PROPERTIES	R. WHELAN	MP
6:15	CONTAMINATION	K. MASON	CO
6:30	MAGNETICS	R. VASSAR	MA
6:40	SAFETY	J. CALAHANE	SA
7:00	RELIABILITY	J. SUTY	RL
7:15	QUALITY ASSURANCE	J. LEPETICH	QA
7:30	VERIFICATION AND SYSTEM TEST	A. NAKASHIMA	VT
7:50	P/L INTEGRATION & OPERATIONS	J. GRADY	OP
8:00	ADJOURN		

INTRODUCTION

RICHARD VASSAR

SM DEWAR CDR OBJECTIVES

- DETERMINE THAT THE DETAILED DESIGN OF THE SCIENCE MISSION DEWAR MEETS THE APPLICABLE REQUIREMENTS OF THE SCIENCE PAYLOAD SPECIFICATION AND THE SPACECRAFT TO PAYLOAD INTERFACE CONTROL DOCUMENT
  - SHOW CLOSURE OF ACTION ITEMS FROM EFD PDR
  - REVIEW DETAILED DESIGN
  - REVIEW REQUIREMENTS VERIFICATION STATUS
- REVIEW SCIENCE MISSION DEWAR RISK AREAS ON A TECHNICAL, COST, AND SCHEDULE BASIS
- OBTAIN CUSTOMER APPROVAL TO PROCEED WITH REMAINING SCIENCE MISSION DEWAR FABRICATION AND ASSEMBLY

IN - 3

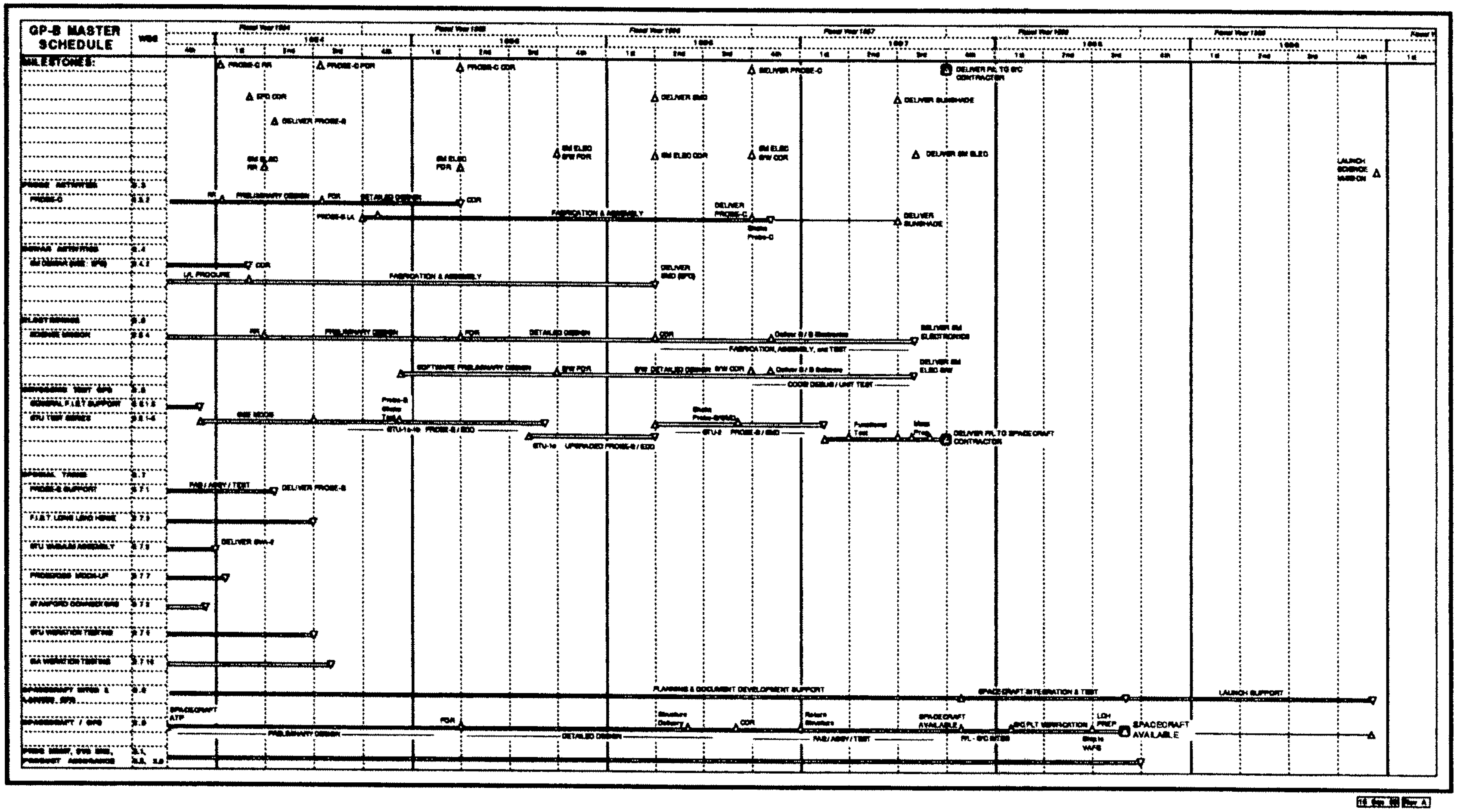
PAYLOAD MASTER SCHEDULE

STANFORD

Lockheed

LMSC-P088357

2,3 MAR 94



DEWAR DESIGN REVIEW HISTORY

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

REVIEW	DATE
FLIGHT COMPONENT DEWAR PDR	16 AUGUST 1991
ENGINEERING FLIGHT DEWAR PDR	29 & 30 JUNE 1992
SM DEWAR INTERNAL DESIGN REVIEWS	
MAIN TANK IDR	27 OCTOBER 1993
VACUUM SHELL IDR	15 DECEMBER 1993

DOCUMENTATION STATUS

- THE FOLLOWING DOCUMENTS ARE BEING SUBMITTED IN FULFILLMENT THE CDR DOCUMENTATION REQUIREMENTS

LSE-01	MASS PROPERTIES REPORT
LSE-02	SCIENCE PAYLOAD SPECIFICATION
LSE-06	SPACECRAFT TO SCIENCE PAYLOAD INTERFACE CONTROL DOCUMENT
LSE-08	SMD DESIGN REVIEW DATA PACKAGE » CDR PRESENTATION CHARTS » DRAWING PACKAGE » ANALYSIS ENGINEERING MEMOS » DEVELOPMENT TEST RESULTS » COMPONENT SPECIFICATIONS
LSE-09	SMD VERIFICATION AND TEST PLAN
LSE-10	SMD VERIFICATION REQUIREMENTS COMPLIANCE DOCUMENT
LSE-12	SMD FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS
LSE-13	SMD CRITICAL ITEMS LIST
LSA-02	SMD SAFETY COMPLIANCE DATA
LOP-01	PAYLOAD OPERATIONS REQUIREMENTS DOCUMENT

SM DEWAR MATURITY AT CDR

• DOCUMENTATION	100% DOCUMENTS COMPLETE
• DRAWINGS	34% DRAWINGS RELEASED
	55% DRAWINGS INTO CHECK
• MASS PROPERTIES CONTINGENCY	10% DRY SM DEWAR
• REQUIREMENTS VERIFICATION	75% ANALYSIS COMPLETE

IN - 7

CDR ACTION ITEM FORM

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

GRAVITY PROBE-B

SCIENCE MISSION DEWAR
CRITICAL DESIGN REVIEW

MARCH 2, 1994

ACTION ITEM

AUTHOR ____________________ DUE DATE ______________

PROPOSED ASSIGNEE: Stanford Lockheed

ACTION:

ACTION ITEM NUMBER _____

INDIVIDUAL RESPONSIBLE FOR CLOSURE: ____________________

OTHER INDIVIDUALS INVOLVED: ____________________

____

DUE DATE: ____________

STANFORD
Lockheed
LMSC-P088357
2 MAR 94

SCIENCE MISSION DEWAR DESIGN OVERVIEW

BILL FOSTER

STANFORD

Lockheed

LMSC-P088357

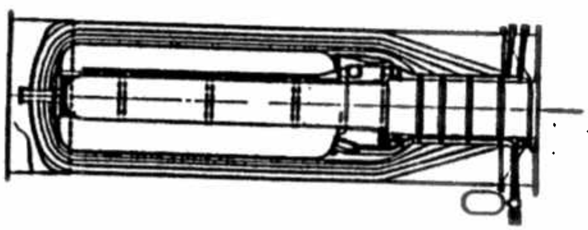
2 MAR 94

OV - 2

GP-B DEWAR TECHNOLOGY HERITAGE

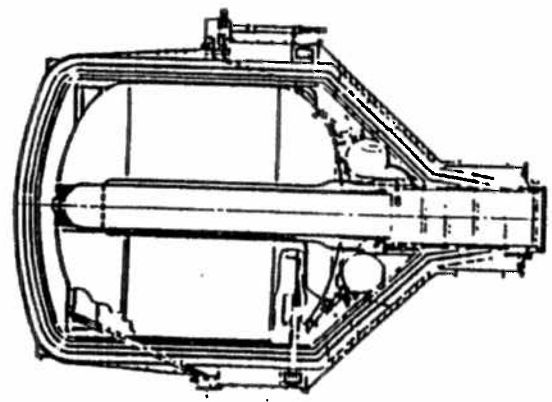
ENGINEERING DEVELOPMENT DEWAR (EDD)

1. AXIAL LOK
2. WELL
3. CRYOPERM SHIELD
4. LEAD BAG
5. LEAD BAG RETAINER
6. AIRLOCK CYLINDER/GUIDE RODS/PISTON
7. THERMAL STOP RINGS
8. PROBE INTERFACES
9. LIQUID LEVEL SENSORS
10. COLD VALVES



SCIENCE MISSION DEWAR (SMD)

11. SFHe TANK PLUS C.G. CONTROL
12. GUARD TANK
13. VCS's
14. MLI
15. PODS SUPPORTS (12 EA.)
16. VACUUM SHELL
17. SPACECRAFT INTERFACES
18. LAUNCH/ORBIT FREQUENCIES
19. AIRLOCK INTERFACE PLATE
20. TOP PLATE/BELLOWS
21. COMPOSITE NECK TUBE
22. VENT HEAT EXCHANGERS
23. POROUS PLUG
24. TANK FILL LINE
25. VENT LINE
26. WELL FILL HEAT EXCHANGER
27. COLD BURST DISCS/VENT LINES
28. FOUNTAIN EFFECT PUMP
29. FLOW METER
30. HEAT PULSE METER
31. MAIN TANK TEMP RISE RATE (GROUND HOLD)
32. TEMP SENSORS, HEATERS, LIQUID LEVEL SENSORS, ACCELEROMETERS
33. INSTRUMENTATION ON VCS'S
34. OSR
35. LIFETIME



SCIENCE MISSION DEWAR (SMD) DESCRIPTION

- THE EFD WAS REPLACED WITH THE SMD

  --- HAVING A BACK-UP DEWAR IS NOT PRACTICAL WITH THE FUNDING LIMITS

  --- NO ADVERSE IMPACT TO PROGRAM SINCE THE EFD WAS IDENTICAL TO THE SMD EXCEPT FOR ADDITIONAL INSULATION AND FLIGHT TYPE VAPOR COOLED SHIELDS

  --- COBE, IRAS, AND CLAES DEWARS DID NOT HAVE A FLIGHT BACK-UP

  --- WARM SHAKE OF PROBE-B REMOVES THE DEWAR FROM THE CRITICAL PATH

EDD LESSONS LEARNED (1)

- COMPOSITE NECK TUBE ASSEMBLY

    --- RESIN SELECTION (SCI REZ 081)

    --- COMPOSITE TUBE FABRICATION PROCESS (RIB FABRICATION DEMONSTRATED ON PROBE NECK TUBE)

    --- MODULAR DESIGN

    --- LEAK TIGHT JOINT DESIGN

- HEAT EXCHANGERS (HEX)

    --- NEED HEX-0 FOR GROUND OPERATIONS

    --- SPLIT HEX DESIGN

    ---HEX FABRICATION PROCESS

EDD LESSONS LEARNED (2)

- THERMAL STOP RINGS (TSR)

  --- ADJUSTABLE TSR ALLOWS WARM INSTALLATION INTO NECK TUBE

  --- REDUCED RISK

- AXIAL LOK

  --- DESIGN IMPROVEMENTS
  >>ELIMINATE WEAR PROBLEMS
  >>ADDRESS MAGNETIC PARTICLE GENERATION CONCERNS
  >>REPLACED ROLL PIN

  --- TESTING REQUIREMENTS DEFINED

-

EDD LESSONS LEARNED (3)

- PLUMBING

  --- TANK TO WELL TRANSFER

  --- AXIAL LOK TUNNELS AND WELL PLUMBED TOGETHER

  --- IMPROVED MOTORIZED COLD VALVES

- TANK FABRICATION

  --- MACHINING AND FABRICATION SEQUENCE DEFINED

  --- CRYOGENIC STRESS RELIEVING USED TO STABILIZE PARTS

  --- CRYOPERM SHIELD FAB AND INSTALLATION

- LEAD BAG RETAINER

  --- IDENTIFIED PROBLEMS WITH BERYLLIUM COPPER RETAINER

  --- MATERIAL CHANGED AND LOWER END REDESIGNED

EDD LESSONS LEARNED (4)

- LEAD BAG INSERTION GSE

  --- VALIDATED GSE DESIGN WITH SUCCESSFUL LEAD BAG AND COLD PROBE INSERTIONS

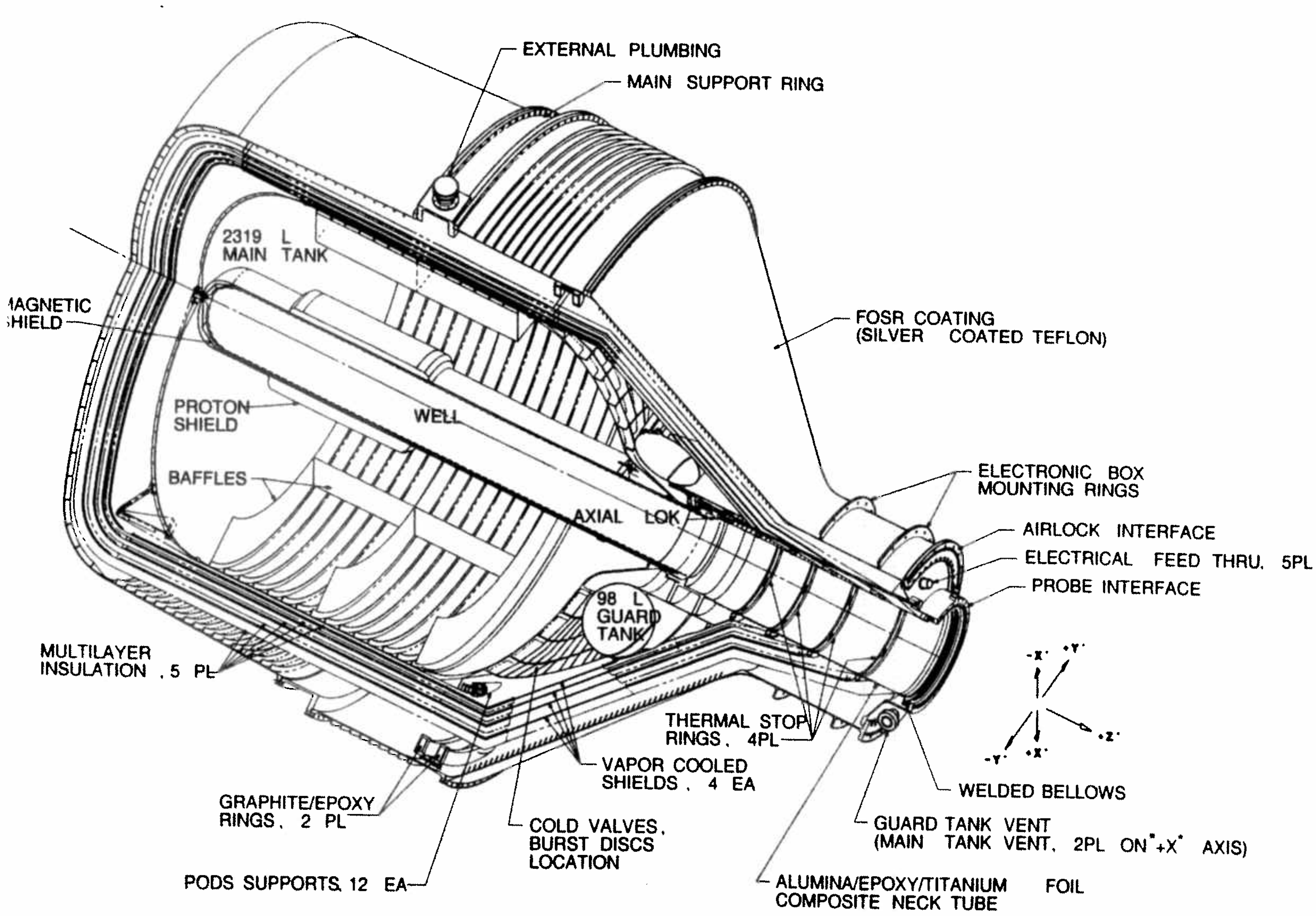
- OPERATIONAL EXPERIENCE

  --- DEVELOPED PROCEDURES FOR LEAD BAG AND PROBE INSERTION OPERATIONS

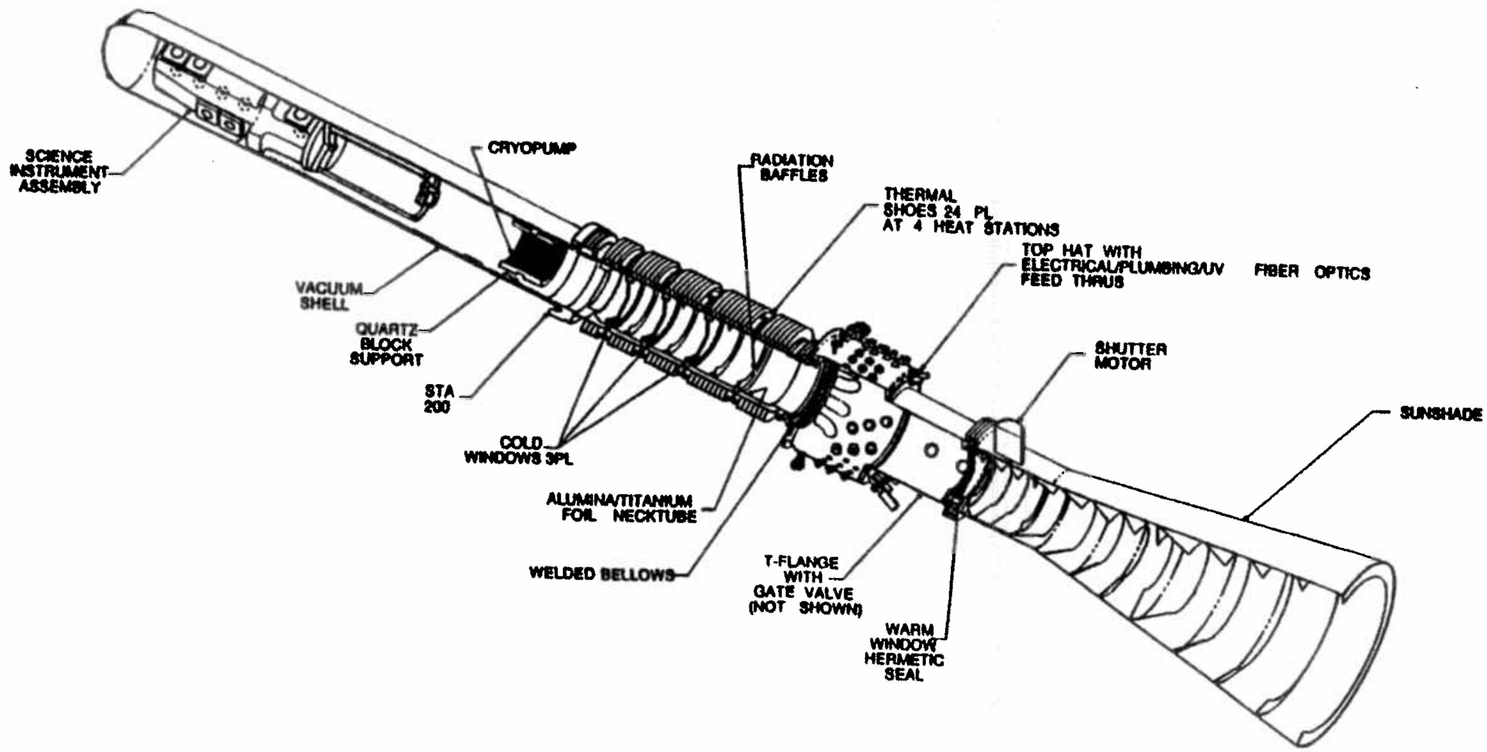
OV - 8

DEWAR LAYOUT

STANFORD
Lockheed
LMSC-P088357
2 MAR 94

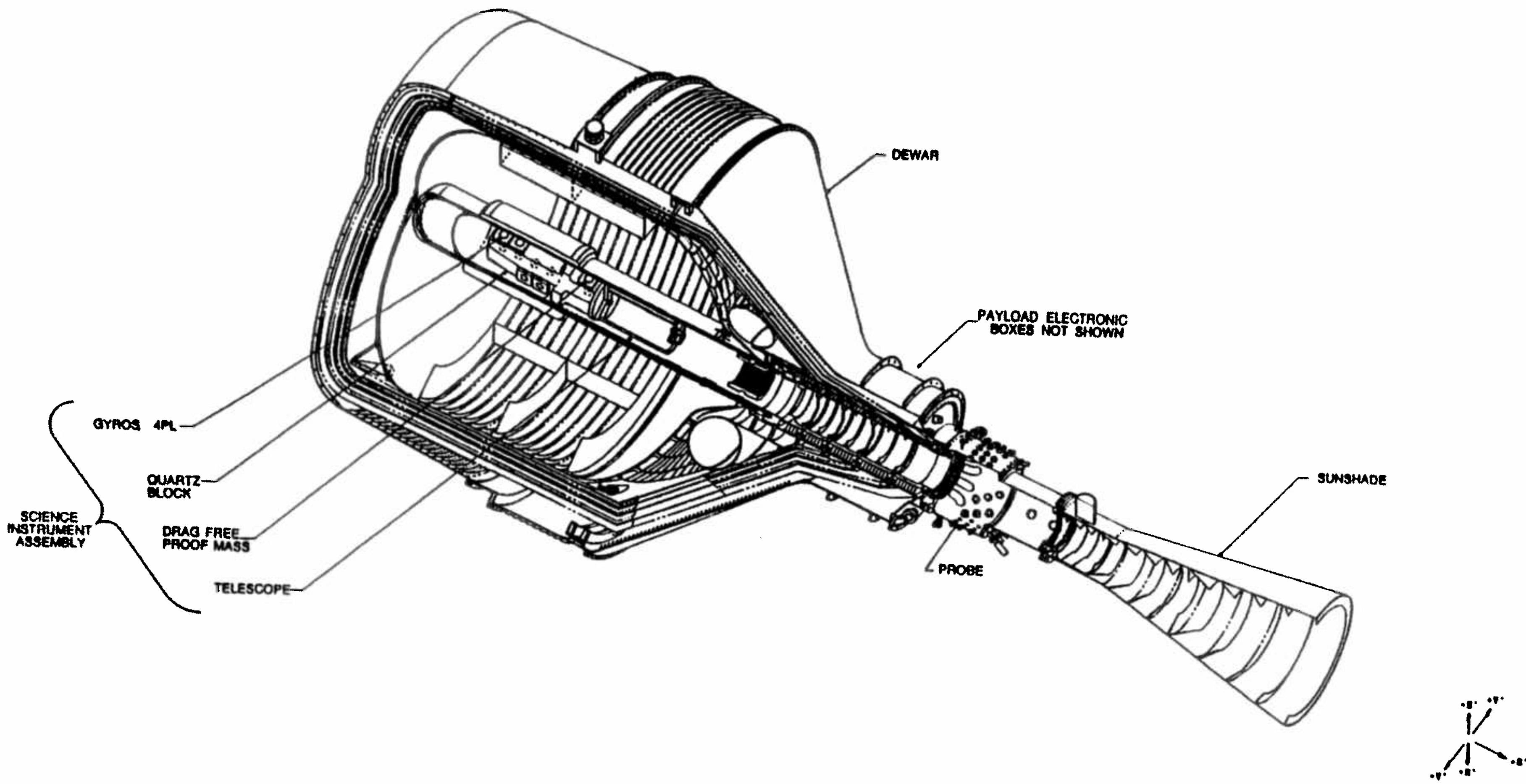


PROBE LAYOUT



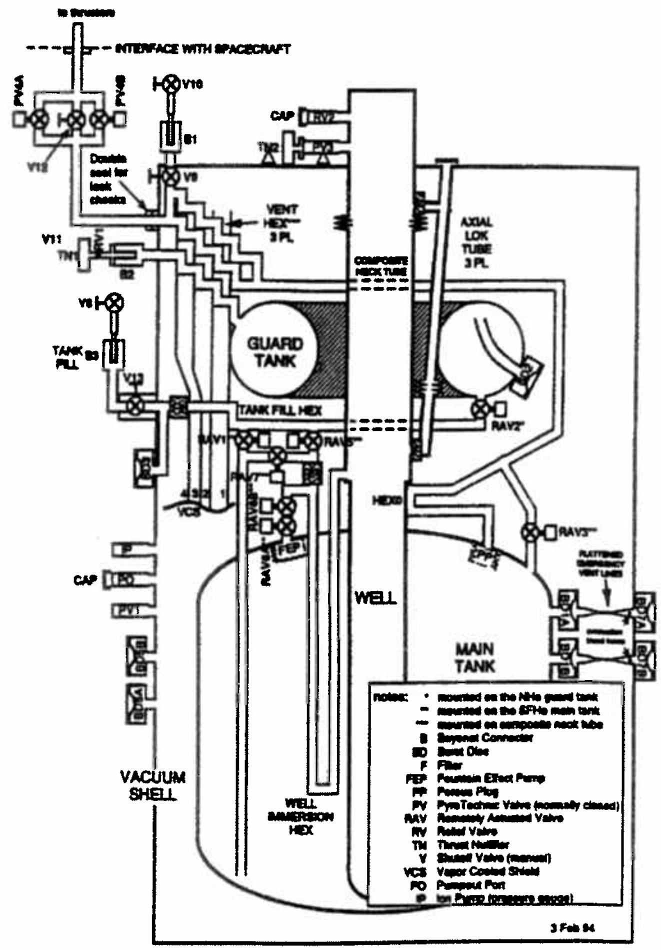
INTEGRATED SYSTEM

STANFORD
Lockheed
LMSC-P088357
2 MAR 94



SMD PLUMBING SCHEMATIC

STANFORD
Lockheed
LMSC-P088357
2 MAR 94



CHANGES FROM PDR (1)

- MAIN TANK BAFFLES
  - --- CENTER OF MASS CONTROL BAFFLE NOT NEEDED
  - --- RADIAL AND AXIAL BAFFLES USED FOR SLOSH CONTROL
- PLUMBING
  - --- SEPARATE VENTS FOR MAIN AND GUARD TANKS
  - --- ONLY ONE COLD VALVE NEEDS TO BE OPERATED AFTER LAUNCH
  - --- ELIMINATED GUARD TANK FLEXIBLE EMERGENCY VENT LINES
  - --- PYROVALVES USED FOR MAIN TANK VENT
  - --- MULTIPLE TEST ORIENTATIONS POSSIBLE

CHANGES FROM PDR (2)

- LEAD BAG RETAINER

  --- MATERIAL CHANGED FROM BeCu TO TiCu

  --- LOWER END DESIGNED TO FORM CLOSED DOME

- VACUUM SHELL ALLOY CHANGED FROM 8090 ALUMINUM TO 2219 ALUMINUM

  --- CHANGE REDUCES FABRICATION RISK AND COST

  --- 32Kg INCREASE IN VACUUM SHELL WEIGHT

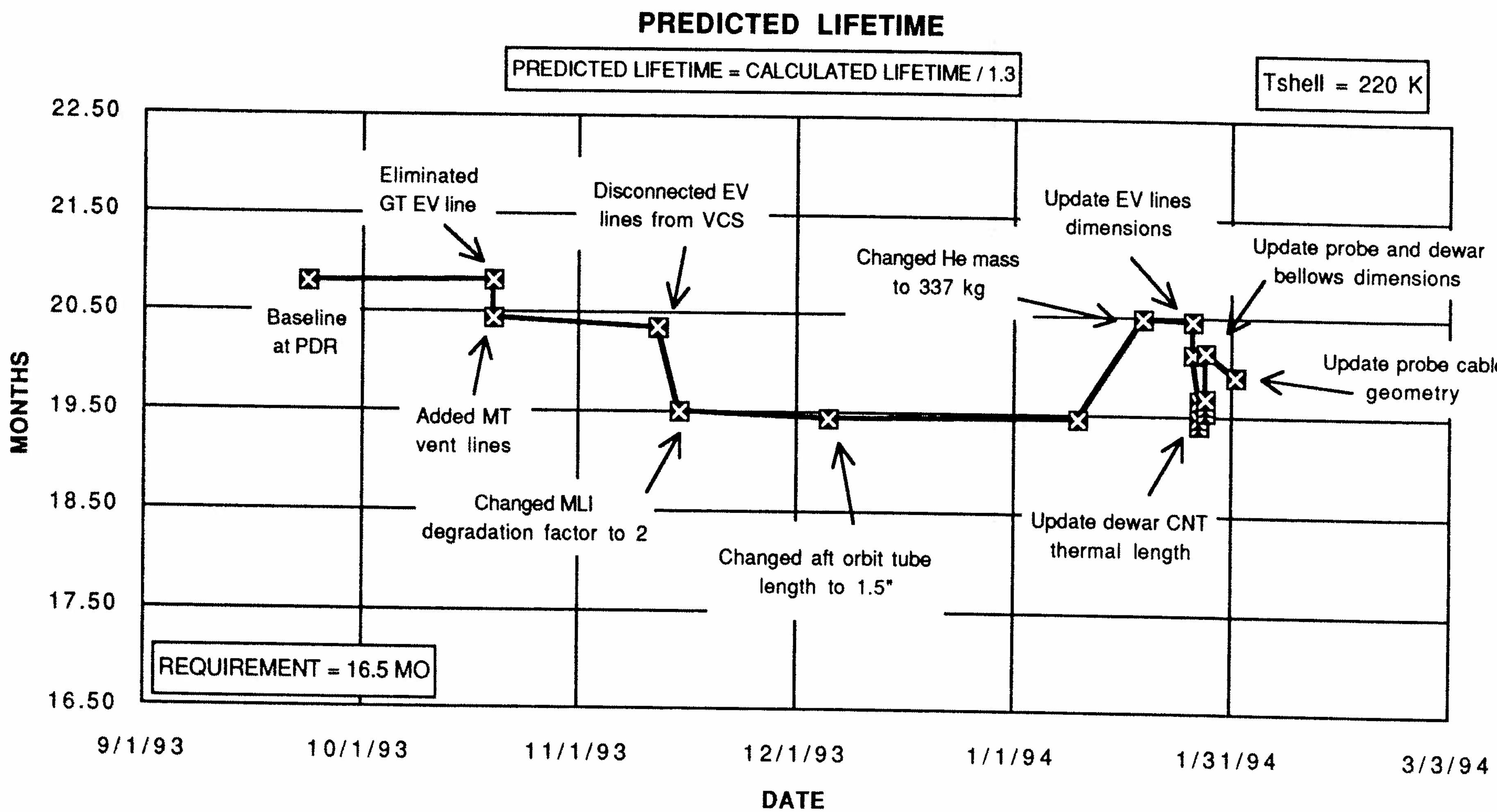
- COMPOSITE NECK TUBE SHORTENED

  --- ALLOWS LONGER BELLOWS SECTION FOR REDUCED LATERAL STIFFNESS

  --- RESULTS IN SLIGHT INCREASE IN LIFETIME

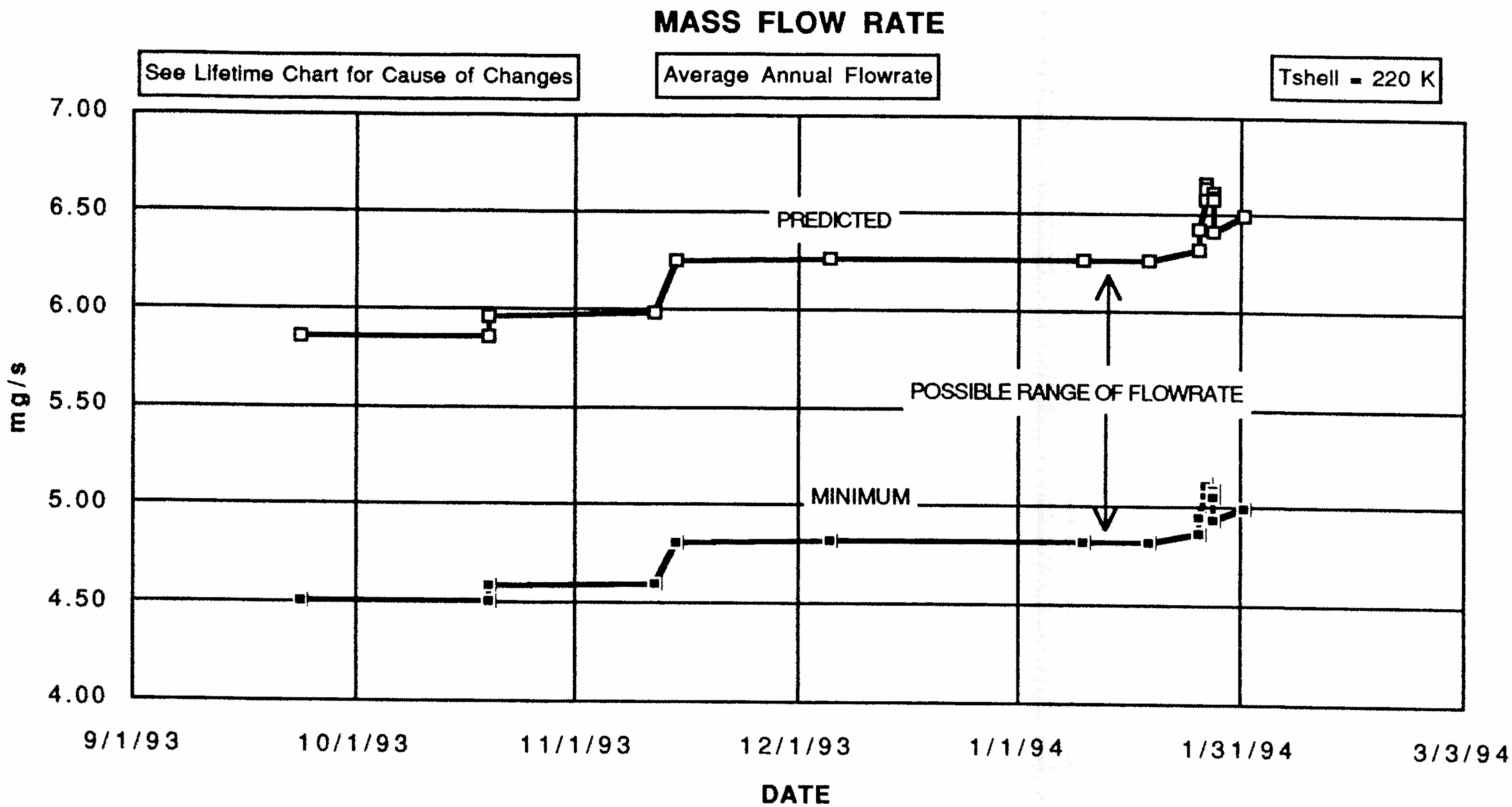
PREDICTED LIFETIME HISTORY

STANFORD
Lockheed
LMSC-P088357
2 MAR 94



PREDICTED MASS FLOW RATE HISTORY

STANFORD
Lockheed
LMSC-P088357
2 MAR 94



STANFORD
Lockheed

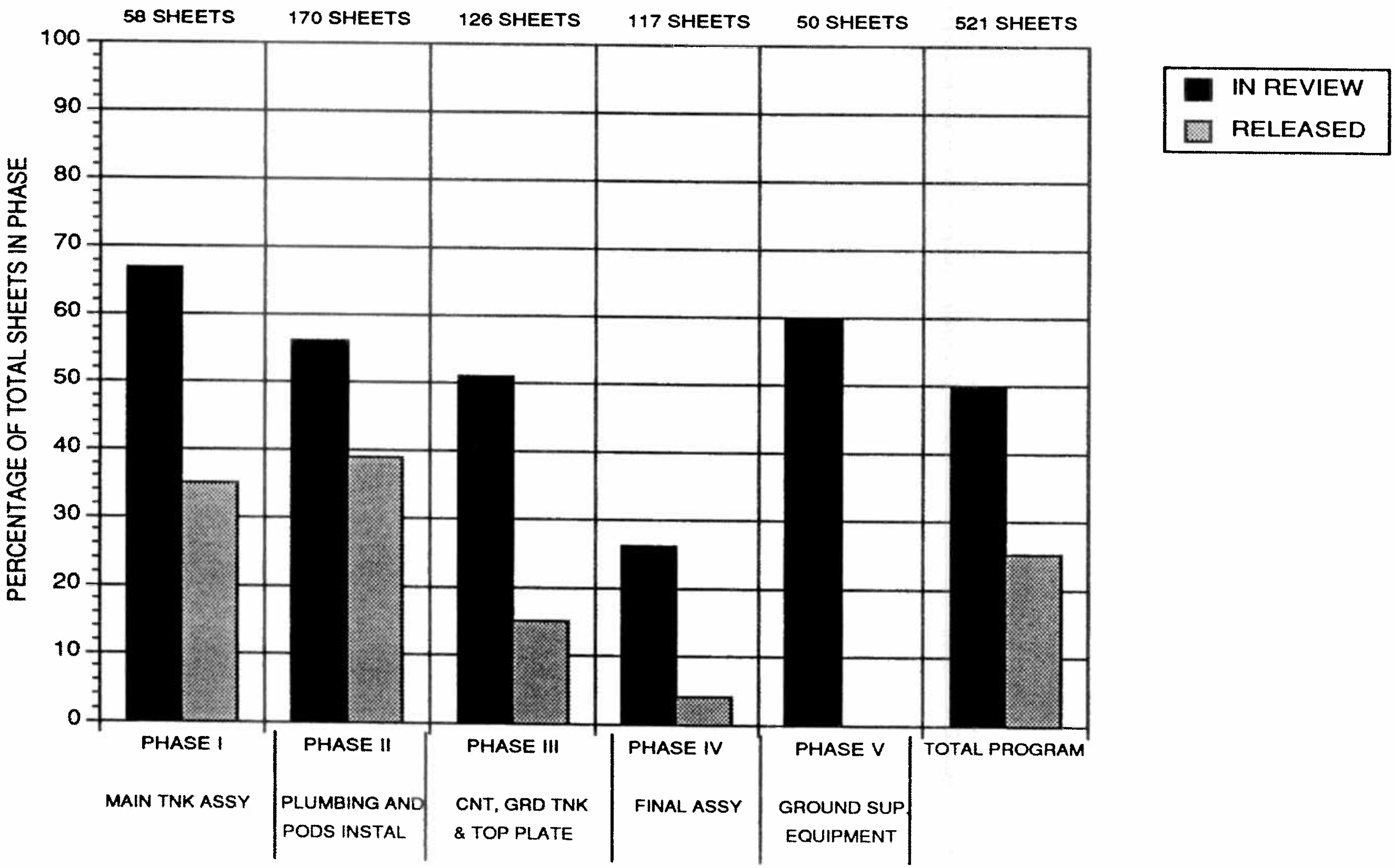
LMSC-P088357
2 MAR 94

DESIGN STATUS

- TOTAL DRAWING COUNT (INCLUDES GSE) — DWGS-----356, SHEETS---524
- RELEASED DRAWINGS — DWGS-----120, SHEETS---167
- DRAWINGS IN RELEASE CYCLE — DWGS-----75, SHEETS---127
- NUMBER OF REVISIONS — DWGS----1
- CRITICAL PATH DRAWINGS ARE BEING WORKED TO SUPPORT THE FABRICATION SCHEDULE

OV - 17

ENGINEERING DRAWING STATUS



OV - 18

DEVELOPMENT TEST STATUS

- FLEXIBLE EMERGENCY VENT LINE COMPLETE
- COMPOSITE NECK TUBE STRUCTURAL TESTS COMPLETE
- SMALL HELICOFLEX SEALS TESTS COMPLETE
- AXIAL LOK TEST COMPONENTS IN HOUSE
- COLD ELECTRICAL CONNECTORS DESIGNED AND TEST APPARATUS IN ASSEMBLY
- POROUS PLUG, HEAT PULSE METER TEST APPARATUS IN ASSEMBLY

MANUFACTURING STATUS

- MAIN TANK FORGINGS ARE ON SCHEDULE
- MACHINING OF MAIN TANK COMPONENTS (DOMES) HAS STARTED CHEMTRONICS IS MACHINING THE FWD DOME
- AXIAL LOK PARTS ARE COMPLETE
- COLD VALVES ARE ON ORDER
- COLD BURST DISKS ARE ON ORDER
- ASSEMBLY STAND LONG LEAD ITEMS ON ORDER

RISK ASSESSMENT

- RISKS DUE TO NOT BUILDING THE EFD

ITEM	RISK LEVEL	MITIGATION
• FABRICATION	MODERATE	PROTOTYPING BEING USED. CRITICAL VENDORS FUNDED FOR DEVELOPMENT OF PROCESSES. FABRICATION EXTRAS PURCHASED
• INTERFACES	LOW	LOCKHEED BUILDING PROBE AND SPACECRAFT. INTERFACE WORKING GROUP ESTABLISHED
• PERFORMANCE	LOW/MODERATE	MAJOR COMPONETS TESTED ON IDD AND EDD AND OTHER CRYO-STATS. EARLY DEVELOPMENT TESTS ON COMPONENTS NOT PREVIOUSLY TESTED

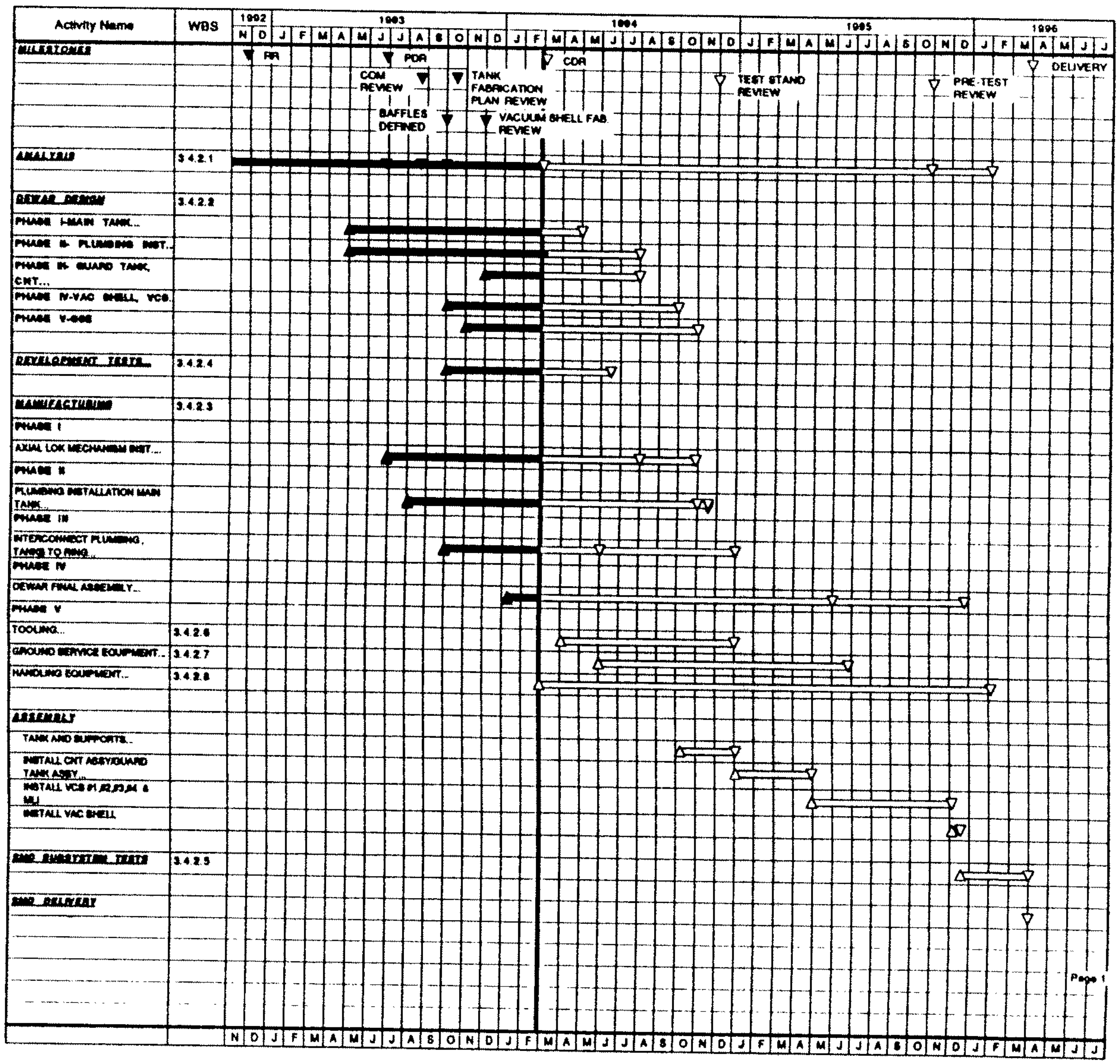
RISK ASSESSMENT

STANFORD
Lockheed
LMSC-P088357
2 MAR 94

•RISKS DUE TO NOT BUILDING THE EFD

ITEM	RISK LEVEL	MITIGATION
• SCHEDULE	MODERATE	CRITICAL PATH DEFINED FOR DESIGN, FAB, AND ASSY. WORKING CLOSELY WITH VENDORS TO MEET SCHEDULE
•		

SMD SCHEDULE



STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

SMD REQUIREMENTS

ART NAKASHIMA

SOURCES OF REQUIREMENTS

- SCIENCE PAYLOAD SPECIFICATION F277277 V 2.5
  - SECTION 3.7.5 DEWAR *(CROSS REFERENCES SECTION 3.2)*
  - SECTION 3.3 DESIGN & CONSTRUCTION
  - SECTION 3.7.4 PROBE-TO-DEWAR INTERFACE
    - » DEWAR-TO-PROBE INTERFACE DRAWING, 5833117
  - SECTION 3.7.6 PROBE/DEWAR ASSY TO OTHER PAYLOAD ASSEMBLIES
    - » INTERFACES OF PROBE AND DEWAR TO ELECTRONICS, GAS MANAGEMENT ASSEMBLIES
    - » TOP HAT INTERFACE DRAWING, 5833116
- SPACECRAFT-TO-PAYLOAD INTERFACE CONTROL DOCUMENT F277233, V1.8
  - S/C TO P/L INTERFACE DRAWING, 5833115

RQ - 3

FUNCTIONAL REQUIREMENTS (1 OF 3)

REQUIREMENT	HOW SATISFIED
PROVIDE CRYOGENIC ENVIRONMENT FOR PROBE AND SIA PROVIDE ORBITAL LIFE ≥ 16.5 MO, OPTIMIZE THERMAL PERFORMANCE	(2318 Liters of He in tank) 2400 L TANK TO HOLD HE II, WELL TO HOUSE PROBE, GUARD VACUUM AND SHELL, FOSR, VCS AND MLI, CNT TO ISOLATE VAC SPACE FROM WELL, PODS TO SUPPORT TANK AND PROVIDE THERMAL ISOLATION FROM SHELL
VENT HE BOILOFF TO S/C THRUSTERS	REDUNDANT VENT PATHS, VENT MODULE, POROUS PLUG FOR LIQUID/VAPOR SEPARATION, HEAT EXCHANGERS FOR THERMAL CONTROL
PROVIDE FOR GROUND OPERATIONS ALLOW 90 D GROUND HOLD WITH NO VENTING OF MAIN TANK PROVIDE FOR FILLING AND VENTING IN VARIOUS ORIENTATIONS	99 L GUARD TANK TO HOLD HE I, BAYONET VENT AND FILL LINES, REMOTELY ACTUATED COLD VALVES
MEET MAGNETIC ATTENUATION RQMTS	CRYOPERM SHIELD AROUND WELL, LEAD BAG INSIDE WELL CONTAMINATION CONTROL OF PARTICLES

STANFORD

Lockheed

RQ - 4

FUNCTIONAL REQUIREMENTS (2 OF 3)

LMSC-P088357
2,3 MAR 94

REQUIREMENT	HOW SATISFIED
PROVIDE PROTON SHIELD AROUND SIA	PROTON SHIELD
SURVIVE EXPECTED ENVIRONMENTS GROUND, LAUNCH, ORBIT	LOAD FACTORS DERIVED IN EM 310A USED FOR DESIGN. MARGINS BUILT INTO DESIGN. MATERIAL SELECTION, FOUNTAIN EFFECT PUMP FOR INTERNAL WELL FILL, IF REQUIRED
MEET SAFETY REQUIREMENTS	TWO FAULT TOLERANT AGAINST CATASTROPHIC FAILURES, POSITIVE MARGINS OF SAFETY, REDUNDANT BURST DISCS ON MAIN TANK AND SHELL, EMERGENCY VENT LINES ON MAIN TANK, BURST DISC ON GUARD TANK, FILL LINE, WELL
MEET CENTER OF MASS, SLOSH CONTROL REQUIREMENTS	BAFFLES FOR SLOSH, NONE REQUIRED FOR CM CONTROL
MEET MASS PROPERTIES RQMTS	OPTIMIZE DESIGN, MATERIAL SELECTION
PROVIDE INSTRUMENTATION	TEMPERATURE SENSORS, HEATERS, LIQUID LEVEL SENSORS, HEAT PULSE METER, FLOW METER, ACCELEROMETERS, PODS CONTACT SENSORS COLD VALVE MICROSWITCHES

FUNCTIONAL REQUIREMENTS (3 OF 3)

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

REQUIREMENT	HOW SATISFIED
MEET CONTAMINATION RQMTS	DESIGN TO CONTAMINATION CONTROL PLAN
MEET ELECTRICAL GROUNDING RQMTS	DESIGN WITH BONDED JOINTS FOR THERMAL LOOPS, COMPONENTS GROUNDED TO TOP PLATE
PROVIDE GROUND SUPPORT EQUIPMENT AND INTERFACES	SUPPORT MODULES, SHIPPING CONTAINER ASSEMBLY STAND, LIFTING DEVICE, LEAD BAG INSTALLATION EQUIPMENT, PROBE INTEGRATION EQUIPMENT, CRYOGENIC SERVICE EQUIPMENT
PROVIDE PROBE PHYSICAL INTERFACES	AXIAL LOK, AXIAL LOK RING, AXIAL LOK TUBES, LEAD BAG RETAINER, TOP PLATE, THERMAL STOP RINGS
PROVIDE SPACECRAFT PHYSICAL INTERFACES	SUPPORT RING WITH S/C SUPPORT HOLES, STAR TRACKER PEDESTALS ON GRAPHITE RINGS, BOLT HOLES FOR THRUSTERS, SOLAR ARRAYS, GPS ANTENNAE

DEWAR ENVIRONMENTAL DISTURBANCES

- LOAD FACTORS REFERENCE EM 310A / P030739A
  - DERIVES COMBINED LOAD FACTORS FROM RANDOM (TRANSONIC), TRANSIENT (LIFT-OFF), ACOUSTIC, AND QUASI-STATIC (MECO) LOADS (SEE DYNAMICS SECTION)
  - PROVIDES SECONDARY STRUCTURE DESIGN LOAD FACTORS
- ORBITAL ENVIRONMENT
  - THERMAL — 220 ± 10 K
  - VACUUM — 5×10^{-8} PA ($\approx 4 \times 10^{-10}$ TORR) @ 650 KM ALT.
  - MAGNETIC — 6×10^{-5} TESLA
  - ELECTRON RADIATION — SPEC TABLES 3.2.5-3 (MAX) AND 3.2.5-4 (INTEGRATED)
  - PROTON RADIATION — SPEC TABLES 3.2.5-5 (MAX) AND 3.2.5-6 (INTEGRATED)

STANFORD
Lockheed

PERFORMANCE REQUIREMENTS (1 OF 4)

LMSC-P088357
2,3 MAR 94

ITEM	REQUIREMENT	PERFORMANCE	VERIFICATION
ORBITAL LIFETIME (Tshell = 220 K)	$\geq$ 16.5 MOS	19.8 MONTHS (TRACKED AS TPM)	GP-B THERMAL MODEL
He BATH TEMP	$\leq$ 1.8 K	1.8 K	GP-B THERMAL MODEL
LEAD BAG TEMP	$\leq$ 6.5 K	HE II IN WELL IS BACKUP TO VACUUM IN WELL	PR-B / SMD VIBRATION TEST
DEWAR MASS (DRY)	$\leq$ 936 Kg (ALLOCATION)	850 Kg (TRACKED AS P/L TPM)	MASS PROP ANALYSIS, TEST
MAGNETIC SHIELDING AT SIA STEADY STATE CRYOPERM SHIELD LEAD BAG ATTENUATION FACTOR CRYOPERM SHIELD LEAD BAG	 $\leq 3 \times 10^{-5}$ TESLA $\leq 9 \times 10^{-12}$ TESLA $\leq 5 \times 10^{-2}$ T, LONG $\leq 5 \times 10^{-3}$ T, TRAN $\leq 1 \times 10^{-10}$ T, LONG $\leq 1.7 \times 10^{-6}$ T, TRANS	MEETS RQMTS BY DESIGN TO MAGNETIC CONTROL PLAN AND PROCEDURE	GTU TESTING, MAGNETIC SCREENING OF CRYOPERM, WELL, LEAD BAG AND RETAINER

PERFORMANCE REQUIREMENTS (2 OF 4)

ITEM	REQUIREMENT	PERFORMANCE	VERIFICATION
LHE CM SHIFT	SEE COM SECTION (90 MM, AXIAL, FULL TANK) (90 MM, RADIAL, FULL@.1RPM)	UNBAFFLED TANK	ANALYSIS, P088355 FLOW 3D- CFD CODE CLOSED FORM SOLUTIONS SURFACE EVOLVER PGM 1-G SCALE MODEL TESTS
LHE SLOSH	MINIMIZE	4" WIDE BAFFLES, 4 RADIAL, 3 PARALLEL	CFD ANALYSIS
S/V FIRST STRUCTURAL RESONANCE - LAUNCH	≥ 35 HZ, AXIAL ≥ 12 HZ, LATERAL	29.4 HZ, AXIAL * 10.9 HZ, LATERAL*	LOADS ANALYSIS (EM 310A)
P/L FIRST STRUCTURAL RESONANCE - ORBIT	≥ 10 HZ	15 HZ	PODS OPTIMIZATION ANALYSIS (EM 326)
HELIUM BOILOFF RATE	4 - 16 MG/S (GOAL 4 - 12)	4 - 16 MG/S	PRESSURE DROP ANALYSIS (GPB-100145), GP-B THERMAL MODEL

* NON-COMPLIANT

PERFORMANCE REQUIREMENTS (3 OF 4)

ITEM	REQUIREMENT	PERFORMANCE	VERIFICATION
CONTAMINATION	ZONES VIII, X (100A) ZONES IX, XI (250A)	MEETS RQMTS BY DESIGNING TO CONTAM CONTROL PLAN	TEST AT COMPONENT, SUBASSEMBLY LEVELS
SOLAR ABSORPTIVITY EMISSIVITY	< 0.09 SOLAR ABS > 0.8 IR EMISS	MEETS RQMTS WITH FOSR	ANALYSIS EM 126, VENDOR TEST
WELL FILL CAPABILITY	WITHOUT EXT PLUMBING	MEETS RQMT	TK TO WELL TRANSFER, FEP TESTS
INLET TEMP	≤ 6.5 K	5 K	GTU TESTING
DIMENSIONAL			
REFERENCE TO SIA	± 0.25 °, 3 AXES	MET BY REF AT TOP PLATE	TEST
FIT IN DELTA II FAIRING	≤ 10 FT LONG, ≤ 8 FT DIAM	9.937 FT LONG 6.731 FT DIAM	BY DESIGN
STAR SENSOR THERMAL STABILITY	GOAL ≤ 10 ARC-SEC	MET BY DESIGN USING G/E RINGS	ANALYSIS EM 187

PERFORMANCE REQUIREMENTS (4 OF 4)

ITEM	REQUIREMENT	PERFORMANCE	VERIFICATION
LAUNCH READY LIFE GUARD TANK MAIN TANK (NON-VENTED)	≥ 7 DAYS ≥ 90 DAYS	7.85 DAYS 90 DAYS	GP-B THERMAL MODEL
GROUND OPERATIONS ATTITUDES	SEE PLUMBING SECTION	MEETS RQMTS	BY DESIGN
PROTON SHIELDING	20 G/CM² AL EQUIVALENT	MEETS RQMTS	STANFORD ANALYSIS
SAFETY	TWO FAULT TOLERANT FOR CRITICAL FAILURES,	MEETS RQMTS	BY DESIGN,
<u>FACTORS</u>	POSITIVE MARGIN OF SAFETY		ANALYSIS
PRESSURE -INT	1.5 PROOF, 2.0 YIELD, 4.0 ULT		PROOF PRESSURE TESTS
PRESSURE -EXT	1.0 PROOF, 2.0 ULTIMATE		
STRENGTH -METALLIC	1.25 YIELD, 1.5 ULT, 1.25 TEST		
STRENGTH- NON-MET	1.5 ULT-CONT, 2.0 ULT DISC, 1.25 TEST		

RQ - 11 ELECTRICAL GROUNDING REQUIREMENTS

REQUIREMENT	HOW MET	VERIFICATION
CONDUCTIVE LOOPS IN "ISOTHERMAL" ($\Delta T < 5$ K) REGIONS ARE ACCEPTABLE. - MAIN TANK / PLUMBING - GUARD TANK / PLUMBING - VAPOR COOLED SHIELDS, INDIVIDUALLY	GP-B THERMAL MODEL PREDICTS ISOTHERMAL TERMPERATURES	TEMPERATURES MEASURED DURING GROUND TESTS
BALANCED (ELEC SYMMETRIC) LOOPS REQUIRE $1\ \Omega \le R$ BALANCED LOOPS BETWEEN VAPOR COOLED SHIELDS REQUIRE $1\ \Omega \le R \le 10\ \Omega$	USE SIMILAR MATERIALS FROM SAME HEAT. BONDED JOINTS WITH METAL JUMPER WIRES	IN-PROCESS TEST
UNBALANCED LOOPS WITH TEMPERATURE GRADIENTS > 5 K REQUIRE $20\ \Omega \le R \le 1\ M\Omega$	BONDED JOINTS, AQUA DAG JOINT COATING	IN-PROCESS TEST
MLI IS GROUNDED IN EACH BLANKET, INNER TO OUTER SHIELD, WITH $R \le 1\ M\Omega$ AND INNER SHIELD TO VCS $R \le 1\ \Omega$	TAPED ALUMINIZED MYLAR	IN-PROCESS TEST
ALL CONDUCTIVE COMPONENTS SHALL BE GROUNDED TO THE TOP PLATE WITH RESISTANCE $\le 1\ M\Omega$	BY DESIGN	IN-PROCESS TEST
DEWAR INSTRUMENTATION DOES NOT REQUIRE FILTERS OR SHIELDING	N /A	

SMD INTERFACES

ART NAKASHIMA

DEWAR INTERFACES

- PROBE / DEWAR INTERFACES
  - MECHANICAL
  - THERMAL
- DEWAR / PAYLOAD ELECTRONICS INTERFACES
  - MECHANICAL
  - ELECTRICAL
- DEWAR / SPACECRAFT INTERFACES
  - MECHANICAL
  - VENTING
  - ELECTRICAL
- DEWAR / GSE INTERFACES
  - MECHANICAL
  - VENTING
  - FILLING
  - VACUUM
  - ELECTRICAL

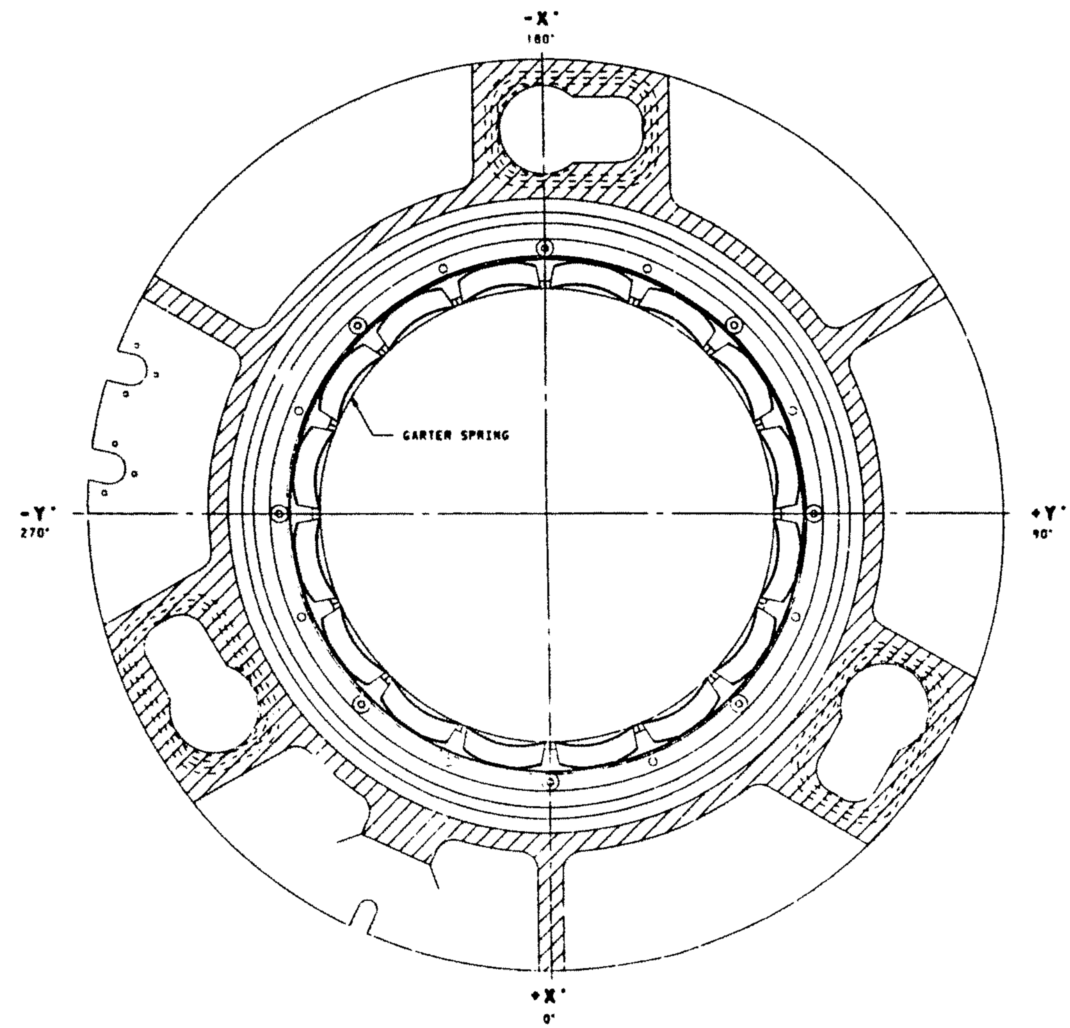
DEWAR INTERFACES TO PROBE

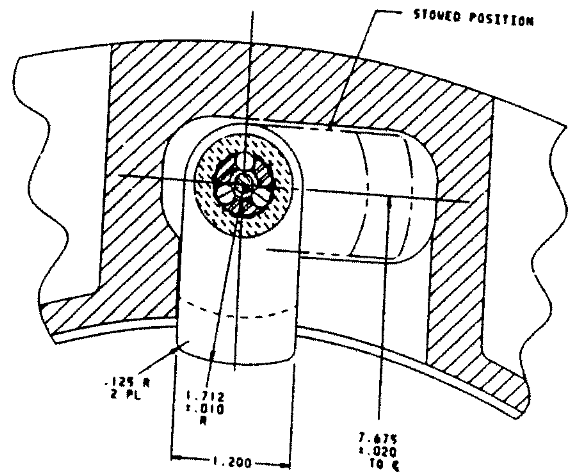
- AXIAL LOK ON DEWAR SECURES PROBE TO DEWAR
  - AXIAL LOK DOGS LOCATED AT 120° INTERVALS CLAMP PROBE STATION 200 RING WITH INDIUM PLATING TO AXIAL LOK RING
- LEAD BAG RETAINERS PROVIDE PHYSICAL INTERFACE BETWEEN PROBE AND LEAD BAG
  - SPRING ENSURES CENTERING OF PROBE DURING INSERTION
  - PREVENTS LEAD BAG FROM FALLING DURING LAUNCH
- PROBE TOP HAT IS BOLTED TO DEWAR TOP PLATE
  - REF: PROBE/DEWAR INTERFACE TOLERANCE STUDY, F386792 / EM210
- PROBE THERMALLY GROUNDED TO DEWAR BY CONTACT OF PROBE THERMAL SHOES TO DEWAR THERMAL STOP RINGS
  - 6 PER RING AT EACH OF 4 HEAT EXCHANGER LOCATIONS
  - CLOCKED SO THAT THERE IS NO INTERFERENCE ON PROBE INSERTION
  - REF: THERMAL SHOE CONTACT CONDUCTANCE, F386748 / EM 205
- REFERENCE PROBE/DEWAR INTERFACE DRAWING 5833117

IF - 4

PROBE TO DEWAR INTERFACE AT STATION 200

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94





IF - 5

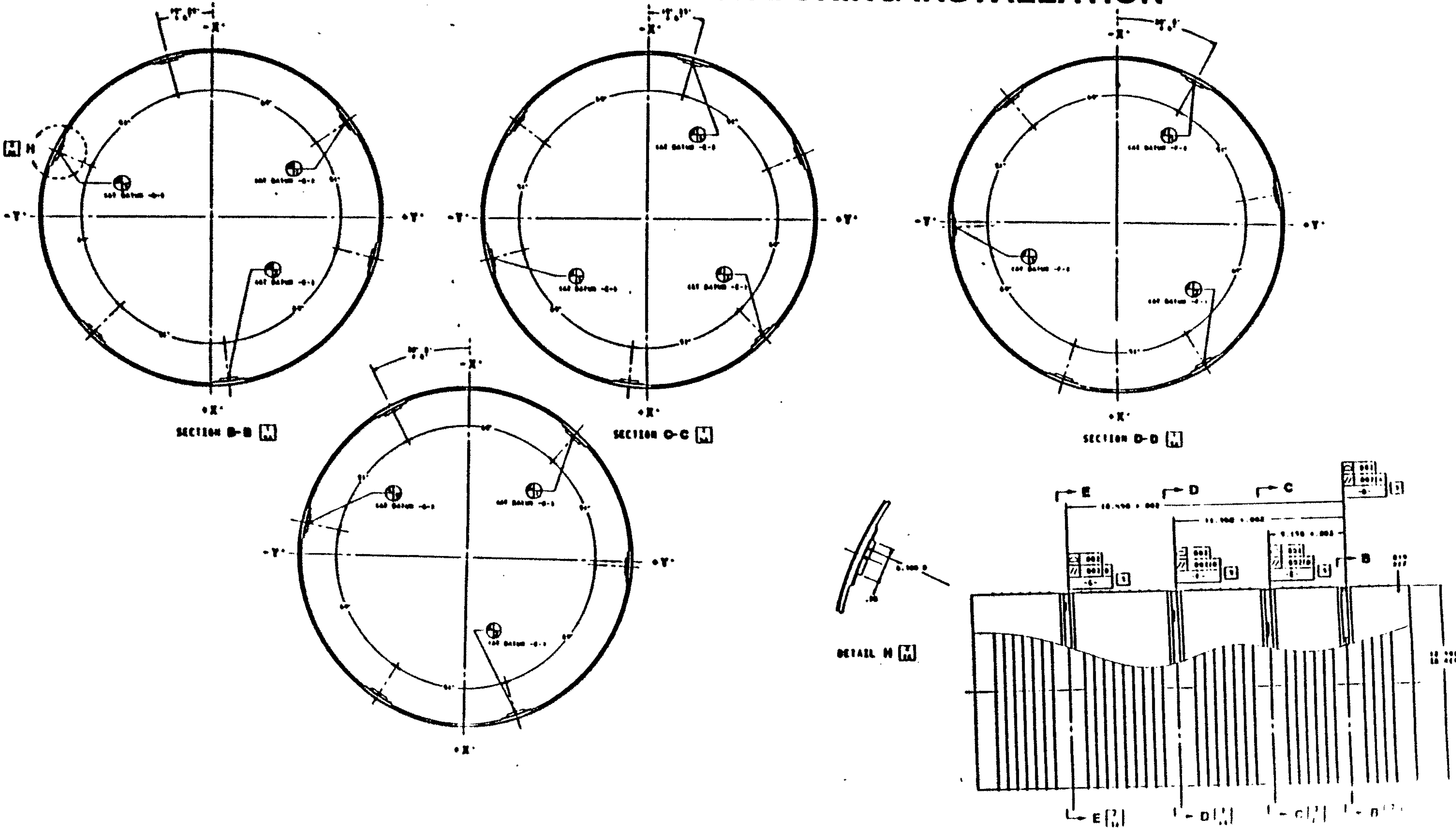
CLOCKING OF THERMAL STOP RINGS / THERMAL SHOES

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

ALL THERMAL STOPS CLOCKED DIFFERENTLY TO PREVENT PROBE THERMAL SHOE INTERFERENCE DURING INSTALLATION



DEWAR TO PAYLOAD ELECTRONICS INTERFACES

- PAYLOAD ELECTRONIC BOXES MOUNTED ON FORWARD EQUIPMENT SECTION AROUND DEWAR NECK
  - 8 PLATFORMS WITH SPACING FOR S/C ATTACHMENTS
- FEEDTHROUGH CONNECTORS P801(TEMP SENSORS), P802(HEATERS, PODS CONTACT SENSORS), P805(TEMP SENSORS) ON TOP PLATE CONNECT TO PAYLOAD ELECTRONICS FOR FLIGHT OPERATION (SEE INSTRUMENTATION SECTION FOR DETAILS)
- COMMANDS TO DEWAR HARDWARE FROM PAYLOAD ELECTRONICS
  - COMMAND GUARD TANK FILL VALVE ON LAUNCH PAD THROUGH UMBILICAL
- REFERENCE TOP HAT EXTERNAL INTERFACE DRAWING 5833116

IF - 7

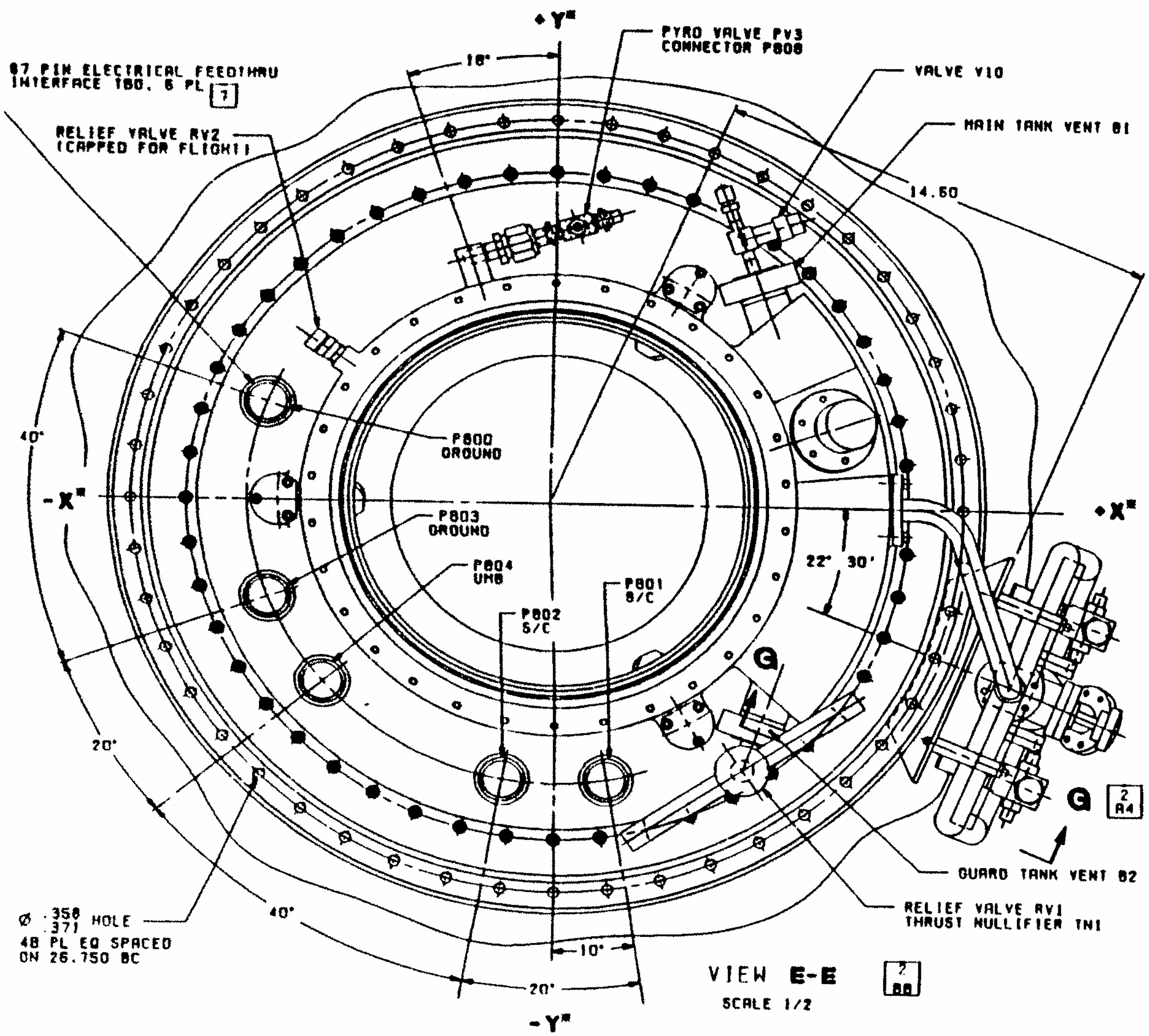
TOP PLATE INTERFACES TO ELECTRONICS

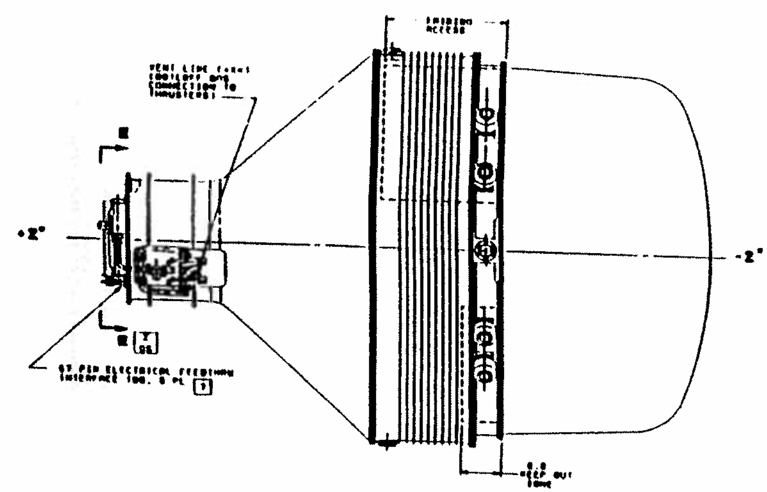
STANFORD

Lockheed

LMSC-P088357

2,3 MAR 94





DEWAR TO SPACECRAFT INTERFACES

- 3 HOLES IN SUPPORT RING FOR SUPPORTING SPACECRAFT
  - 2 DOF TRUNNIONS SPACED 120° APART
- 2 STAR TRACKER PEDESTALS FOR SUPPORTING STAR TRACKER PLATFORMS
  - MOUNTED ON POST ATTACHED TO GRAPHITE RINGS FOR TEMPERATURE STABILITY, SPACED 180° APART
- BOLT HOLES FOR 2 THRUSTER TRUSS STRUCTURES, 2 GPS ANTENNAE, AND 4 SOLAR PANELS ON FORWARD EQUIPMENT SECTION
- VENT LINE (NOT VACUUM JACKETED) FROM VENT MODULE TO THRUSTER MANIFOLD
  - USED ONLY IN SPACE AND THERMAL VAC CHAMBER
  - REDUNDANT PATHS WITH PYROVALVES TO OPEN IN SPACE
  - MANUAL BYPASS VALVE FOR VENTING IN THERMAL/VAC
- CONNECTORS P806,P808,P809, P810 (PYROVALVES) CONNECT TO SPACECRAFT ELECTRONICS
  - P806 ON SUPPORT RING (PV1)
  - P808 ON WELL (PV3)
  - P809 AND P810 IN THRUSTER VENT MODULE (PV 4A&4B)
- S/C ALSO COMMANDS GT FILL VALVE (RAV2) TO OPEN IN ORBIT
- REFERENCE PAYLOAD TO SPACECRAFT INTERFACE DRAWING 5833115

IF - 9

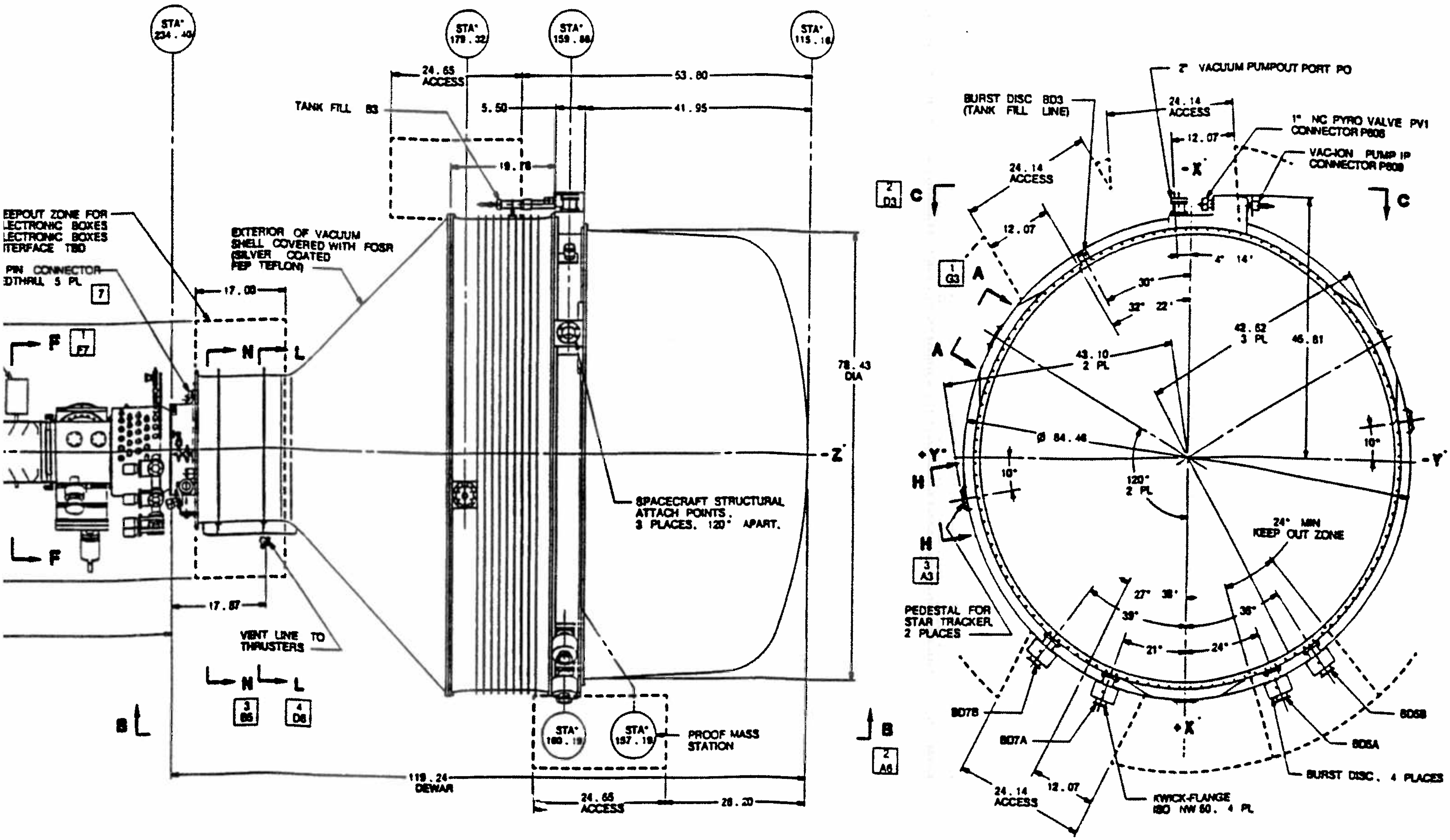
P/L TO S/C INTERFACE DRAWING

STANFORD

Lockheed

LMSC-P088357

2,3 MAR 94



IF - 10

DEWAR INTERFACES TO GSE (1 OF 2)

- SPACECRAFT ATTACH POINTS ON SUPPORT RING ARE ALSO ATTACH POINTS FOR ASSEMBLY STAND AND TILT STAND
- BAYONET (B3) FILL LINE ATTACHES TO VACUUM JACKETED TRANSFER LINE
- MAIN TANK VENT BAYONET (B1) ATTACHES TO GSE EXHAUST MODULE
- PUMPOUT PORT ON SUPPORT RING INTERFACES WITH VACUUM MODULE
- μMETAL GSE EXTENSION OF CRYOPERM SHIELD INTERFACES WITH AXIAL LOK RING
- AXIAL LOK TUBES FOR AXIAL LOK TOOL TO ROTATE DOGS
- GSE AIRLOCK ADAPTER PLATE ATTACHES TO TOP PLATE
- GSE CLOSEOUT PLATE ATTACHES TO TOP PLATE WHEN PROBE NOT INSTALLED
- GSE LIFTING DEVICE ATTACHES TO DEWAR NEAR GRAPHITE RING
- ION PUMP PORT ON SUPPORT RING ATTACHES TO ELECTRICAL MODULE FOR VACUUM SPACE MONITORING

DEWAR INTERFACES TO GSE (2 OF 2)

- BURST DISCS ON VACUUM SHELL ATTACHED TO GSE RELIEF VALVES, REMOVED IN FAIRING OR IMMEDIATELY PRIOR TO ENTERING FAIRING
  - GSE FACILITY VENT LINES (PROVIDED BY S/C) ATTACHED TO BD 7A&B
- FEEDTHROUGH CONNECTORS P800 AND P803 ON TOP PLATE FOR INSTRUMENTATION READOUT ON GROUND
- FEEDTHROUGH CONNECTOR P804 ON TOP PLATE CONNECTS TO UMBILICAL FOR LAUNCH PAD GSE
- CONNECTOR P811 ON SUPPORT RING FOR VACUUM ION PUMP GSE
- REFERENCE DEWAR TO GSE INTERFACE DRAWING 5833504

RISK AREAS / NON COMPLIANCE

ART NAKASHIMA

DEWAR RISK AREAS

- SMD RISK AREAS ARE CATEGORIZED AS FOLLOWS
  - EXPERIMENT RISKS
    - » THOSE RISKS FOR WHICH FAILURE WOULD JEOPARDIZE OR GREATLY COMPROMISE THE MISSION
  - GROUND SAFETY RISKS
    - » THOSE RISKS FOR WHICH FAILURE COULD INJURE PERSONNEL DURING GROUND OPERATIONS
  - SCHEDULE RISKS
    - » THOSE RISKS FOR WHICH FAILURE WOULD SIGNIFICANTLY IMPACT SCHEDULE

EXPERIMENT RISKS

RISK	APPROACH TO RISK REDUCTION
LAUNCH VIBRATION CAUSES LEAD BAG TO WARM ABOVE ITS TRANSITION TEMPERATURE	DEWAR IS DESIGNED TO FILL WELL WITH HE II ON LAUNCH PAD. VIBRATION TEST WITH PROBE-B WILL DETERMINE WHETHER LIQUID IN WELL IS REQUIRED.
PODS THERMALLY SHORT IN ORBIT, DECREASING LIFETIME	WELL DEVELOPED TECHNOLOGY FROM ID DEWAR PROGRAM. RIGOROUS ACCEPTANCE TESTING AT PODS ASSEMBLY LEVEL. SMD VIBRATION TEST.
HELICOFLEX SEAL OR ELECTRICAL FEEDTHROUGH LEAKS, INCREASING TANK VENT RATE	DEVELOPMENT TESTS OF SEALS AND FEEDTHROUGHS. RIGOROUS ACCEPTANCE TESTING. SMD VIBRATION TEST
POROUS PLUG BREAKTHROUGH (TOO LOW HEAT RATE) OR CHOKING (TOO HIGH VENT RATE)	DEVELOPMENT TESTS TO DETERMINE POROUS PLUG RANGE OF OPERATION. ANALYSIS TO DETERMINE HEAT RATE DURING ALL OPERATIONS.

GROUND SAFETY RISK

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

RISK	APPROACH TO RISK REDUCTION
OVERPRESSURIZATION OF MAIN TANK CAUSES BURST DISCS/EMERGENCY VENT LINES TO ACTIVATE, AND EV LINES LEAKS OR BURSTS ABOVE VACUUM SHELL CAPACITY TO VENT	DEVELOPMENT TESTS OF EMERGENCY VENT LINE. RECENT ANALYSIS CONFIRMS LEAK BEFORE BURST OF VACUUM SHELL AND MAIN TANK THOROUGH REVIEW AND CONTROL OF PROCEDURES TO PREVENT OPERATOR ERROR OF GSE AND VALVE OPERATIONS (CAUSING LOSS OF GUARD VACUUM). TEMPERATURE OF MAIN TANK CAREFULLY MONITORED DURING NON-VENTING OPERATIONS

SCHEDULE RISKS

RISK	APPROACH TO RISK REDUCTION
VIBRATION TEST WARMS LEAD BAG ABOVE ITS TRANSITION TEMPERATURE	GTU-2 PLANNING WOULD HAVE TO BE RE-WORKED TO ALLOW FOR 3 MO LEAD BAGS RE-EXPANSION.
VIBRATION TEST DAMAGES DEWAR, REQUIRING REMOVAL OF INSULATION SYSTEM AND PROBE	LOADS ANALYSIS, CONSERVATIVE DESIGN FACTORS.
COLD VALVE FAILURE AFTER ASSEMBLY COMPLETE RAV2 OPENED IN FLIGHT RAV6 (FEP) ON LAUNCH PAD RAV 1,3,5,7 FOR GROUND SERVICING	EXTENSIVE QUALIFICATION TESTING OF TWO VALVES. VIBRATION, THERMAL CYCLE OF FLIGHT VALVES. ACCESS PORTS IN VCS AND MLI. FAILURE OF RAV2 TO OPEN NOT CATASTROPHIC. REDUNDANT VALVES FOR RAV 6.
STRUCTURAL RESONANCE TOO LOW	MODIFIED S/C TRUNNION INTERFACE FOR STIFFER DESIGN. LOAD CYCLE ANALYSIS WHEN DATA AVAILABLE
WELD OR OTHER MANUFACTURING LEAKS ON TANKS OR VACUUM SHELL	THOROUGH TESTING DURING MANUFACTURING - LEAK CHECKS, THERMAL CYCLE, PROOF PRESSURE BONDED DOUBLERS

NON-COMPLIANCE

- FIRST STRUCTURAL SPACE VEHICLE MODES NOT MET
  - AXIAL: REQUIREMENT-12 HZ, PREDICTED - 10.9 HZ
  - LATERAL: REQUIREMENT - 35 HZ, PREDICTED - 29.4 HZ
- REQUIREMENTS ARE RECOMMENDATIONS BY MCDONNELL DOUGLAS TO AVOID COUPLING WITH DELTA II LAUNCH VEHICLE LOW MODES
  - REAL REQUIREMENT NOT KNOWN WITHOUT DETAILED LOAD CYCLE OF COUPLED SPACECRAFT/LAUNCH VEHICLE
  - IT IS EXPECTED THAT THESE REQUIRED VALUES ARE CONSERVATIVE
    - » EXPERIENCE WITH OTHER SPACECRAFT WITH LOWER FREQUENCIES
- VERBAL AGREEMENT WITH STANFORD THAT CURRENT DESIGN IS SATISFACTORY
  - WAIT FOR DETAILED LOAD CYCLE BEFORE REACTING TO EXPENSIVE DESIGN CHANGES

DEVELOPMENT TESTS

DEAN READ

DEVELOPMENT TESTS

- COMPOSITE NECK TUBE
- HELICOFLEX SEAL
- COLD ELECTRICAL FEEDTHROUGH
- AXIAL LOK
- FLEXIBLE EMERGENCY VENT LINE
- POROUS PLUG AND HEAT PULSE METER

COMPOSITE NECK TUBE TEST

OBJECTIVES

- DEMONSTRATE STRUCTURAL CAPABILITY AND VACUUM INTEGRITY OF TUBE ASSEMBLY
  - EXTERNAL PRESSURE TO 37.4 PSID (2x MAXIMUM PRESSURE)
  - INTERNAL PRESSURE TO 28.5 PSID (1.5x MAXIMUM PRESSURE)
  - THERMAL CYCLE TO STRESS BOND JOINTS
  - SIDE LOAD TO SIMULATE LATERAL LOAD FROM BELLOWS
  - AXIAL LOAD TO FAILURE (DETERMINE MARGINS)
- DEMONSTRATE FABRICATION AND ASSEMBLY PROCESS
- DEVELOP ACCEPTANCE TEST PROCEDURE FOR FLIGHT ARTICLE
- PERFORM THERMAL AND STRUCTURAL PROPERTIES TESTING

STATUS

- TESTING COMPLETE (TEST REPORT EM #379)
- COUPON TESTING IN PROGRESS

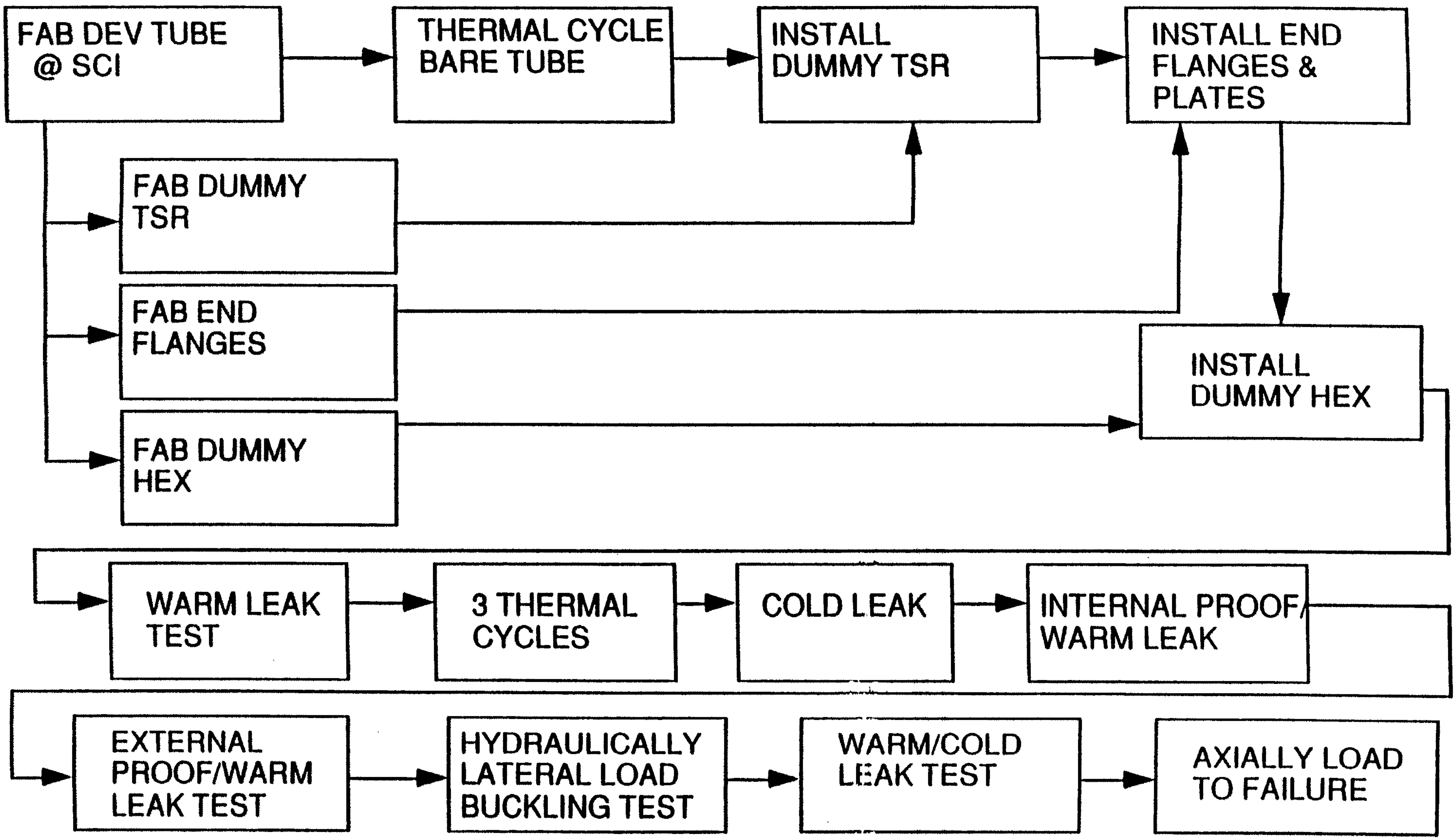
DT - 4

COMPOSITE NECK TUBE TEST FLOW

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94



COMPOSITE NECK TUBE TEST RESULTS

- THERMAL CYCLE AND LEAK CHECK OF END FLANGES
  - $< 1 \times 10^{-8}$ SCC He/S FOR ALL COLD LEAK CHECKS AND AFTER THERMAL CYCLES
- INTERNAL PRESSURE TO 28.5 PSID
- EXTERNAL PRESSURE TO 34 PSID
  - MINOR RIB DE-BONDING OCCURRED
  - REBONDED PER BONDING PROCEDURE PRIOR TO PROCEEDING
- LATERAL LOAD OF 705 LBS TO SIMULATE ULTIMATE LATERAL LOADS
  - NO STRUCTURAL FAILURE OR LEAKAGE
- EXTERNAL PRESSURE TO ULTIMATE PRESSURE ([14.7+4]x2=37.4)
  - SIMULATES 4 PSID VACUUM SHELL BURST DISK
- AXIAL LOAD TO FAILURE
  - ONSET OF BUCKLING OCCURRED AT 9133 LBS
  - 8500 LBS PREDICTED USING 2σ KNOCK-DOWN FACTOR

COMPOSITE NECK TUBE TEST CONCLUSIONS

- COMPOSITE NECK TUBE DESIGN MET ALL TESTING REQUIREMENTS
  - LEAKAGE
  - STRUCTURAL
- DIFFERENCES BETWEEN DEVELOPMENT TEST AND ACCEPTANCE TESTING
  - EXTERNAL PRESSURE LEVELS
    - » DEVELOPMENT TEST - 2 X 18.7 = 37.4 PSID
    - » ACCEPTANCE TEST - 1.5 X 18.7 = 28.1 PSID
  - NO AXIAL COMPRESSION TEST

HELICOFLEX SEAL TEST (1 OF 2)

OBJECTIVES

- DEMONSTRATE LEAK TIGHT SEAL
  - $< 1 \times 10^{-8}$ SCC He/S
  - LIQUID NITROGEN THERMAL CYCLING
  - STAINLESS STEEL TO ALUMINUM JOINT REPRESENTATIVE OF TANK TOP DOME JOINT DESIGN

STATUS

- TEST OF 2" SEAL IS COMPLETE (TEST REPORT GPB-100111)
- DESIGN OF FIXTURE TO TEST 20" SEAL TO 200 K IS IN PROGRESS

HELICOFLEX SEAL TEST (2 OF 2)

DESCRIPTION

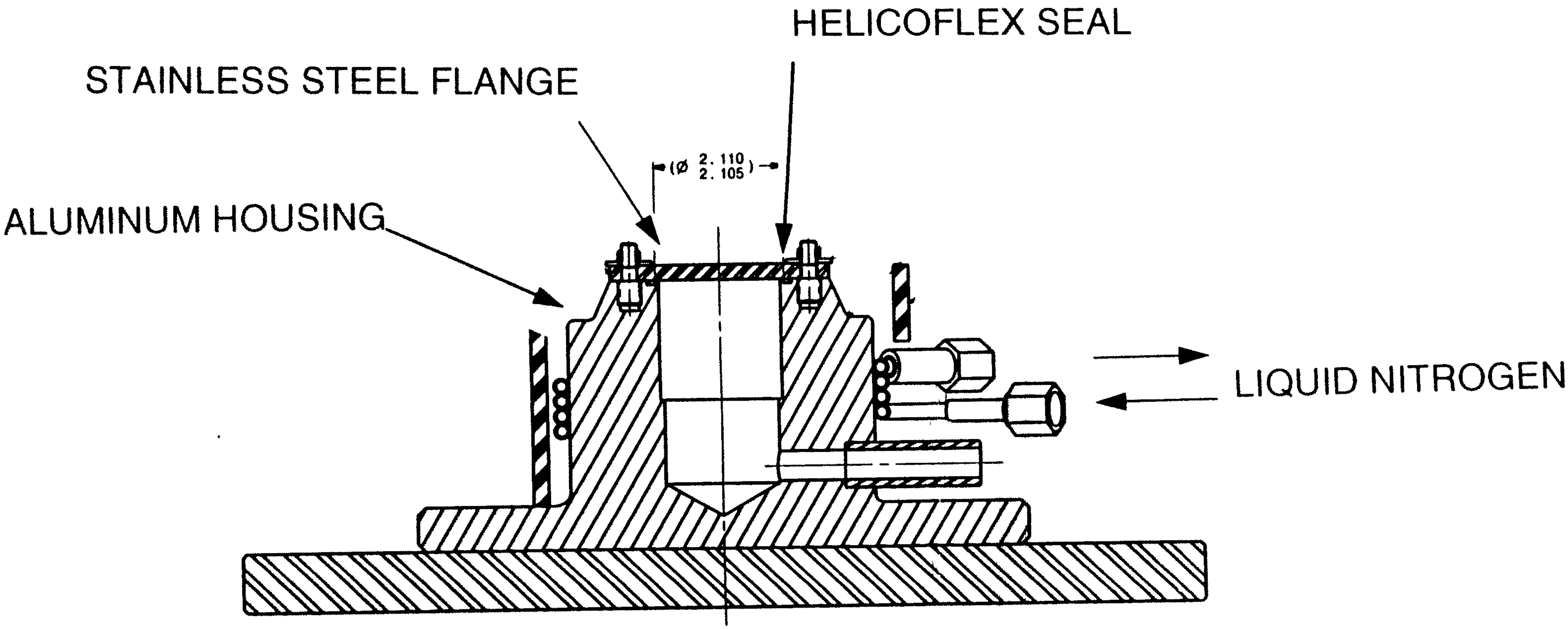
- 2" DIAMETER SEAL APPARATUS
  - REPRESENTATIVE OF THE LARGEST PENETRATION ON THE TANK DOME
  - STAINLESS STEEL FLANGE BOLTED TO ALUMINUM FIXTURE
  - 3 THERMAL CYCLES; COLD AND WARM LEAK CHECKS
  - THERMAL SHOCK TEST WITH COLD LEAK CHECK

RESULTS

- 2" SEAL TEST
  - 2 SEALS TESTED
  - NO LEAKAGE DURING THERMAL CYCLING OR THERMAL SHOCK

HELICOFLEX SEAL TEST APPARATUS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



HELICOFLEX SEAL TEST CONCLUSIONS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- TEST DEMONSTRATED THAT THE HELICOFLEX SEAL AND JOINT DESIGN USED ON TANK PENETRATIONS MEETS THE LEAKAGE REQUIREMENTS

- TOP PLATE TO VACUUM SHELL SEAL CONFIGURATION WILL BE TESTED
  - 20" DIAMETER ALUMINUM TO STAINLESS STEEL JOINT
  - COOLED TO 200 K IN THERMAL-VACUUM TESTING

COLD ELECTRICAL FEEDTHROUGH TEST

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

OBJECTIVES

- VERIFY TANK AND WELL ELECTRICAL FEEDTHROUGHS MEET LEAKAGE REQUIREMENTS ($<1 \times 10^{-9}$ SCC He/S)

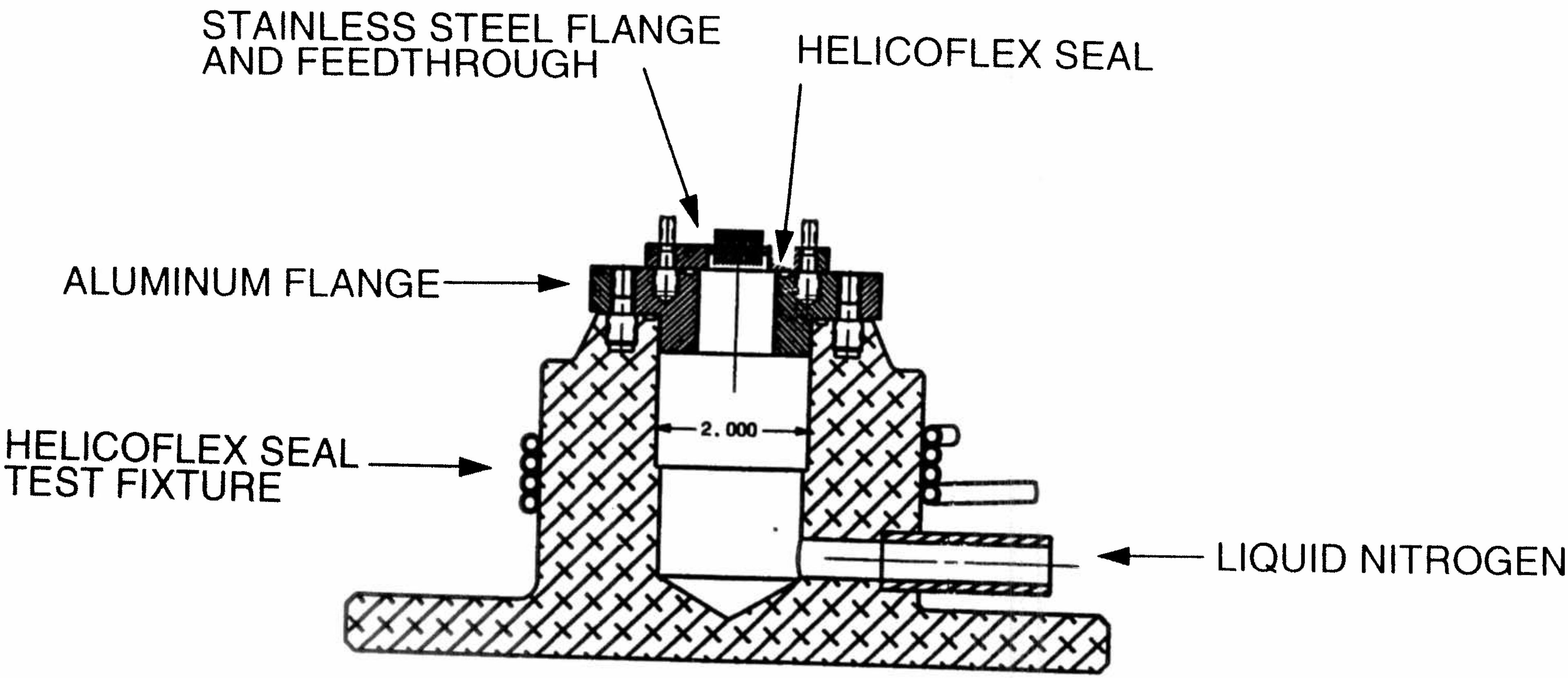
STATUS

- FEEDTHROUGH FABRICATION COMPETE
- TEST FIXTURE FABRICATION COMPLETE

DESCRIPTION

- WARM LEAK CHECK
- 3 THERMAL CYCLES WITH LIQUID NITROGEN AND COLD LEAK CHECK
- WARM LEAK CHECK
- THERMAL SHOCK AND COLD LEAK CHECK

COLD ELECTRICAL FEEDTHROUGH TEST APPARATUS



AXIAL LOK TEST

OBJECTIVES

- CHARACTERIZE PERFORMANCE OF MODIFIED AXIAL LOK DESIGN
  - LOAD VS TORQUE CHARACTERISTICS FOR BOTH WARM AND COLD OPERATION
  - BREAK-IN CHARACTERISTICS
  - VIBRATION PERFORMANCE
    - » LOAD MAINTAINED DURING VIBRATION
    - » TEST FOR PARTICLE GENERATION
- RESOLVE CONTAMINATION ISSUES
  - MEASURE TYPE AND QUANTITY OF PARTICLES GENERATED DURING NORMAL OPERATION
  - DEMONSTRATE THAT SEALS AND FILTERS PROHIBIT PARTICLE MIGRATION INTO THE WELL

STATUS

- AXIAL LOK PART FABRICATION COMPLETE
- TEST FIXTURE FABRICATION COMPLETE

AXIAL LOK TEST DESCRIPTION

- WARM AND COLD (77 K) TESTING
  - MEASURE LOAD VS TORQUE OVER 20 CYCLES
  - DETERMINE IF SEALS AND FILTERS ELIMINATE POTENTIAL CONTAMINATION OF THE WELL
  - MEASURE QUANTITY AND TYPE OF PARTICLES GENERATED

- VIBRATION TESTING
  - ROOM TEMPERATURE TEST
  - MONITOR CLAMPING LOAD DURING VIBRATION
  - MEASURE QUANTITY AND TYPE OF PARTICLES GENERATED

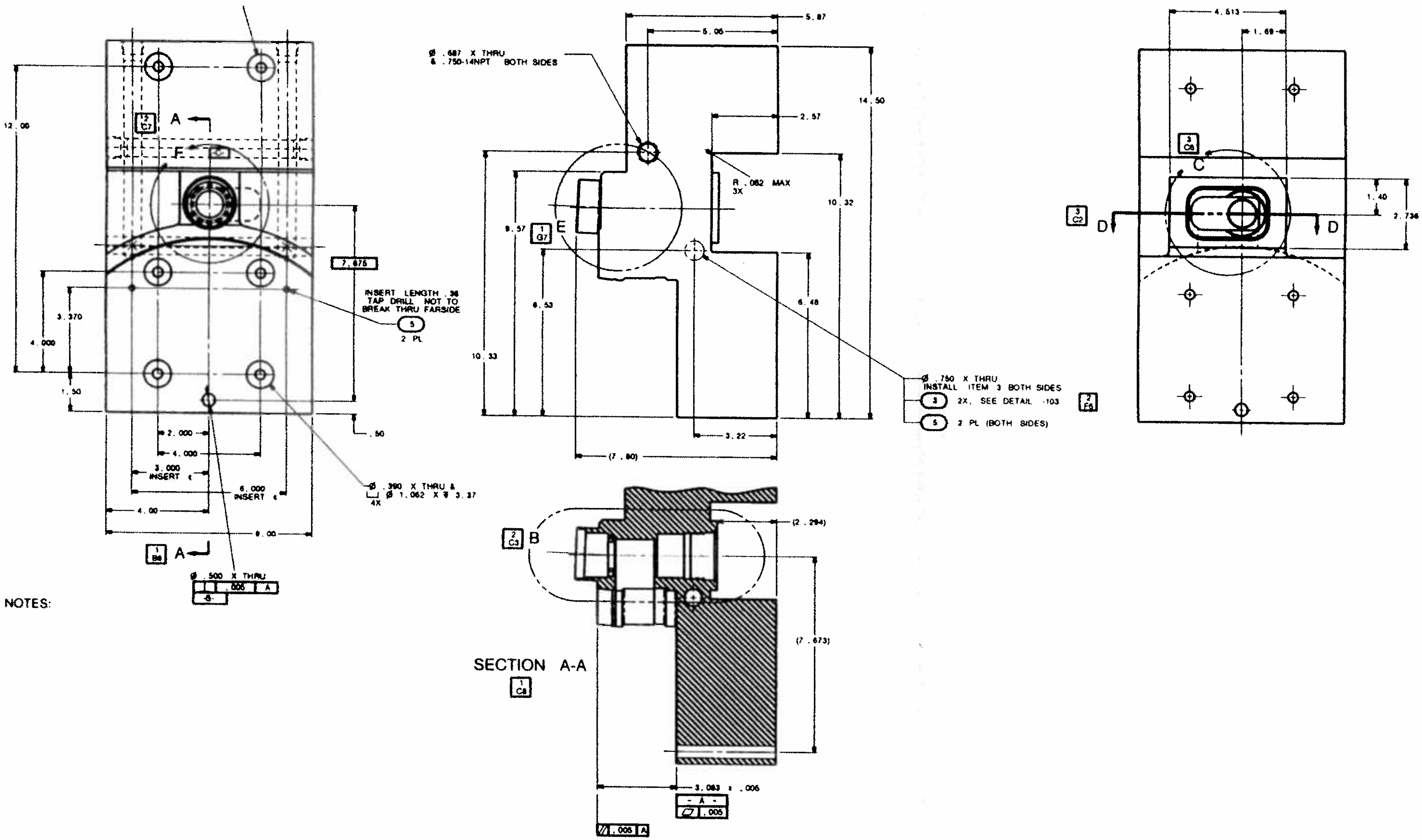
DT - 15

AXIAL LOK TEST FIXTURE

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94



NOTES:

FLEXIBLE VENT LINE TEST

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

OBJECTIVES

- DEVELOP DESIGN OF FLEXIBLE EMERGENCY VENT LINE TO BE USED IN SMD
  - TUBE CONSTRUCTION
  - FOLD PATTERN
  - END FLANGE DESIGN
  - VAPOR COOLED SHIELD INTERFACE
- DEVELOP ACCEPTANCE TEST REQUIREMENTS AND PROCEDURE FOR FLIGHT ARTICLES
- MEASURE LEAKAGE THROUGH VENT LINE

STATUS

- TESTING COMPLETE (TEST REPORT EM #373)

FLEXIBLE VENT LINE TEST DESCRIPTION

- DESIGN PARAMETERS TESTED
  - TWO END FLANGE DESIGNS TESTED
    - » CONICAL AND PYRAMID
  - TWO FOLD TYPES TESTED
    - » FLAT FOLD AND ACCORDION FOLD
  - DIFFERENT TUBE CONSTRUCTIONS TESTED
    - » 1 PLY, 2 PLY, AND 3 PLY
    - » REINFORCEMENT AT END FITTINGS

- TEST SEQUENCE
  - WARM EVACUATION AND LEAK BACK TEST
  - WARM PROOF PRESSURE AND LEAK TEST
  - RAPID PRESSURIZATION WHILE SUBMERGED IN LIQUID NITROGEN
    - » LEAKAGE MEASUREMENT AT 38 PSID
  - BURST PRESSURE TEST WHILE SUBMERGED IN LIQUID NITROGEN

FLEXIBLE VENT LINE RESULTS - TEST #11

- CONFIGURATION
  - 3 - 0.0005" MYLAR PLY CENTER SECTION
  - 5 - 0.0005" MYLAR PLY END SECTIONS
  - ACCORDION FOLD
  - CONICAL END FITTINGS
  - SIMULATED DEWAR GEOMETRY

- TEST RESULTS
  - EVACUATION AND LEAK CHECK - NO LEAKS
  - PROOF PRESSURE TO 54 PSID - NO LEAKS
  - RAPID PRESSURIZATION IN LIQUID NITROGEN - 3,000 L/HR AT 38 PSID (< 10,000 L/HR REQUIRED)
  - BURST PRESSURE TEST - ACHIEVED 200 PSID WITHOUT RUPTURE

FLEXIBLE VENT LINE TEST SUMMARY/CONCLUSIONS

- SMD BASELINE DESIGN
  - CONICAL END FITTING
  - ACCORDION FOLD
  - 3 MYLAR PLY CENTER SECTION; 5 PLY END CUFFS

- SELECTED DESIGN HAS LEAKAGE RATE 10 TIMES LOWER THAN THE CAPABILITY OF A SINGLE VACUUM SHELL BURST DISC

- ACCEPTANCE TEST FOR FLIGHT ARTICLES
  - 3 THERMAL CYCLES OF BOND JOINTS
  - WARM PROOF PRESSURE (54 PSID) AND LEAK CHECK
  - ADDITIONAL TESTING ON LINES FROM SAME LOT
    - » RAPID EXPANSION IN LIQUID NITROGEN BATH AND LEAK CHECK
    - » WARM BURST TEST TO AT LEAST 200 PSID

POROUS PLUG AND HEAT PULSE METER TEST

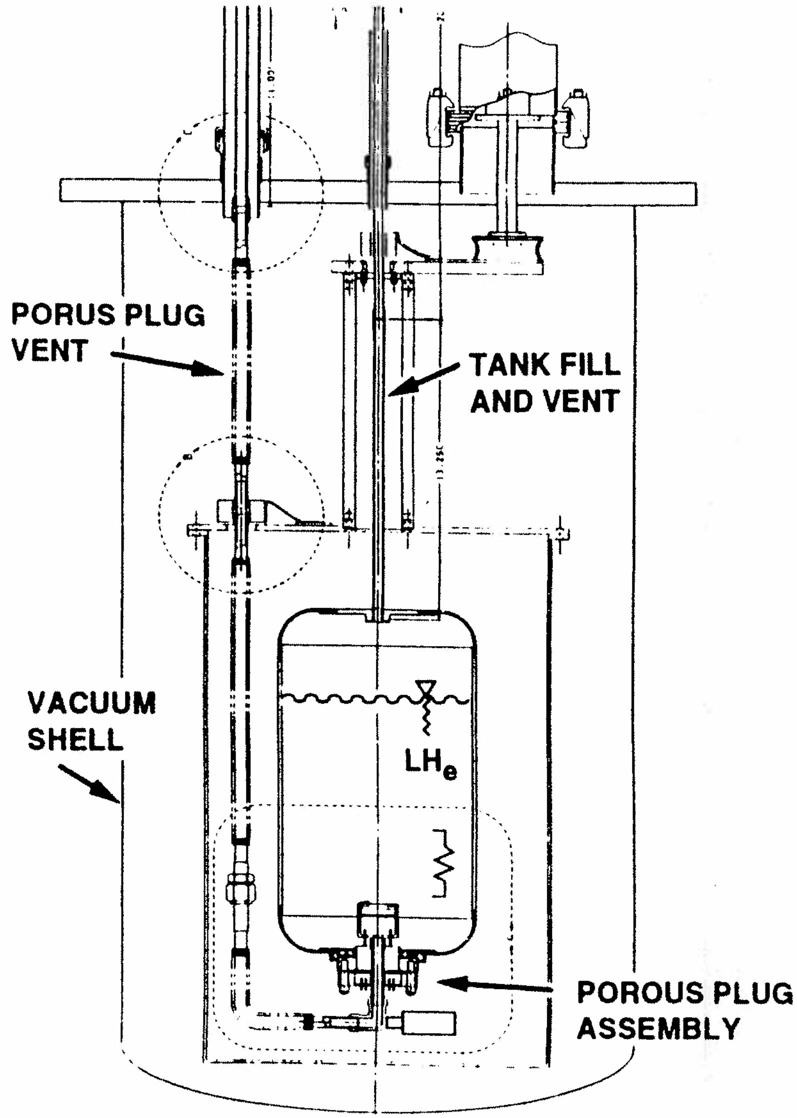
OBJECTIVES

- DEMONSTRATE OPERATING CHARACTERISTICS OF THE SMD POROUS PLUG
  - LOW TEMPERATURE PHASE SEPARATION
  - LIQUID BREAK THROUGH CONDITIONS
  - CHOKED FLOW CONDITIONS
- VALIDATE DESIGN AND ASSEMBLY PROCEDURES FOR THE FLIGHT ARTICLE
- DEMONSTRATE HEAT PULSE METER OPERATION

STATUS

- COMPONENTS AND INSTRUMENTATION ON ORDER
- TEST DEWAR ASSEMBLED

TEST APPARATUS



DYNAMICS ANALYSIS

LARRY SOKOLSKY

DYNAMIC ANALYSIS OBJECTIVES

- DERIVE SET OF LOADS FOR DEWAR AND PROBE DESIGN
  - RETAIN ADEQUATE CONSERVATISM
  - AVOID EXCESSIVE OVERDESIGN
- FLOW DOWN LOADS TO STRESS ANALYSIS
- MEET SPACE VEHICLE FREQUENCY REQUIREMENTS
  - 12 HZ LATERAL MODE REQUIREMENT
  - 35 HZ AXIAL MODE REQUIREMENT
- VERIFY DESIGN LOADS WITH COUPLED LOADS ANALYSIS
- DEVELOP STRUCTURAL DYNAMICS VERIFICATION PLAN
  - PROBE B, C SHAKE
  - PROBE B IN SMD COLD SHAKE
  - STATIC STRENGTH AND STIFFNESS TESTS

DYNAMIC ANALYSIS APPROACH

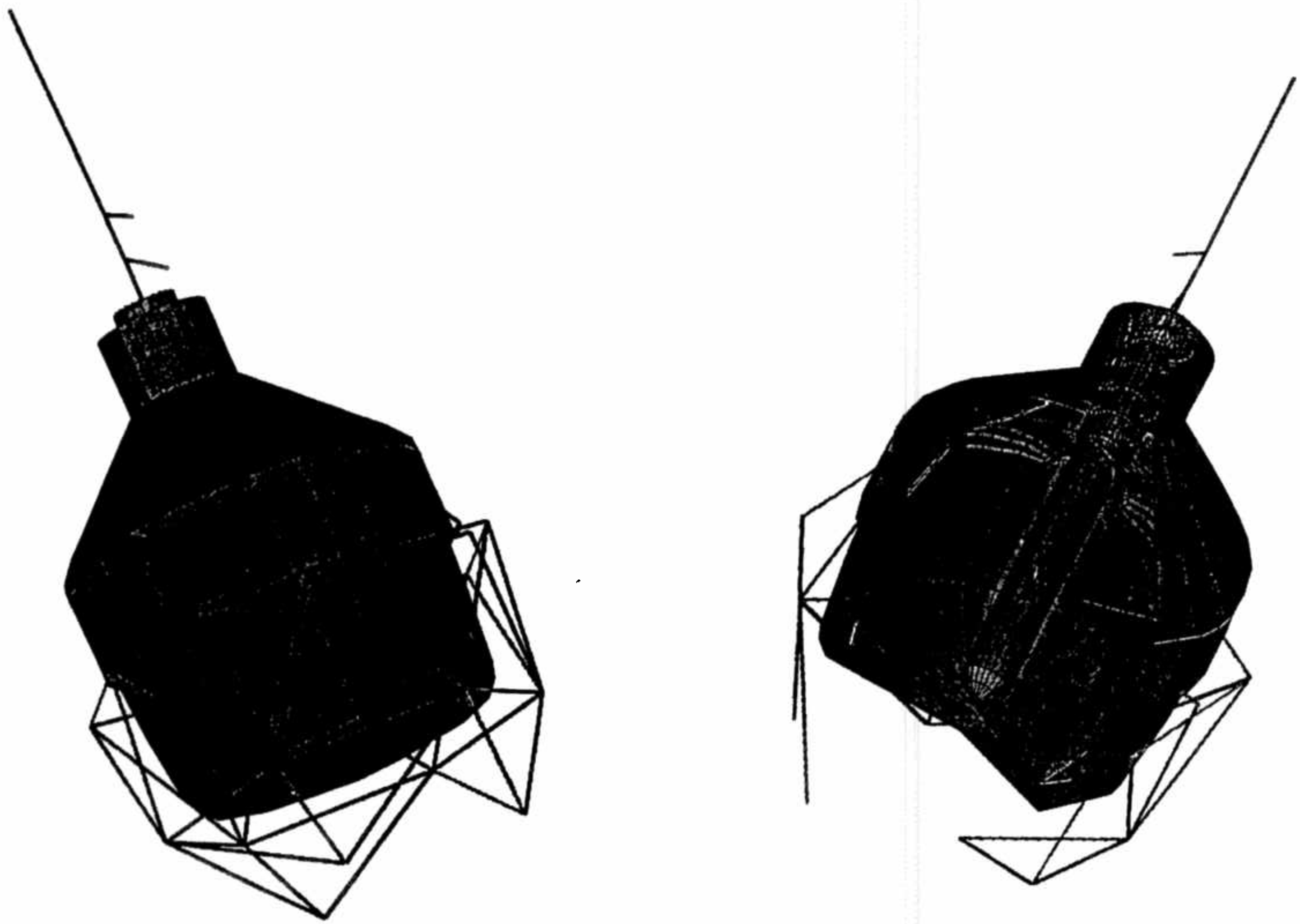
- BUILD PAYLOAD DYNAMIC MODEL USING SDRC-IDEAS AND MSC/NASTRAN
- COUPLE TO LMSC SPACECRAFT MODEL
- APPLY LAUNCH (TRANSIENT) TRANSONIC (RANDOM) VIBRATION INPUTS TO BASE OF SPACE VEHICLE MODEL
- APPLY ACOUSTIC LOADS WHERE APPLICABLE
- APPLY MUFs (MODEL UNCERTAINTY FACTORS) FOR CONSERVATISM
- TABULATE PAYLOAD RESPONSES FOR CRITICAL COMPONENTS
- UPDATE LOAD FACTORS WITH COUPLED LOADS ANALYSIS RESULTS WHEN AVAILABLE
- DYNAMICS AND LOADS ANALYSIS DOCUMENTED IN EM 310A

JUSTIFICATION FOR GP-B DESIGN LOADS APPROACH

- MOTIVATION
  - COMPLETE LOAD CYCLE RESULTS WERE NOT AVAILABLE TO SUPPORT DEWAR DESIGN
  - GENERIC LOADS WOULD LEAD TO HARDWARE OVERDESIGN
- GUIDELINES
  - APPROACH MUST CONTAIN ADEQUATE CONSERVATISM
  - USE REALISTIC INPUTS TO DERIVE DESIGN LOADS

LOADS ANALYSIS METHODOLOGY

- CREATE DETAILED FINITE ELEMENT MODEL OF PAYLOAD (DEWAR, PROBE, AND ATTACHED ELECTRONICS), COUPLE TO LMSC SPACECRAFT MODEL
- DYNAMIC LOADS FROM FSAT LOAD CYCLE
  - FSAT MASS AND CG SIMILAR TO GPB
  - LAUNCH VEHICLE DOMINATES INPUT
- ADD ACOUSTIC LOADS WHERE APPLICABLE (DERIVED FROM GPS FLIGHT DATA)
- ADEQUATE MUFs USED TO RETAIN CONSERVATISM
  - 1.5 FOR TRANSONIC ANALYSIS (RANDOM INPUT)
  - 1.75 FOR LAUNCH ANALYSIS (TRANSIENT INPUT)
- MAIN ENGINE CUT-OFF (MECO) DETERMINES AXIAL LOAD FACTORS (FROM DELTA II COMMERCIAL PAYLOAD PLANNER'S GUIDE)
- TRANSIENT ANALYSIS PARAMETERS
  - KEEP LOADS TO 200 HZ
  - 1% CRITICAL DAMPING ON ALL MODES
  - MODE ACCELERATION METHOD FOR TRANSIENT ANALYSIS
- DYNAMIC LOAD FACTOR IS MAXIMUM OF LAUNCH TRANSIENT AND TRANSONIC RANDOM
- COMBINED LOAD FACTOR = MUF*(DYNAMIC)+ACOUSTIC
- X* AND Y* LOADS RSSd TO CREATE SINGLE LATERAL LOAD FACTOR
- SSD SECONDARY STRUCTURE LOAD FACTORS USED FOR LIGHTWEIGHT HARDWARE (i.e. PLUMBING AND ELECTRONICS)



INTEGRATED SPACE VEHICLE MODE FREQUENCIES AND MODE PARTICIPATION FACTORS TO 50 HZ

STANFORD
Lockheed
LMSC P088357
2, 3 MAR 94

Mode	Freq (hz)	P_x (%)	P_y (%)	P_z (%)	P_{rx} (%)	P_{ry} (%)	P_{rz} (%)
1	10.86	10.1	53.6	---	66.7	13.7	---
2	10.90	54.6	10.8	---	13.5	68.0	---
3	18.24	---	2.5	---	---	---	---
4	18.48	3.0	---	---	---	0.1	---
5	29.45	---	---	62.4	---	---	---
6	30.97	---	1.6	0.4	2.9	0.2	---
7	31.69	---	0.3	---	0.4	0.1	1.5
8	31.77	0.2	2.3	0.1	3.6	0.6	---
9	32.94	2.5	0.2	0.4	0.3	4.6	---
10	37.73	---	---	---	---	---	1.3
11	39.32	0.4	---	---	---	0.4	0.8
12	39.51	---	---	0.7	---	---	1.7
13	39.76	0.2	0.7	---	0.4	0.1	20.1
14	39.89	0.1	0.6	---	0.3	0.1	22.9
15	41.97	---	10.5	---	6.3	---	5.9
16	42.23	---	---	0.4	---	---	0.5
17	44.72	10.4	---	---	---	6.3	0.1
Total Mass % to 50 hz		81.5	83.1	64.1	94.4	94.2	54.8
Total Mass % to 120 hz		95.3	95.2	92.8	98.3	98.4	96.6

DESIGN EFFORT TO INCREASE SPACE VEHICLE MODAL FREQUENCIES

- BASELINE DESIGN DID NOT MEET FREQUENCY REQUIREMENTS
- DEWAR STIFFENED AS MUCH AS POSSIBLE
  - FWD DOME RIB STIFFENING
  - INCREASED PODS STIFFNESS
  - OPTIMIZED SPACECRAFT INTERFACE (TRUNNION WITH RADIAL RELEASE)
- RESULTING MODAL FREQUENCIES
  - LATERAL: 10.86 HZ
  - AXIAL: 29.45 HZ
- LATERAL FREQUENCIES OF OTHER PAYLOADS (SOURCE-MDSSC)
  - UUV < 9 HZ
  - MSX 8.5 HZ
  - MANY OTHERS IN 7-9 HZ RANGE
  - IMPACT OF LATERAL FREQUENCIES IN 10-11 HZ RANGE-NONE
- AXIAL FREQUENCIES OF OTHER PAYLOADS (SOURCE-MDSSC)
  - MOST PAYLOADS ABOVE 35 HZ
  - MSX 30 HZ
  - IMPACT: MAY INCREASE QUASISTATIC LOADS SLIGHTLY (~.25 HZ)
- CONCLUSION - CURRENT SPACE VEHICLE MODAL FREQUENCIES ARE ACCEPTABLE

QUASISTATIC AND ACOUSTIC LOAD FACTORS

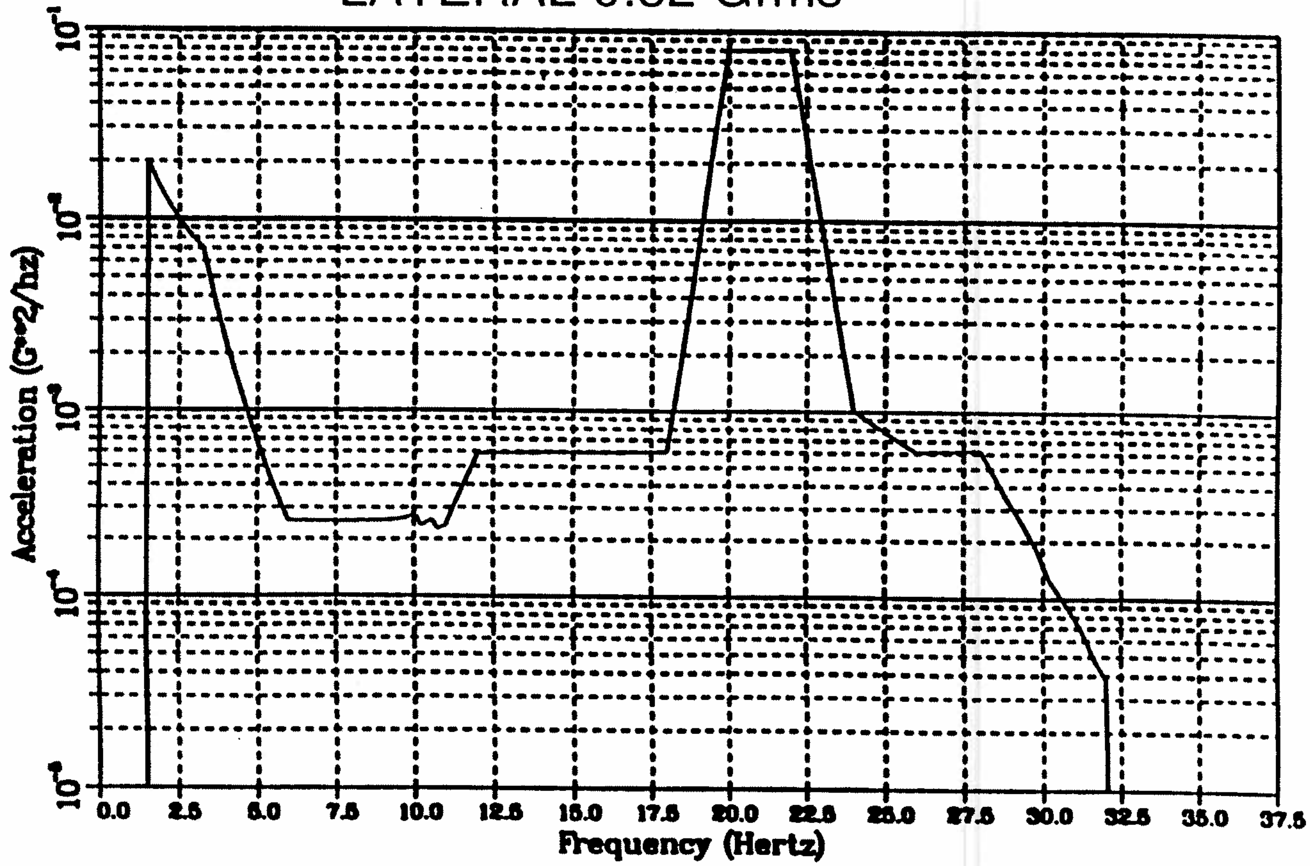
- QUASISTATIC LOAD FACTORS (SOURCE: DELTA-II HDBK)
  - LIFT-OFF LOAD FACTORS (G)
    - » LATERAL +/- 2.5 (G)
    - » AXIAL +2.2/-0.2 (G)
  - MECO
    - » AXIAL +6.3 (G)
- ACOUSTIC LOAD FACTORS (SOURCE-DELTA-II POST-FLIGHT ANALYSIS (MCD H5858)
  - LATERAL 1.6 (G)
  - AXIAL 3.5 (G)

1-σ PSD BASE INPUTS FROM FSAT

STANFORD
Lockheed
LMSC P088357
2, 3 MAR 94

DY-10

LATERAL 0.52 Grms

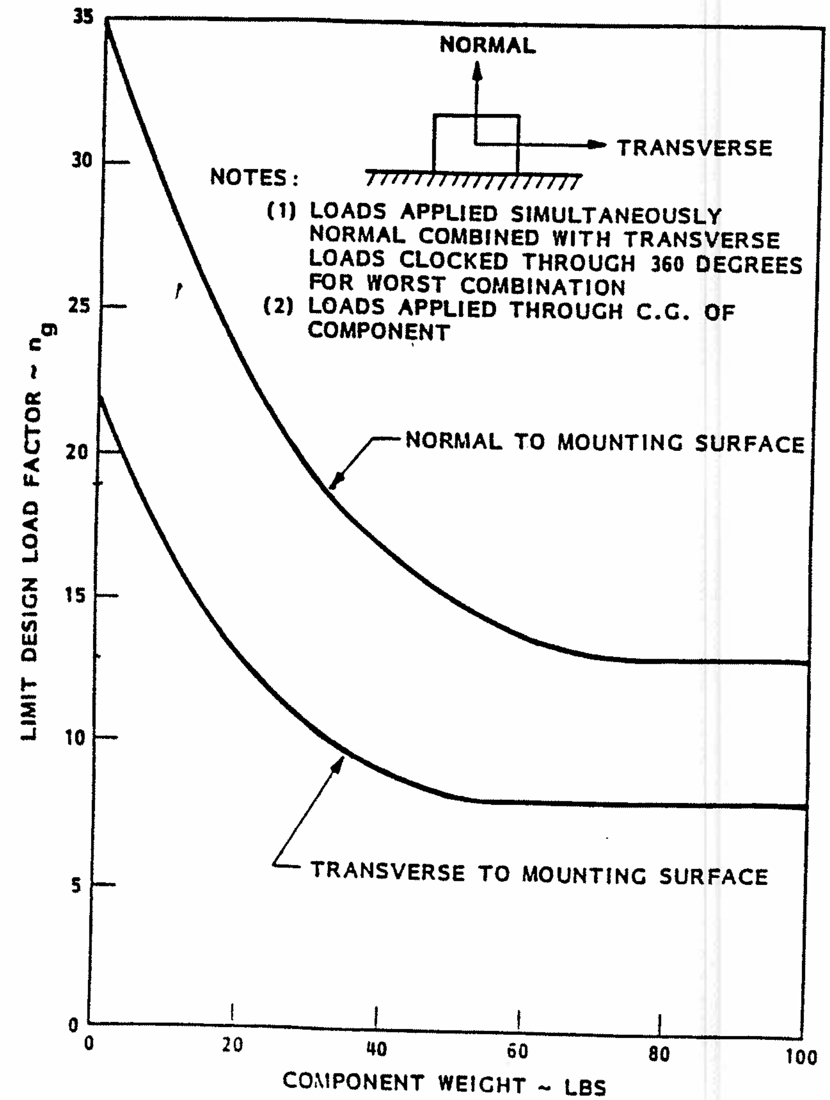


- ENVELOPING MADE MORE CONSERVATIVE FROM PDR
- AXIAL TRANSONIC LOAD CASE NOT USED BECAUSE OF LOW INPUT LEVEL (NO SIGNIFICANT RESPONSE)

COMBINED LOAD FACTORS

Location	Lateral (g)	PDR Lateral (g)	Axial Load Factor (g)
SFHe Tank	6.0	5.2	6.3
Well	6.0	5.2	6.3
Dewar Main Support Ring	6.0	7.0	6.3
Axial Lok	6.2	6.2	6.3
Sunshade	28.2	26.5	9.8
QBA-SIA	5.2	5.3	6.3
Tophat/T-Flange	8.9	8.9	9.8
Vacuum Shell	6.6	6.6	6.3
Gate Valve	10.6	10.5	9.8

SSD SECONDARY STRUCTURE LOAD FACTOR CURVES



STRUCTURAL DYNAMICS VERIFICATION PLANS

- DETAILED MODAL TEST NOT PRACTICAL
  - NO MODAL TEST UNIT
  - DIFFICULT TO INSTRUMENT COLD AREAS OF DEWAR AND PROBE
- PERFORM MODAL *IDENTIFICATION* DURING SHAKE TESTS
  - COMMENTS APPLY TO BOTH PROBE AND INTEGRATED PAYLOAD SHAKE TESTS
    - » IDENTIFY PRIMARY MODE FREQUENCIES AND DIRECTIONS
    - » INSTRUMENT SPACECRAFT AND EXTERNAL DEWAR STRUCTURE TO VERIFY GLOBAL MODE SHAPES
    - » FOUR INTERNAL DEWAR TRIAXIAL ACCELEROMETERS INCLUDED IN DEWAR INSTRUMENTATION
- PERFORM STIFFNESS TESTS ON PODS
  - VERIFIES STIFFNESSES IN FINITE ELEMENT MODEL
  - RELATIVELY CHEAP, SIMPLE, AND ACCURATE
- PROTOQUAL VIBRATION TESTS
  - PROBE B/C VIBRATION
  - PROBE B IN SMD VIBRATION WITH SPACECRAFT SIMULATOR
  - FULL-UP ACOUSTIC TEST

CONCLUSIONS

- SPACE VEHICLE MODAL FREQUENCIES
  - FIRST AXIAL PAYLOAD MODE 29.45 HZ (35 HZ REQUIREMENT
  - FIRST LATERAL PAYLOAD MODE 10.86 HZ (12 HZ REQUIREMENT)
  - EXPERIENCE ON OTHER SPACECRAFT PROGRAMS INDICATE THAT THESE FREQUENCIES ARE MOST LIKELY ACCEPTABLE
- DETAILED LOAD FACTORS HAVE BEEN FLOWED DOWN TO STRESS ANALYSIS
- PRELIMINARY COUPLED LOADS ANALYSIS (IN PROCESS) NOT EXPECTED TO MODIFY DESIGN LOADS SIGNIFICANTLY

STRESS ANALYSIS

LARRY SOKOLSKY

STRUCTURAL ANALYSIS OBJECTIVES

- ANALYZE ALL STRUCTURE IN DETAIL FOR INERTIAL AND PRESSURE LOADS
- ACCOMODATE MANUFACTURING AND COST CONSIDERATIONS IN DESIGN ALTERNATIVES
- USE CONSERVATIVE ANALYSIS APPROACHES TO INSURE STRUCTURAL DESIGN

REQUIREMENTS - SAFETY FACTORS

- INTERNAL PRESSURE
  - FACTOR OF 4 FOR STRESS AND BUCKLING
  - FACTOR OF 1.5 FOR PROOF PRESSURE TEST
- EXTERNAL PRESSURE
  - FACTOR OF 2 FOR STRESS AND BUCKLING
- MECHANICAL LOADS (METALLIC)
  - FACTOR OF 1.25 FOR YIELD
  - FACTOR OF 1.5 FOR ULTIMATE
  - FACTOR OF 1.25 FOR TEST
- MECHANICAL LOADS (NON-METALLIC)
  - FACTOR OF 2.0 FOR ULTIMATE
  - FACTOR OF 1.25 FOR TEST
- GROUND SUPPORT EQUIPMENT
  - FACTOR OF 3.0 FOR ULTIMATE (GROUND HANDLING EQUIPMENT)
  - FACTOR OF 5.0 FOR ULTIMATE (LIFTING EQUIPMENT)

DEWAR STRESS ANALYSIS REQUIREMENTS - LOADS

- INTERNAL PRESSURE
  - TANK AND PLUMBING - .26 MPA (38 PSID DESIGN - 152 PSID ULTIMATE)
  - WELL - .13 MPA (19 PSID DESIGN - 76 PSID ULTIMATE)
  - VACUUM SHELL - .06 MPA (8 PSID DESIGN - 32 PSID ULTIMATE)
  - GUARD TANK - .37 MPA (55 PSID DESIGN - 220 PSID ULTIMATE)
- EXTERNAL PRESSURE
  - TANK AND PLUMBING - .13 MPA (19 PSID DESIGN - 38 PSID ULTIMATE)
  - WELL - .36 MPA (53 PSID DESIGN - 106 PSID ULTIMATE)
  - VACUUM SHELL - .10 MPA (15 PSID DESIGN - 30 PSID ULTIMATE)
- INERTIAL LOADS
  - SEE DYNAMICS AND LOADS SECTION
- AXIAL LOK COMPRESSIVE LOAD 10889 N/CLAMP (2448 LB/CLAMP)

STRUCTURAL ANALYSIS APPROACH

- USE APPROPRIATE ANALYTICAL TOOLS FOR JOB
  - PANDA FOR DESIGN, ANALYSIS AND WEIGHT OPTIMIZATION OF CYLLINDRICAL SHELLS
  - BOSOR4 FOR LINEAR, MODAL AND BUCKLING ANALYSIS OF AXISYMMETRIC SHELLS
  - STAGS, DIAL, SDRC/IDEAS, MSC/NASTRAN AND NEPSAP FOR LINEAR, NONLINEAR, MODAL AND BUCKLING ANALYSIS OF GENERAL STRUCTURES USING FINITE ELEMENT TECHNIQUES
  - CLASSICAL ANALYSIS TECHNIQUES WHERE APPROPRIATE
- ALL ANALYSIS TOOLS HAVE BEEN USED AND VERIFIED ON OTHER LMSC SPACE PROGRAMS
- INERTIAL LOADS USED IN STRESS ANALYSES FROM EM 310A (DYNAMICS AND LOADS FINAL REPORT)
- MARGIN OF SAFETY > 0.0 CRITERIA FOR SUCCESS

  - F_a = MATERIAL ALLOWABLE
  - F.S. = FACTOR OF SAFETY
  - σ_a = CALCULATED STRESS

$$\text{MARGIN OF SAFETY} = \frac{F_a}{\sigma_a * F.S.} - 1$$

STRESS ANALYSIS DOCUMENTATION

ST-6

STANFORD

Lockheed

LMSC P088357

2, 3 MAR 94

- EM310A (P030739) 'INTEGRATED PAYLOAD/SPACECRAFT LAUNCH LOADS', 15 DECEMBER 1993, BY L.SOKOLSKY
- GPB-100108, 'SCIENCE MISSION DEWAR MAIN TANK AFT DOME STRUCTURAL ANALYSIS', BY A.G. VOGEL, 25 JANUARY 1994
- GPB-100126, 'STRESS ANALYSIS OF EFD CRYOPERM 10 PIN JOINT DUE TO SHEAR LOADING', BY A.G. VOGEL, 4 SEPTEMBER 1993
- GPB-100127, 'ADHESIVE-BONDED JOINTS AND THE GPB DEWAR/TANK JOINT', 1 FEBRUARY 1994, BY A.G. VOGEL
- GPB-100128, 'GP-B DEWAR AXIAL-LOK AND AXIAL-LOK COMPONENTS ANALYSIS', 18 OCTOBER 1993, BY A.G. VOGEL
- GPB-100129, 'SCIENCE MISSION DEWAR PROTON SHIELD STRESS ANALYSIS', 20 OCTOBER 1993, BY A.G. VOGEL
- GPB-100130, 'SCIENCE MISSION DEWAR GRAPHITE RING ATTACHMENT FITTINGS BOND ANALYSIS', 1 FEBRUARY 1994, BY A.G. VOGEL
- GPB-100143, 'DEWAR MAIN TANK FRACTURE AND SAFE-LIFE ANALYSIS, 7 FEBRUARY 1994, BY A.G. VOGEL
- P-0889331, 'ANALYSIS OF LOCAL STRESSES OF MAIN TANK PENETRATIONS', 17 NOVEMBER 1993, BY L.W. WANG
- GPB-100135, 'STRESS ANALYSIS OF PENETRATIONS', 4 FEBRUARY 1994, BY L.W. WANG
- GPB-100140, 'STRESS ANALYSIS OF BAFFLE PLATES', 5 FEBRUARY 1994, BY L.W. WANG
- GPB-100144, 'STRESS ANALYSIS OF FLEXURE', 8 FEBRUARY 1994, BY L.W. WANG
- GPB-100146, 'STRESS ANALYSIS OF THE ASSEMBLY STAND', 9 FEBRUARY 1994, BY L.W. WANG
- GPB-100156, 'STRESSES CALCULATED IN GP-B VAPOR-COOLED SHIELDS', 20 JANUARY 1994, BY S. McHUGH
- GPB-100157, 'BUCKLING OF GP-B COMPOSITE NECK TUBE, VAPOR COOLED SHIELDS, AND PODS', 21 JANUARY 1994, BY S. McHUGH
- GPB-100158, 'STRESS AND BUCKLING ANALYSIS OF THE SMD GUARD TANK', 17 FEBRUARY 1994, BY N.D. NGUYEN AND L. SOKOLSKY
- GPB-100159, 'STRESS ANALYSIS OF THE SMD SFHe TANK FORWARD DOME', 17 FEBRUARY 1994, BY N.D. NGUYEN
- GPB-100160, 'STRESS ANALYSIS OF THE SMD STAR TRACKER MOUNTING PEDESTAL', 17 FEBRUARY 1994, BY N.D. NGUYEN
- GPB-100161, 'STRESS ANALYSIS OF THE SMD AFT PODS TANK MOUNTING BRACKET, 17 FEBRUARY 1994, BY L. SOKOLSKY

MATERIAL PROPERTIES

MATERIAL	TEMPER CONDITION	THICKNESS (INCHES)	WELDMENT OR FORGING ORIENTATION	MODULUS OF ELASTICITY (MSI)	POISSON'S RATIO μ	F_{tu} (KSI)	F_{ty} (KSI)	F_{su} (KSI)
AL 2219	T851/T852	<4.0	LONG	10.5	.33	62	50	37
AL 2219	T851/T852	"	LONG TRANS	"	"	62	49	36
AL 2219	T851/T852	"	SHORT TRANS	"	"	60	46	32
AL 2219	AS-WELDED MECHANIZED WELDMENT	<0.5	TRANS	10.5	.33	27	N/A	19
AL 6063	T651/T652	<6.0	LONG	10.0	.33	30	25	19
AL 6063	T651/T652	"	LONG TRANS	"	"	29	24	19
AL 6063	T651/T652	"	SHORT TRANS	"	"	28	23	19
AL 6063	T6511	<2.0	LONG	10.0	.33	30	25	19
AL 6063	POST-WELD AGED MECHANIZED WELDMENT	<.5	TRANS	10.0	"	24	N/A	16
BE/CU-165 (C17000)	H	<1.0	LONG	19	.30	90	75	54
BE/CU-165 (C17000)	H	>1.0	LONG	19	.30	85	75	51
AL 1100	H14	ALL	LONG	10.0	.33	18	17	9
TI-CU	1/4 HT	ALL	LONG	18.0	.30	80	100	N/A

SFHe TANK STRESS ANALYSIS

- FORWARD DOME
  - WAFFLED CONSTRUCTION FOR STIFFNESS (DRIVES UP FIRST AXIAL MODAL FREQUENCY)
  - FINITE ELEMENT MODEL WITH PENETRATION DETAILS FOR STRESS
  - BOSOR4 MODEL FOR BUCKLING
- RIBBED CYLINDER MODELLED USING BOSOR4
- LOWER DOME
  - WAFFLED FOR WEIGHT SAVINGS
  - FINITE ELEMENT MODEL FOR STRESS
  - BOSOR4 MODEL FOR BUCKLING
  - DETAILED FINITE ELEMENT MODEL FOR LOCAL PODS STRESS
- PODS BRACKETS
- WELL
  - MONOCOQUE CONSTRUCTION
  - BOSOR4 MODEL FOR STRESS AND BUCKLING

SFHe TANK STRESS ANALYSIS (CONTINUED)

- AXIAL LOK
  - MAJOR LOAD IS STA 200 CLAMPING LOAD
  - SCALED FLICOMP PDR ANALYSIS FOR NEW LOADS
- TANK-TO-WELL BOND JOINT
  - ORIGINALLY DESIGNED AS WELD
  - CHEMTRONICS PREFERRED BOND (LESS RISK)
  - JOINT OPTIMIZED TO REDUCE PEEL STRESSES
- CRYOPERM SHIELD
  - LARGEST LOADS ARE ON RESTRAINING PIN AT BASE OF TANK
  - STRESSES MUST BE KEPT BELOW YIELD TO PRECLUDE LOSS OF SHIELDING FROM WORK HARDENING
- PROTON SHIELD
  - LOADED INERTIALLY FROM WEIGHT OF SHIELDING MATERIAL AROUND GYRO AREA

SFHe TANK GEOMETRY

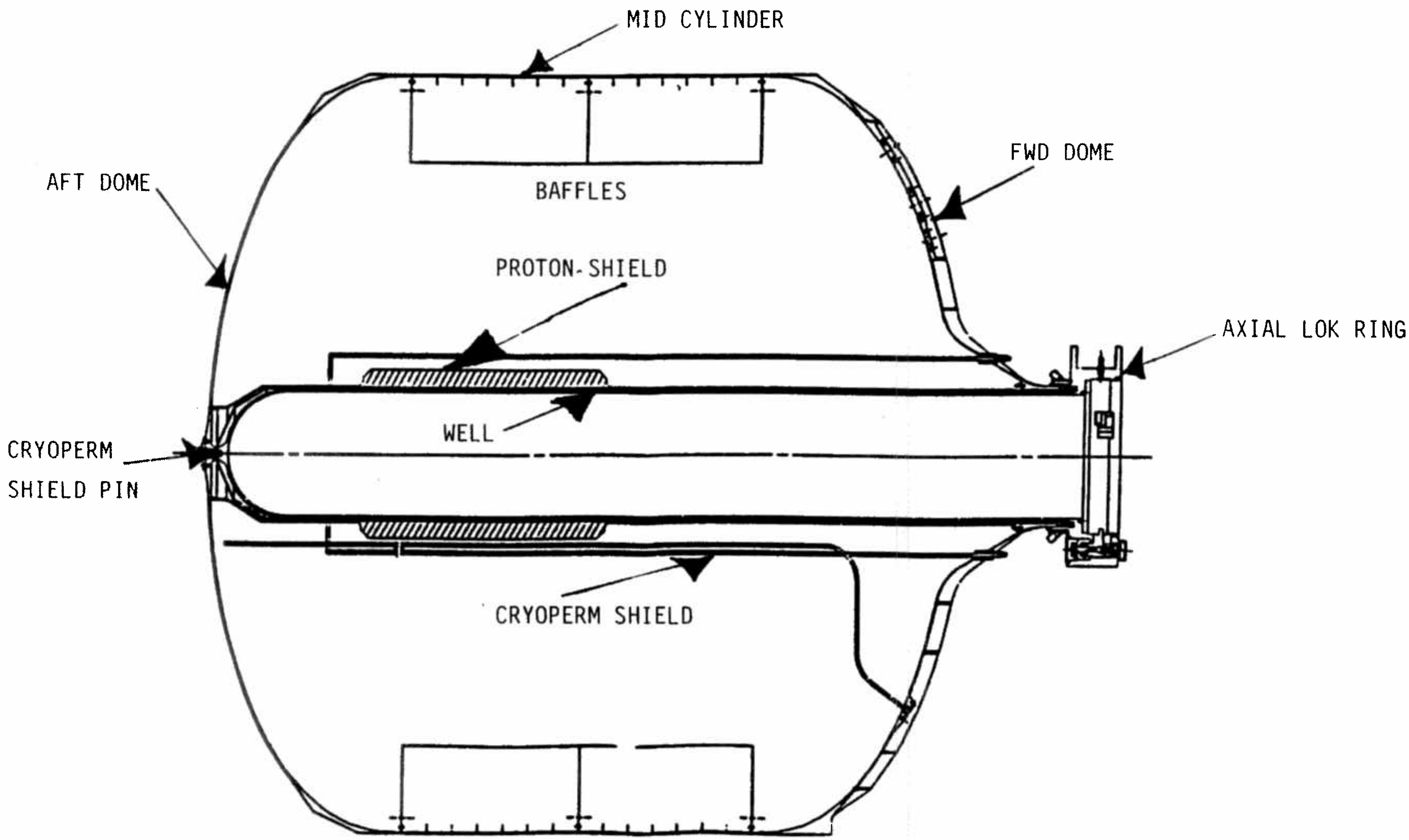
ST-10

STANFORD

Lockheed

LMSC P088357

2, 3 MAR 94



TANK STRESS ANALYSIS RESULTS: MARGINS OF SAFETY

- FORWARD DOME
  - BUCKLING MARGINS (KNOCKDOWN FACTOR = 0.67)
    - » INTERNAL PRESSURE M.S. = +4.04
    - » EXTERNAL PRESSIRE M.S. = +0.28
  - STRESS MARGINS
    - » SHELL ULTIMATE M.S. = +0.02
    - » WELD AREA ULTIMATE M.S. = +0.09
    - » RINGS ULTIMATE M.S. = +0.13
    - » STRINGERS ULTIMATE M.S. = +0.02

TANK MARGINS OF SAFETY (CONTINUED)

- AFT DOME
  - BUCKLING M.S. = +0.21 ULTIMATE (KNOCKDOWN FACTOR = 0.67)
  - STRESS MARGINS
    - » SHELL ULTIMATE M.S. = +0.01
- WELD AREAS AREAS ULTIMATE M.S = +0.02
- AFT PODS MOUNTING BRACKET
  - STRESS YIELD M.S. = +0.10
  - STRESS ULTIMATE M.S. = +0.05
- CYLINDER
  - BUCKLING M.S. = +0.23 (KNOCKDOWN FACTOR = 0.67)
  - STRESS M.S. = +0.13
- WELL
  - STRESS ULTIMATE M.S. HIGH
  - BUCKLING M.S. > +1.01

TANK FRACTURE/SAFE LIFE ANALYSIS

- ANALYSIS PERFORMED IN FLAGRO
- ALLOWABLE FLAWS
  - MAX ALLOWABLE FLAW SIZE IS 1.14 MM (0.045 IN)
  - INSPECT BY DYE PENETRANT, X-RAY OR EDDY CURRENT NDE
- SAFE LIFE OF 283 LIFETIMES (REQUIREMENT IS 4)
- ANALYSIS SHOWS THAT DESIGN IS LEAK-BEFORE-BURST

ST-14

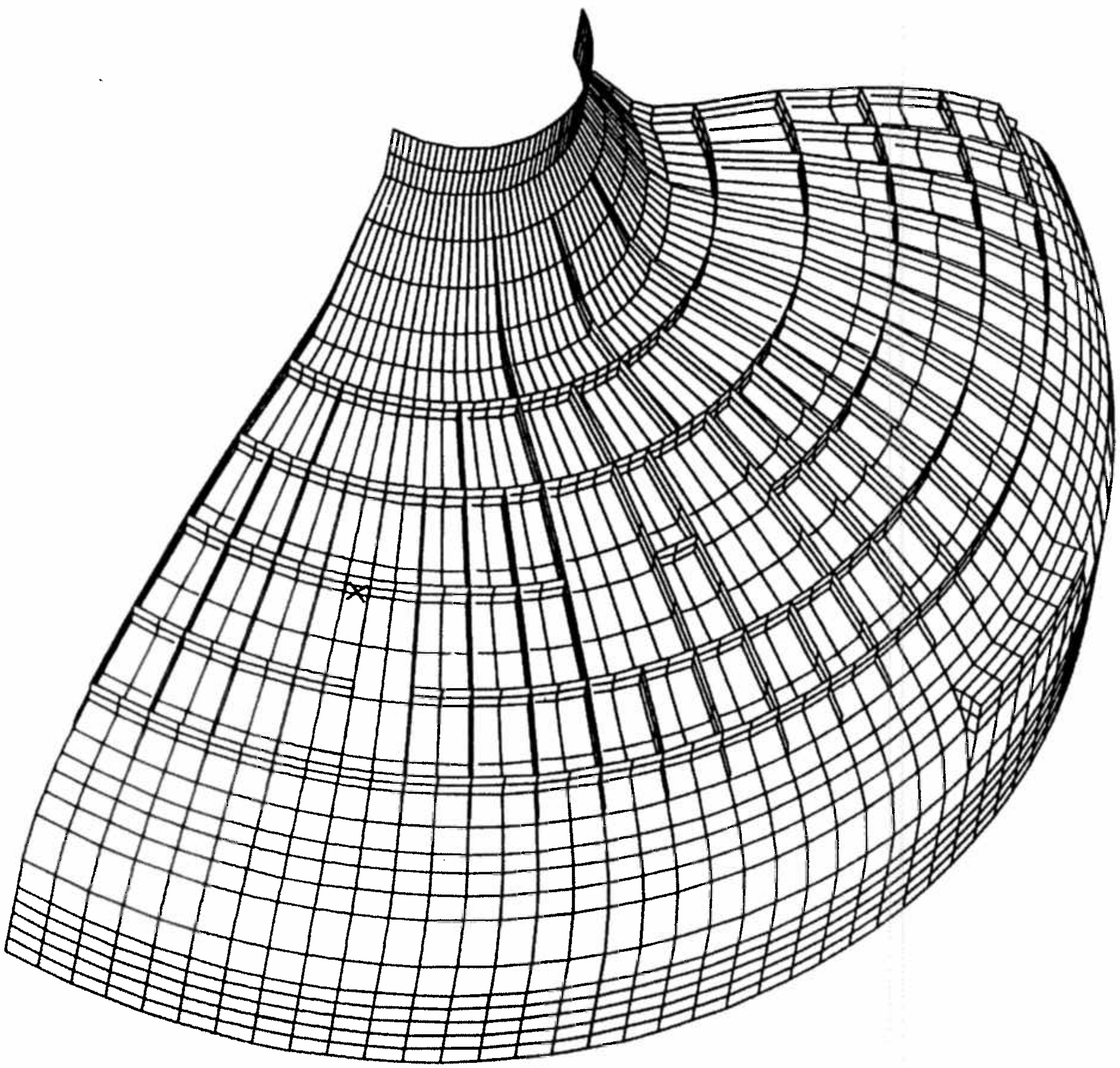
TANK FORWARD DOME FINITE ELEMENT MODEL

STANFORD

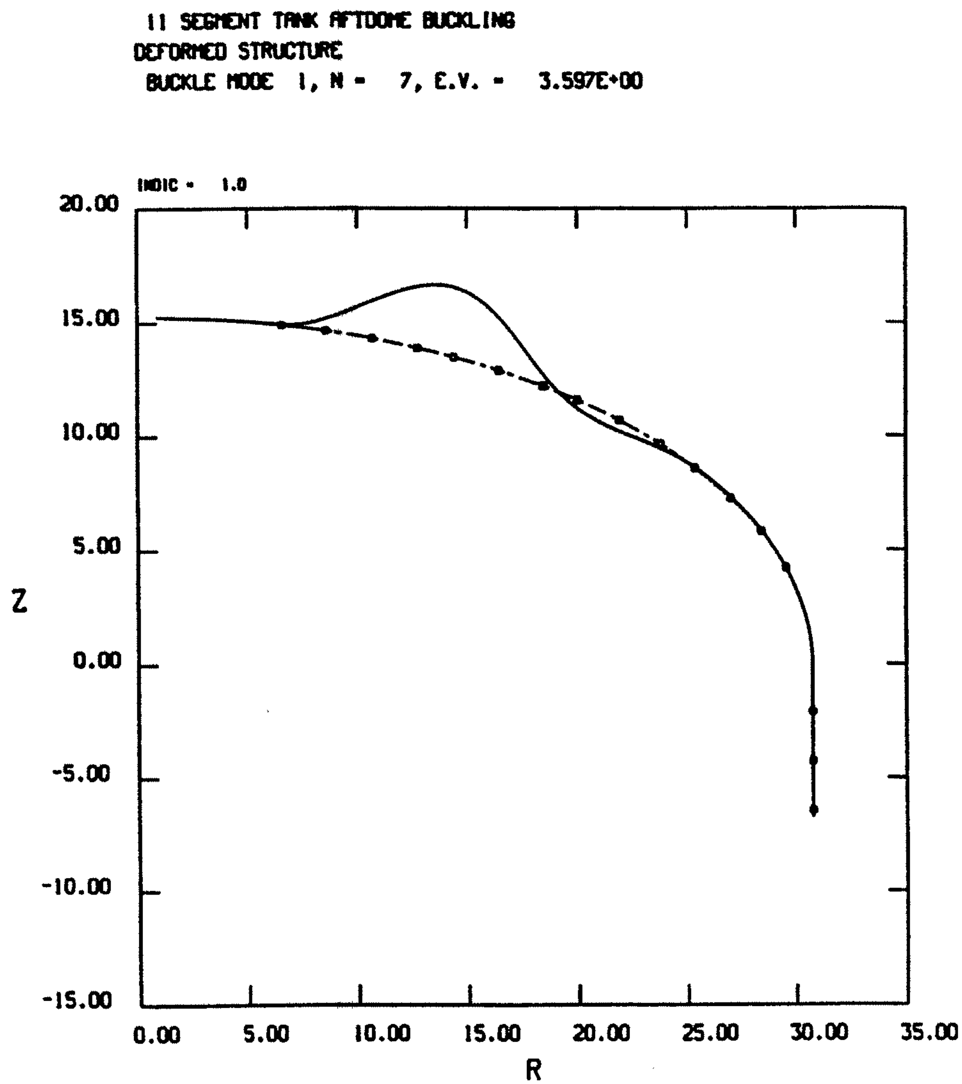
Lockheed

LMSC P088357

2, 3 MAR 94



TANK AFT DOME BUCKLED SHAPE



ST-16

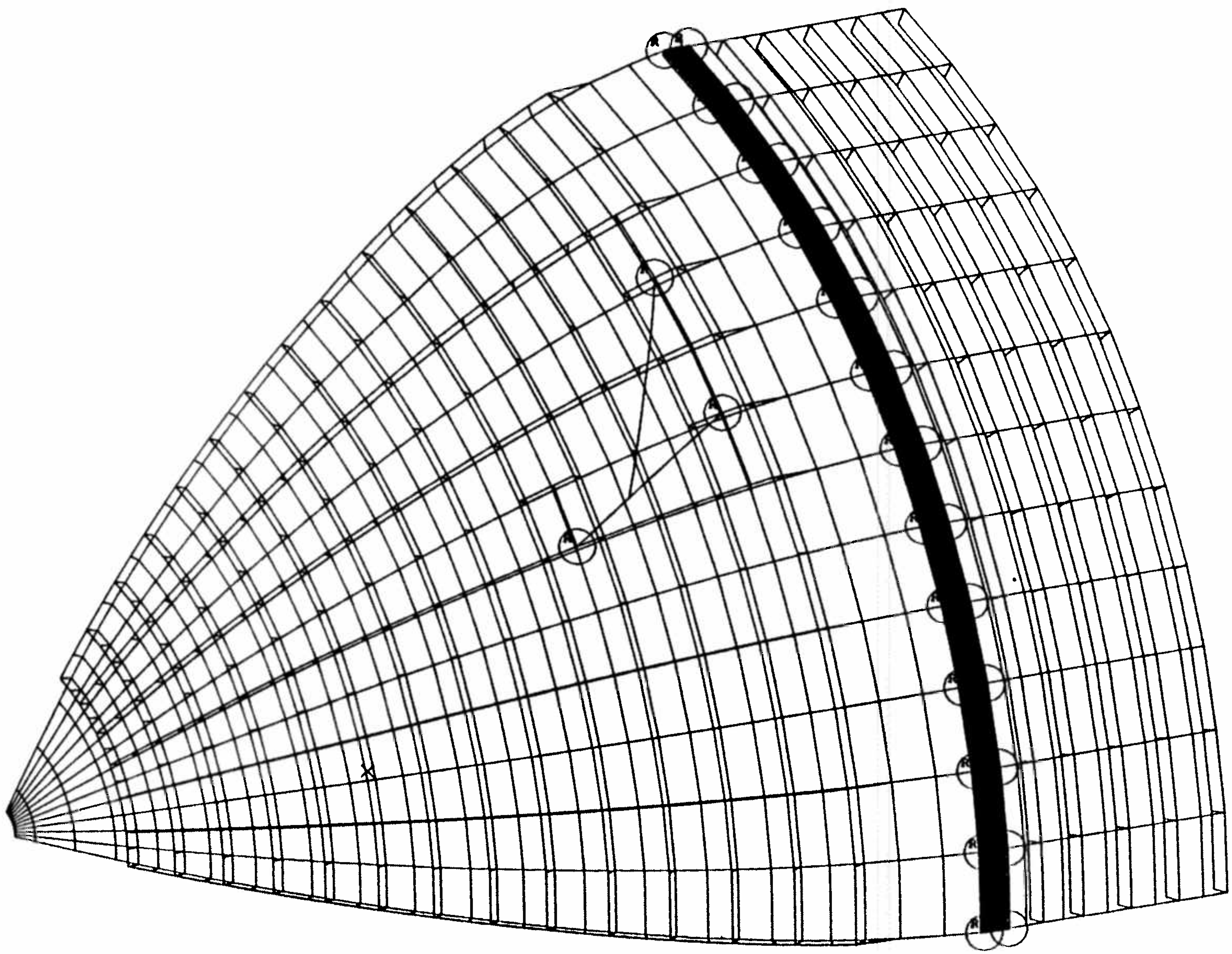
TANK LOWER DOME FINITE ELEMENT MODEL

STANFORD

Lockheed

LMSC P088357

2, 3 MAR 94



AXIAL LOK RING STRESS ANALYSIS

- RESULTS SCALED FROM FLICOMP PDR FOR SMD INERTIAL AND CLAMPING LOADS
- FINITE ELEMENT MODEL MADE FOR DOG-EAR CLAMP (NEGATIVE MARGIN FOR FLICOMP ANALYSIS)
- MARGINS OF SAFETY:
  - INTERNAL PRESSURE (ULTIMATE): +8.90
  - DOG CLAMPING ON RING (ULTIMATE): +0.95
  - LATERAL ACCELERATION (ULTIMATE): +1.73
  - AXIAL ACCELERATION (ULTIMATE): HIGH
  - DOG-EAR CLAMP
    - » YIELD +2.12
    - » ULTIMATE +2.26
  - THREAD RETAINER (ULTIMATE): +4.18
  - SPECIAL SCREW
    - » TENSILE YIELD: +0.67
    - » SHEAR ULTIMATE: +1.56
  - AXIAL LOK PLUG (ULTIMATE): HIGH
  - BALL LOCK CONE (YIELD): +0.13

PROTON SHIELD STRESS ANALYSIS

- ANALYSIS MODEL
  - MODELLED IN BOSOR4
  - SHIELD MATERIAL IS 6063-T6
  - BOUNDARY CONDITIONS
    - » FIXED AT STA 196.67 WHERE BOLTED TO TANK
    - » RADIAL RESTRAINT AT STA 125.61 AT AFT END OF TANK
  - INERTIALLY LOADED DUE TO WEIGHTOF SHIELDING MATERIAL
- STRESS RESULTS
  - MAXIMUM STRESS = 2.92 MPa (4240 PSI)
  - M.S. ULTIMATE = +4.50
  - M.S. YIELD = +4.85
- DISPLACEMENT RESULTS
  - RADIAL (INWARD/OUTWARD) DISPLACEMENT = 0.17 MM (0.0066 IN)
  - AXIAL (LENGTH) DISPLACEMENT = .061 MM (0.0024 IN)
  - CONCLUSION: WILL NOT STRIKE CRYOPERM SHIELD DURING LAUNCH

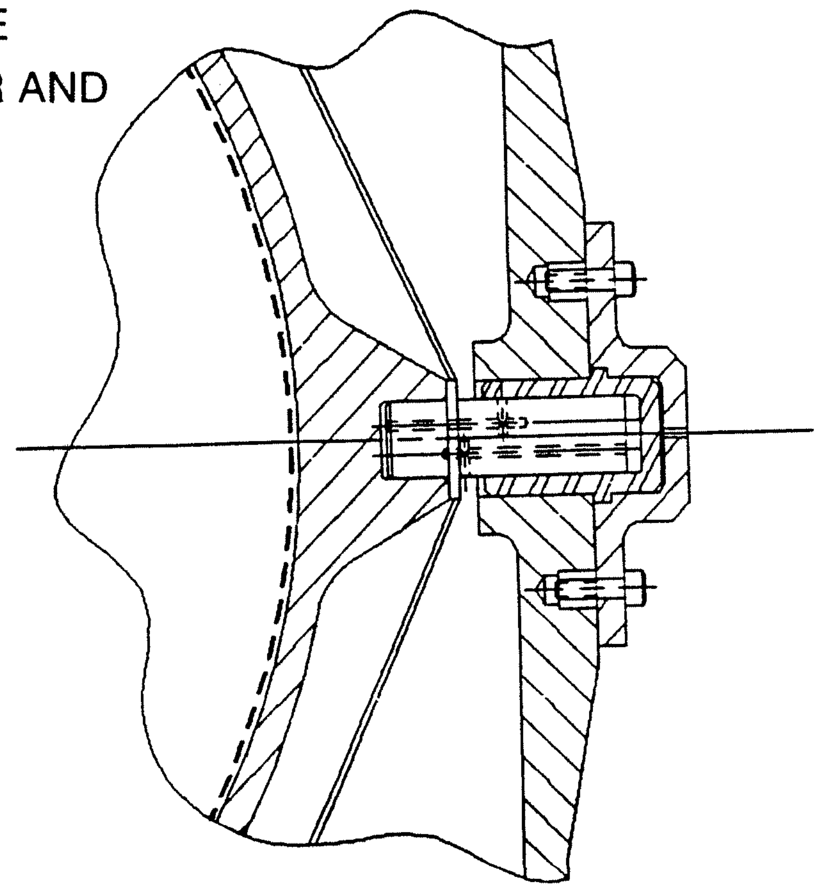
DEWAR/TANK BONDED JOINT STRESS ANALYSIS

- ANALYSIS PERFORMED USING THE NEPSAP FINITE ELEMENT CODE
  - HAS JOINT ELEMENT IN ITS DATABASE
  - PRODUCES SHEAR AND PEEL STRESSES
- JOINT DESIGN MODIFIED TO REDUCE STRESS IN THE ADHESIVE
  - SHEAR
    - » MAXIMUM SHEAR STRESS =6.31 MPa (915 PSI)
    - » ULTIMATE M.S. = +0.01
  - PEEL
    - » MAXIMUM PEEL RESULTANT = 1.2 N/MM (7.0 LB/IN)
    - » ULTIMATE M.S. = +0.03

CRYOPERM SHIELD PIN JOINT STRESS ANALYSIS

STANFORD
Lockheed
LMSC P088357
2, 3 MAR 94

- ANALYSIS OF THE CRYOPERM SHIELD WAS PERFORMED USING THE NEPSAP AND BOSOR4 COMPUTER CODES
- GEOMETRY
  - CONNECTS AFT PORTION OF THE DEWAR WELL AND CRYOPERM SHIELD TO MAIN TANK AFT DOME
  - JOINT DESIGNED TO REACT LOADS IN SHEAR AND BENDING ONLY
- DEWAR WELL STRESS RESULTS
  - MAXIMUM STRESS = 120.07 MPa (17,415 PSI)
    - » ULTIMATE M.S. = +0.34
    - » YIELD M.S = +0.42
- CRYOPERM SHIELD STRESS RESULTS
  - MAXIMUM STRESS =50.25 MPa (7288 PSI)
    - » ULTIMATE M.S. > 0.99
    - » YIELD M.S. = +1.39

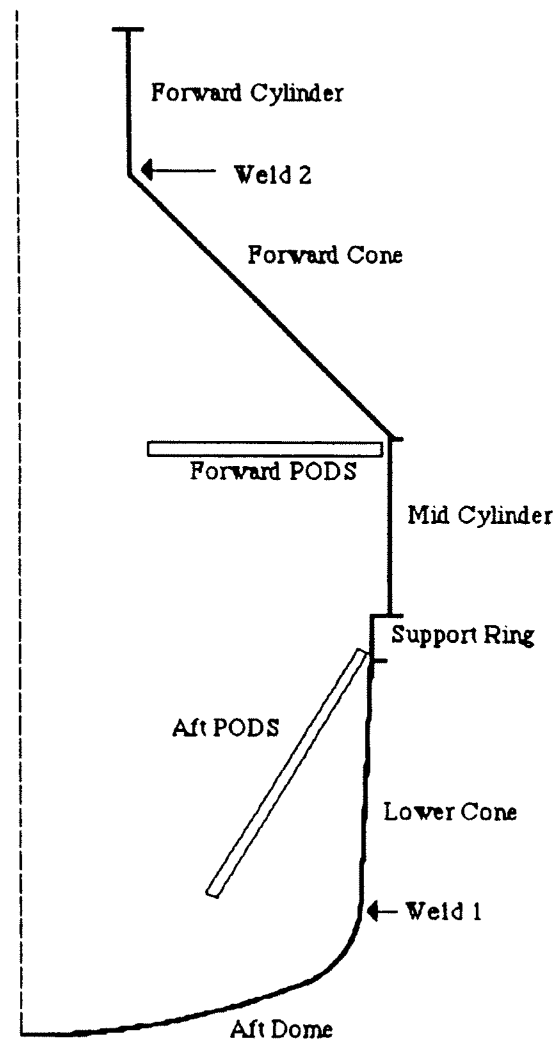


SMD VACUUM SHELL STRESS ANALYSIS

- THE SMD VACUUM SHELL MUST CARRY THE PRESSURE AND ACCELERATION LOADS FROM THE EXPERIMENT
- ALL SHELLS WERE ANALYZED FOR STRESS AND BUCKLING USING BOSOR4
- SEALS AND MAIN SUPPORT RING WERE ANALYZED USING A DIAL FINITE ELEMENT MODEL
- AFT DOME ANALYZED WITH DIAL FINITE ELEMENT MODEL BECAUSE OF POCKETED CONSTRUCTION FOR WEIGHT SAVINGS
- MATERIALS CHANGED FROM 8090 TO 2219 SINCE PDR

VACUUM SHELL GEOMETRY

STANFORD
Lockheed
LMSC P088357
2, 3 MAR 94



SMD DEWAR SUPPORT RING LOADS

- SUPPORT RING CARRIES HIGH POINT LOADS FROM THE TRUNNIONS AND THE AFT PODS. THE MAIN LOADS CARRIED BY THE SUPPORT RING ARE AS FOLLOWS:
- CASE 1: POD LOADS
  1091 KG (2400 LB) X 6.3 G AXIAL ACCELERATION, CARRIED BY 6 PODS TO LUGS ON SUPPORT RING
- CASE 2: TRUNNION LOADS
  F_z = 58240 N (13000 Lb)
  F_θ = 111200 N (25000 Lb)
  M_z = 8814 N-M (78000 in-lb)
  M_θ = 2825 M-M (25000 in-lb)
- HELICOFLEX DELTA SEAL LOAD 140.1 N/MM (800 LB/IN)

SMD VACUUM SHELL ANALYSIS: INTERNAL PRESSURE STRESS RESULTS

- STRESSES AND MARGINS OF SAFETY DUE TO INTERNAL PRESSURES. TABLE GIVES SHELL CAPABILITIES. ALL MARGINS ARE POSITIVE

Region	DESIGN CAPABILITY (PSI)	ULTIMATE CAPABILITY (PSI)	MS
Aft Dome	12.50	50.00	0.20
Lower Cone	2.96	11.84	4.07
Support Ring	1.05	4.20	9.00
Mid Cylinder	3.52	14.08	3.26
Forward Cone	9.04	36.16	0.66
Forward Cylinder	>1.76	>7.04	>7.52
Weld 1	1.20	4.80	4.63
Weld 2	0.80	3.20	7.44

SMD VACUUM SHELL ANALYSIS: EXTERNAL PRESSURE BUCKLING RESULTS

- THE VACUUM SHELL MUST BE CAPABLE OF CARRYING AN EXTERNAL PRESSURE OF 0.10 MPa (15 PSI) WITH A SAFETY FACTOR OF 2. USING A KNOCKDOWN FACTOR OF 0.67 RESULTS IN A MINIMUM THEORETICAL BUCKLING PRESSURE OF 0.31 MPa (45 PSI). ALL MARGINS ARE POSITIVE

LOCATION	BUCKLING PRESSURE (PSI)
AFT DOME	55.0
LOWER CONE	52.7
MID CYLINDER	53.2
FORWARD CONE	47.6
FORWARD CYLINDER	>48.3

SMD VACUUM SHELL ANALYSIS: AFT DOME PRESSURE STRESSES

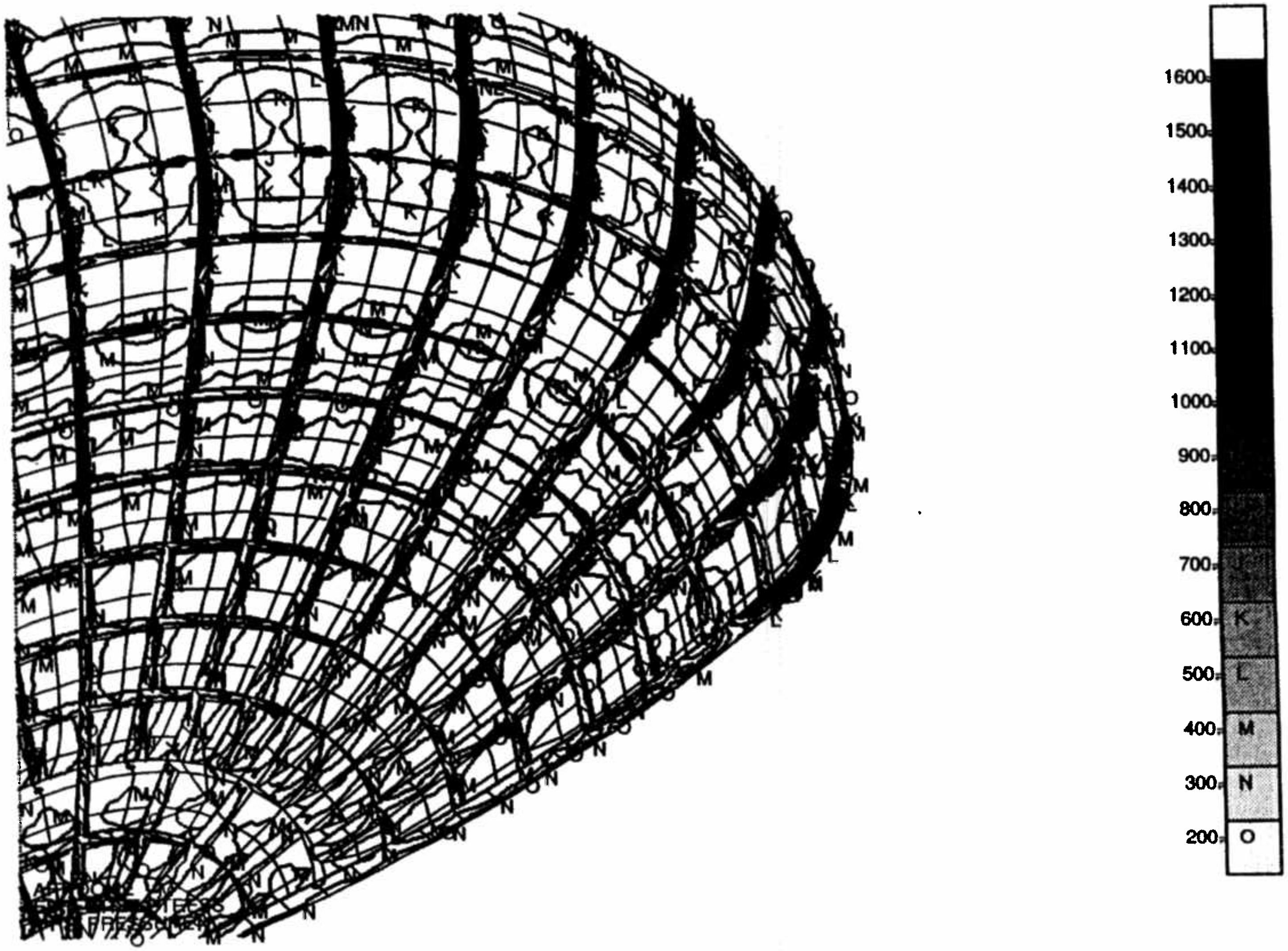
STANFORD

Lockheed

LMSC P088357

ST-26

2, 3 MAR 94



SMD VACUUM SHELL FINAL
SHELL DIMENSIONS

ST-27

STANFORD
Lockheed
LMSC P088357
2, 3 MAR 94

	LOWER CONE	MID CYLINDER	FORWARD CONE	FORWARD CYLINDER
WALL THICKNESS(IN)	0.080	0.080	0.090	0.110
RING HEIGHT (IN)	0.699	0.690	0.630	(MONOCOQUE CONSTRUCTION)
RING THICKNESS (IN)	0.045	0.045	0.050	
RING SPACING (IN)	1.450	1.415	0.760	

AFT DOME

WALL THICKNESS (IN)	0.100
RING HEIGHT (IN)	0.750
RADIAL STIFFENER THICKNESS (IN)	0.052
RADIAL STIFFENER SPACING (DEG)	10
RING THICKNESS (IN)	0.040
RING SPACING (IN)	3.01
OUTER BAY RADIAL STIFFENER THICKNESS (IN)	0.110

DEWAR SUPPORT RING ANALYSIS: STRESS MARGINS OF SAFETY

- THE ONLY SIGNIFICANT ACCELERATION STRESSES ARE IN THE SUPPORT RING, WHERE THE PODS ATTACH AND AT THE TRUNNION PIN.

REGION	POD LOAD (KSI)	M.S.	PIN LOAD (KSI)	M.S.
POD LUG	7.8	+6.94	7.8	+6.94
PIN SOCKET	-	HIGH	28.0	+1.21
GUSSET	-	HIGH	27.0	+1.30

- RING DEFLECTION BETWEEN BOLTS DUE TO SEALS MUST NOT EXCEED .0015 IN
- 140.1 N/MM (800 LB/IN) MINIMUM LINE LOAD ON SEALS
- RESULTS:

	DEFLECTION (MIL)
RING TO LOWER CONE:	0.0037
RING TO MID CYLINDER:	0.0045

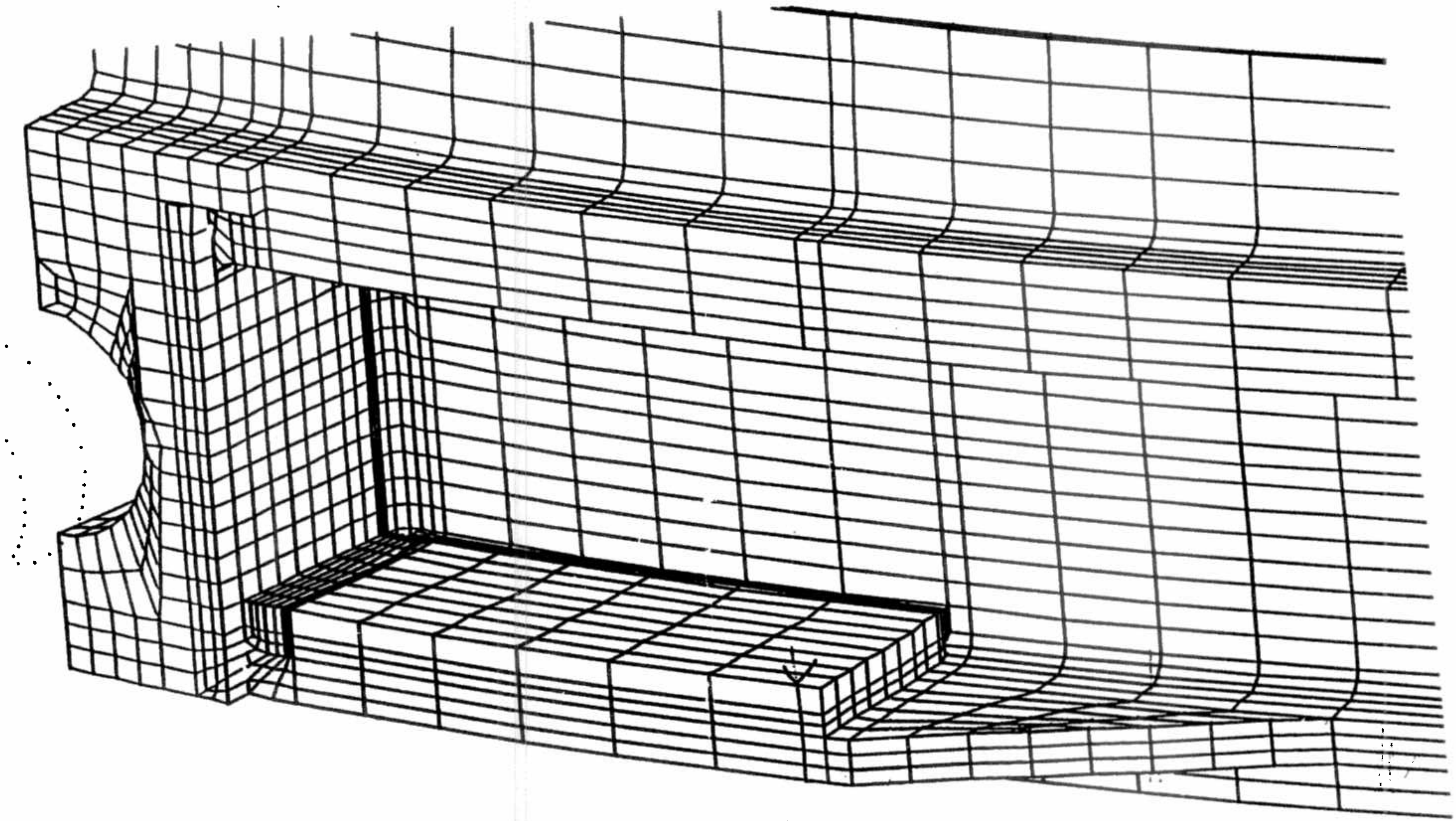
ASSUMES 7117 N (1600 LB) BOLT PRELOAD

- CONCLUSION: SEAL DESIGN IS CONSERVATIVE

DEWAR SUPPORT RING FINITE ELEMENT MODEL

STANFORD
Lockheed

LMSC P088357
2, 3 MAR 94



ELECTRONICS BOX LOADS

- APPROX 136 KG (300) LB OF ELECTRONICS BOXES ARE SUPPORTED BY THE FORWARD CYLINDER ATTACHMENT RINGS.
- ASSUMING THAT THE MASS IS EVENLY DISTRIBUTED ABOUT THE CIRCUMRERENCE AND THE ACCELERATION IS 6.3 G AXIAL AND 6.6 G LATERAL:
- STRESS = 20.6 MPa (3 KSI) IN FORWARD CYLINDER
- MARGIN OF SAFETY = HIGH
- BUCKLING WAS NOT CONSIDERED IN THIS ANALYSIS. RISK OF REDESIGN IS LOW

SMD VACUUM SHELL FRACTURE AND LEAK-BEFORE BURST ANALYSIS

- THE ONLY SIGNIFICANT CYCLIC LOADING IS IN THE SUPPORT RING NEAR THE TRUNNION PIN AND POD LUG.
- USE THE GODDARD LAUNCH LOAD SPECTRUM
- MINIMUM OF 4 LIFETIMES IS REQUIRED
- NASA/FLAGRO USED FOR COMPUTATIONS
- THIS ANALYSIS VERIFIES THAT THE VACUUM SHELL IS LEAK-BEFORE BURST (CRACK PENETRATES VACUUM SHELL BEFORE RUNAWAY CRACK GROWTH BEGINS)

REGION	CRACK CASE	ai	a/c	LIFETIMES
POD LUG	CC03	0.05	1.0	50
PIN SOCKET	CC02	0.05	1.0	6
RING GUSSET	CC01	0.10	1.0	>100

SMD VACUUM SHELL STRESSES DUE TO INTEGRATED PAYLOAD HANDLING LOADS

STANFORD
Lockheed
LMSC P088357
2, 3 MAR 94

- INTEGRATED PAYLOAD WILL BE LIFTED BY REMOVING THREE BOLTS AT THE TOP OF THE MID CYLINDER AND INSERTING HOIST RINGS
- STRESS ANALYSIS OF MID-CYLINDER UNDER LIFTING LOADS IN PROGRESS
- LIFTING LOAD IS 1.5 G WITH FULL DEWAR WEIGHT (2000 DG/4400 LB)
- FACTOR OF SAFETY FOR DEWAR HARDWARE IS 1.5. FACTOR OF SAFETY FOR EXTERNAL LIFTING HARDWARE IS 5.0
- INITIAL ANALYSIS SHOWS THAT LIFTING STRESSES ARE LOW. EXACT MARGIN OF SAFETY TBD

GRAPHITE RING ANALYSIS

- ANALYSIS
  - THORNEL P-120S 2K HIGH MODULUS, HIGH STRENGTH FIBERS USED IN RING CONSTRUCTION, WITH FIBERS ORIENTED IN HOOP DIRECTION
  - DIAL FINITE ELEMENT MODEL CONSTRUCTED
  - RULE-OF-MIXTURES AND ASSUMPTION OF TRANSVERSE ISOTROPY USED TO DERIVE APPROXIMATE ELASTIC PROPERTIES
  - PODS LOADS DERIVED WITH DYNAMICS MODEL, THEN APPLIED TO RING
- RESULTS

STRESS COMPONENT	MAX STRESS (PSI)
SIGX (HOOP)	39500
SIGY (AXIAL)	475
SIGZ (RADIAL)	1510
TAUXY	488
TAUYZ	231
TAUZX	1416

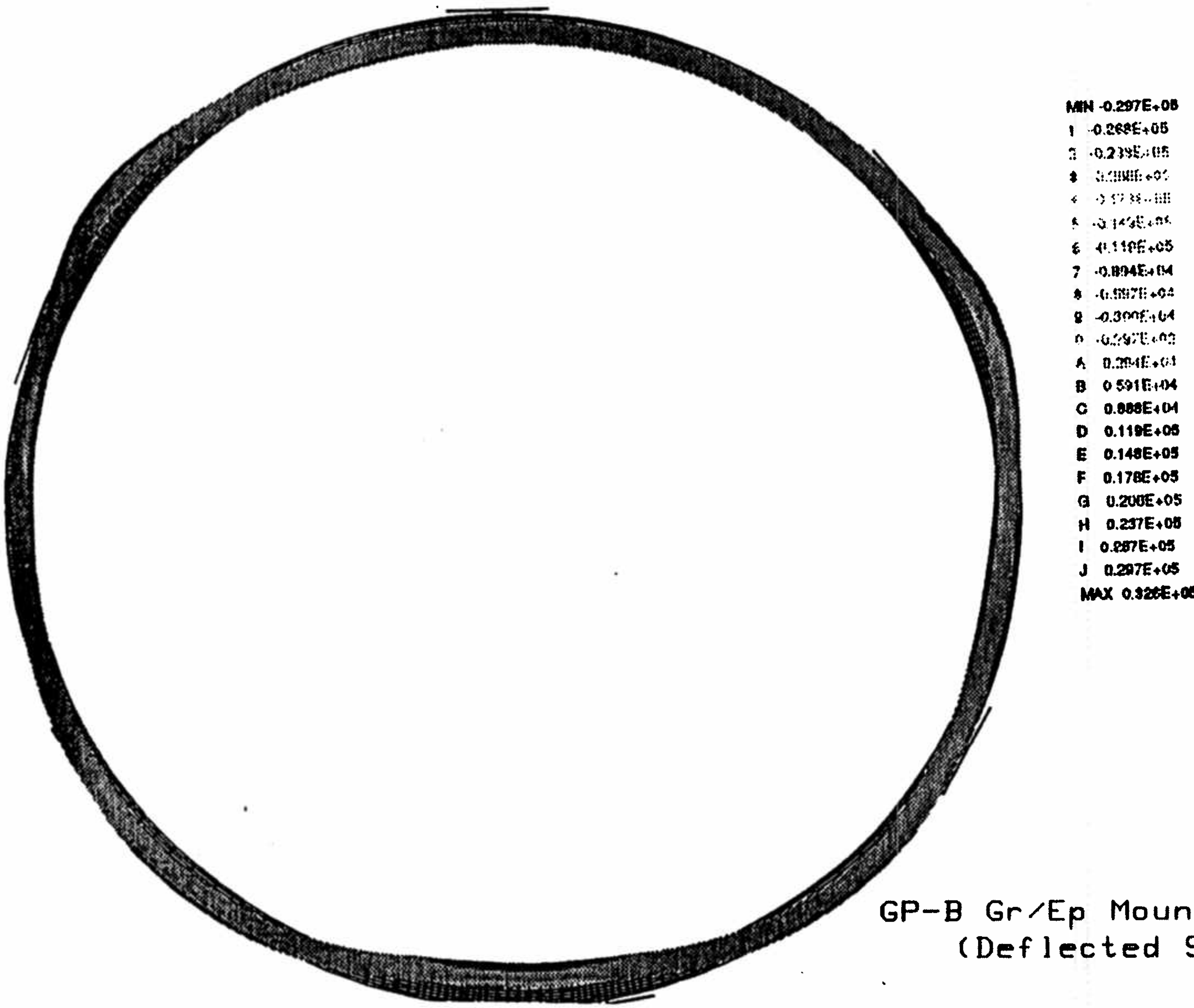
→ WELL BELOW THE ALLOWABLE STRESSES OF TYPICAL Gr/Ep MATERIAL SYSTEMS

- WHILE THE STRESSES FROM THE APPLIED LOADS ARE BELOW TYPICAL ALLOWABLES, MATERIAL TESTING IS REQUIRED TO ESTABLISH FINAL ALLOWABLE STRESSES AND STRAINS

GRAPHITE RING F.E. MODEL

STANFORD
Lockheed
LMSC P088357
2, 3 MAR 94

ST-34



GP-B Gr/Ep Mounting Ring, Hoop Stress
(Deflected Shape is Magnified)

GRAPHITE RING STABILIZER FITTING STRESS ANALYSIS

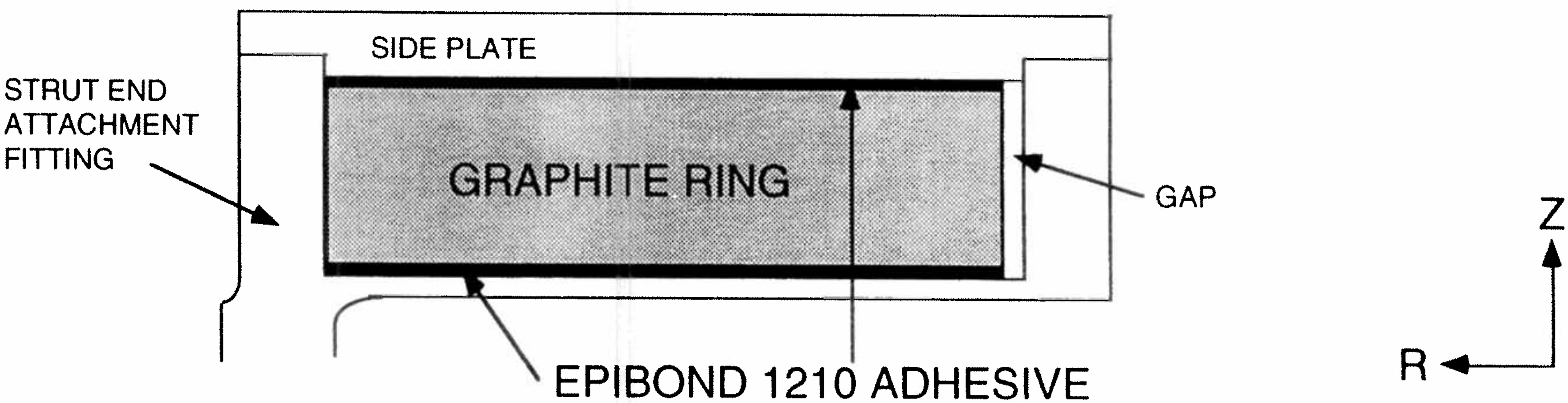
STANFORD
Lockheed

LMSC P088357
2, 3 MAR 94

ANALYSIS PERFORMED USING BOTH THE NEPSAP FINITE ELEMENT CODE & CLASSICAL HAND ANALYSIS

SHEAR STRESS = .724 MPa 105$_{ULT}$ PSI; MS= +7.57

PEEL RESULTANT = 0.01 LB/IN; MS_{ULT} = HIGH



GUARD TANK STRUCTURAL ANALYSIS

- ANALYSIS UPDATED TO REFLECT NEW BURST DISK SETTING
- BOSOR4 USED TO DETERMINE STRESS AND BUCKLING MARGINS FOR:
  - 0.26 MPa (38 PSI) EXTERNAL PRESSURE
  - 1.52 MPa (220 PSI) INTERNAL PRESSURE
  - INERTIAL LOADS
- BOSOR4 ANALYSES
  - 2-D AXISYMMETRIC
  - AL 2219 MATERIAL FOR TANK
  - AL 6063 STRUCTURE FOR SUPPORT STRUCTURE
  - FIXED CIRCUMFERENCE FOR CYLINDRICAL SUPPORT
  - 0.67 BUCKLING KNOCKDOWN FACTOR
- FINITE ELEMENT ANALYSIS
  - FINITE ELEMENT MODEL MADE FOR STRESS AND BUCKLING OF THE ATTACHMENT CONE AND CYLINDER UNDER INERTIAL LOADS
  - 0.67 BUCKLING KNOCKDOWN FACTOR

GUARD TANK FINITE ELEMENT MODEL - CONE BUCKLED SHAPE

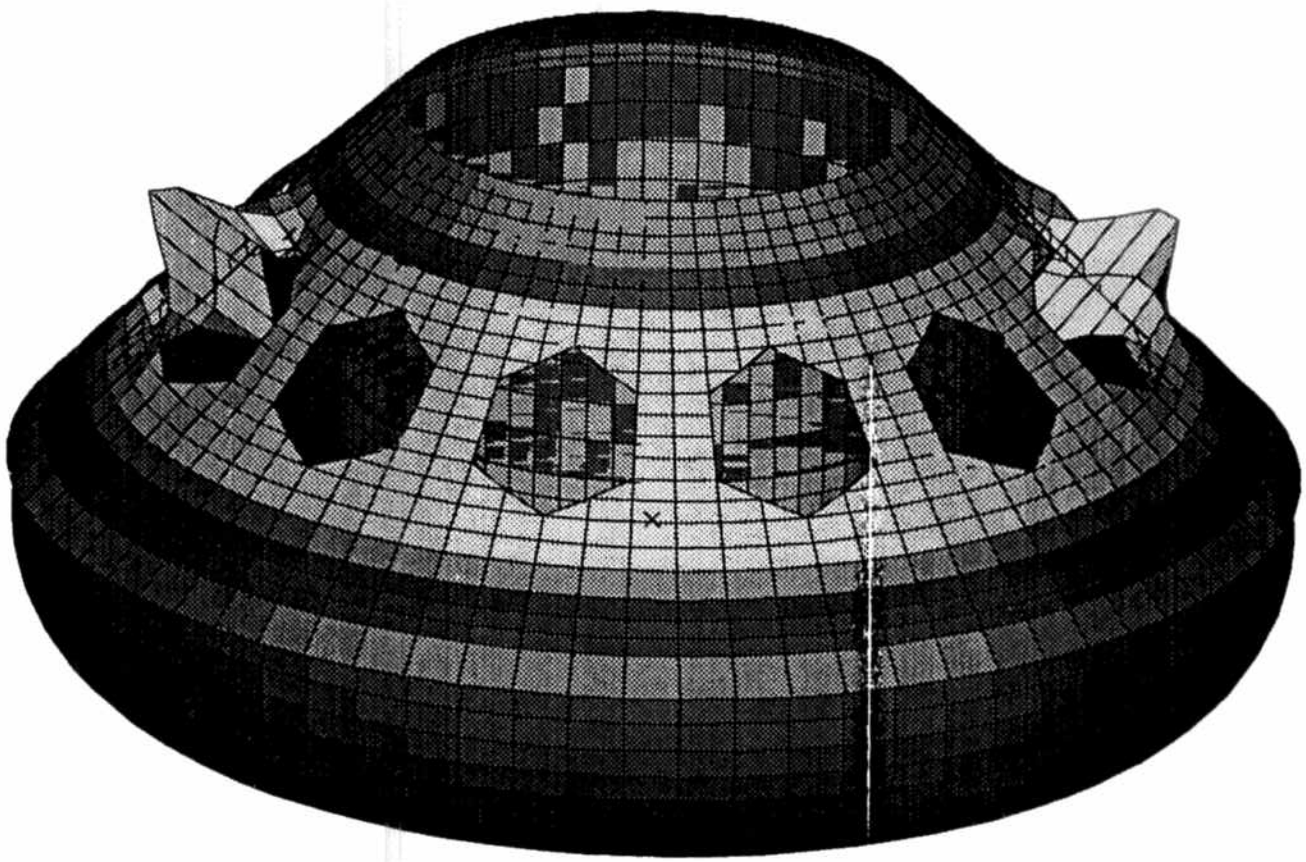
ST-37

STANFORD

Lockheed

LMSC P088357

2, 3 MAR 94

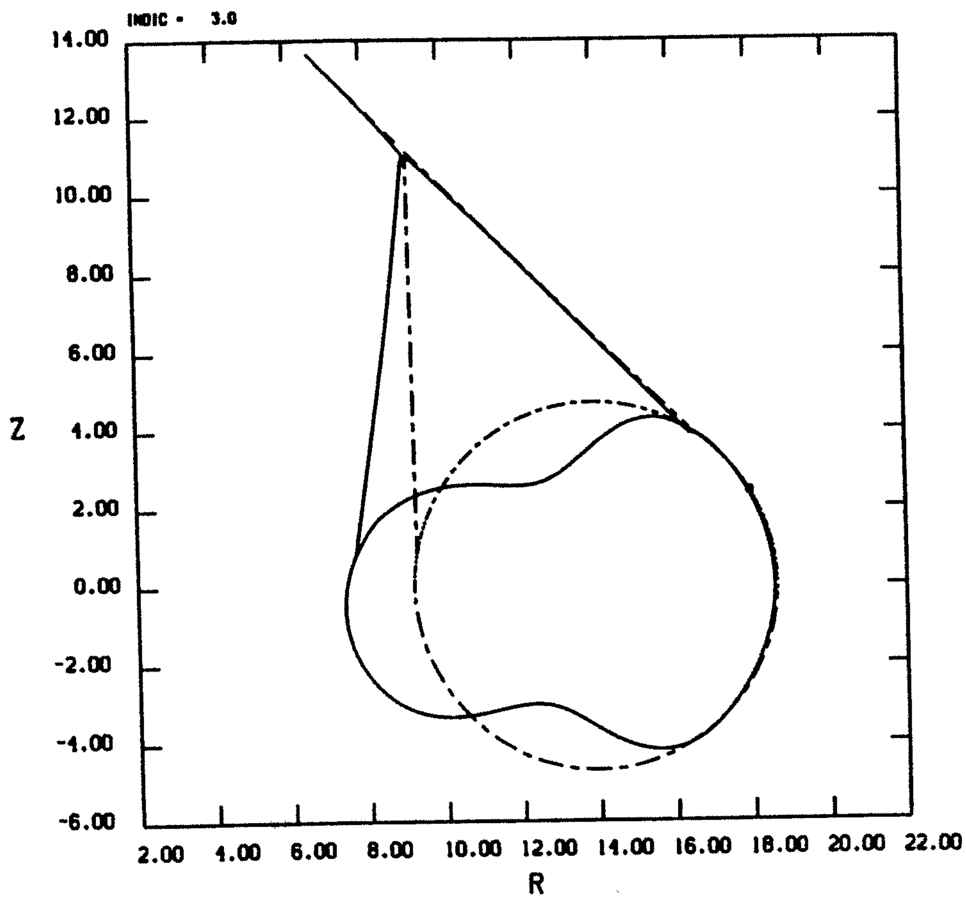


GUARD TANK STRESS ANALYSIS RESULTS: SAFETY MARGINS

- INTERNAL PRESSURE ULTIMATE STRESS M.S. = +1.87
- WELD PRESSURE ULTIMATE STRESS M.S. = +0.65
- EXTERNAL PRESSURE ULTIMATE BUCKLING M.S. = +0.41
- UPPER CONE AND CYLINDER INTERTIAL LOADS
  - ULTIMATE STRESS M.S. = 2.04
  - BUCKLING M.S. = 1.83
    - » ORIGINAL CYLINDER DESIGN SUFFERED FROM PREMATURE BUCKLING
      - LIGHTENING HOLES WERE REMOVED
      - INNER CYLINDER WALL WAS THEN ABLE TO BE THINNED FROM 13.9 MM (0.55 IN) TO 7.6 MM (0.30 IN)

GUARD TANK BUCKLED SHAPE INTERNAL AND EXTERNAL PRESSURE

guard tank, with buckling, external pres. -
DEFORMED STRUCTURE
BUCKLE MODE 1, N = 2, E.V. = 2.159E+00



PODS OPTIMIZATION ANALYSIS

- *DEWAR* COMPUTER CODE FOR OPTIMAL DESIGN OF DEWAR SUPPORT SYSTEMS USED
  - MINIMIZES SUPPORT SYSTEM THERMAL CONDUCTANCE, SUBJECT TO STRUCTURAL CONSTRAINTS
    - » LAUNCH AND ORBIT FREQUENCIES
    - » STRESS AND STRAIN OF PODS SUPPORT TUBES
    - » SUPPORT SYSTEM CLEARANCE
  - USED TO DEVELOP ORIGINAL SMD DESIGN
  - RECENTLY UPDATED AND VERIFIED AGAINST DETAILED FINITE ELEMENT MODELS
- PODS DESIGN REVISED SINCE PDR TO PREVENT THERMAL SHORTING OF PODS DUE TO VACUUM SHELL COOLING DURING THERMOVAC TESTING OR ON-ORBIT COOLING
- FINAL CONFIGURATION SHOWN BELOW:

TUBE	LOCATION	OD (MM/IN)	THICKNESS PER PLY (MM/IN)	LAYUP (DEG)	ORBIT TUBE LENGTH (MM/IN) 1
LAUNCH	FWD	42.8/1.69	0.229/0.009	[10,-10,-10,10]	---
LAUNCH	AFT	42.8/1.69	0.381/0.015	[10,-10,-10,10]	---
ORBIT	FWD	13.0/0.512	0.127/0.005	[10,-10]	134.6/5.30
ORBIT	AFT	18.0/0.710	0.127/0.005	[10,-10]	76.2/3.00

(1) TOTAL LENGTH, FOLDED TUBE DESIGN

PODS DETAIL STRESS ANALYSIS

- CRITICAL MODES ARE PODS BUCKLING AND BOND STRESSES
  - -- NO ACCOUNT FOR VCS SIDE LOADS IN *DEWAR* OPTIMIZATION ANALYSIS
  - -- BUCKLING AS SHELL STRUCTURE AND AS COLUMN ANALYZED
  - -- STRESS MARGINS FOR FITTINGS HIGH (> 10)

- BOUNDING LOADS USED FOR CONSERVATISM
  - -- MAX. AXIAL LOADS FROM *DEWAR* ANALYSIS +
    MAX. SIDE LOADS FROM VCS STRUCTURAL ANALYSIS

- <u>RESULTS</u>

  -- BUCKLING

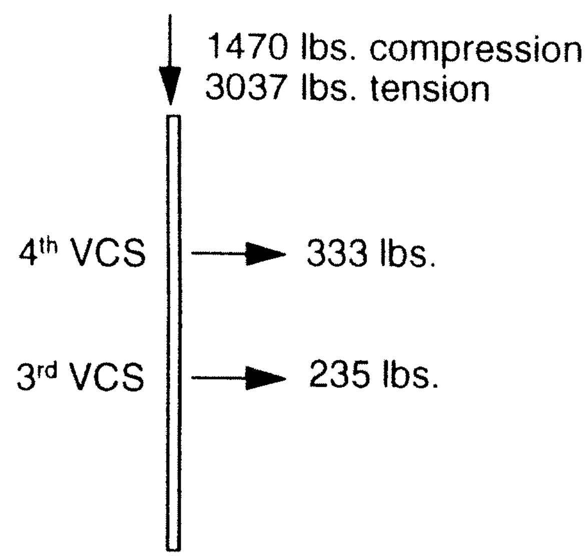
Buckling Type	Theoretical Buckling Load Factor	MARGIN
SHELL	19.4	8.0
COLUMN	8.9	3.2

  -- BOND STRESSES

  Average Bond Shear Stress = 824 psi
  Allowable Average Shear Stress = 1800 psi
  (Based on test data)
  Factor of Safety = 2.0

  $\boxed{\text{MARGIN} = +0.09}$

<u>BOUNDING LOADS</u>



VAPOR COOLED SHIELDS STRUCTURAL ANALYSIS

- 3-D DIAL FINITE ELEMENT ANALYSIS CONTAINS:
  - 4 VAPOR-COOLED SHIELDS + MLI
    - VCS-1: 23 KG (51 LB)
    - VCS-2: 26 KG (58 LB)
    - VCS-3: 27 KG (60 LB)
    - VCS-4: 39 KG (85 LB)
  - GUARD TANK
    - TOROIDAL TANK PLUS LIQUID HELIUM: 17.9 KG (39.4 LB)
  - COMPOSITE NECK TUBE WITH HEX RINGS
  - 6 FWD PODS
  - 6 AFT PODS

VAPOR COOLED SHIELDS STRUCTURAL ANALYSIS (CONT.)

STANFORD
Lockheed
LMSC P088357
2, 3 MAR 94

- CONSTRAINTS
  - NODES AT TOP OF VCS-1 AND VCS-2 EQUIVALENCED TO CNT
  - VCS-3 AND VCS-4 NOT ATTACHED TO CNT
  - INTERSECTION POINTS OF ALL VCS AND FWD PODS: ROTATIONAL DOFS EQUIVALENCED
  - INTERSECTIONAL POINTS OF VCS-1 AND VCS-2 WITH AFT PODS: ROTATIONAL DOFS EQUIVALENCED
  - INTERSECTION POINTS OF VCS-3 AND VCS-4 WITH AFT PODS: RIGIDLY ATTACHED
  - BASE OF CNT FIXED
  - TOP OF CNT: FREE IN AXIAL DIRECTION ONLY
  - ENDS OF PODS CAN ROTATE BUT NOT TRANSLATE

VAPOR COOLED SHIELD MODEL

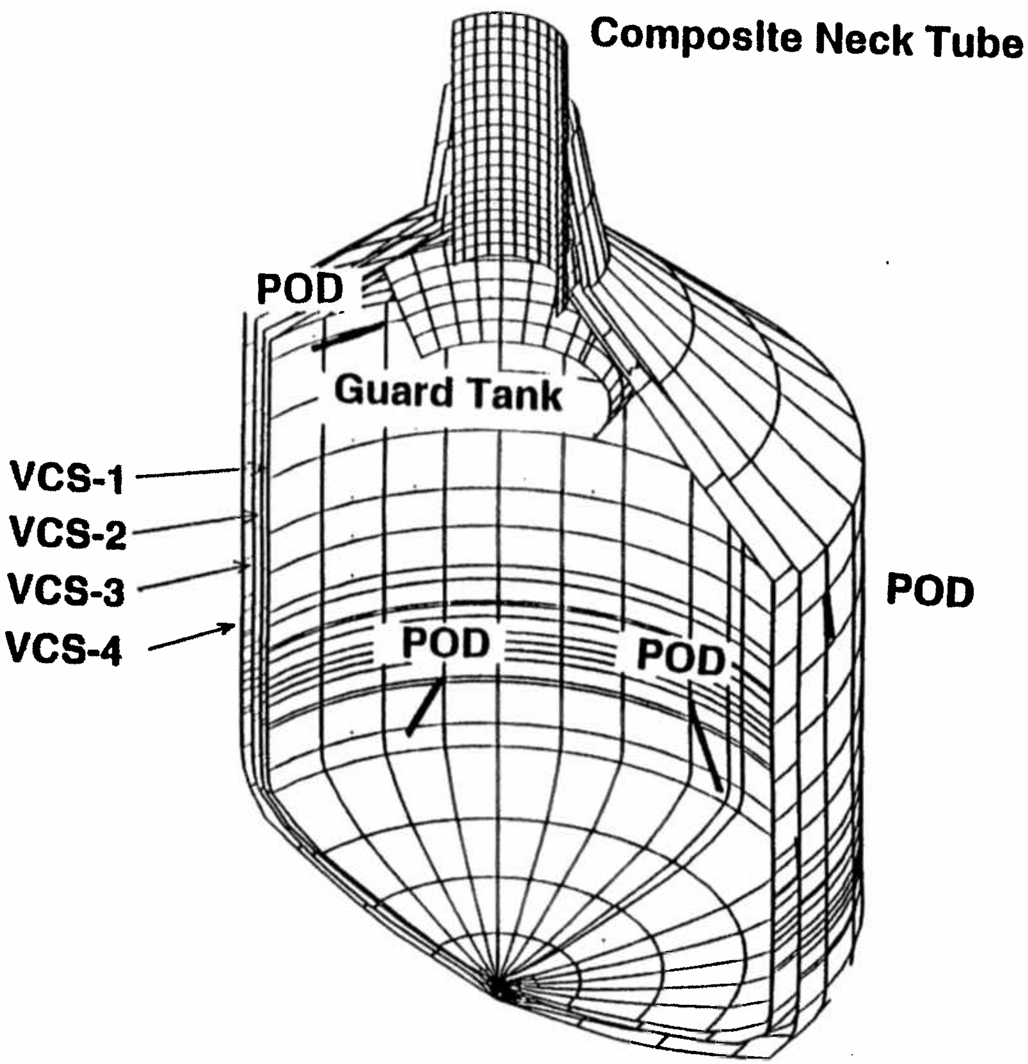
STANFORD

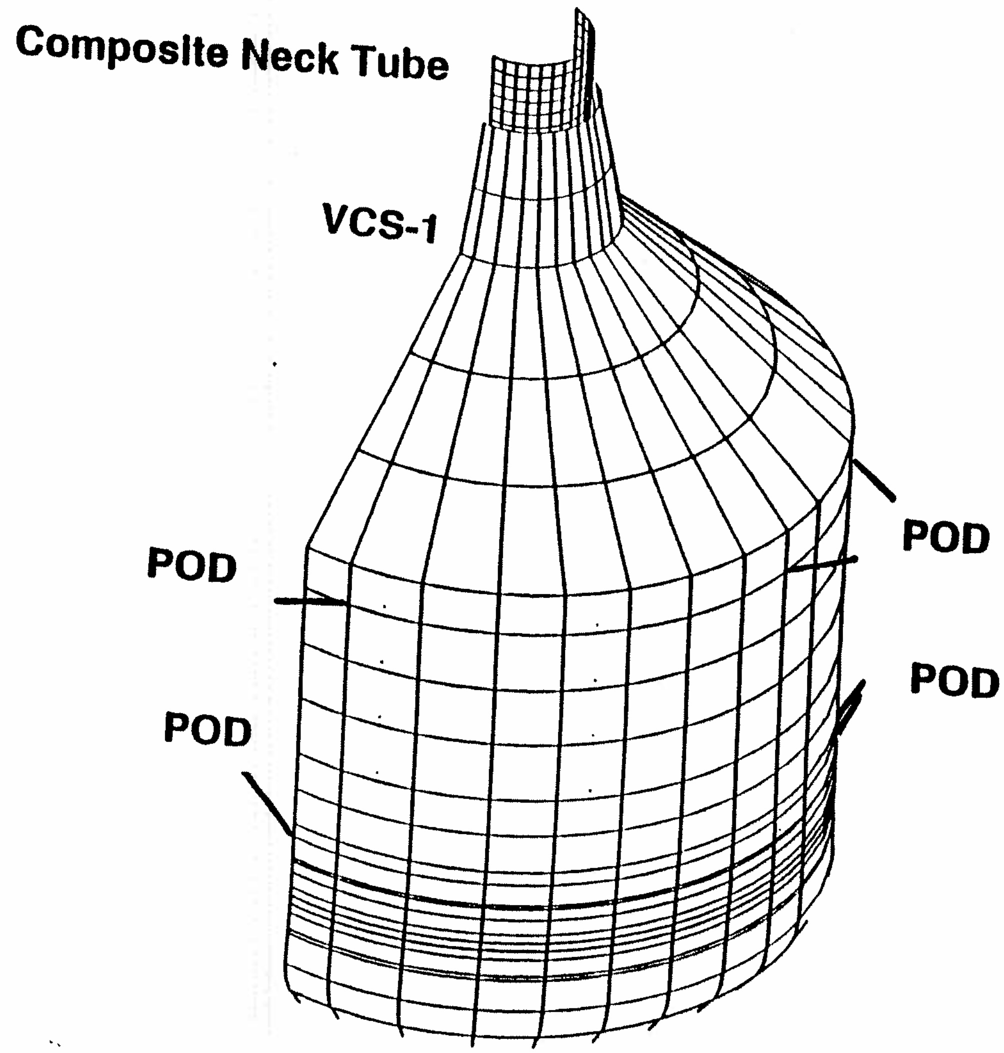
Lockheed

LMSC P088357

ST-44

2, 3 MAR 94





VAPOR COOLED SHIELDS ANALYSIS RESULTS

- SHIELD LOADS ON PODS BELOW:

LOAD DIRECTION	FAZ (LB)	MZZ (IN-LB)	MYY (IN-LB)	TORQUE (IN-LB)	SHEAR-Y (LB)	SHEAR-Z (LB)
LATERAL	258.	241.	660.	11.	15.	39.
AXIAL	98..	212.	177.	4.	10.	11.

- SHIELD STRESS MARGINS OF SAFETY
  - DOMES - M.S. = LARGE
  - HONEYCOMB
    - » ALL CORE MATERIAL MARGINS OF SAFETY ARE LARGE
    - » FACE SHEETS
      - VCS-1 M.S. = +1.62
      - VCS-2 M.S. = -0.27 (LOCAL HIGH STRESS AT TRANSITION ZONE WILL BE ELIMINATED BY DOUBLER
      - VCS-3 M.S. = +0.64
      - VCS-4 M.S. = +0.82
- SHIELD BUCKLING MARGINS OF SAFETY - MINIMUM M.S. = +0.15

ST-46

GRAPHITE RING FLEXURE ANALYSIS

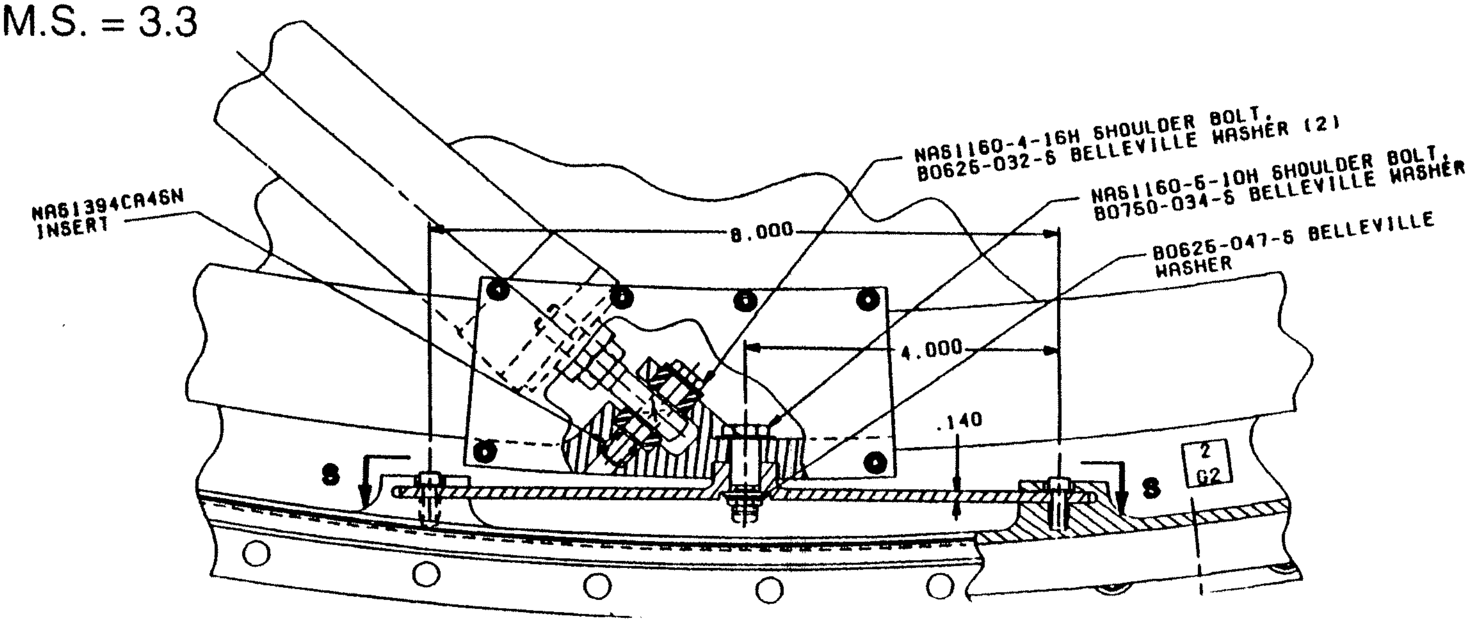
STANFORD

Lockheed

LMSC P088357

2, 3 MAR 94

- FLEXURES DESIGNED TO TRANSFER LOAD FROM GRAPHITE RING TO VACUUM SHELL WHILE ALLOWING RADIAL GROWTH/ SHRINKAGE OF VACUUM SHELL
- LATERAL INERTIAL LOAD APPLIED TO WEIGHT OF HARDWARE SUSPENDED BY FWD PODS
- SIMPLE NASTRAN BEAM MODEL OF PODS AND FLEXURES USED FOR ANALYSIS
  - MAXIMUM RADIAL DISPLACEMENT = 1.7 MM (0.066 IN)
  - ULTIMATE M.S. = 3.3



SLOSH BAFFLE STRESS ANALYSIS

- SLOSH BAFFLES LOADED BY FLUID SLOSHING DURING TRANSPORTATION OF HALF-FULL SFHe TANK (3 G INPUT)
  - FULL RESONANCE OF FLUID ASSUMED
  - AXIAL LOAD =0.47 N/MM (2.67 LB/IN)
  - TANGENTIAL MOMENT = 1.62 N/MM (9.27 IN-LB/IN)
- STRESS RESULTS
  - BAFFLE DISKS AND LONGITUDINAL PLATES INCREASED IN THICKNESS FROM 1.2 MM (.046") TO 1.3 MM (.050")
  - TANK CYLINDER RIBS WHERE BAFFLES ATTACH INCREASED IN THICKNESS FROM 1.2 MM (.046") TO 1.3 MM (.050")
  - SPOT WELDS WERE MODIFIED TO PROVIDE TWO ROWS OF WELDS INSTEAD OF ONE
  - BAFFLE DISKS TO BE MANUFACTURED IN 4 QUADRANTS TO ALLOW MORE OVERLAP ON RIBS
  - MINIMUM STRESS M.S. IS +0.18 AT BASE OF RIBS
- BUCKLING RESULTS
  - BAFFLE DISKS WILL BUCKLE
  - WILL STAY IN ELASTIC RANGE (WILL POP BACK INTO SHAPE WHEN LOAD IS REMOVED)

PENETRATION ANALYSIS

- ALL REMOVABLE SEALS ARE OF HELICOFLEX DELTA DESIGN
  - HIGH SEAL LINE LOAD DUE TO DELTA FEATURE
  - VERY TIGHT REQUIREMENTS OF FLANGE RELATIVE DISPLACEMENT AND SLOPE DRIVE UP FLANGE DIMENSIONS
    - » ALLOWABLE RELATIVE DISPLACEMENT DUE TO LOAD = .041 MM (.0016 IN)
    - » ALLOWABLE TANGENTIAL SLOPE = 0.1%
    - » ALLOWABLE RADIAL SLOPE = 1.%
  - PRESSURE LOAD ADDED TO SEAL LINE LOAD
- RESULTS SHOWN IN FOLLOWING TABLE
- ALL SAFETY MARGINS ARE POSITIVE
- SOME TOP PLATE PENETRATIONS STILL TO BE ANALYZED

PENETRATION ANALYSIS MARGINS OF SAFETY

ST-49

STANFORD

Lockheed

LMSC P088357

2, 3 MAR 94

DESCRIPTION	SFHe TANK BURST DISKS, VACUUM SHELL BURST DISKS, POROUS PLUG	SFHe TANK WELL, ELEX, FEP	STAR TRACKER MOUNT	GUARD TANK RAV, LIQUID LEVEL SENSOR	MAIN MOUNTING RING FILL LINE
PORT ID (IN)	2.00	1.00	2.75	0.625	2.518[1]
DISPLACEMENT AT SEAL (IN)	0.0012	0.0009	0.0015	0.0011	<.0015
RADIAL SLOPE (%)	0.29	0.34	0.33	0.19	<0.33
TANG. SLOPE (%)	0.002	0.001	0.032	0.1	<0.032
STUD YIELD M.S.	0.03	0.073	0.022	0.096	>0.022
FLANGE YIELD M.S.	1.3	1.21	2.19	0.33	>2.19
BOSS YIELD M.S.	0.47	0.35	0.33	1.14	>0.35

[1]THESE FLANGES O.K. BY SIMILARITY TO OTHER SIZED FLANGES

DEWAR ASSEMBLY STAND PRELIMINARY DESIGN ANALYSIS

- LOADED BY DEWAR MOUNTED TO STAND - DESIGNED TO SUPPORT 1591 KG (3500 LB) MAX DEWAR WEIGHT
- MAXIMUM ALLOWED DISTANCE FROM CG OF DEWAR TO PLANE OF BEARING ASSEMBLY = 152 MM (6 IN)
- SAFETY FACTORS
  - GSE GROUND HANDLING EQUIPMENT ULTIMATE SAFETY FACTOR
    - » ULTIMATE = 3.0
    - » YIELD = 2.5
  - LIFTING EQUIPMENT SAFETY FACTOR =5.0
- MINIMUM MARGIN OF SAFETY = +0.07
- DOLLY MUST HAVE RING INSTALLED BEFORE LOADING TO PREVENT EXCESS SAG
- LAYOUT VERIFIED - DETAIL STRESS ANALYSIS STILL NEEDS TO BE PERFORMED

COMPOSITE NECK TUBE ANALYSIS

- ORIGINAL ANALYSIS (SEE FLICOMP PDR) UPDATED TO REFLECT REVISED VCS DESIGN AND LAUNCH LOADS
- LOADS
  - EXTERNAL PRESSURE
  - LOCAL AXIAL AND SHEAR LOADS DUE TO VCS AND MLI
  - LATERAL LOAD FROM BELLOWS
- CNT IS BUCKLING CRITICAL IN TWO MODES, DEPENDING ON LOADING
  - GLOBAL BUCKLING DUE TO EXTERNAL PRESSURE
  - LOCAL BUCKLING OF COLDEST BAY DUE TO MECHANICAL LOADS
- APPROACH
  - ASSESS STRESS STATE AT WHICH BUCKLING IS MOST LIKELY TO OCCUR
    - » DIFFERENT COMBINATIONS OF AXIAL AND SHEAR STRESS
    - » USE STATISTICALLY-BASED KNOCKDOWN FACTORS BASED ON EXPERIMENTAL DATA
  - ASSESS THE STRESSES RESULTING FROM THE APPLIED LOADS
  - COMPARE

COMPOSITE NECK TUBE ANALYSIS (CONT.)

- PRESSURE LOADING AND FACTORS OF SAFETY HAVE NOT CHANGED SINCE ORIGINAL ANALYSIS; NO REVISED ANALYSIS NECESSARY
- FOR A 3σ PROBABILITY OF SUCCESS, THE MAXIMUM ALLOWABLE LATERAL BELLOWS FORCE IS 1957 N (440 LB) (PREDICTED FORCE = 1514.1 N (340.4 LB))
- AN ALLOWABLE BELLOWS LATERAL STIFFNESS OF 1751 N/MM (10,000 LB/IN) HAS BEEN ADOPTED, BASED ON A 2σ PROBABILITY OF SUCCESS
  - A 3σ CRITERIA RESULTS IN INCREASED NECK TUBE THICKNESS AND UNACCEPTABLE THERMAL LOSSES
  - A 100% PROBABILITY-OF-SUCCESS WILL BE DEMONSTRATED VIA STRUCTURAL TESTING
  - THIS APPROACH WAS USED WITH SUCCESS IN OTHER CRYOSTAT PROGRAMS (CLAES, SPIRIT III, ETC.)
  - ACTUAL PROBABILITY OF SUCCESS WILL BE HIGHER THAN 2σ BECAUSE PREDICTED DEWAR BELLOWS STIFFNESS < 876 N/MM (5000 LB/IN)
- DEVELOPMENT NECK TUBE HAS BEEN SUCCESSFULLY TESTED TO ULTIMATE LOADS

CONCLUSIONS AND CONCERNS

- ALL DEWAR STRUCTURE HAS BEEN ANALYZED AND ALL STRUCTURAL MARGINS ARE POSITIVE
- SOME DETAIL ANALYSIS STILL NEEDS TO BE COMPLETED
- NO SIGNIFICANT STRENGTH PROBLEMS ARE ANTICIPATED

THERMAL ANALYSIS

DEAN READ / JACK GOODMAN

SM PAYLOAD THERMAL ANALYSIS OBJECTIVES

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- PREDICT HELIUM LIFETIME, HEAT RATE AND VENT RATE
- PREDICT DEWAR AND PROBE TEMPERATURES (BOTH STEADY STATE AND TRANSIENT) DURING PAYLOAD OPERATIONS
  - GROUND HOLD
  - LAUNCH
  - ORBIT
- PERFORM SENSITIVITY STUDIES
- EVALUATE IMPACT OF DESIGN CHANGES ON PERFORMANCE

SM PAYLOAD
THERMAL MATH MODEL

- **SINDA** NETWORK ANALYZER COMPUTER CODE FOR THERMAL SYSTEMS WHICH CAN BE REPRESENTED IN LUMPED PARAMETER FORM

- STEADY-STATE MODEL FOR ORBIT AND GROUND BOUNDARY CONDITIONS

  267 NODES AND 521 CONDUCTORS

- TRANSIENT MODEL IS A REDUCED NODE VERSION OF THE STEADY STATE MODEL

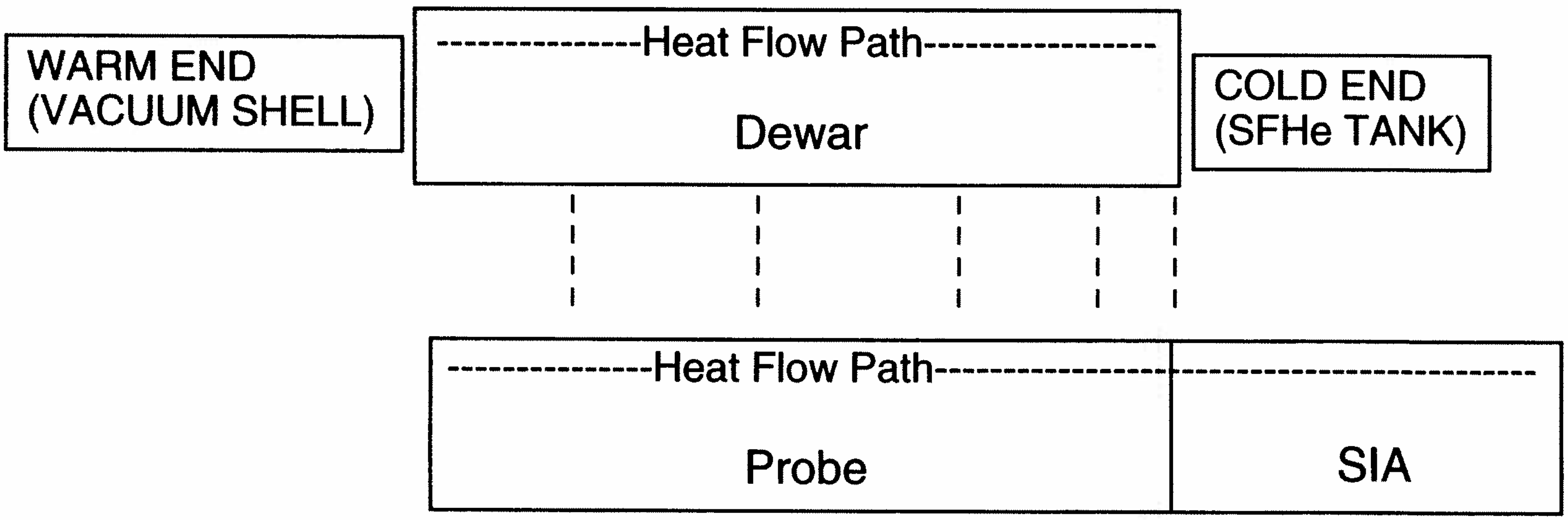
  110 NODES AND 333 CONDUCTORS

- THERMAL MODEL IS MATURE AND IS REPRESENTATIVE OF CURRENT HARDWARE DESIGN

TH - 4

SM PAYLOAD THERMAL MODEL

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



<u>DEWAR HEAT FLOW PATHS</u>

- MLI
- PODS
- FILL LINE
- EMERGENCY VENT LINES
- WIRES
- AXIAL LOCK TUBES
- NECKTUBE + LINER
- VENT GAS COOLING

<u>PROBE HEAT FLOW PATHS</u>

- NECKTUBE + LINER
- FIBER OPTICS
- PROBE WIRES
- SIA CABLES/WIRES
- PRESSURE SENSE LINE
- CAGING LINES
- SPINUP/EXHAUST LINES

SM PAYLOAD GROUND HOLD 300 K WARM BOUNDARY

EXPECTED PERFORMANCE *

GUARD TANK

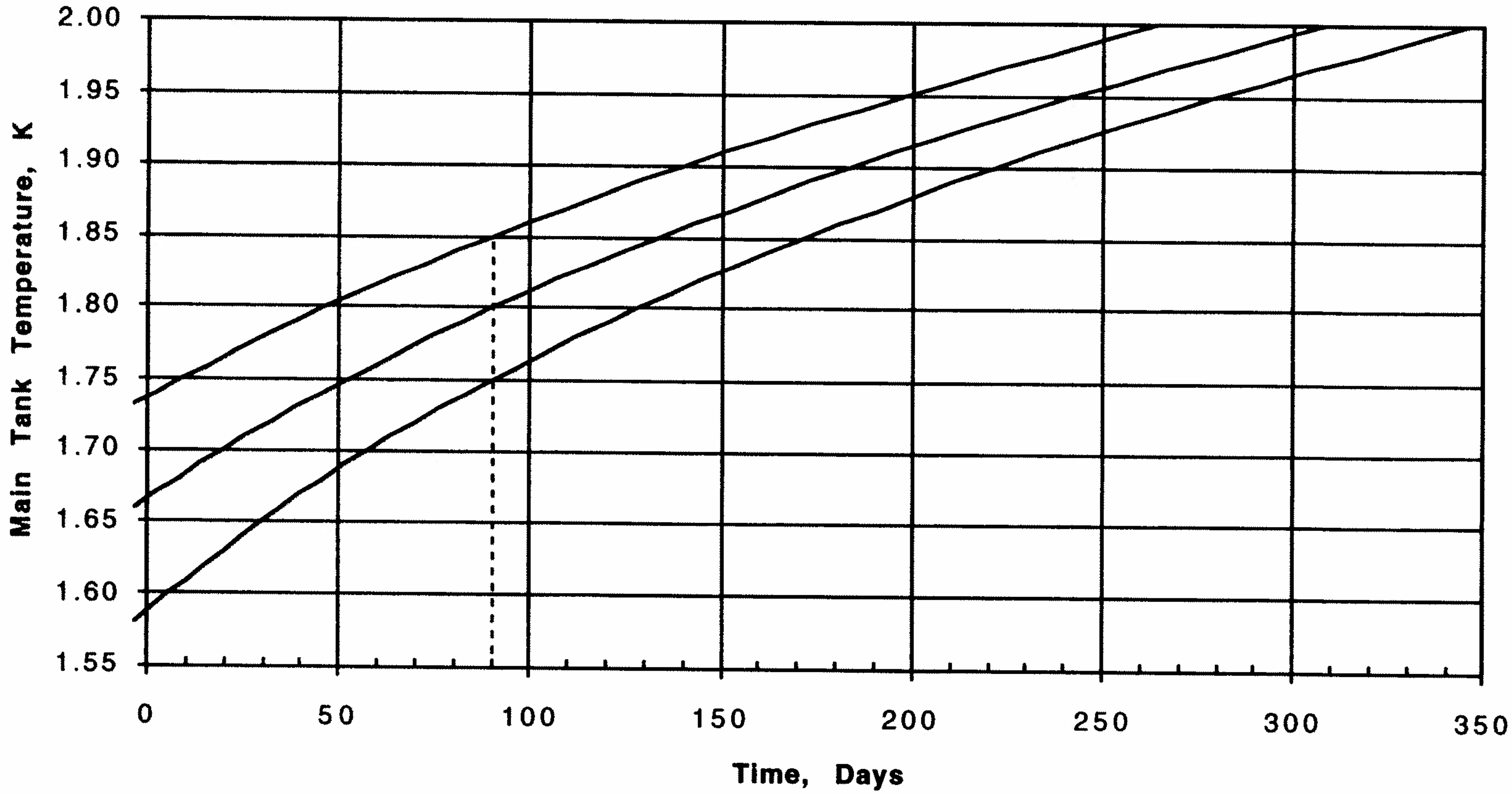
HOLD TIME (DAYS)	BOIL OFF (mg/s)
7.85	15.8

* INCLUDES 30% MARGIN

TEMPERATURE RISE OF NON-VENTED MAIN TANK ON THE GROUND

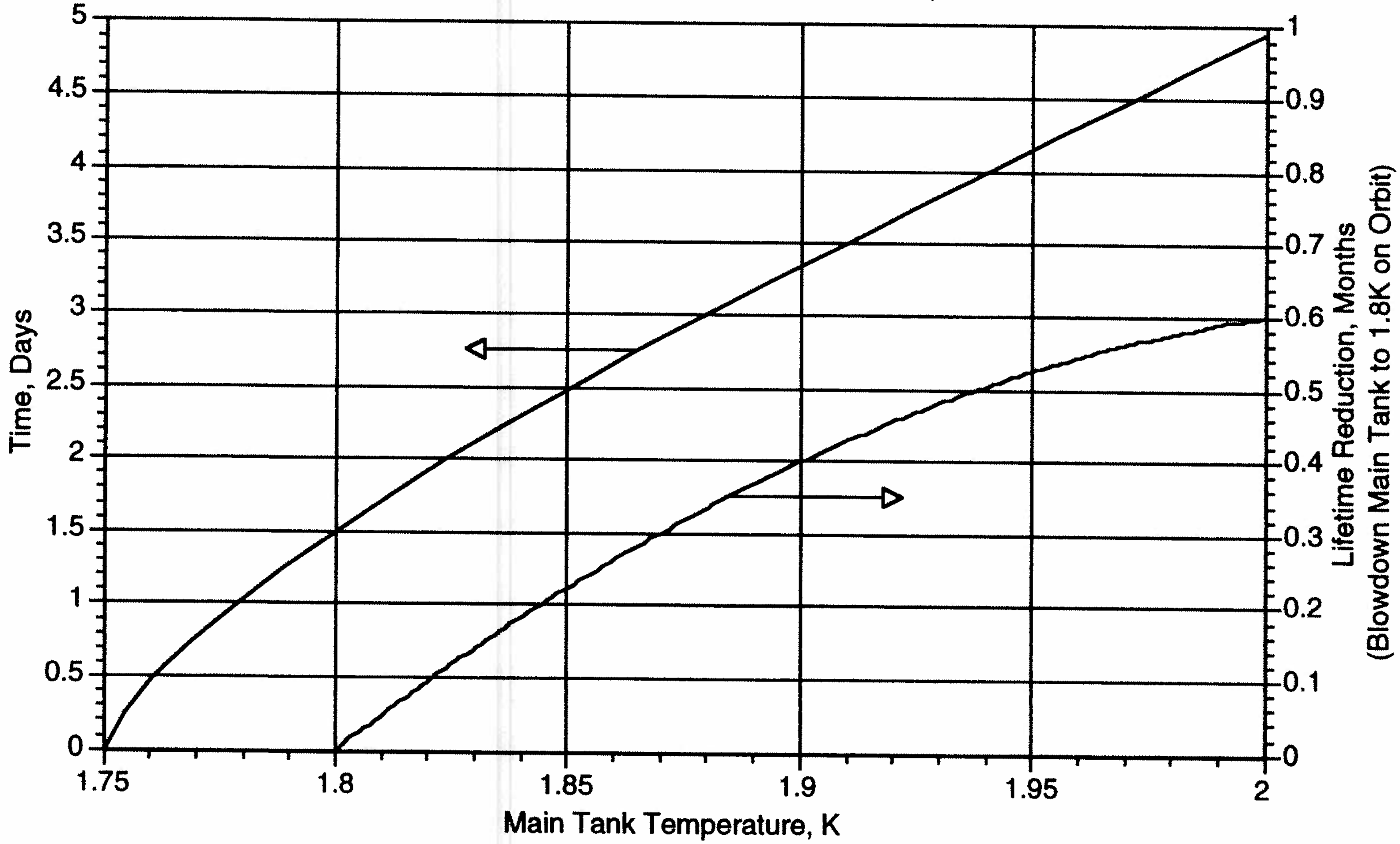
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

(WITH GUARD TANK FILLED)
(INCLUDES 30% MARGIN)



TEMPERATURE RISE OF NON-VENTED MAIN TANK ON THE GROUND

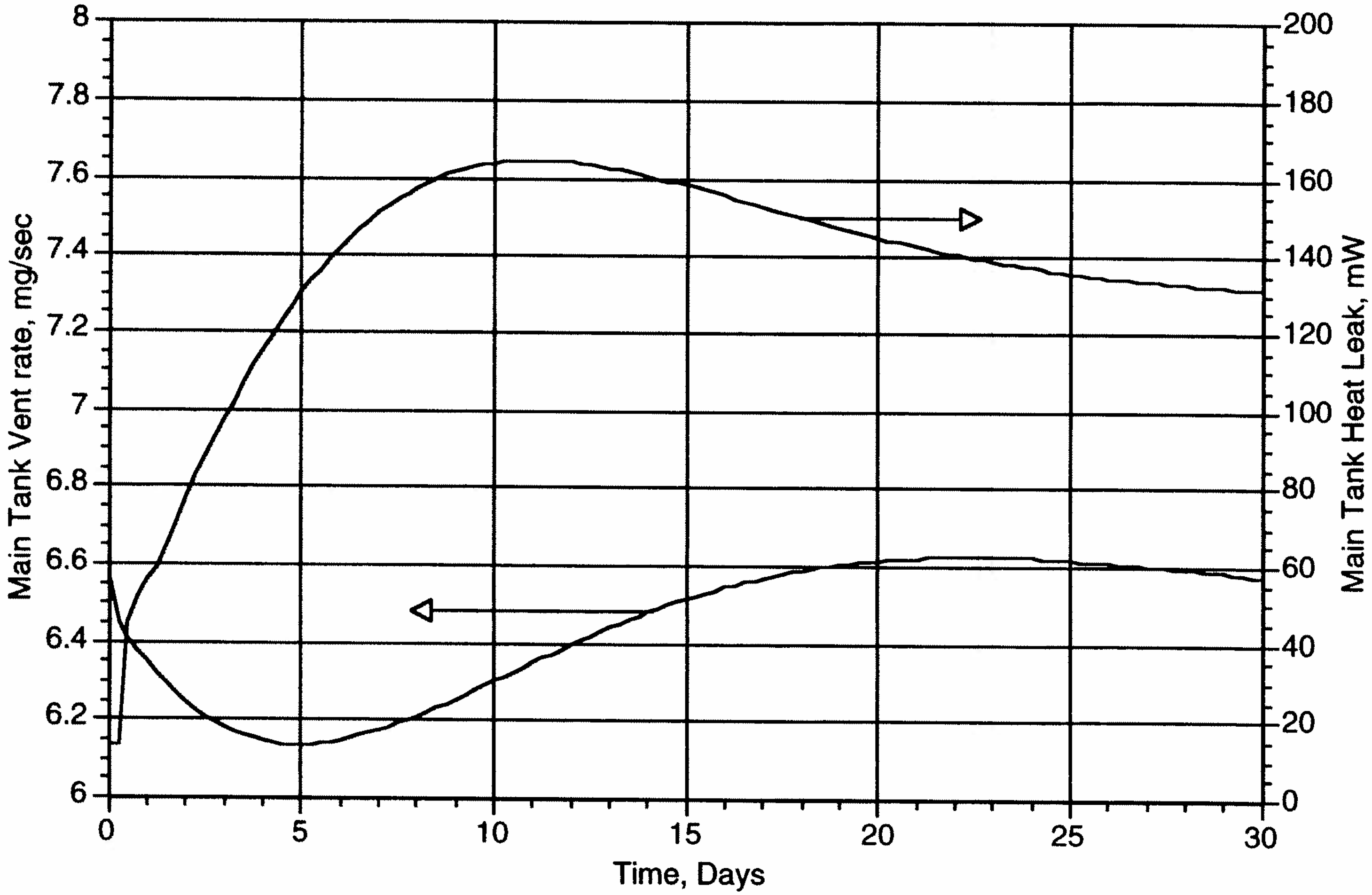
(WITH GUARD TANK EMPTY)
(INCLUDES 30% MARGIN)



MAIN TANK VENT RATE AND HEAT LEAK RATE AFTER LAUNCH

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

VACUUM SHELL DECREASES FROM 300 K TO 220 K IN 24 HOURS
GUARD TANK EMPTY AT LAUNCH (INCLUDES 30% MARGIN)



SM PAYLOAD THERMAL PERFORMANCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

REFERENCE PERFORMANCE VALUES (INCLUDES 30% MARGIN*)

LIFETIME = 19.8 Months
VENT RATE = 6.48 mg/s
WARM BOUNDARY = 220K
COLD BOUNDARY = 1.8K

HEAT FLOW PATHS
(DOES NOT INCLUDE 30% MARGIN*)

DEWAR	mW	%
MLI	26.6	22.8
TITANIUM LINER	1.9	1.6
COMPOSITE NECK TUBE	12.2	10.4
PODS, 12 ea.	7.8	6.7
AXIAL LOCK TUBE, 3 ea.	5.6	4.8
FILL LINE	1.1	0.9
WIRES	6.8	5.8
VENT GAS	- 0.3	0.0
SFHe TANK EMG VENT LINES	5.5	4.8
DEWAR TOTAL	67.2	57.7

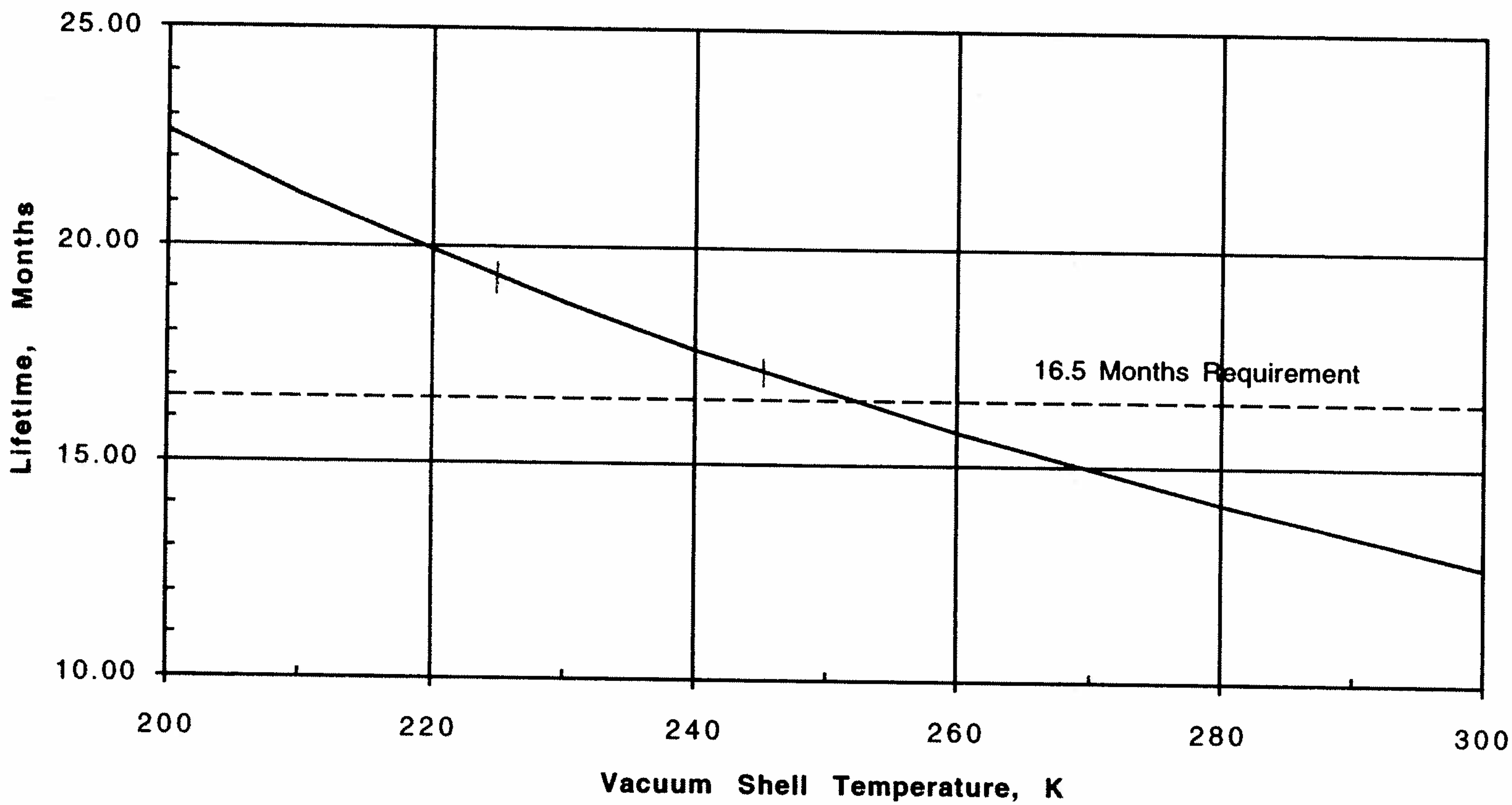
PROBE C	mW	%
CABLES/WIRES	27.9	24.0
TITANIUM LINER	1.9	1.6
COMPOSITE NECK TUBE	11.3	9.6
CAGING LINES	0.0	0.0
EXHAUST LINES	3.1	2.6
SIA SUPPORT TUBE	3.0	2.6
SPINUP LINES	1.2	1.0
FIBER OPTICS	0.9	0.7
PROBE TOTAL	49.3	42.3

*30% BASED ON MEASURED VS. PREDICTED LIFETIME PERFORMANCES ON OTHER DEWAR PROGRAMS

SM PAYLOAD LIFETIME

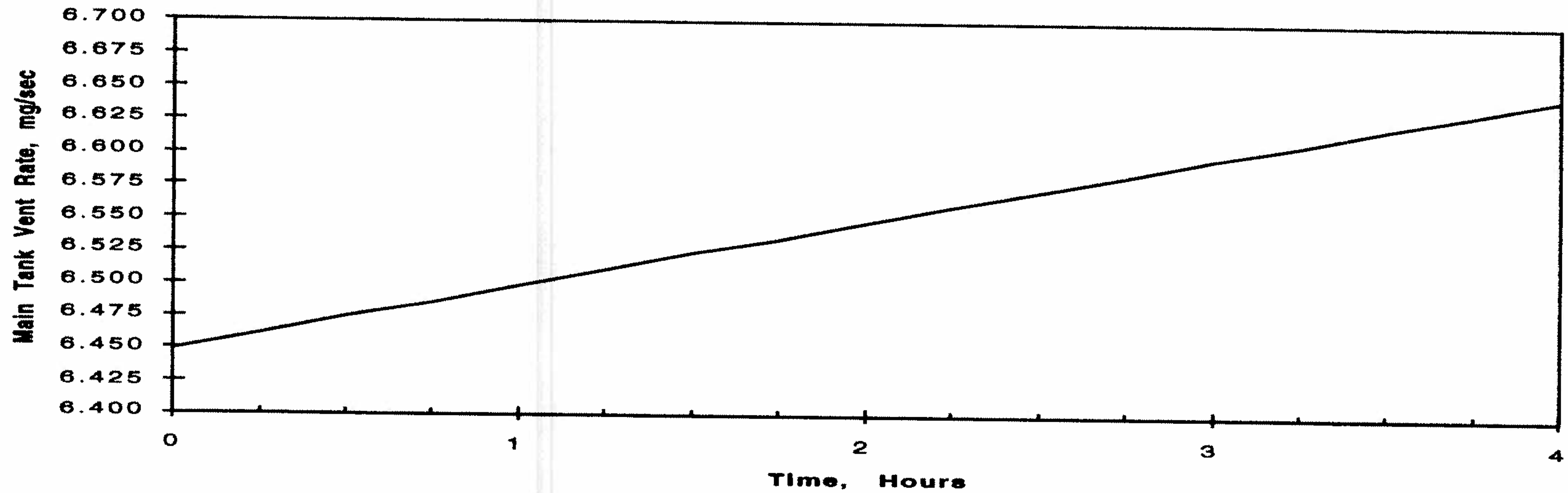
STANFORD
Lockheed

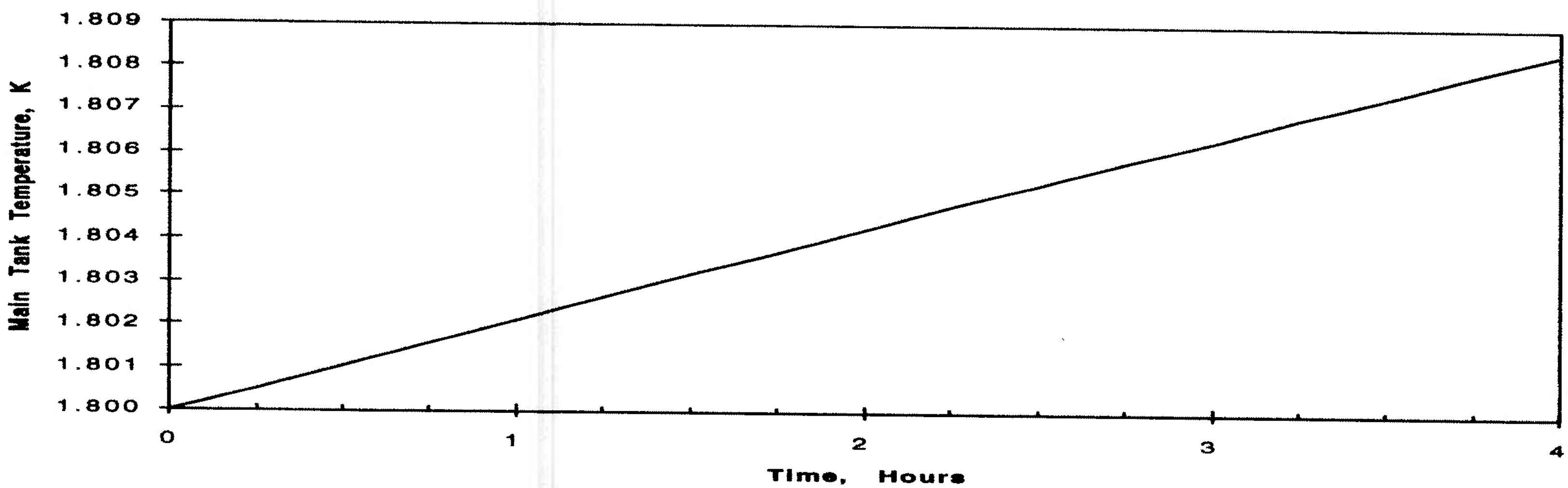
LMSC-P088357
2,3 MAR 94



IMPACT OF FLUX FLUSHING ON MAIN TANK VENT RATE AND TEMPERATURE (QBS HEATER = 600 mW)

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94





THERMAL ANALYSIS SUMMARY

- STEADY STATE THERMAL MODEL IS UP TO DATE WITH CURRENT DESIGN
- TRANSIENT THERMAL MODEL IS BEING USED TO EVALUATE DEWAR AND PROBE OPERATIONS
- DESIGN CHANGES/TRADE STUDIES ARE EASILY INCORPORATED INTO MODEL
- THERMAL PERFORMANCE CRITERIA ARE MET WITH A HIGH DEGREE OF CONFIDENCE IN RESULTS
  - REQUIREMENTS:

    LIFETIME > 16.5 MONTHS (19.8 PREDICTED)

    VENT RATE = 4-16 mg/sec (6.48 NOMINAL)

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

EMERGENCY VENT ANALYSIS

DEAN READ / JACK GOODMAN

EMERGENCY VENTING ANALYSIS OBJECTIVE

ANALYZE THE FOLLOWING VENTING SCENARIOS AND SIZE APPROPRIATE BURST DISKS AND FLOW LINES SO THAT SAFE PRESSURES ARE MAINTAINED DURING EMERGENCY VENTING

(1) MAIN TANK

- SEAL LEAKAGE/CATASTROPHIC LOSS OF WELL OR DEWAR GUARD VACUUM

(2) GUARD TANK

- SEAL LEAKAGE/CATASTROPHIC LOSS OF DEWAR GUARD VACUUM

(3) VACUUM SHELL

- LEAKAGE/FAILURE OF MAIN OR GUARD TANK PLUMBING DURING CATASTROPHIC EVENT
- BURST OF GUARD TANK BURST DISK

APPROACH

- DEVELOP VENTING MODEL BASED ON CONSERVATION OF MASS AND ENERGY IN THE TANKS COUPLED WITH PRESSURE DROP IN THE FLOW PATH

- USE MODEL TO PERFORM TRADE STUDIES WITH THE VARIOUS INITIAL AND BOUNDARY CONDITIONS TO CALCULATE PRESSURE HISTORIES AND DETERMINE MAXIMUM PRESSURES

- MAXIMUM ALLOWABLE DIFFERENTIAL PRESSURE:
  - SFHe TANK = 0.26 MPa (38 psi)
  - GUARD TANK = 0.38 MPa (55psi)
  - VACUUM SHELL = 0.055 MPa (8 psi)

- DESIGN APPROACH
  - SFHe TANK
    - REDUNDANT FLOW PATHS EACH CONSISTING OF COLD BURST DISK CONNECTED TO WARM BURST DISK BY INFLATABLE VENT LINE
  - GUARD TANK
    - SIZE NORMAL VENT LINE FOR EMERGENCY FLOW
    - ADD COLD BURST WHICH PROVIDES REDUNDANT FLOW PATH
  - VACUUM SHELL
    - REDUNDANT BURST DISKS

EV-4

EMERGENCY VENTING MODEL

- MASS AND ENERGY BALANCE ON CONTROL VOLUME (TANK) GIVES RELATIONSHIP FOR DENSITY AND ENERGY CHANGE IN TIME. THESE TWO VARIABLES ARE USED WITH THERMODYNAMIC TABLES TO DETERMINE PRESSURE AND TEMPERATURE HISTORIES.

$$dm = - m \, dt$$

$$du = \frac{1}{m}\left[Q - m(h - u) \right] dt$$

$$m_{i+1} = m_i + dm$$

$$u_{i+1} = u_i + du$$

EMERGENCY VENTING MODEL

- MASS FLOWRATE IS DETERMINED BY PRESSURE DIFFERENCE ACROSS THE BURST DISK (ASSUMED AN ORIFICE WITH A DISCHARGE COEFFICIENT) OR VENT LINE
  - VAPOR FLOW → COMPRESSIBLE; ISENTROPIC OR FANNO
  - LIQUID FLOW → INCOMPRESSIBLE; BERNOULLI EQUATION
  - TWO-PHASE → VAPOR

- INITIAL/BOUNDARY CONDITIONS:
  - TANK VOLUME AND SURFACE AREA
  - FLOW PATH GEOMETRY
  - BURST DISK DIAMETER
  - INITIAL ULLAGE
  - AIR CONDENSATION HEAT RATE
  - START TIME IS WHEN TANK REACHES DISK BURST PRESSURE

MAIN TANK EMERGENCY VENT DESIGN

- REDUNDANT FLOW PATHS; EACH FLOW PATH HAS A BURST DISK ON THE TANK AND ON THE VACUUM SHELL, CONNECTED WITH A 2" VENT LINE

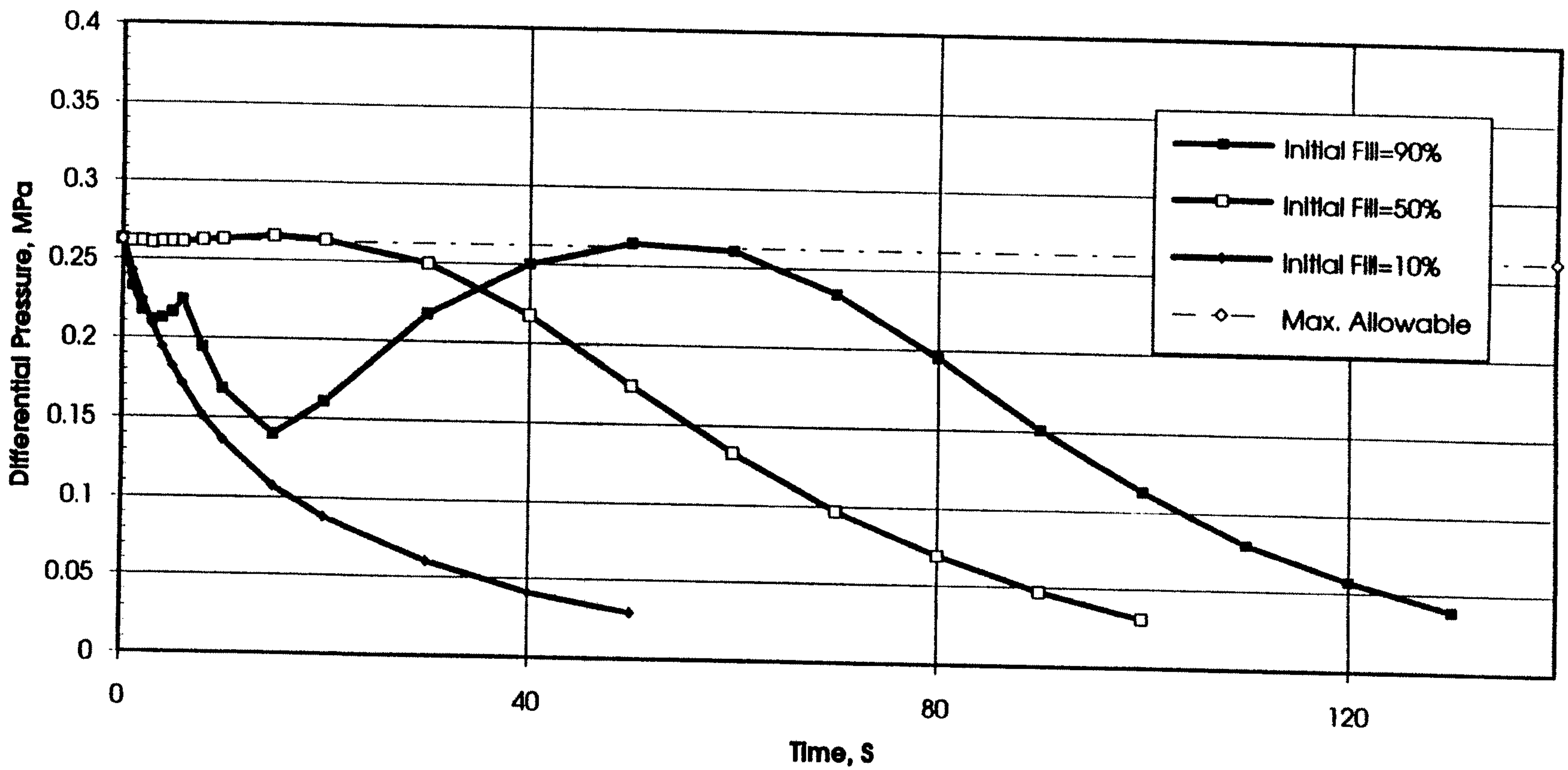
- FLOW IS FROM TANK THORUGH EMERGENGY VENT LINE; COMPLETE FLOW PATH INCLUDES RELIEF VALVE AND GSE VENT LINE

- CONDENSATION HEAT RATE IS A FUNCTION OF THERMODYNAMIC STATE IN TANK
  - LIQUID = 1.5 W/cm^2
  - VAPOR OR SUPERCRITICAL = 0.5 W/cm^2
  - TWO-PHASE = AVERAGED, BASED ON VOID FRACTION

VENTING OF SFHe TANK THROUGH EMERGENCY VENT LINE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

BURST PRESSURE = 0.262 MPa (38 psid)
BACK PRESSURE = 0.021 MPa (3 psid)
LINE DIAMETER = 5.08 cm (2")



EMERGENCY VENTING OF GUARD TANK

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- NORMAL VENT LINE ALSO SERVES AS EMERGENCY VENT LINE
  - EMERGENCY VENTING SIZES LINE DIAMETER

- SECONDARY FLOW PATH FOR EMERGENCY VENTING IS THROUGH BURST DISK (0.46") ON TANK AND BURST DISK (2") ON VACUUM SHELL

EV-9

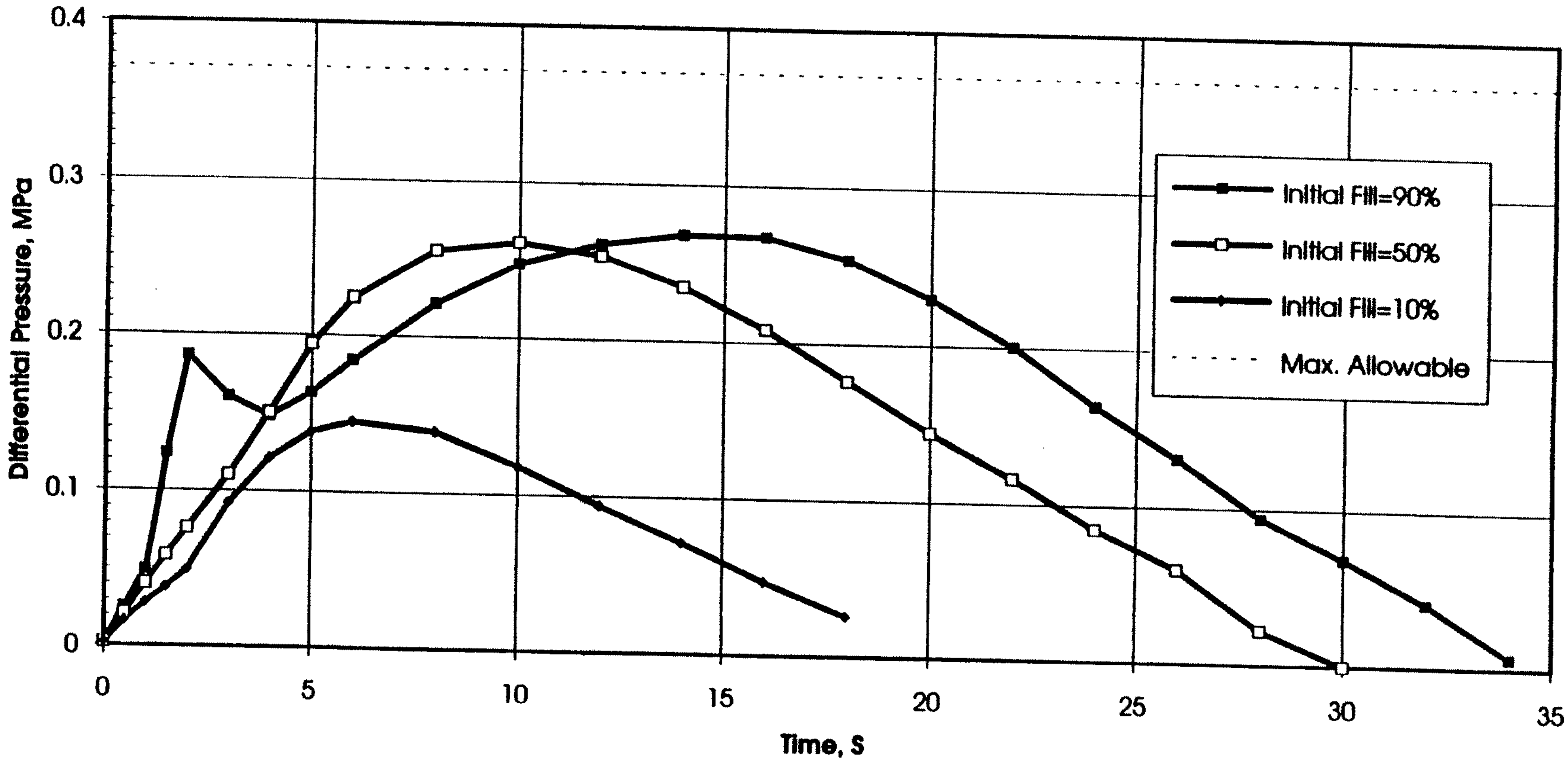
EMERGENCY VENTING OF GUARD TANK THROUGH NORMAL VENT LINE

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

INITIAL PRESSURE = 0.0017 MPa (0.25 psid)
BACK PRESSURE = 0.0017 MPa (0.25 psid)
VENT LINE DIAMETER = 1.90 CM (0.75")

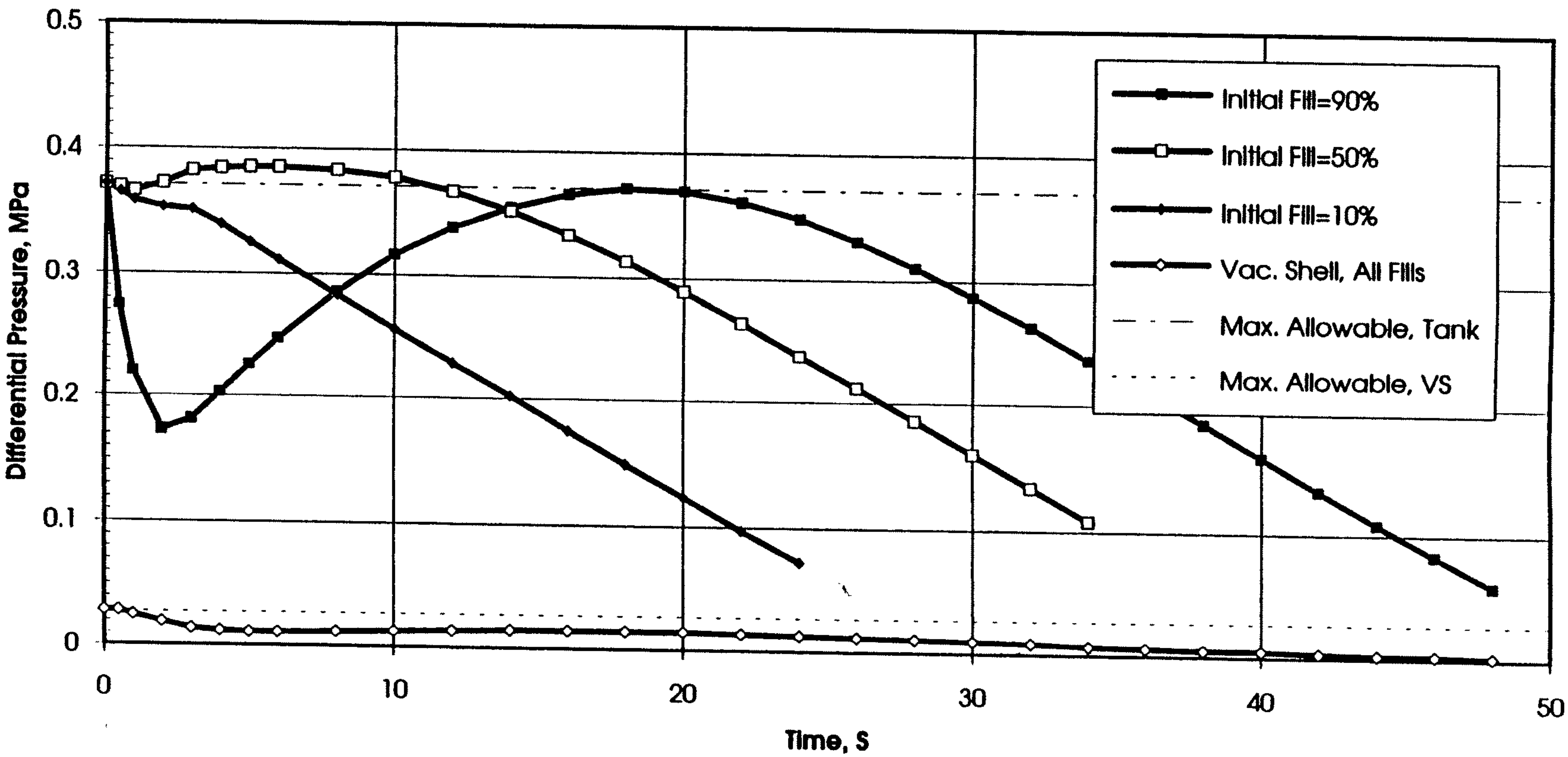


EV-10

EMERGENCY VENTING OF GUARD TANK THROUGH BURST DISK (BD-4)

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

TANK BURST DISK PRESSURE = 0.372 MPa (54 psid)
BURST DISK DIAMETER = 1.17 cm (0.46")
VACUUM SHELL BURST DISK PRESSURE = 0.028 MPa (4 psid)
BURST DISK DIAMETER = 5.08 cm (2")



EMERGENCY VENTING SUMMARY

DIFFERENTIAL PRESSURES MPa (PSI)

	CALCULATED	REQUIREMENT
• MAIN TANK		
LOSS OF GUARD VACUUM	0.26 (38)	0.26 (38)
• GUARD		
NORMAL VENT LINE	0.27 (38.9)	0.38 (55)
BURST OF BD-2	0.39 (56.0)	0.38 (55)
• VACUUM SHELL		
BD-2 BURST ONLY	0.028 (4.0)	0.055 (8)
BD-2 BURST WITH LEAKAGE FROM EV LINE	TBD	0.055 (8)
• DEWAR WELL		
LOSS OF DEWAR GUARD VAC W/O PROBE	<0.17 (24.7)	0.23 (34)
LOSS OF PROBE VACUUM	0.13 (18.9)	0.23 (34)

EV-12

EMERGENCY VENTING CONCLUSIONS

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

- MAIN TANK; MAXIMUM ALLOWABLE PRESSURE = 0.26 MPa (38 PSID)
  - SINGLE 2" VENT LINE IS SUFFICIENT TO MEET THE MAXIMUM ALLOWABLE PRESSURE REQUIREMENT (LINES ARE REDUNDANT FOR RELIABILITY)

- GUARD TANK ; MAIXMUM ALLOWABLE PRESSURE = 0.38 MPa (55 PSID)
  - THE 0.75" NORMAL VENT LINE MEETS THE MAXIMUM ALLOWABLE PRESSURE REQUIREMENT
  - VENTING THROUGH THE REDUNDANT FLOW PATH EXCEEDS THE MAXIMUM ALLOWABLE PRESSURE REQUIREMENT BY 1 PSID (GUARD TANK STILL HAS A POSITIVE STRESS MARGIN)

- VACUUM SHELL; MAXIMUM ALLOWABLE PRESSURE = 0.055 MPa (8 PSID)
  - SINGLE BURST DISK IS SUFFICIENT TO MEET THE MAXIMUM ALLOWABLE PRESSURE REQUIREMENT (BURST DISKS ARE REDUNDANT FOR RELIABILITY)

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

HELIUM CENTER OF MASS AND SLOSH CONTROL

DAVID FRANK

CM - 2

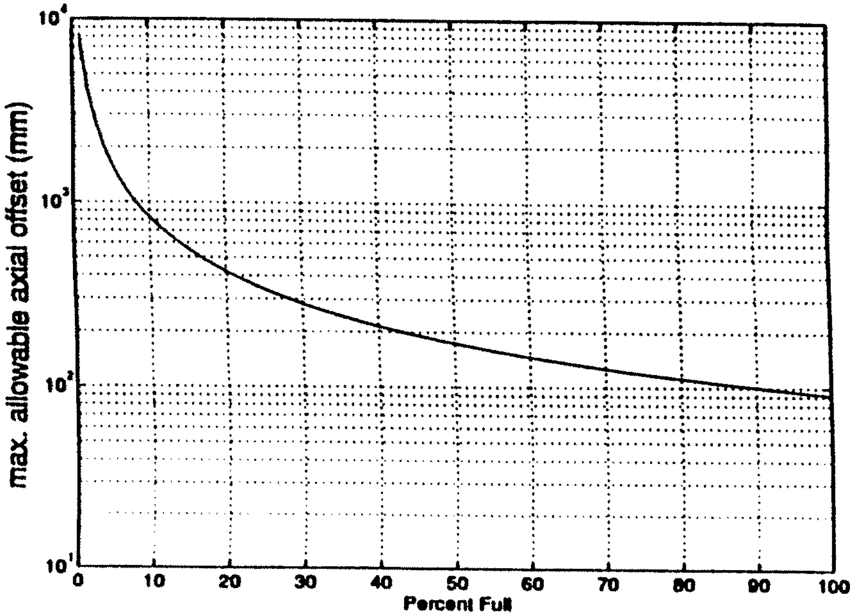
STANFORD

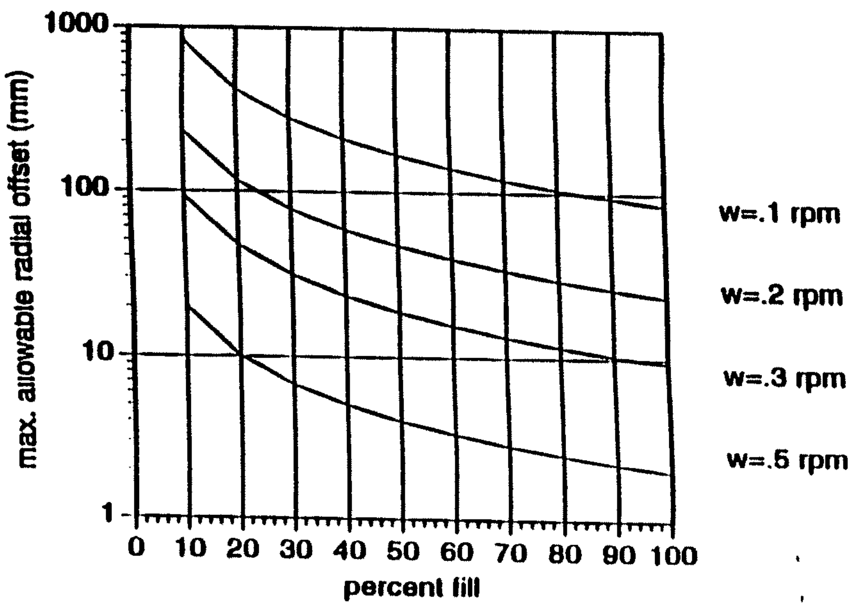
Lockheed

LMSC-P088357
2,3 MAR 94

CENTER OF MASS REQUIREMENT

- SPACECRAFT WILL BE ROLLING BETWEEN 0.1 AND 0.5 RPM
- SPACECRAFT WILL BE IN A DRAG-FREE MODE OF OPERATION
- OFFSET IS THE DISPLACEMENT OF THE CENTER OF MASS LOCATION FROM THE POINT OF SYMMETRY OF THE TANK

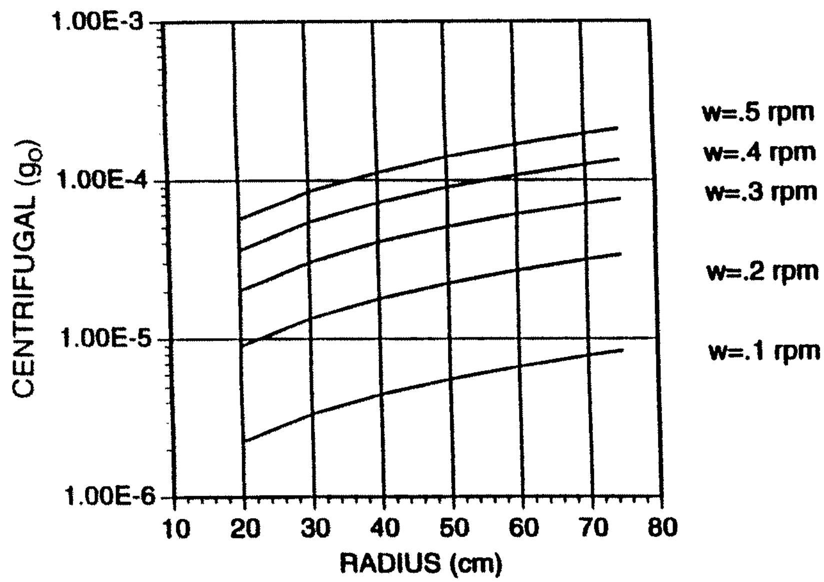


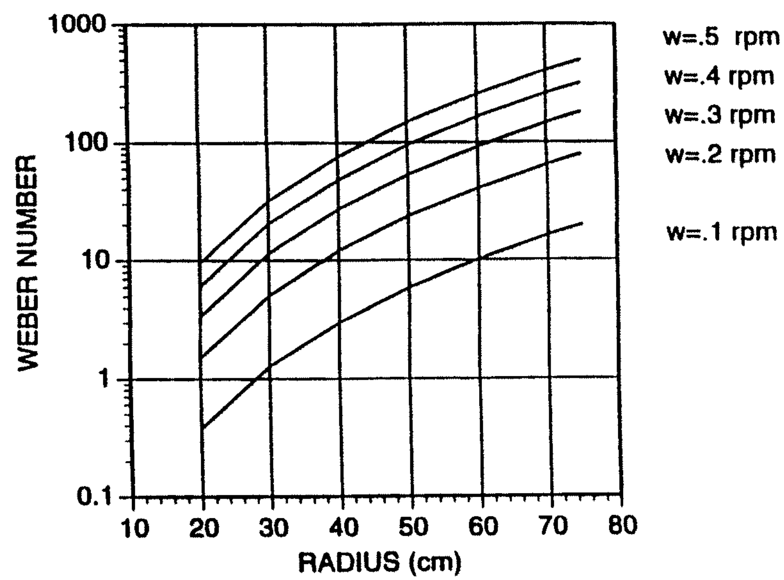


CAPILLARY/CENTRIFUGAL/ GRAVITY FORCES

CM - 3

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94





<u>CENTRIFUGAL FORCES</u>

<u>WEBER # (CENTRIFUGAL/CAPILLARY)</u>

- MAXIMUM GRAVITY GRADIENT FORCE IS LESS THAN 2E-07 g_0

ANALYTICAL TOOLS

- THE ANALYTICAL TOOLS ARE CLOSED FORM SOLUTIONS TO THE LIQUID/ VAPOR INTERFACE AND A COMPUTATIONAL FLUID DYNAMIC (CFD) CODE

- THE CLOSED FORM SOLUTIONS:
  - PERFORMED TWO DIMENSIONAL QUASI-STATIC CALCULATIONS USING SOLUTIONS TO THE LIQUID/VAPOR INTERFACE EQUATION
  - PERFORMED 3D QUASI-STATIC CALCULATIONS USING SURFACE EVOLVER TO ANALYZE THE INITIAL CONFIGURATION OF THE ULLAGE

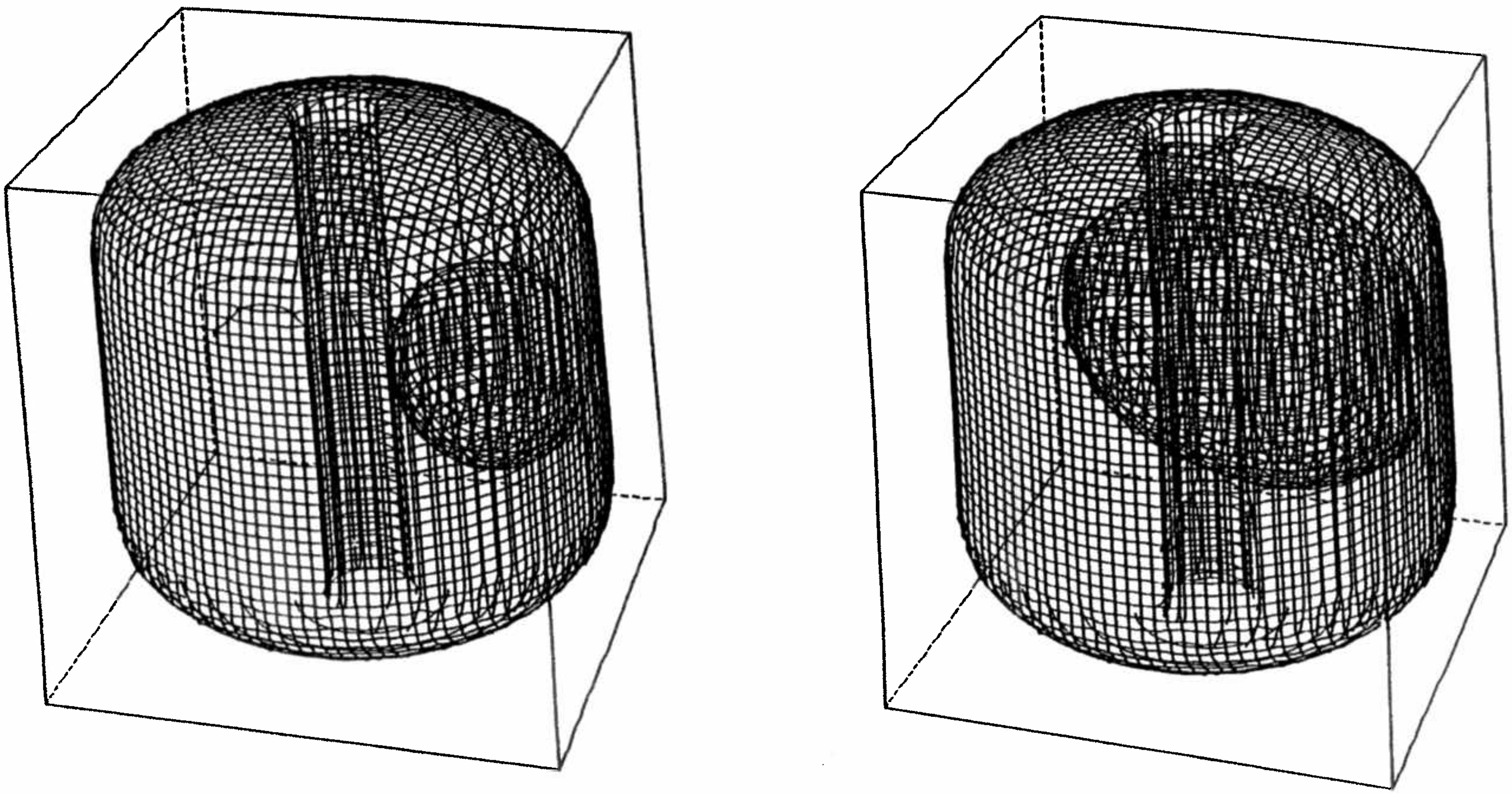
- THE CFD CODE:
  - UTILIZING CFD CODE FLOW 3D WITH MODIFICATIONS PERFORMED BY LMSC AND FLOW SCIENCE
  - PERFORMED TWO AND THREE DIMENSIONAL TRANSIENT AND QUASI-STATIC CALCULATIONS
  - DETERMINED TRANSIENT EFFECTS DUE TO GRAVITY/ ACCELERATION FIELD CHANGES
  - COMPUTED FORCES AND RESPONSES TO INPUT DISTURBANCES

ULLAGE PROFILES AT ZERO RPM

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

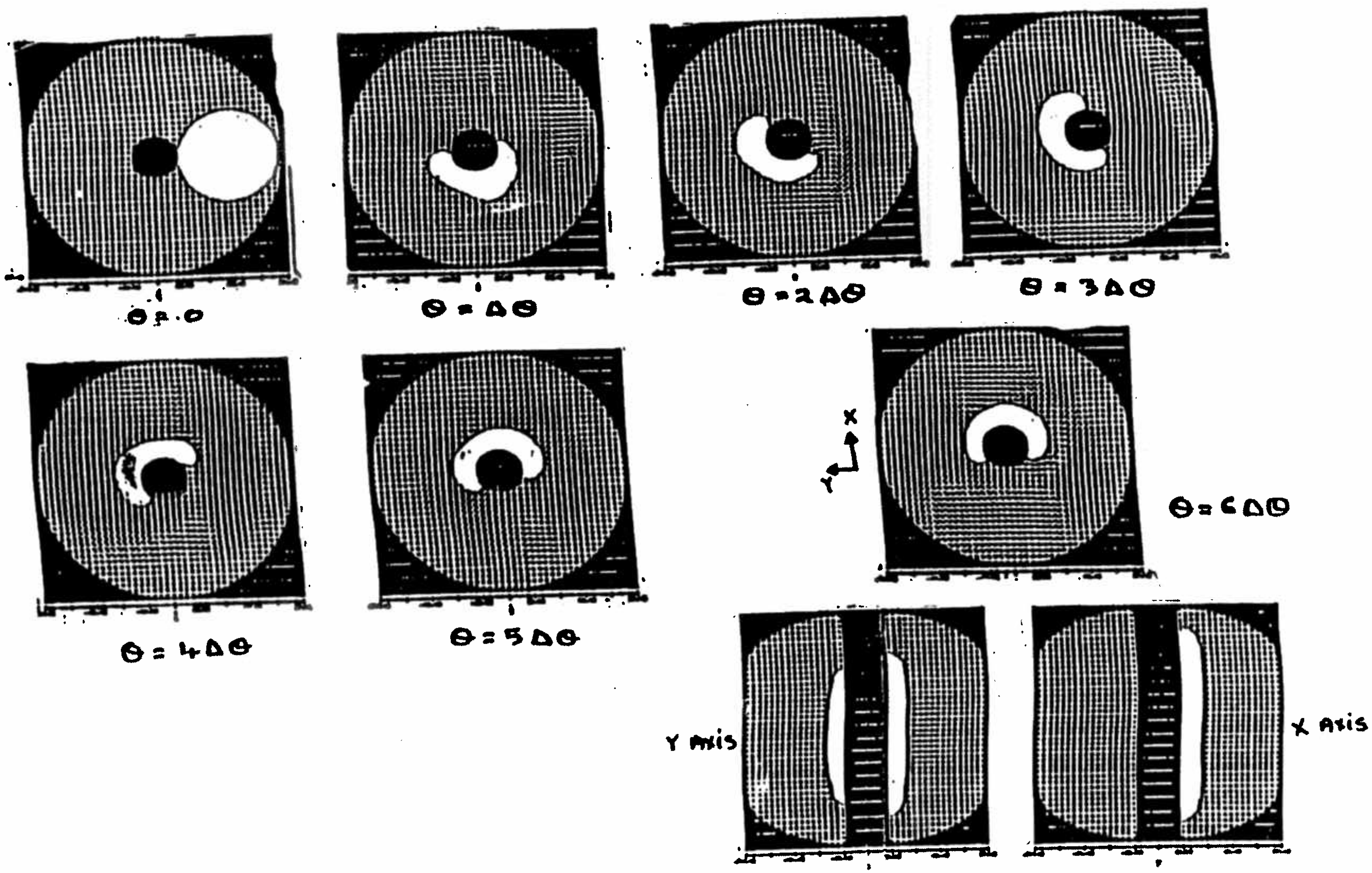
- THE FOLLOWING SHOWS THE ULLAGE PROFILE FOR THE 95 AND 83% FULL TANK AT ZERO RPM
  - THE RADIAL OFFSET FOR 95% IS 2.3 CM, AND APPROXIMATELY 8.2 CM AT 83% (STEADY STATE USAGE IS 6%/MONTH)



95% FULL UN-BAFFLED TANK INITIAL ON-ORBIT (1 OF 2)

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- SPIN-UP FOR A ROLL RATE OF 0.4 RPM WITHOUT ANY GRAVITATIONAL FIELD COMPUTED WITH THE 3D CFD CODE

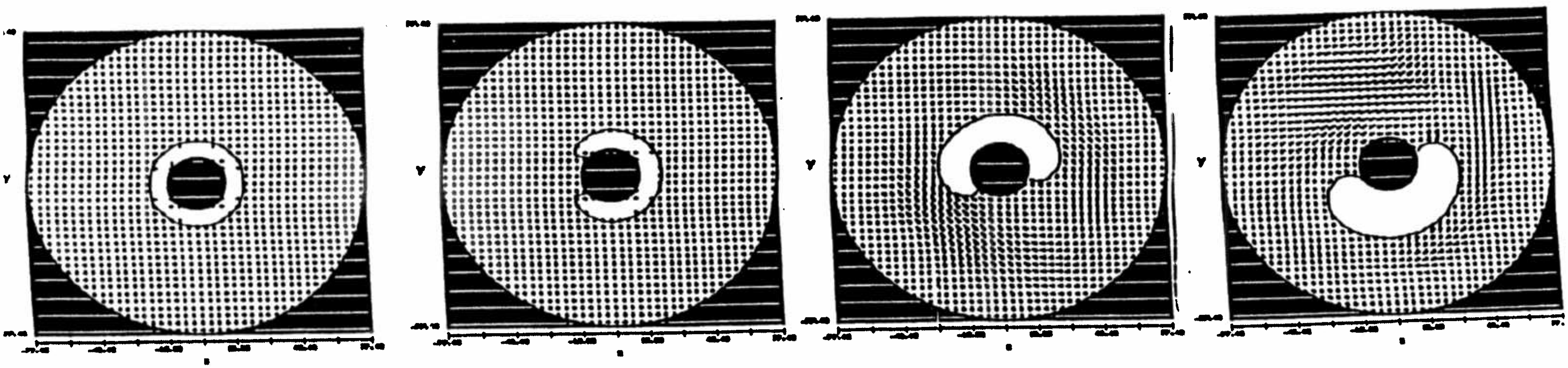


CM - 7

95% FULL UN-BAFFLED TANK INITIAL ON-ORBIT (2 OF 2)

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- COMPUTED THE INITIAL ROLL RATE REQUIRED FOR A 95% FULL TANK TO ACHIEVE AXISYMMETRIC PROFILE WITHOUT ANY GRAVITATIONAL FIELD USING THE CFD CODE

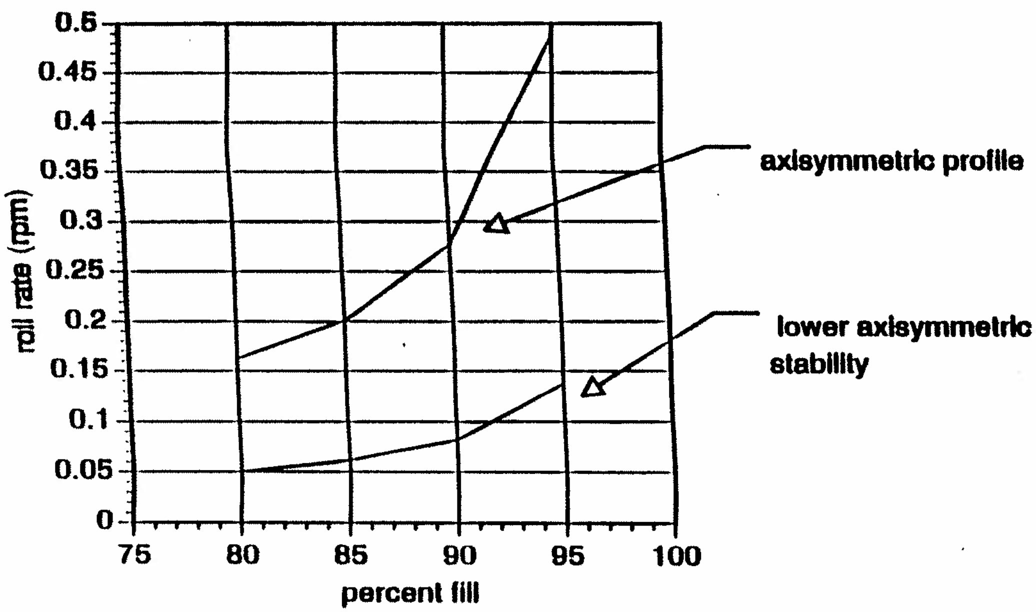


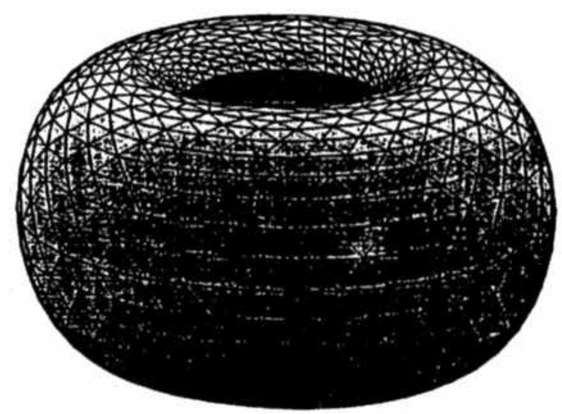
0.6 rpm   0.5 rpm   0.4 rpm   0.2rpm

- THE RESULTS SHOW THAT A ROLL RATE OF 0.5 - 0.6 RPM IS REQUIRED TO ACHIEVE AN AXISYMMETRIC CONFIGURATION

AXISYMMETRIC ULLAGE PROFILE

- SURFACE EVOLVER CODE WAS UTILIZED TO ANALYZE THE ROLL RATE DEPENDENCY ON ACHIEVING AN AXISYMMETRIC PROFILE
  - THE ROLL RATE TO ACHIEVE AN AXISYMMETRIC PROFILE WAS CALCULATED
  - THE LOWER STABILITY LIMIT OF THE AXISYMMETRIC PROFILE WAS CALCULATED
  - RESULTS SHOW THAT ONCE AN AXISYMMETRIC PROFILE WAS ACHIEVED, THE ROLL RATE COULD BE LOWERED TO 0.15 RPM



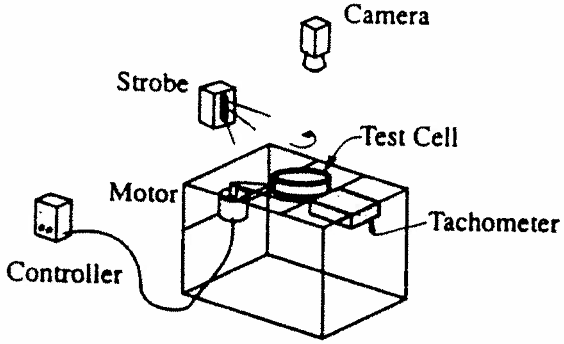


SCALE MODEL SPIN TESTING

- SCALE MODEL SPIN TESTS ARE BEING PERFORMED IN 1-G TO VERIFY THE PREDICTIONS BY THE SURFACE EVOLVER CODE ON THE LOWER STABILITY OF THE AXISYMMETRIC ULLAGE
  - TESTS WERE PERFORMED BY THE SCHOOL OF AERONAUTICS & ASTRONAUTICS OF PURDUE UNIVERSITY UNDER THE SUPERVISION OF PROF. STEVEN COLLICOTT
  - TESTS WERE DONE WITH STORABLE FLUIDS (WATER & AIR)
- MODEL DESIGNS ARE BASED ON THE RELEVANT SCALING LAWS
  - WEBER NUMBER IS MATCHED
  - BOND NUMBER IS MINIMIZED
  - FROUDE NUMBER IS MAXIMIZED
- IDEAL MODE, AS FAR AS MATCHING BOND AND FROUDE NUMBERS IS CONCERNED, ARE INFINITELY SMALL, SPINNING INFINITELY FAST.
  - THUS MODELS ARE INHERENTLY A COMPROMISE
- SURFACE EVOLVER IS ADAPTED TO SIMULATE THE 1-G SPIN TESTS

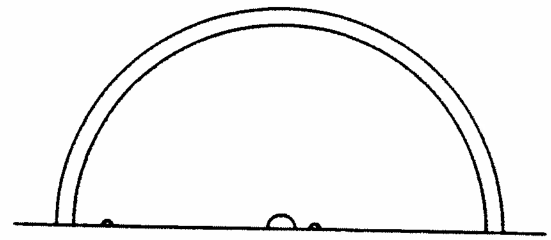
SCALE MODEL SPIN TEST FACILITY

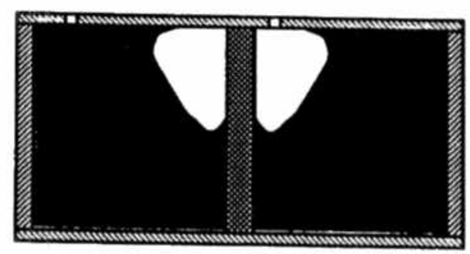
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



Thick 1-g Test Model

- 1/27 scale model.
- Orbital Weber number range is matched.
- Stroboscopic video data acquisition.
- Glass and acrylic to contain water and air.





SCALE MODEL TEST RESULTS

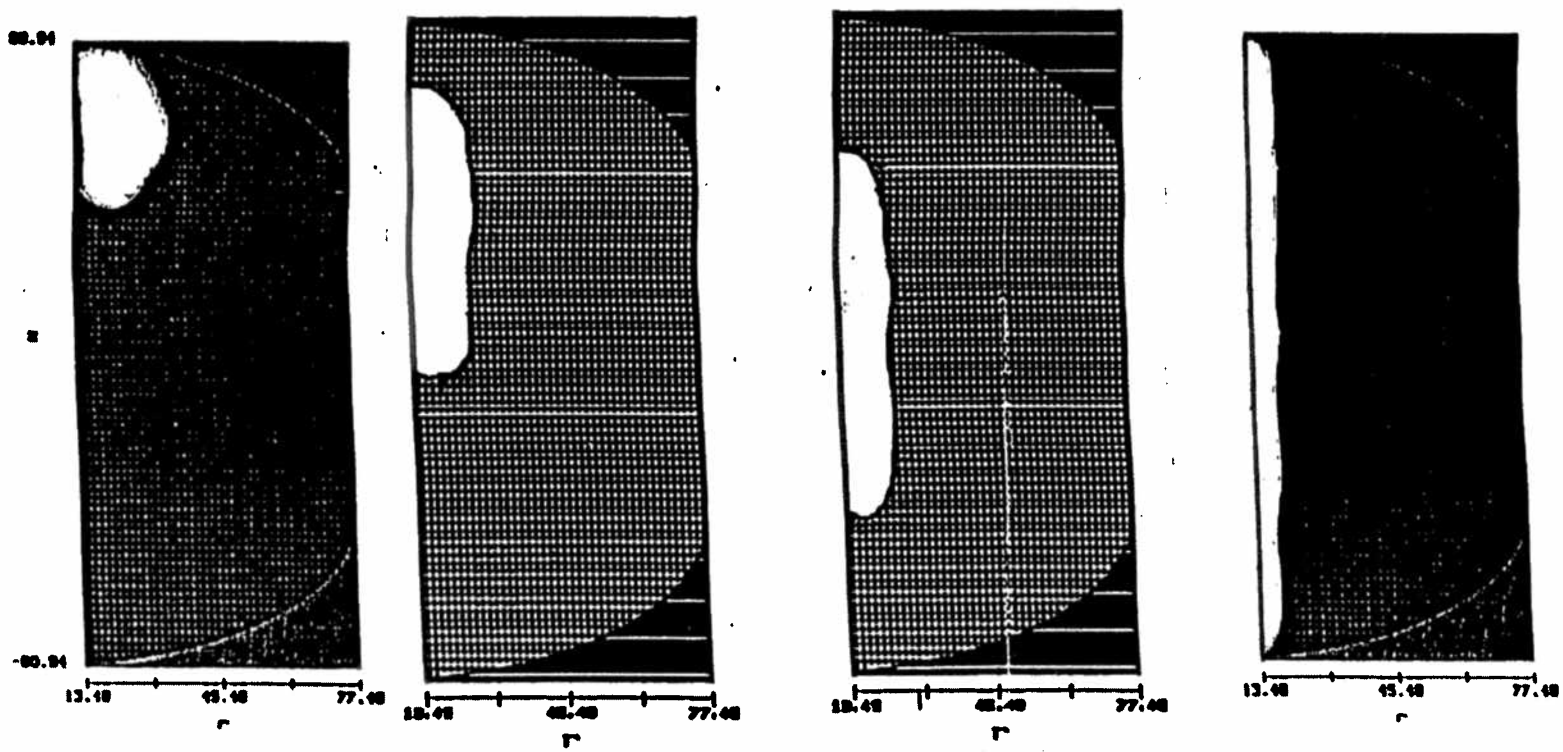
- TWO EXPERIMENTAL MODELS WERE BUILT AND TESTED OVER A WIDE RANGE OF GPB FILL LEVELS AND SPIN RATES
  - "THIN MODEL" - EXAMINE BALANCE OF CENTRIFUGAL AND CAPILLARY FORCES WHEN GRAVITY IS NEGLIGIBLE
  - - "THICK MODEL" - EXAMINE BALANCE OF CENTRIFUGAL AND CAPILLARY FORCES WHEN GRAVITY IS NOT NEGLIGIBLE
- SURFACE EVOLVER PREDICTIONS FOR BOTH MODELS SHOWED THAT THE AXISYMMETRIC SHAPE WAS STABLE DOWN TO ZERO RPM.
  - THUS THESE $1g_o$ TESTS COULD NOT MODEL A LOWER STABILITY FOR A NON-ZERO SPIN RATE
- THE HYSTERESIS PREDICTED BY SURFACE EVOLVER WAS VERIFIED BY THE EXPERIMENTAL DATA
  - STABLE AS THE SPIN RATE WAS REDUCED ALL THE WAY DOWN TO NO SPIN AT ALL
- OVER THE RANGE OF FILL LEVELS AND SPIN RATES, THE ULLAGE SHAPE AND TRENDS BETWEEN EXPERIMENT AND SIMULATIONS WERE GOOD

CENTER OF MASS DISPLACEMENTS

CM - 12

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- GRAVITY GRADIENTS ARE SUCH THAT AN ULLAGE THAT IS ONLY IN CONTACT WITH THE INNER WALL CAN BE PUSHED INTO DIFFERENT AXIAL POSITIONS
  - THIS WILL CAUSE CENTER OF MASS DISPLACEMENTS
- THE FOLLOWING FIGURE SHOWS THE PROFILE OF A 5% ULLAGE TRANSITIONING FROM 0.1 TO 1.0 RPM



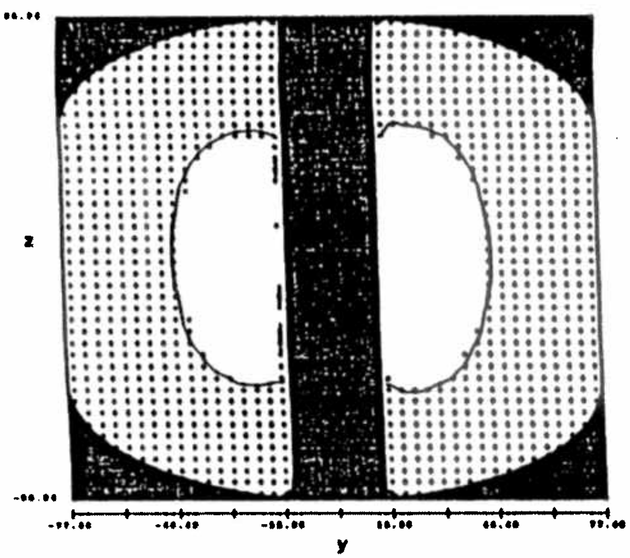
0.1 rpm　　0.3 rpm　　0.5 rpm　　1.0 rpm

STEADY STATE PROFILES W/O GRAVITY GRADIENTS

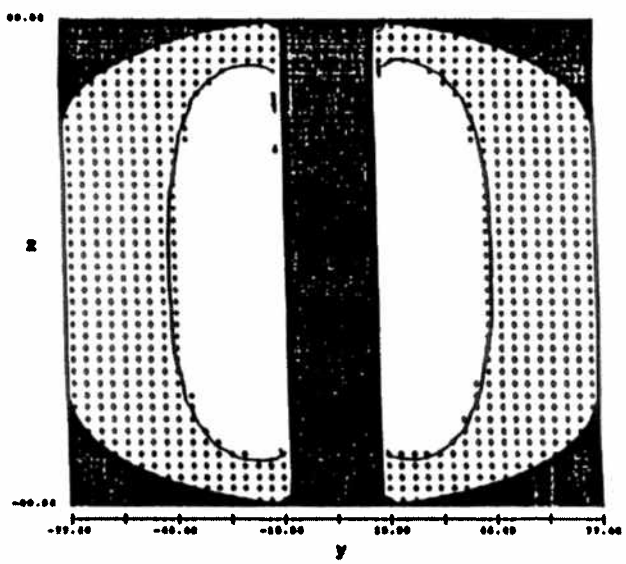
CM - 13

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

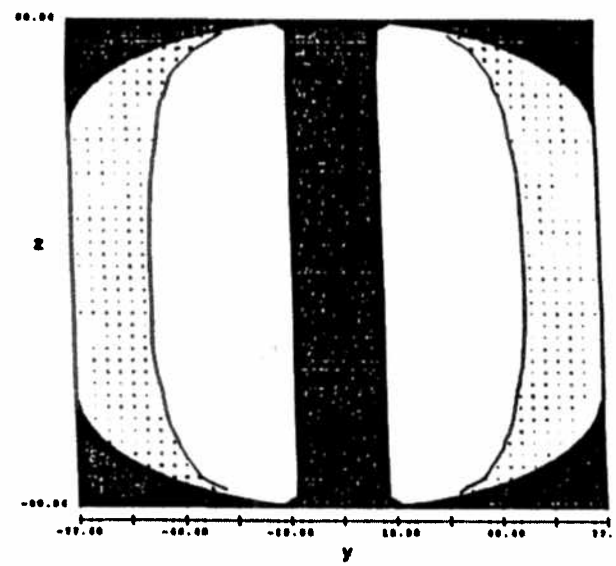
- DETERMINED STEADY STATE PROFILES WITH BOTH 2D AND 3D CFD CODE
- FIGURE SHOWS RESULTS FOR W=0.1 RPM AT VARIOUS FILL LEVELS
  - APPROXIMATE ROLL RATE REQUIRED TO FLATTEN THE LIQUID/VAPOR INTERFACE SUFFICIENTLY SUCH THAT THE ULLAGE STRETCHES THE LENGTH OF THE TANK:
    - » > 0.5 RPM FOR 95% FILL, 0.3 RPM FOR 83% FILL, 0.2 RPM FOR 72% FILL, 0.1 RPM FOR 52% FILL



82 %



72%



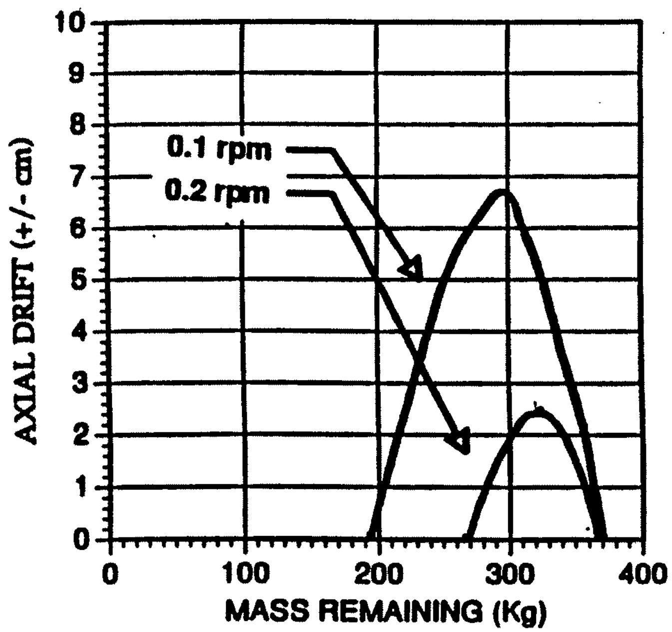
53%

UNBAFFLED TANK PERFORMANCE

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

- THE FOLLOWING CHART SHOWS THE AXIAL DRIFT OF THE CENTER OF MASS ABOUT THE POINT OF SYMMETRY OF THE TANK
  - RESULTS SHOW THE MAXIMUM DRIFT OF THE CENTER OF MASS IS APPROXIMATELY +/- 6.7 CM WHICH OCCURS WHEN THE TANK IS APPROXIMATELY 80% FULL AT 0.1 RPM



- THE PERFORMANCE OF AN UNBAFFLED TANK MEETS THE AXIAL DISPLACEMENT REQUIREMENTS

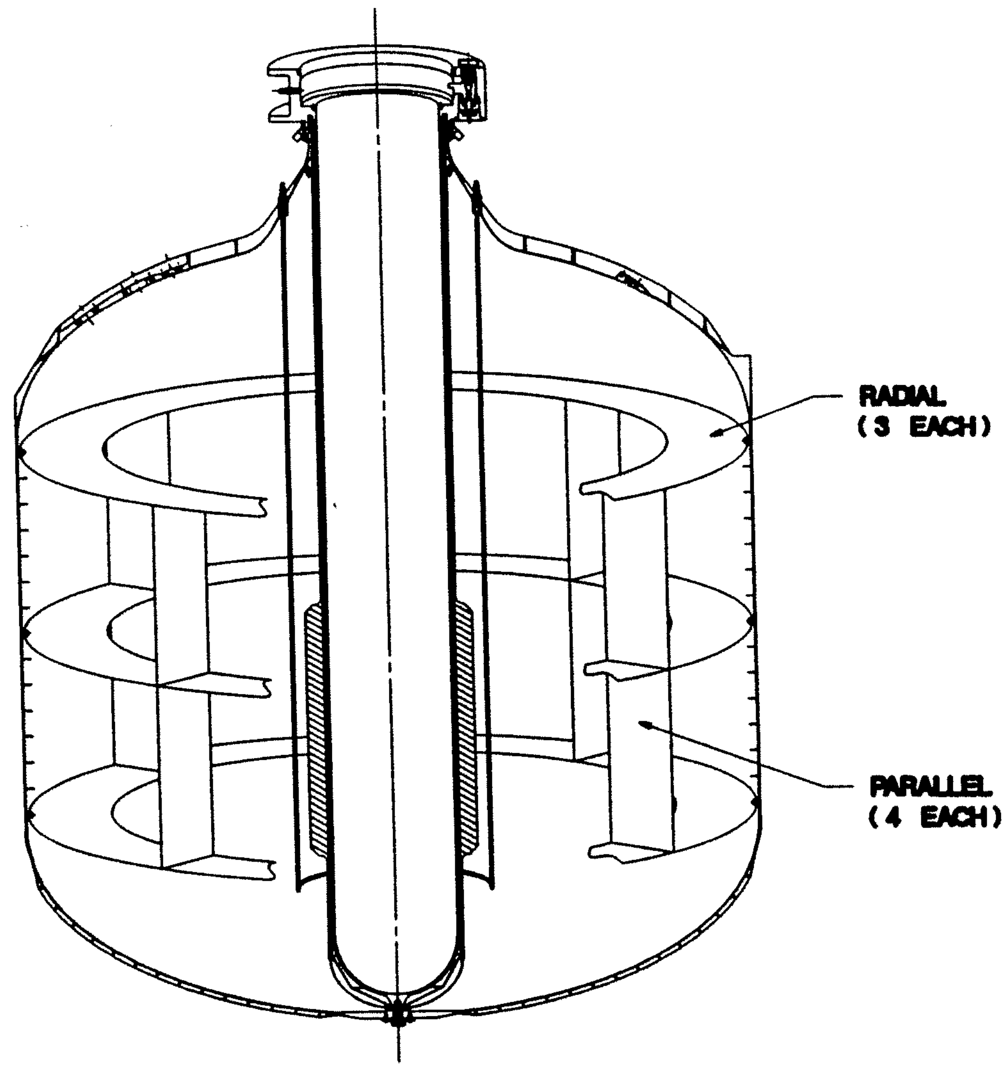
CENTER OF MASS CONTROL SUMMARY

- NO BAFFLES ARE REQUIRED TO CONTROL THE FLUID CENTER OF MASS
- SOME OPERATIONAL CONSTRAINTS ARE IMPOSED IN THE EARLY PORTION OF THE MISSION:
  - THE FLUID MUST BE SPUN UP TO APPROXIMATELY 1 RPM PRIOR TO OPERATING IN A DRAG FREE MODE
    - » HIGH ROLL RATE MUST BE MAINTAINED LONG ENOUGH TO GET THE FLUID AND TANK ROTATING AS A SOLID BODY
    - » THIS IS TO POSITION THE FLUID IN AN AXISYMMETRIC CONFIGURATION
  - THE ROLL RATE CAN THEN BE LOWERED TO A MINIMUM ROLL RATE DEPENDING ON THE FILL LEVEL
    - » THIS PERFORMANCE IS BASED ON THE LOWER STABILITY OF THE AXISYMMETRIC PROFILE
    - » MINIMUM ROLL RATE OF 0.14 RPM IS REQUIRED WHEN THE TANK IS 95% FULL
    - » THE MINIMUM ROLL RATE DECREASES AS THE FLUID IS DEPLETED (I.E. 0.1 RPM AT 91%)

DYNAMIC FLUID MOTION

- A STUDY WAS PERFORMED TO SELECT A CONFIGURATION THAT WOULD DAMPEN FLUID MOTION IN THE TANK
  - THERE WERE NO SPECIFIC REQUIREMENTS AT THE TIME OF THIS STUDY
- PARALLEL AND RADIAL BAFFLE CONFIGURATIONS WERE STUDIED
  - CANDIDATE DESIGNS WERE SUCH THAT THEY WOULD NOT INTERFERE WITH AN ULLAGE WHOSE LIQUID/VAPOR INTERFACE HAD NOT STRETCHED THE ENTIRE LENGTH OF THE TANK
- BASED ON THIS STUDY A CONFIGURATION WITH FOUR RADIAL AND THREE PARALLEL BAFFLES WAS SELECTED
- THE 3D CFD CODE WAS RUN TO DETERMINE THE FLUID DISPLACEMENT AND FORCES DUE TO AN IMPULSE DISTURBANCE
  - DATA WAS GENERATED FOR USE BY THE SPACECRAFT CONTROL MODEL

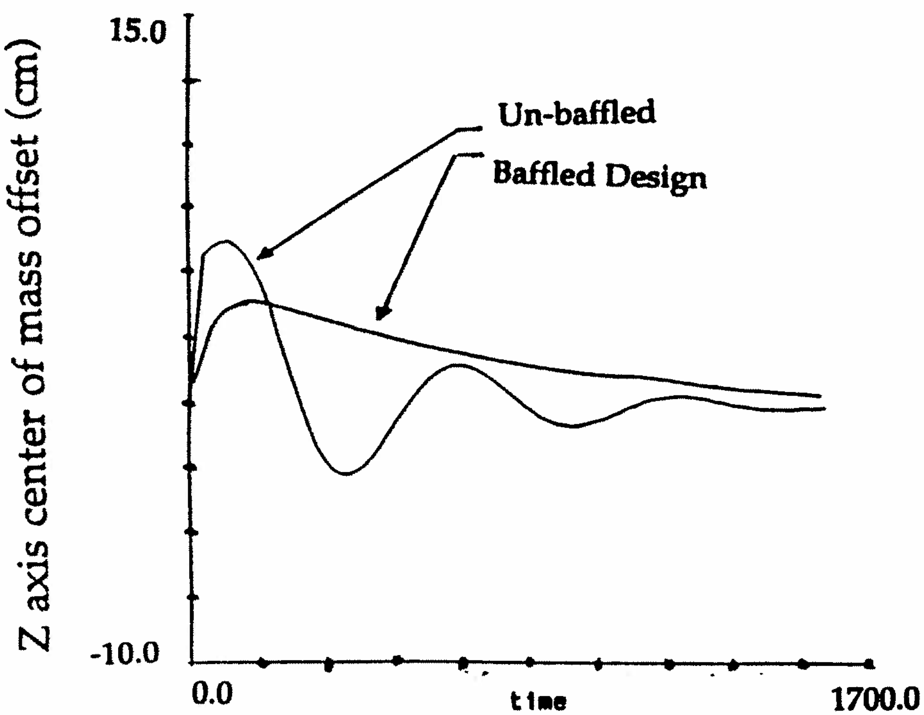
SLOSH BAFFLE CONFIGURATION

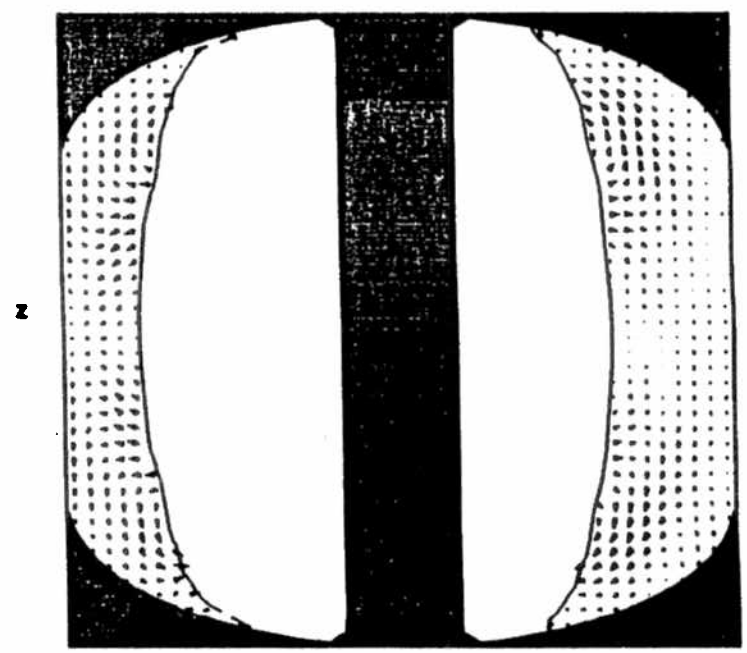


STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

AXIAL FLUID MOTION

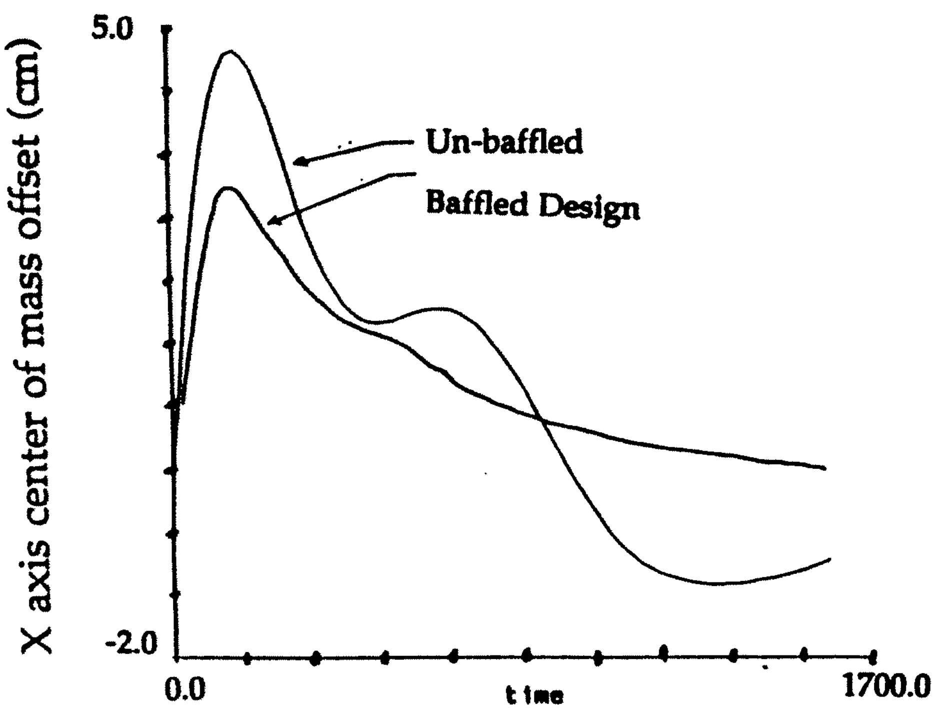
- THE 3D MODEL WAS USED TO DETERMINE THE FLUID MOTION DUE TO A DISTURBANCE (0.01 g_O FOR 10 ms) IN THE AXIAL DIRECTION
- FIGURES SHOW THE RESULTS FOR THE BAFFLED AND UNBAFFLED TANK WITH 60% REMAINING AT 0.1 RPM
  - BAFFLES PROVIDE GOOD DAMPING OF THE FLUID MOTION

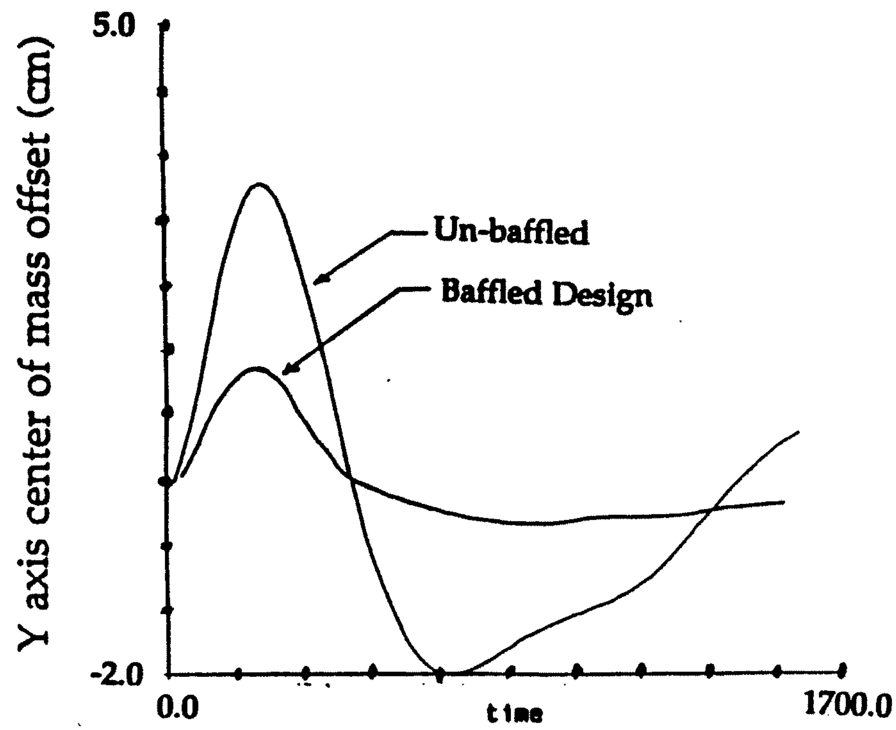




LATERAL FLUID MOTION

- THE 3D MODEL WAS USED TO DETERMINE THE FLUID MOTION DUE TO A DISTURBANCE (0.01 g_o FOR 10 ms) IN THE LATERAL DIRECTION
- FIGURES SHOW THE RESULTS FOR THE BAFFLED AND UNBAFFLED TANK WITH 60% REMAINING AT 0.1 RPM
  - RESULTS ARE SHOWN IN BODY-FIXED COORDINATES
  - BAFFLES PROVIDE GOOD DAMPING OF THE FLUID MOTION





STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

TANKS AND SUBASSEMBLIES

RICHARD PARMLEY

HARDWARE DISCUSSED IN THIS SECTION

- MAIN TANK AND WELL
- MAIN TANK SUBASSEMBLIES
  - AXIAL LOK
  - CRYOPERM SHIELD
  - PROTON SHIELD
- LEAD BAG AND RETAINER
- GUARD TANK

MAIN TANK AND SUBASSEMBLIES

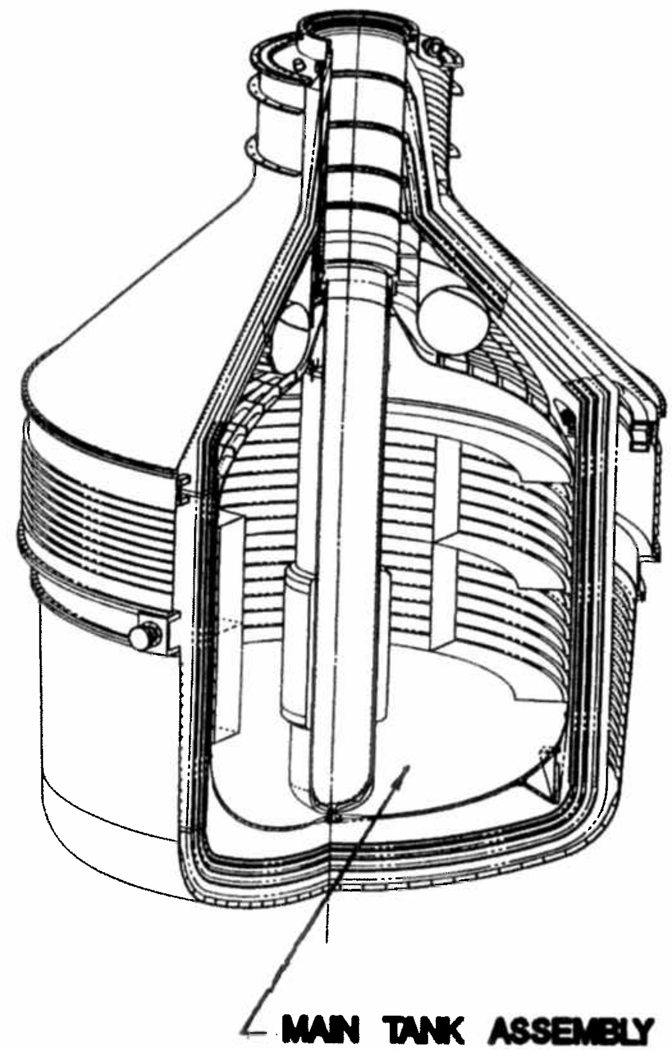
- FUNCTIONS
- REQUIREMENTS
- DESIGN DESCRIPTION
- RISKS AND RISKS REDUCTION
- STATUS

MAIN TANK FUNCTIONS AND VERIFICATION

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

FUNCTIONS:
1) CONTAIN He II FOR SIA COOLING AND USE OF BOILOFF IN SPACECRAFT PROPORTIONAL THRUSTERS
2) PROVIDE WELL, STA 200 AND AXIAL LOK FOR PROBE SUPPORT, COOLING
3) PROVIDE LOW MAGNETIC FIELDS FOR SIA USING CRYOPERM SHIELD AND EXPANDED LEAD BAG
4) PROVIDE PROTON SHIELDING FOR SIA
5) PROVIDE CENTER OF MASS CONTROL (COM) OF He II

VERIFICATION:
1) PROOF PRESSURE TEST, WARM
2) LEAK TESTS, WARM AND COLD
3) AXIAL LOK FUNCTIONAL TEST
4) INSTRUMENTATION C/O
5) WELL MAGNETIC MAPPING, WARM
6) PROTON SHIELDING BY ANALYSIS
7) COM CONTROL BY ANALYSIS



DERIVED
TANK DESIGN REQUIREMENTS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

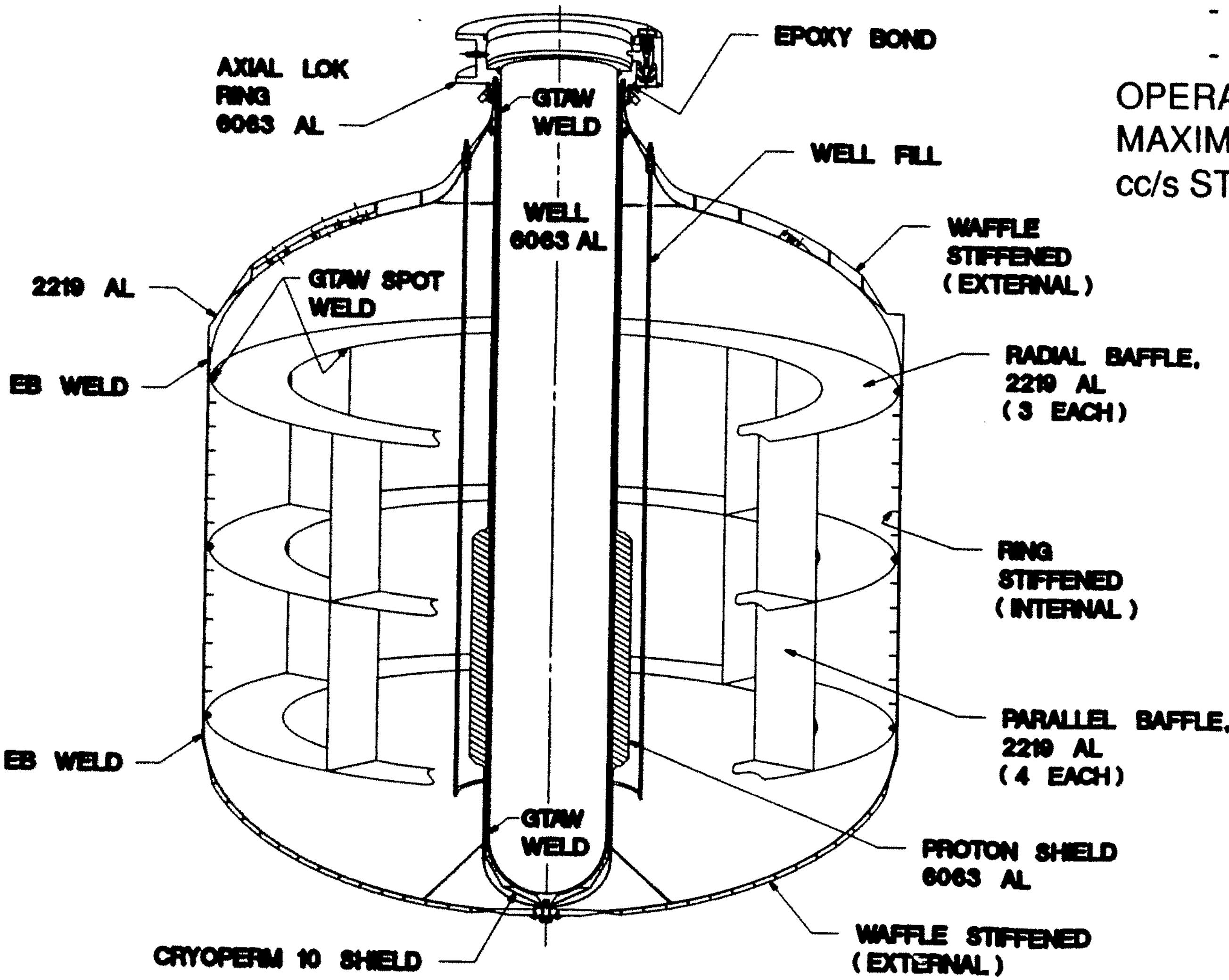
ITEM	REQUIREMENT	MEETS REQMT	VERIFICATION
HELIUM LEAK RATE	< 1 X 10^{-8} SCC/S	√	BY DESIGN
TANK MAX OPERATING PRESSURE			
INTERNAL	.26 MPa (38 PSID)	√	ANALYSIS
EXTERNAL	.13 MPa (19 PSID)	√	ANALYSIS
WELL MAX OPERATING PRESSURE			
INTERNAL	.13 MPa (19 PSID)	√	ANALYSIS
EXTERNAL	.36 MPa (53 PSID)	√	ANALYSIS
TANK DESIGN LOADS			
LATERAL	6.0 g	√	ANALYSIS
AXIAL	6.3 g	√	ANALYSIS
INTERFACES	-LEAD BAG & RETAINER -PLUMBING -CNT -PODS -INSTRUMENTATION		

STANFORD

Lockheed

MAIN TANK DESIGN

LMSC-P088357
2,3 MAR 94



MAXIMUM PRESSURE, MPa	
- OPERATING	.26
- PROOF	.39
OPERATING TEMPERATURE, K	1.8
MAXIMUM LEAK RATE, cc/s STP GHe	$<10^{-8}$

MAIN TANK VOLUME (LITERS)

STANFORD
Lockheed

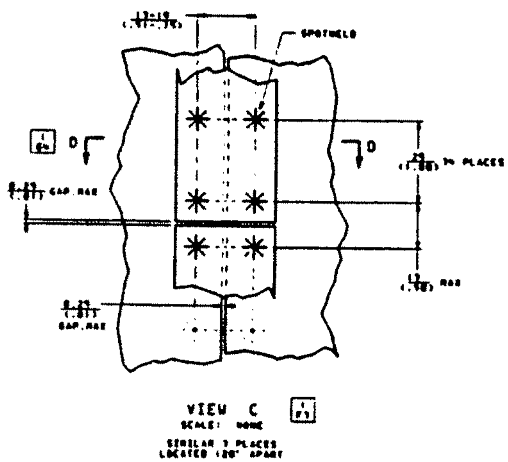
LMSC-P088357
2,3 MAR 94

AT TEMPERATURE = 1.8 K

MAIN TANK, COLD	2471.9
CRYOPERM SHIELD	- 1.7
PROTON SHIELD	- 20.7
BAFFLES	- 3.3
PLUMBING, INSTRUMENTATION	- 5.0
USABLE VOLUME	2441.2
- LIQUID	2319.1 (337 kg)
- GAS	122.1 (5%)

CRYOPERM SHIELD DESIGN

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



RQMT AT SIA, STEADY STATE

$\leq 3 \times 10^{-5}$ TESLA

ATTENUATION FACTOR RQMT

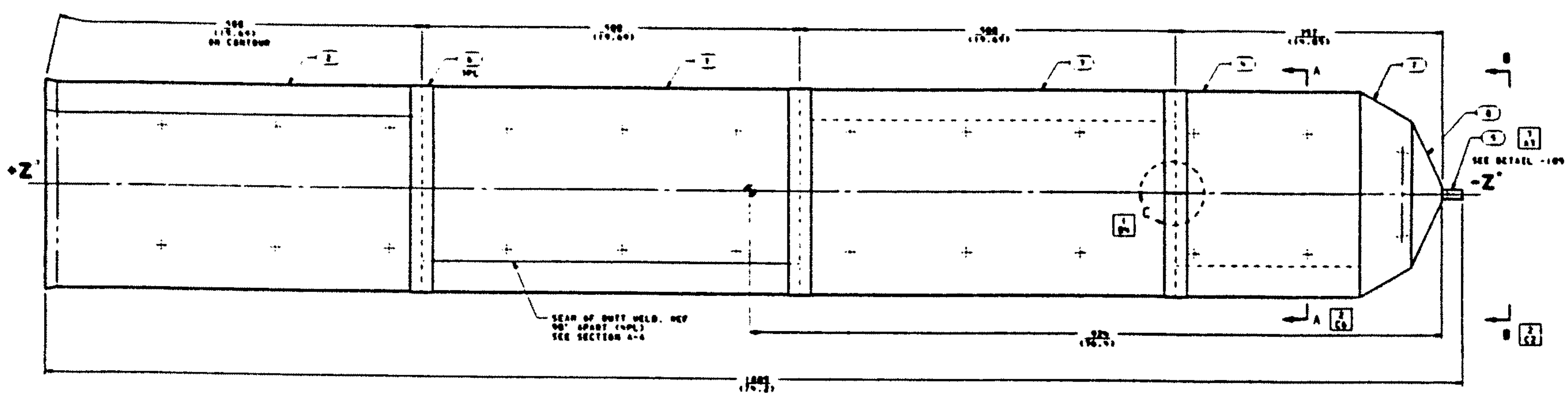
$\leq 5 \times 10\text{-}2$ T, LONG

$\leq 5 \times 10\text{-}3$ T, TRANS

MATERIAL

SHIELD: CRYOPERM 10

PIN: μ-METAL

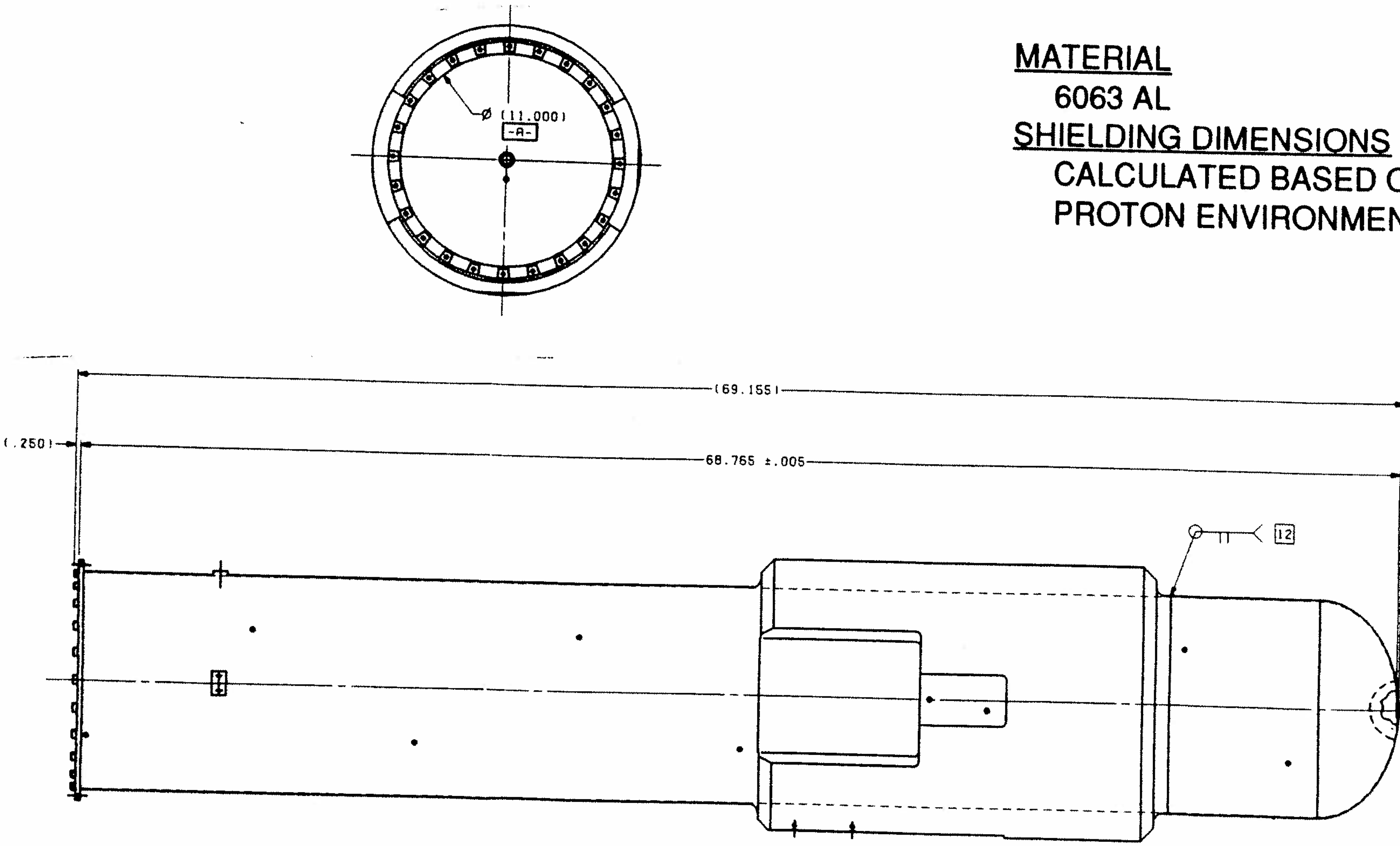


TK - 9

PROTON SHIELD DESIGN

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

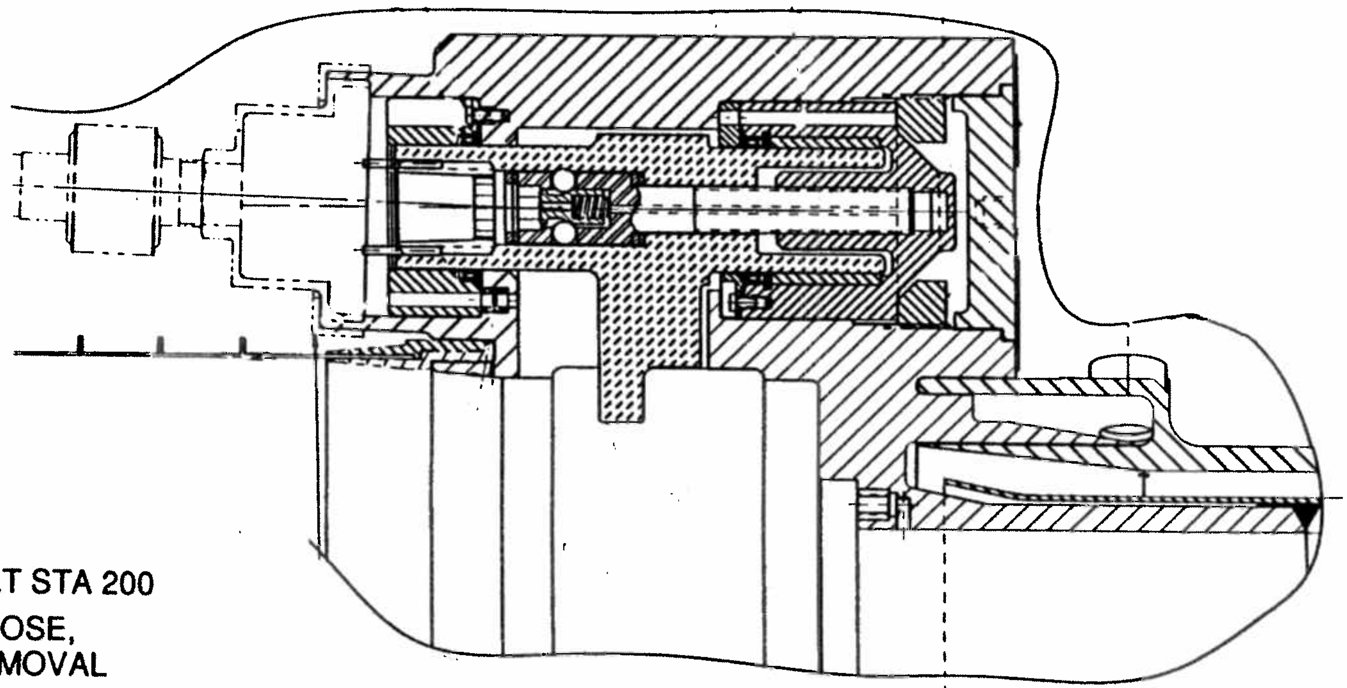


MATERIAL
6063 AL

SHIELDING DIMENSIONS
CALCULATED BASED ON
PROTON ENVIRONMENT

AXIAL LOK MECHANISM

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



FUNCTIONS

- CLAMPS PROBE AT STA 200
- BREAK PROBE LOOSE, IF REQ'D. FOR REMOVAL
- EXPANDS PROBE BELLOWS AND COMPRESSES 24 PROBE THERMAL SHOES DURING PROBE INSERTION

VERIFICATION

- EDD / PROBE-A TESTS
- FLIGHT VERSION IN DEV.TEST (SECTION DT)

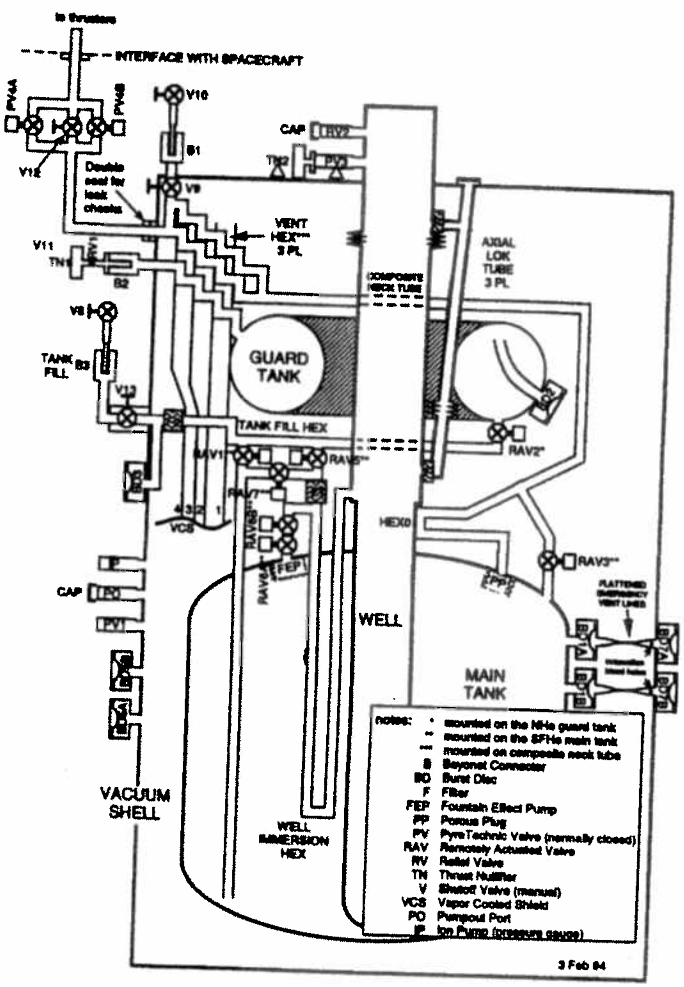
CHANGES SINCE PDR

- THREAD PITCH FROM 1/24 TO 1/40
- TEFLON SEALS, 2 PLACES
- 2 μ FILTERS
- MATERIAL CHANGES(MAGNETIC REASONS)
  - BALL LOCKING CONE: 304 L TO BeCu #25
  - BALL BEARING: 440 CRES TO Ti 6AL-4V

MAIN TANK PLUMBING FUNCTIONS

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94



- <u>EVACUATION, PURGE OF PLUMBING/TANKS</u>
- <u>FILL OF MAIN TANK WITH He I OR He II</u>
- <u>DRAIN OF MAIN TANK</u>
- FILL OF GUARD TANK WITH He I
- EMPTYING GUARD TANK WITH HEATERS
- COOLDOWN OF BYPASS FILL LINE
- <u>FILL OF WELL WITH He I AT < 6.5 K FROM EXTERNAL SOURCE OR MAIN TANK</u>
- <u>FILL OF WELL WITH 12 TORR GHe OR He II</u> (IF REQUIRED)
- <u>VENTING OF TANKS, LINES TO SPACE</u>
- <u>OVERPRESSURE PROTECTION FOR ALL CLOSED VOLUMES</u>

MAIN TANK RISKS AND RISK REDUCTION

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

RISKS	RISK REDUCTION
• WAFFLE DOMES ARE COMPLICATED MACHININGS	• C/O NC PROGRAM ON PLASTIC OR LOWER COST CASTING (DUPLICATES ORDERED)
• HIGH COST/SCHEDULE IMPACT IF FINAL WELDS NOT SATISFACTORY	• WELD DEVELOPMENT ON ALL WELDS, LEAK CHECKS, BONDED DOUBLER
• LEAKAGE OF ELECTRICAL FEEDTHRUS	• THERMALLY CYCLE TO 77 K AND LEAK CHECK FEEDTHRUS PRIOR TO INSTALLATION (REF DEV. TEST SECTION)
• LEAKAGE OF HELICOFLEX SEALS FOR PP AND FEP	• HELICOFLEX SEAL QUALIFIED (SEE SECTION DT)

MAIN TANK STATUS

- DETAILED DWG'S. COMPLETE
- CHEMTRONICS SELECTED TO BUILD TANK
- CRYOPERM SHIELD ON ORDER (VACUUMSCHMELZE)
- FORGINGS
  - RECEIVED
    - » FORWARD DOME
    - » AXIAL LOK RING
    - » WELL CYLINDER
    - » WELL HEMISPHERE
  - ON ORDER
    - » AFT DOME
    - » CYLINDER
    - » PROTON SHIELD
- MACHINING IN PROGRESS
  - AXIAL LOK RING
  - FORWARD DOME
  - WELL CYLINDER

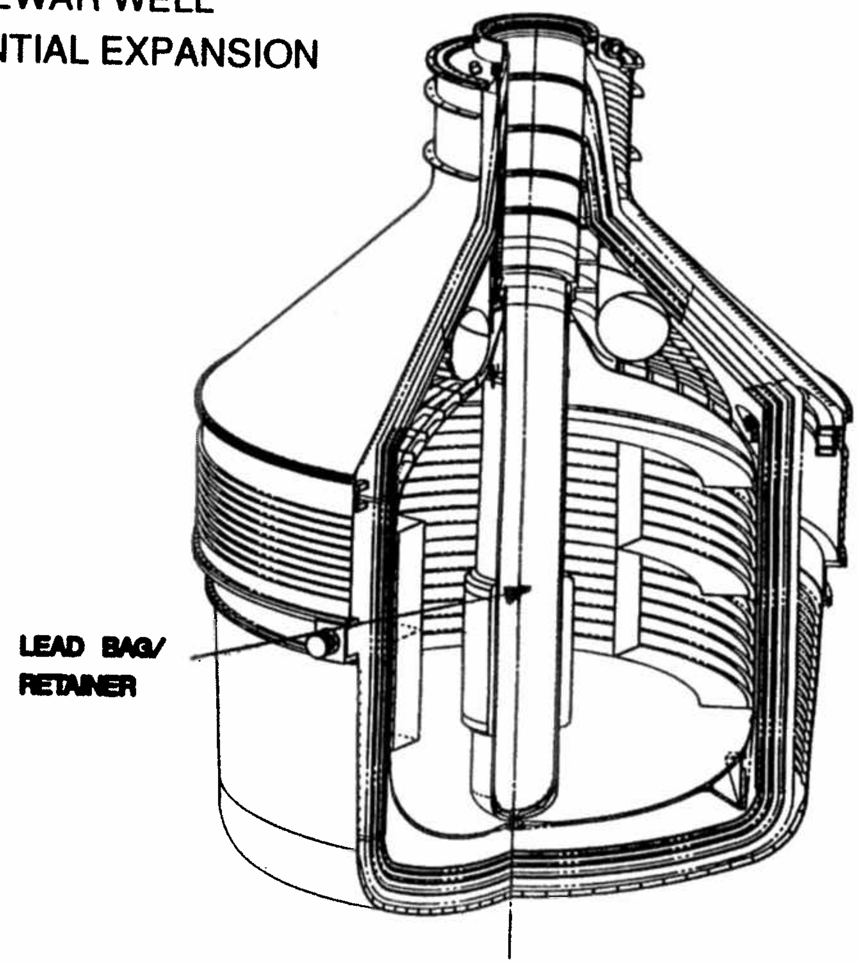
LEAD BAG AND RETAINER

- FUNCTIONS, REQUIREMENTS
- PERFORMANCE
- DESIGN
- STATUS

LEAD BAG AND RETAINER FUNCTIONS, REQUIREMENTS

- LEAD BAG
  - ESTABLISH AND MAINTAIN MAGNETICALLY SHIELDED REGION OF < 1 X 10 E-7 GAUSS FOR SIA IN DEWAR WELL
  - LOW FIELD ESTABLISHED THROUGH SEQUENTIAL EXPANSION OF SUPERCONDUCTING LEAD FOIL BAGS
- LEAD BAG RETAINER
  - PROBE CENTERING DURING INSERTION
  - ENSURE THERMAL CONTACT BETWEEN BAG AND WELL
  - PREVENT BAG FROM FALLING DOWN INTO WELL ON ASCENT
  - SUPPORT CANTILEVERED PROBE DURING ASCENT
  - PROBE INSERTION FRICTION

    FORCE < 318 KG (<700 LB)
  - INTERFACE: INSERTS AT STA 200
- GSE: ALL EXISTING EQUIPMENT



LEAD BAG AND RETAINER PERFORMANCE

- AFTER INSTALLAT ION OF RETAINER INTO EDD,
  LEAD BAG MAGNETIC FIELD INCREASED FROM $1x10^{-7}$ TO $4x10^{-6}$ GAUSS
  - Be Cu SHEET MATERIAL THE PROBLEM
  - COUPONS PASS CRYO SCREENING, ASSEMBLY PASSES R.T. SCREENING
  - BOTTOM 35" OF SPRINGS CUT OFF AS TEMPORARY FIX FOR EDD ONLY
  - BRUSH ALLOY 199 SUBSTITUTED FOR BeCu FOR NEW RETAINER
- SURVIVAL OF LEAD BAG IN VIBRATION ENVIRONMENTS
  - PRELIMINARY ANALYSES SHOW LEAD BAG HEATING (> 6.5 K) DURING LAUNCH MAY BE A PROBLEM
  - CONSEQUENTLY THE SMD PLUMBING WAS MODIFIED TO ALLOW EITHER GHe OR He II FILL OF THE WELL JUST PRIOR TO LAUNCH, TO FACILITATE HEAT TRANSFER
- GROUND VIBRATION TESTS OF PROBE-B IN SMD WILL DETERMINE WHETHER VACUUM OR HE II IS USED DURING LAUNCH. ALSO WILL EVALUATE MECHANICAL DAMAGE.

MATERIAL SUBSTITUTION FOR LEAD BAG RETAINER SPRINGS

TK - 17

(DUE TO UNSATISFACTORY MAGNETIC PROPERTIES)

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

	BERYLLIUM COPPER CURRENT MATERIAL UNSC - 17200	BERYLLIUM COPPER BINARY*	SUBSTITUTE MATERIAL UNS C19900 BRUSH ALLOY 199
CHEMICAL COMPOSITION,%	Be 1.82, Co .20, Ni .06, Fe .07, Cu BAL	Be 1.8, Cu BAL	Ti 3.0, Cu BALANCE, 1/4 HT
TEST CONDITIONS: 2K, 100G			
SAMPLE SIZE, g	.07	.91	.09
REMANENT MOMENT, emu	6.1×10^{-7}	1.8×10^{-7}	2.2×10^{-7}
SUSCEPTIBILITY,emu/G	4.9×10^{-7}	5.0×10^{-7}	3.0×10^{-8}
MASS SUSCEPTIBILITY	7.0×10^{-6}	5.5×10^{-7}	3.3×10^{-7}
APPROVED FOR USE (J. LOCKHART)	NO	YES	YES
MODULUS, 10^6 psi	18.5		18
YIELD STRENGTH, ksi	70		80
TENSILE STRENGTH, ksi	80		100
THERMAL COND, w/mK	107		69
DENSITY,lb/in^3	.298		0.315

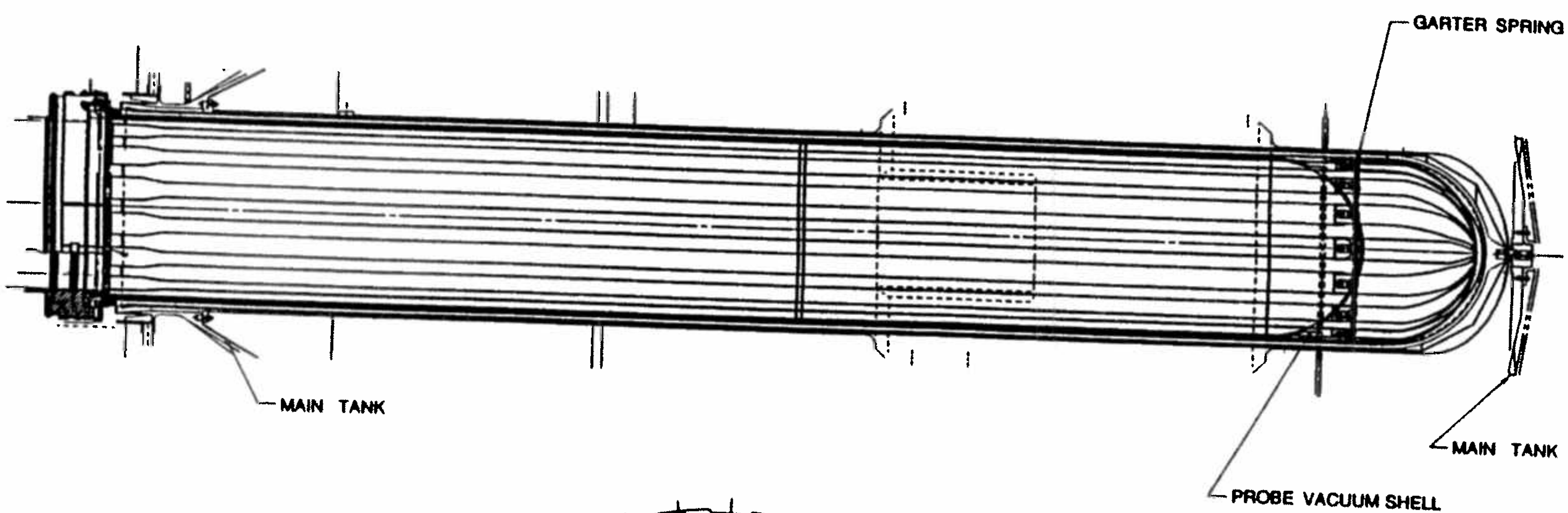
* BINARY BERYLLIUM COPPER ALLOY WITHOUT Co, Ni, Fe HAS LARGE, HARD TO CONTROL GRAIN SIZES. SPECIAL MILL RUN REQUIRED.

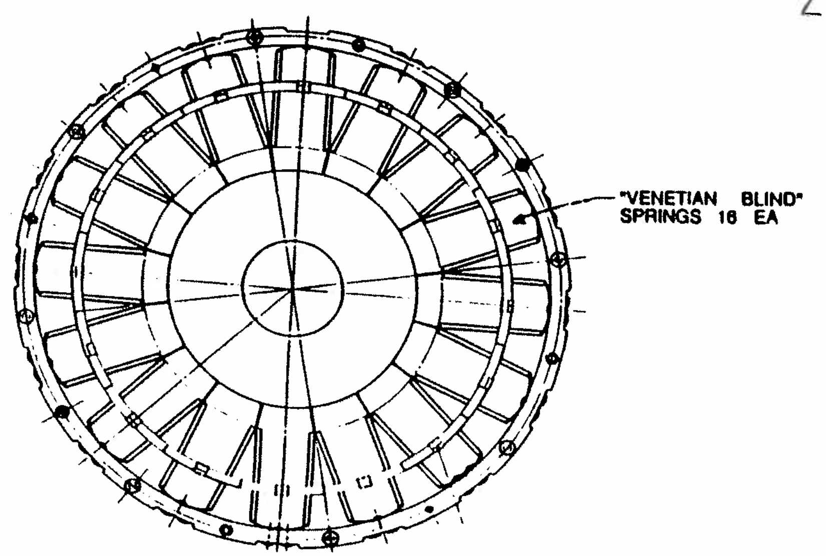
TK - 18

ASSEMBLY DRAWING
LEAD BAG RETAINER

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94





<u>CHANGES SINCE PDR</u>

MATERIAL: BeCu to TiCu

EXTENSION OF SPRINGS
TO BOTTOM OF WELL

LEAD BAG AND RETAINER STATUS

- MAGNETIC FIELD OF 1 X $10E^{-7}$ GAUSS ACHIEVED IN EDD
- FEWER EXPANSIONS REQUIRED THAN EXPECTED
- RETAINER IS PERFORMING ITS PROBE CENTERING FUNCTION WELL IN EDD
- GSE & INSTALLATION PROCEDURES HIGHLY DEVELOPED
- NEW RETAINER TO BE AVAILABLE BY JUNE 1994

GUARD TANK

- FUNCTIONS
- REQUIREMENTS
- DESIGN DESCRIPTION
- RISKS AND RISKS REDUCTION
- STATUS

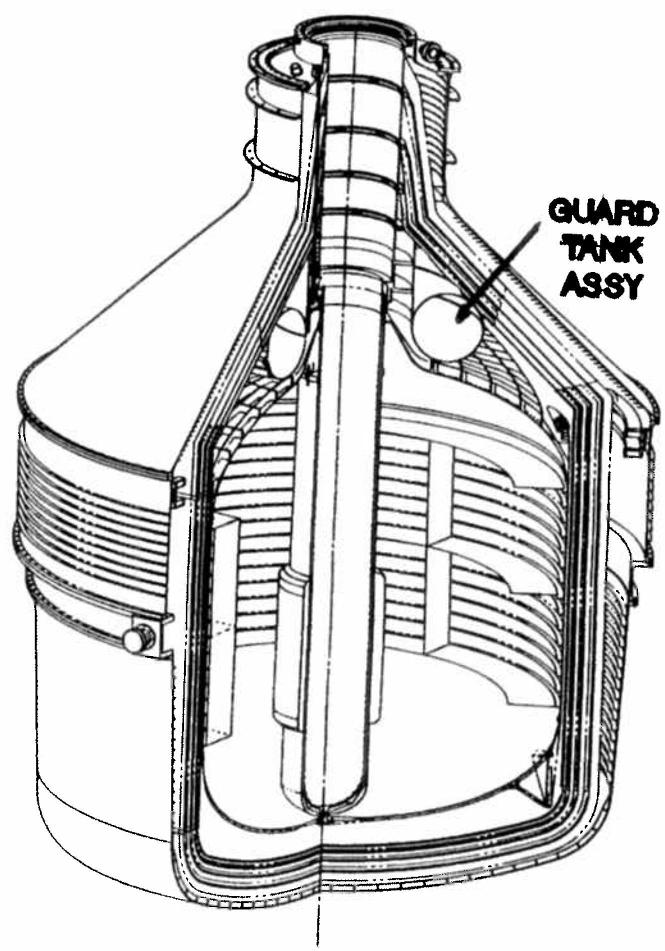
GUARD TANK FUNCTIONS AND VERIFICATION

FUNCTIONS:

1) ALLOWS MAIN TANK TO BE SERVICED AWAY FROM THE LAUNCH PAD AND LEFT NONVENTED FOR UP TO 90 DAYS PRIOR TO LAUNCH
2) ALLOWS FOR UP TO TWO LAUNCH ABORTS PLUS LAUNCH SEPARATED BY 24 HOUR INTERVALS WITHOUT ANY SERVICING REQUIRED ON THE LAUNCH PAD
3) REQUIRES REFILLING ONCE A WEEK WITH He I (4.2 K, 1 ATM)

VERIFICATION:

1) PROOF PRESSURE TEST, WARM
2) VACUUM LOAD TEST (1 ATM ΔP)
3) LEAK TESTS, WARM AND COLD
4) INSTRUMENTATION C/O



DERIVED GUARD TANK DESIGN REQUIREMENTS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

ITEM	REQUIREMENT	MEETS REQMT	VERIFICATION
HELIUM LEAK RATE *	$< 1 \times 10^{-8}$ SCC/S	√	BY DESIGN
TANK MAX OPERATING PRESSURE *			
INTERNAL	.38 MPa (55 PSID)	√	ANALYSIS
EXTERNAL	.13 MPa (19 PSID)	√	ANALYSIS
TANK DESIGN LOADS			
LATERAL	5.2 g	√	ANALYSIS
AXIAL	6.3 g	√	ANALYSIS
INTERFACES	-PLUMBING -CNT -VCS NO. 1 -ELECTRICAL		

* CHANGED FROM PDR

TK - 23

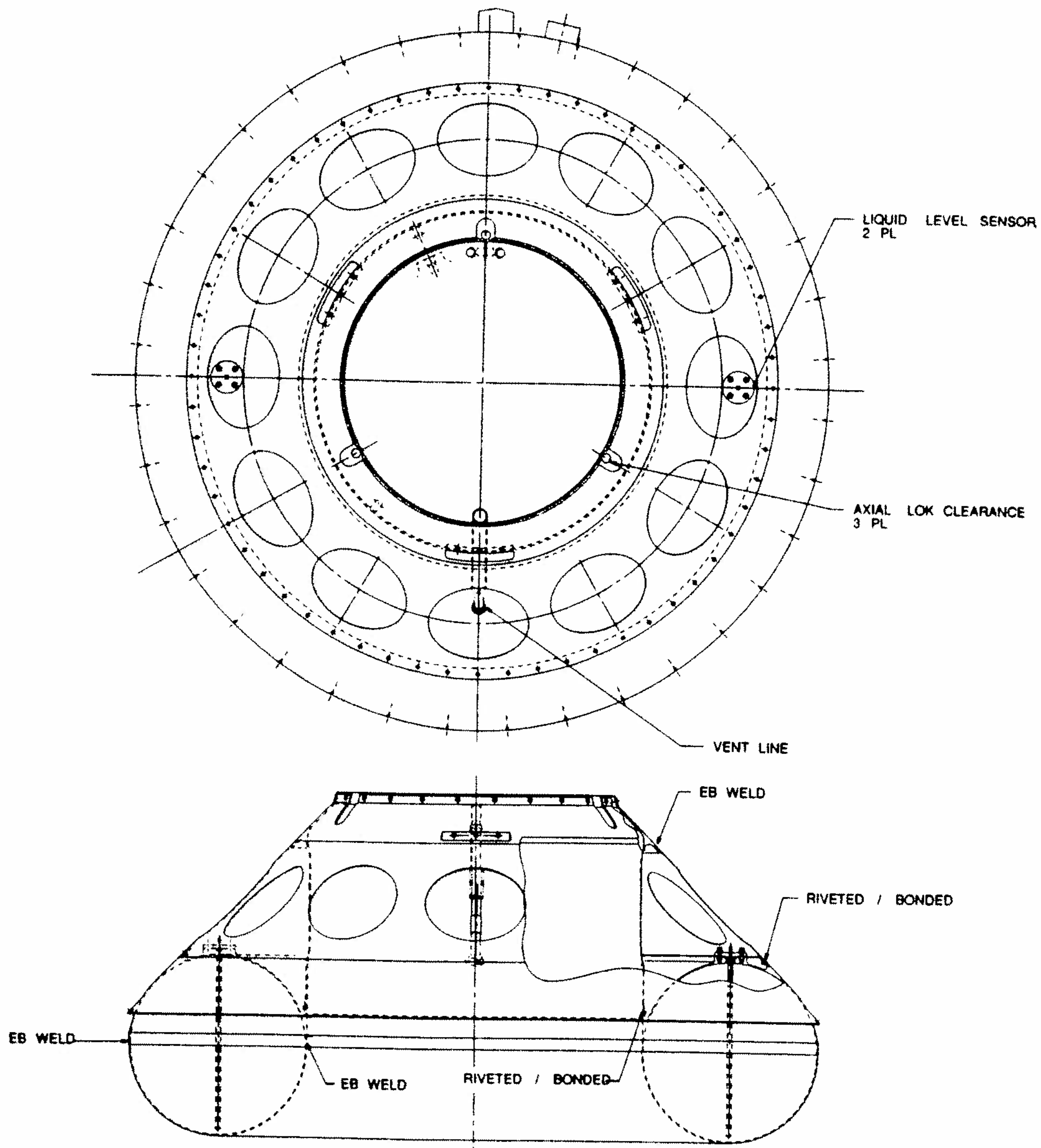
GUARD TANK

(TANK 2219 AL, SUPPORT CYL/CONE 6063 AL)

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94



TANK VOL, LITERS
- WARM 98.8
- COLD 97.6

MAX PRESS*, MPa
- OPERATING .38
- PROOF .57

OPERATING TEMP,K 4.2

MAX LEAK RATE*, cc/s STP GHe $<10^{-8}$

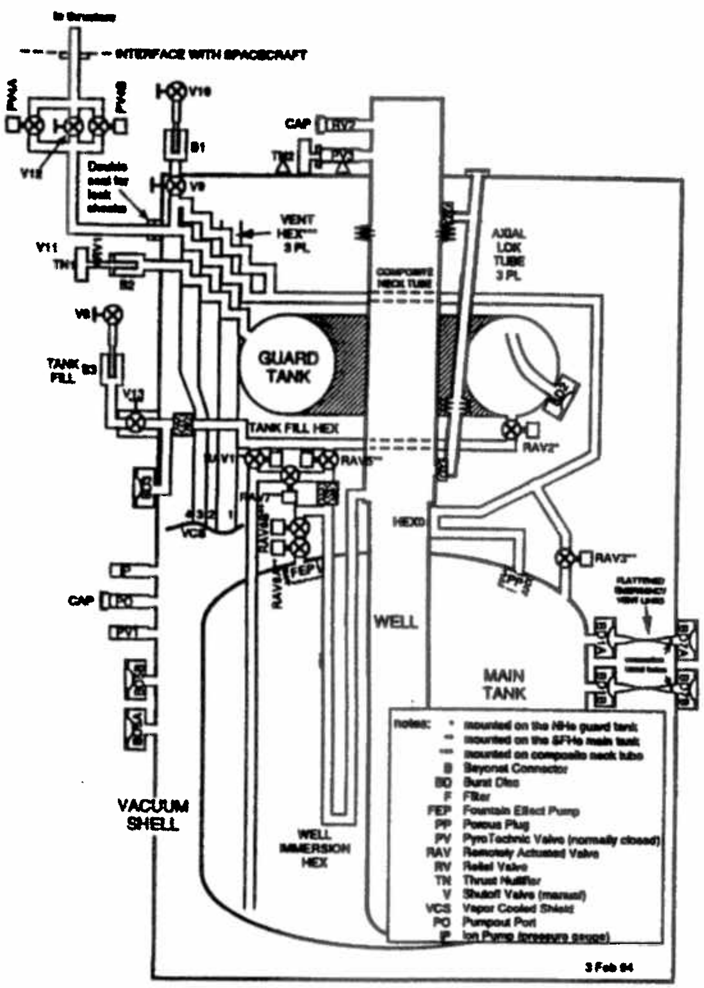
* CHANGED FROM PDR

TK - 24

GUARD TANK PLUMBING FUNCTIONS

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94



- EVACUATION, PURGE OF PLUMBING/TANKS
- FILL OF MAIN TANK WITH He I OR He II
- DRAIN OF MAIN TANK
- FILL OF GUARD TANK WITH He I
- EMPTYING GUARD TANK WITH HEATERS
- COOLDOWN OF BYPASS FILL LINE
- FILL OF WELL WITH He I AT < 6.5 K FROM EXTERNAL SOURCE OR MAIN TANK
- FILL OF WELL WITH 12 TORR GHe OR He II (IF REQUIRED)
- VENTING OF TANKS, LINES TO SPACE
- OVERPRESSURE PROTECTION FOR ALL CLOSED VOLUMES

GUARD TANK RISKS AND RISK REDUCTION

RISK	RISK REDUCTION
•LEAKAGE OF SEALS	• THERMALLY CYCLE TO 77 K, LEAK TEST FEED THRU* AND SEALS*
•LEAKAGE OF WELD	• WELD DEVELOPMENT, BONDED DOUBLER

* SEALS HAVE PASSED THERMAL CYCLING, LEAK TEST; ELECTRICAL FEEDTHRU TESTS ARE SCHEDULED (REF DEV TEST SECTION)

GUARD TANK STATUS

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

- FINAL DESIGN COMPLETE
- FORGINGS ON ORDER
- FABRICATION TO START IN APRIL 94

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

THERMAL PROTECTION SYSTEM

RICHARD PARMLEY

MULTILAYER INSULATION, VAPOR COOLED SHIELDS

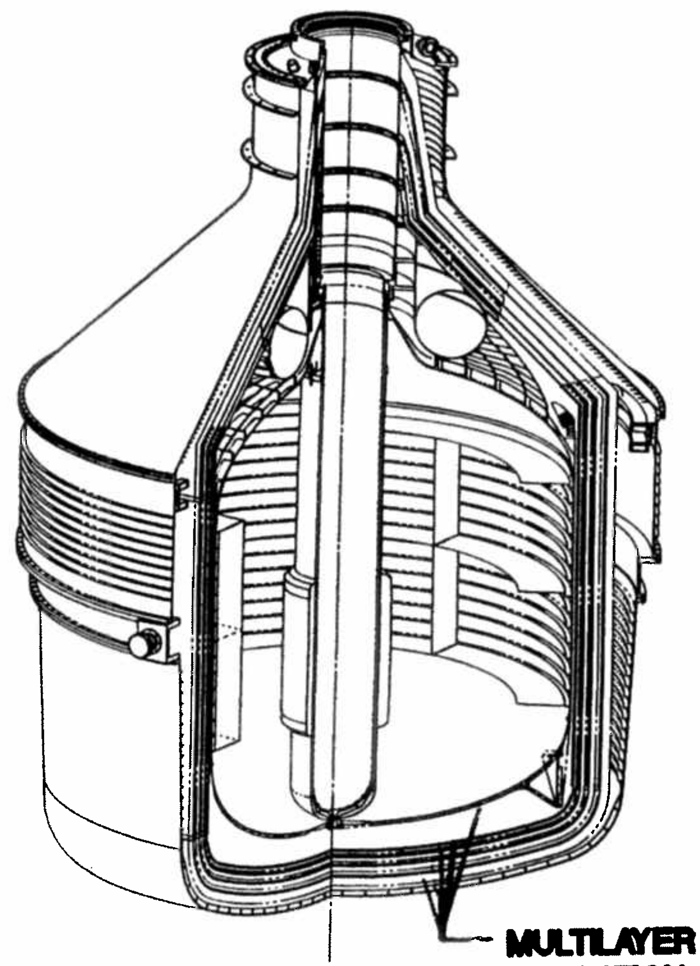
- MULTILAYER INSULATION
  - FUNCTIONS
  - DESIGN
  - CUTTING PATTERNS
- VAPOR COOLED SHIELDS
  - FUNCTIONS
  - DESIGN
- RISK / RISK REDUCTIONS
- STATUS

MULTILAYER INSULATION

FUNCTION: REDUCE PARASITIC RADIATION HEAT LOAD TO HELIUM, INCREASE DEWAR LIFETIME

LIFETIME VERIFICATION PLAN: BOILOFF RATE MEASUREMENTS

SMD: T_H = 300K (LAB)
T_H = 220 (THERMAL VAC)



VS - 4

SM MULTILAYER INSULATION DESIGN

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

	RADIATION SHIELD 15 LAYERS / CM (37 LAYERS/IN) 1/4 MIL ALUMINIZED MYLAR (3 MIL ALUMINIZED MYLAR, ACCESS COVER REGION)			LOW CONDUCTANCE SPACER SWISS SILK NET (UN-SIZED)		
UNIT WEIGHT, kg/m² (PSF)	1/4 MIL 0.00903 (0.00 185)		3 MIL 0.107 (0.022)	0.0076 (0.00155)		
	NO	AVE. AREA, m² (ft²)	WT, kg(lb) (1.2)	NO	AVE. AREA, m² (ft²)	WT, kg(lb) (1.2)
TANK-VCS1	7	9.7 (104)	.7 (1.6)	18 (3 ea)	9.7 (104)	1.6 (3.5)
VCS1-VCS2	14	11.8 (127)	1.8 (3.9)	39 (3 ea)	11.8 (127	4.2 (9.2)
VCS2-VCS3	21	12.6 (136)	2.9 (6.3)	40 (2 ea)	12.6 (136)	4.6 (10.1)
VCS3-VCS4	28	13.7 (147)	4.1 (9.1)	27 (1 ea)	13.7 (147)	3.3 (7.4)
VCS4-VAC SHELL	43	15.6 (168)	7.3 (16.0)	42 (1 ea)	15.6 (168)	5.9 (13.1)
	113		16.8 (36.9)	166		19.6 (43.3)

	VCS GAP cm(in)	MIL THICKNESS, cm(in)	RADIATION GAP (WARM SIDE), cm(in)
TANK-VCS1*	1.02(.40)	.48 (.19)	.53 (.21)
VCS1-VCS2*	1.65 (.65)	.96 (.38)	.69 (.27)
VCS2-VCS3*	2.29 (.90)	1.45 (.57)	.84 (.33)
VCS3-VCS4*	3.18 (1.25)	1.93 (.76)	1.24 (.49)
VCS4-AFT DOME*	4.57 (1.80)	2.95 (1.16)	1.63 (.64)
		7.77 (3.06)	

* EACH BLANKET ELECTRICALLY GROUNDED FROM INNER SHIELD TO OUTER SHIELD WITH TAPED SINGLE ALUMINIZED MYLAR STRIP

INSULATION PENETRATIONS

CNT AREA

- VENT LINES, 3 EA
- AXIAL LOK TUBES, 3 EA
- WIRES

CYLINDRICAL AREA

- PODS, 12 EA
- EMERGENCY VENT LINES, 2 EA
- FILL LINE, 1 EA

CUTTING INSULATION PATTERNS

- ULTRASONIC KNIFE OR LASER CUTTER FACILITY WITH COMPUTER CONTROLLED X-Y TABLE, 20 FT X 6 FT ACCURATE TO 0.014 IN. LOCKHEED FUNDED INSTALLATION IN BLDG. 205. OPERATIONAL DEC 1994

- 3-D MODEL OF DEWAR ALLOWS ITERATION OF PATTERNED CUTS FOR SILK NET AND DOUBLE ALUMINIZED MYLAR (D-A-M). APPROXIMATELY 20,000 PIECES REQ'D.

- SILK NET PIECES SEWN TOGETHER

- D-A-M TAPED TOGETHER WITH ALUMINIZED MYLAR/ACRYLIC TAPE

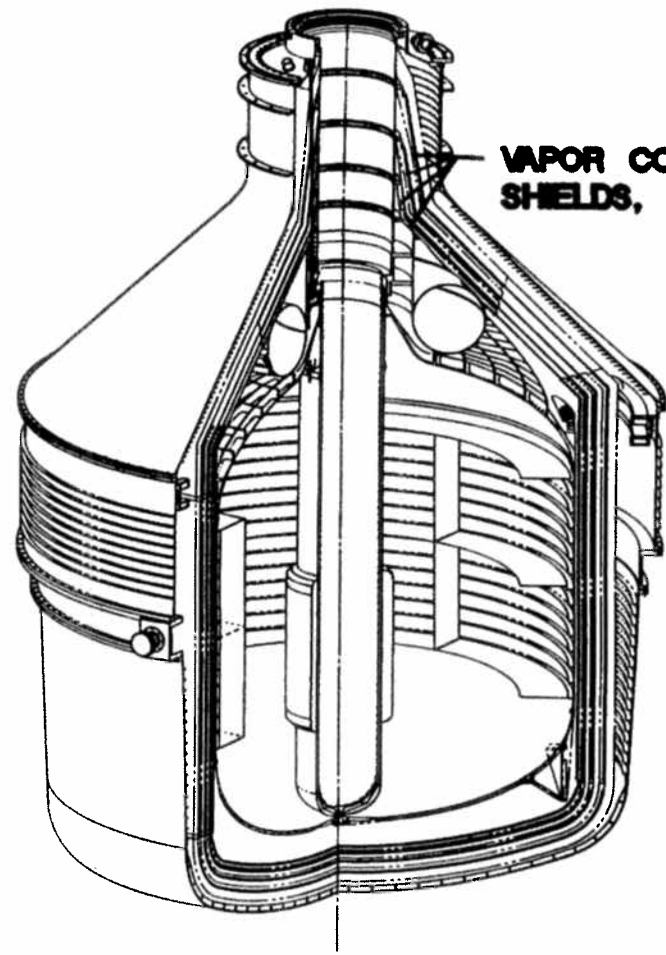
VAPOR COOLED SHIELDS (VCS)

FUNCTION:
1) CONDUCT PARASITIC HEAT LOAD COMING THRU MLI, PODS, WIRING, PLUMBING LINES TO HEX 1,2,3,4. VENT GAS CARRIES OFF HEAT EXTENDING LIFETIME.

2) SUPPORT MLI; MAINTAIN RADIATION GAPS BETWEEN SHIELDS AND MLI.

VERIFICATION:
1) PROBE B/SMD VIBRATION TEST

2) PROBE-C / SMD LIFETIME TEST
T_H = 300 K AT S.U. HEPL
T_H = 220 K AT LMSC (THERMAL VAC)



VAPOR COOLED SHIELD CONSTRUCTION AND SUPPORT

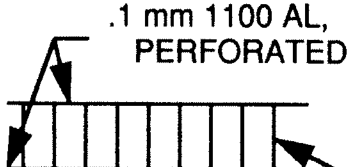
STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

VCS	CONSTRUCTION			SUPPORT		THERMAL GROUNDING
	CONE	CYLINDER	DOME	AXIAL	LATERAL	
1	HONEYCOMB	HONEYCOMB, 6 PANELS	MONOCOQUE	GUARD TANK HEX 1	12 PODS, GUARD TANK	HEX 1, 12 PODS, PLUMBING
2	HONEYCOMB/ MONOCOQUE	HONEYCOMB, 6 PANELS	MONOCOQUE	HEX 2	12 PODS, HEX 2	HEX 2, 12 PODS, PLUMBING
3	HONEYCOMB	HONEYCOMB, 6 PANELS	MONOCOQUE	6 AFT PODS	12 AFT & FORWARD PODS	HEX 3, 12 PODS PLUMBING
4	HONEYCOMB	HONEYCOMB, 6 PANELS	MONOCOQUE	6 AFT PODS	12 AFT & FORWARD PODS	HEX 4, 12 PODS, PLUMBING

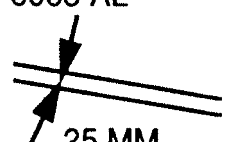
NOTES:

1. HONEYCOMB CONSTRUCTION
   .1 mm 1100 AL,
   PERFORATED FACE SHEETS
   BONDED WITH FM 24
   RETICULATED ADHESIVE



5052 A1 PERFORATED CORE,
.56 cm THICK

2. MONOCOQUE DOME
   6063 AL

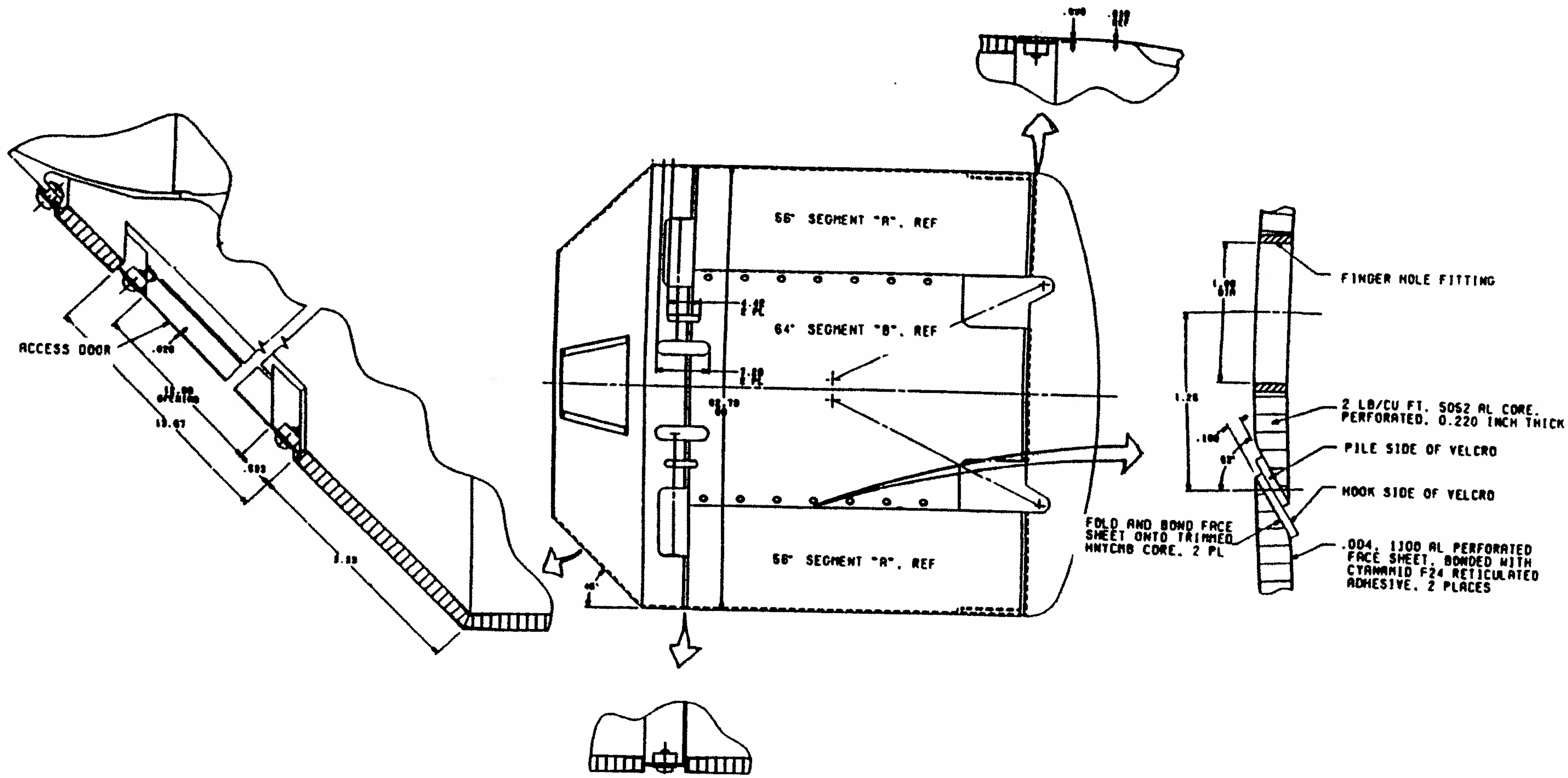


.25 MM

3. JOINTS
   VELCRO FASTENERS
   IN Z PLANE. BOLTED
   JOINTS, EPOXY BONDED
   IN X-Y PLANE

VAPOR COOLED SHIELD NO. 1 DESIGN

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



VS - 10

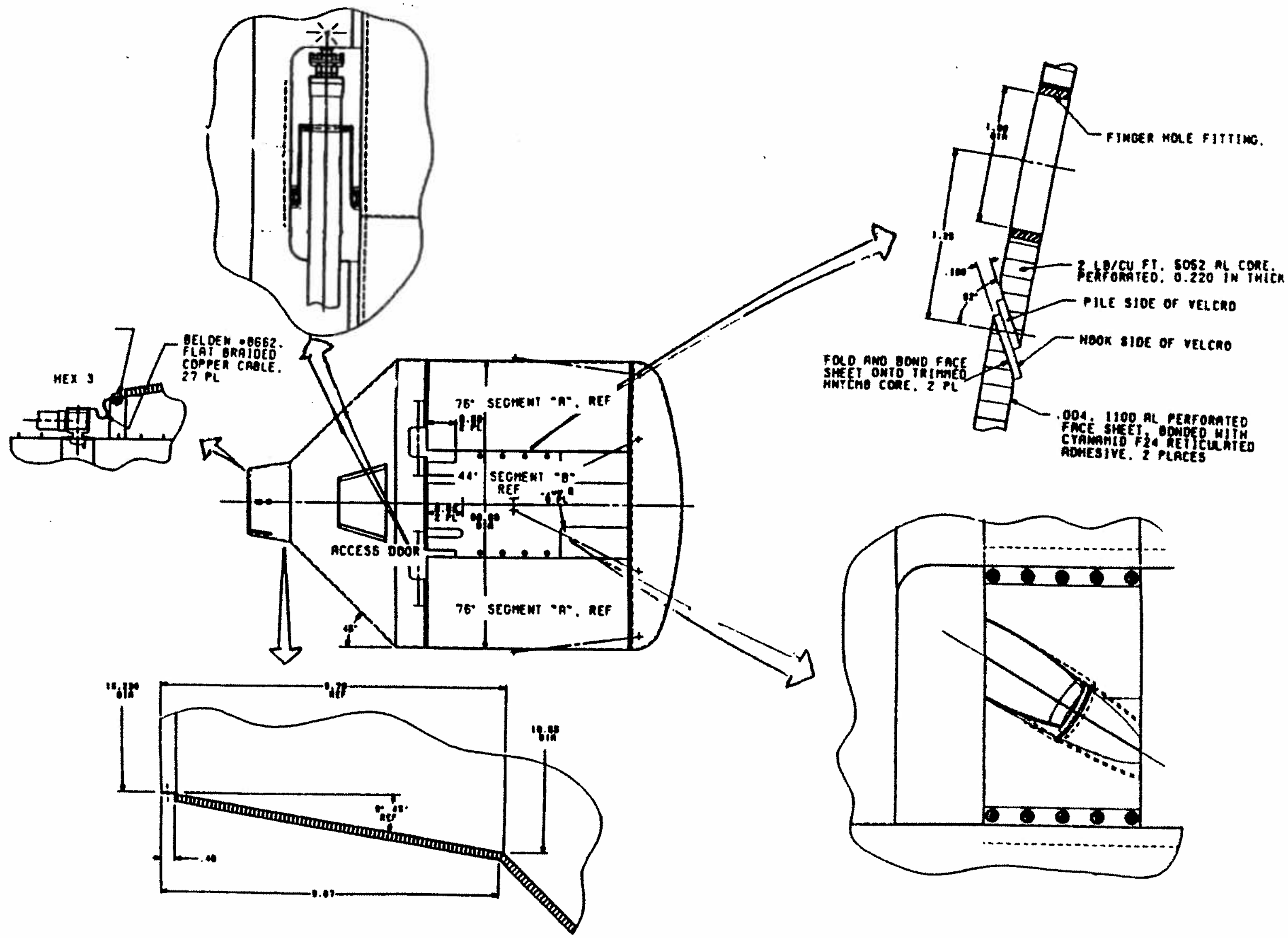
VAPOR COOLED SHIELD NO. 3 DESIGN

STANFORD

Lockheed

LMSC-P088357

2,3 MAR 94



MLI/VCS RISKS AND RISK REDUCTION

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

RISKS / CONCERNS	RISK REDUCTIONS
• THERMAL PERFORMANCE OF SM DEWAR AND PROBE ARE NOT DEMONSTRATED UNTIL LATE IN PROGRAM	• CAREFUL THERMAL MODELLING, MEASURE THERMAL CONDUCTIVITY OF ALL MTLS ROUTED FROM COLD SURFACES TO VAC SHELL. CAREFUL THERMAL GROUNDING OF PENETRATIONS, CAREFUL INSTALLATION OF THERMAL PROTECTION SYSTEM (LAYER DENSITY, FIT AROUND PENETRATIONS)
• INSTALLING THE FLIGHT MLI/VCS's MAY TAKE SIX MONTHS	• USE ULTRASONIC KNIFE OR CO_2 LASER, X-Y TABLE TO CUT PATTERNS ACCURATE TO ± 0.4mm, SPEED UP PROCESS
• IF EMERGENCY VENT OCCURS OR COLD VALVES FAIL, ACCESS THROUGH MLI/VCS IS REQUIRED	• ACCESS THROUGH MLI/VCS IS PROVIDED IN TWO AREAS (WITH FORWARD VACUUM SHELL CONE REMOVED)

MULTILAYER INSULATION AND VAPOR COOLED SHIELD STATUS

MULTILAYER INSULATION

- MATERIALS, NUMBER OF LAYERS SELECTED
- CUTTING FACILITY TO BE OPERATIONAL BY DEC 1994
- 3-D COMPUTER MODEL TO BE COMPLETE BY AUGUST 1994

VAPOR COOLED SHIELDS

- DETAILED DRAWINGS TO BE COMPLETE BY APRIL 1994
- STRESS ANALYSIS IN PROGRESS
- FABRICATOR OF VCS's TO BE SELECTED BY MAY 1994

VACUUM SHELL

- FUNCTIONS
- REQUIREMENTS
- DESIGN
- RISKS AND RISK REDUCTION
- STATUS

VS - 14

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

VACUUM SHELL

FUNCTIONS:

1) PROVIDES GUARD VACUUM AND SUPPORT POINTS (THRU 12 PODS/GRAPHITE RINGS) FOR THERMAL PROTECTION SYSTEM AND CRYOGEN TANKS

2) SUPPORT INTERFACE TO SPACECRAFT, 3 PL

3) SUPPORT FOR PROBE ELECTRONIC BOXES

4) PROBE WELL SEAL AND TOP HAT/TEE FLANGE/SUN SHADE SUPPORT

5) DEWAR PLUMBING AND ELECTRICAL INTERFACES TO GSE AND SPACECRAFT

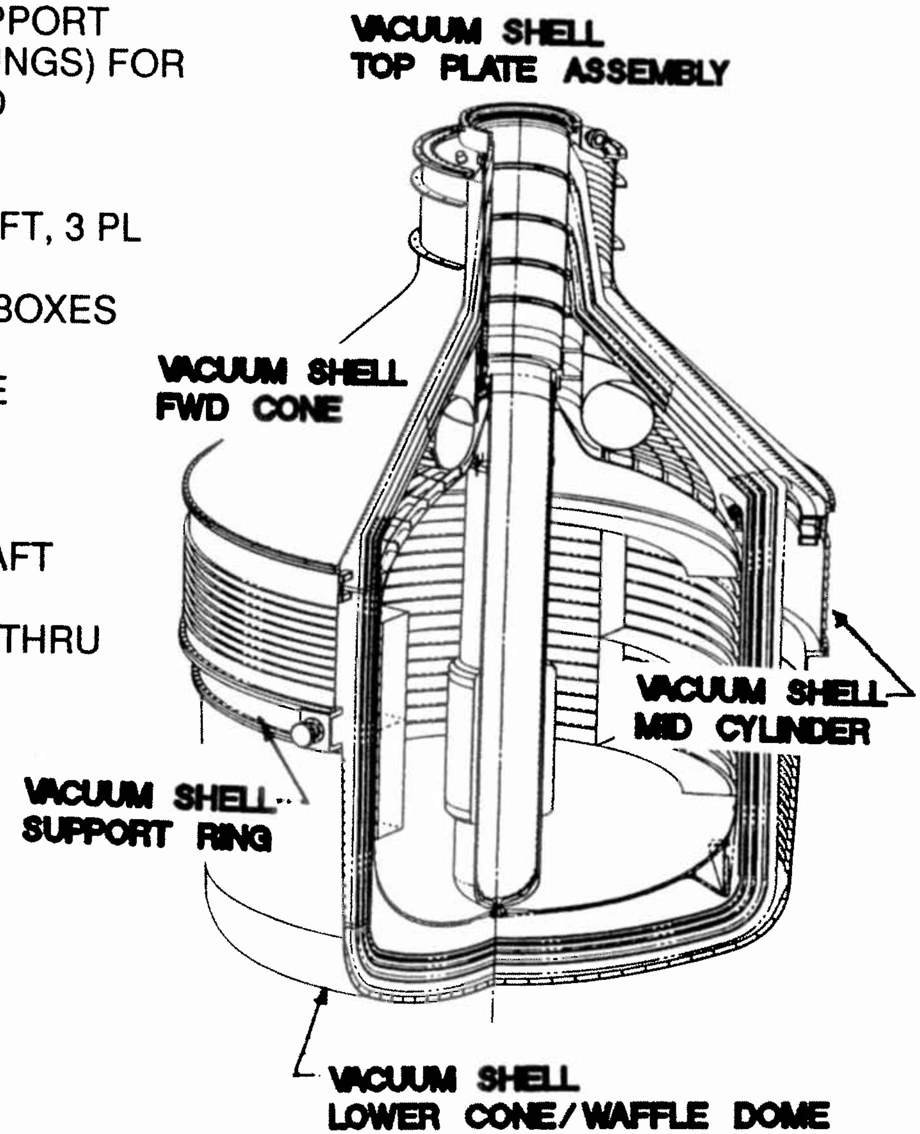
6) SUPPORT AND SEAL TO DEWAR CNT THRU BELLOWS IN TOP PLATE

VERIFICATION:

1) INTERNAL PROOF PRESSURE TEST

2) VACUUM LOAD TEST (1 ATM ΔP)

3) LEAK TEST



DERIVED VACUUM SHELL DESIGN REQUIREMENTS

ITEM	REQUIREMENT	MEETS REQMT	VERIFICATION
HELIUM LEAK RATE	$< 1 \times 10^{-7}$ SCC/S	√	BY DESIGN
VAC SHELL MAX OPERATING PRESSURE			
INTERNAL	.05 MPa (8 PSID)	√	ANALYSIS
EXTERNAL	.10 MPa (15 PSID)	√	ANALYSIS
VAC SHELL DESIGN LOADS			
LATERAL	6.6 g (6.0 SUPPORT RING)	√	ANALYSIS
AXIAL	6.3 g	√	ANALYSIS
INTERFACES	-ELECTRICAL -PLUMBING -CNT -PODS -GRAPHITE RINGS -AXIAL LOK TUNNELS, 3 EA. -PROBE ELECTRONIC BOX MOUNTS -STAR TRACKER MOUNTS, 2 EA. -SPACECRAFT INTERFACES, 3 PL		

STANFORD

Lockheed

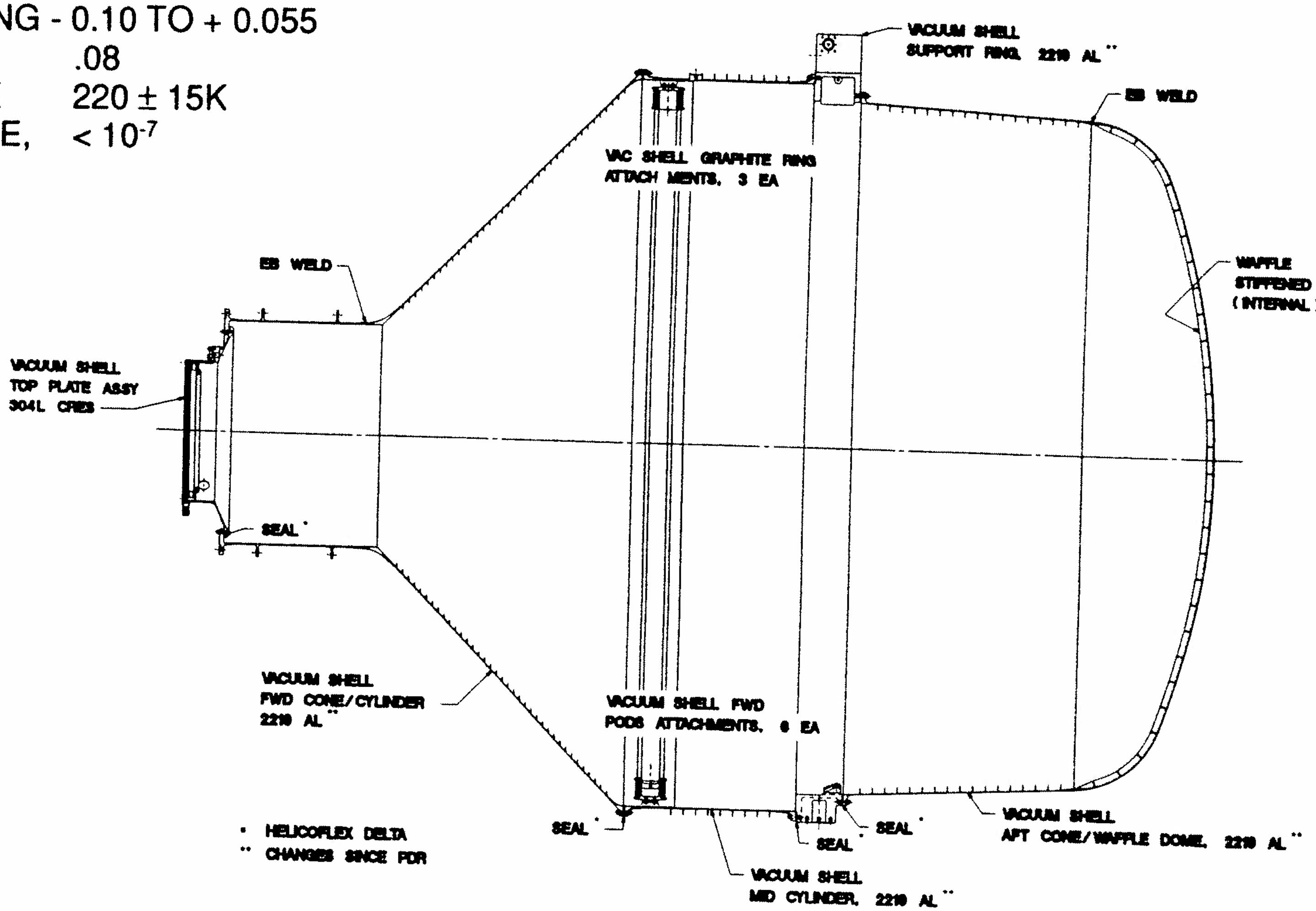
VACUUM SHELL DESIGN

LMSC-P088357
2,3 MAR 94

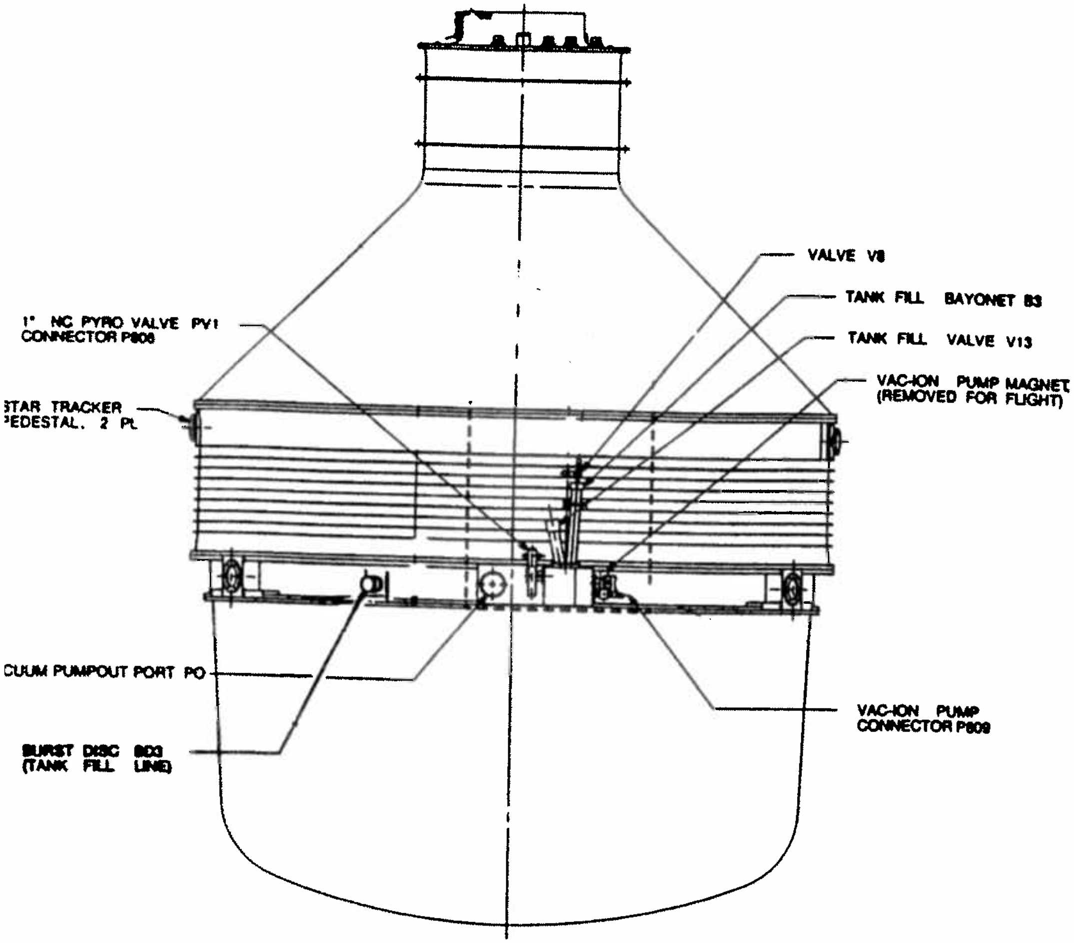
MAX PRESS, MPa
- OPERATING - 0.10 TO + 0.055
- PROOF .08

ORBIT TEMP, K 220 ± 15K

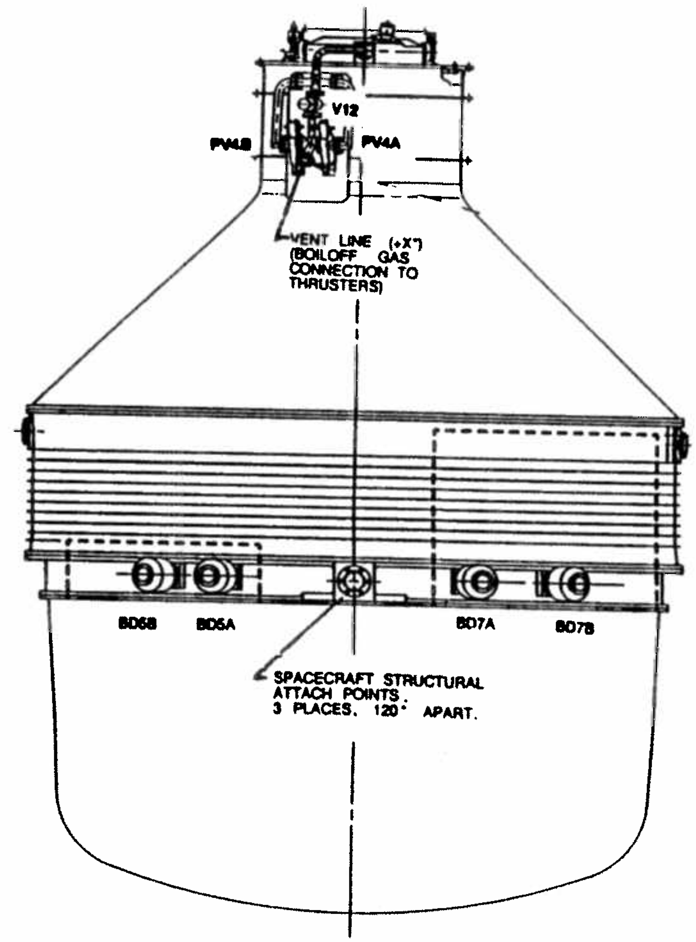
MAX LEAK RATE, cc/s STP GHe < 10^{-7}



VS - 17 VACUUM SHELL PENETRATIONS / ATTACH POINTS

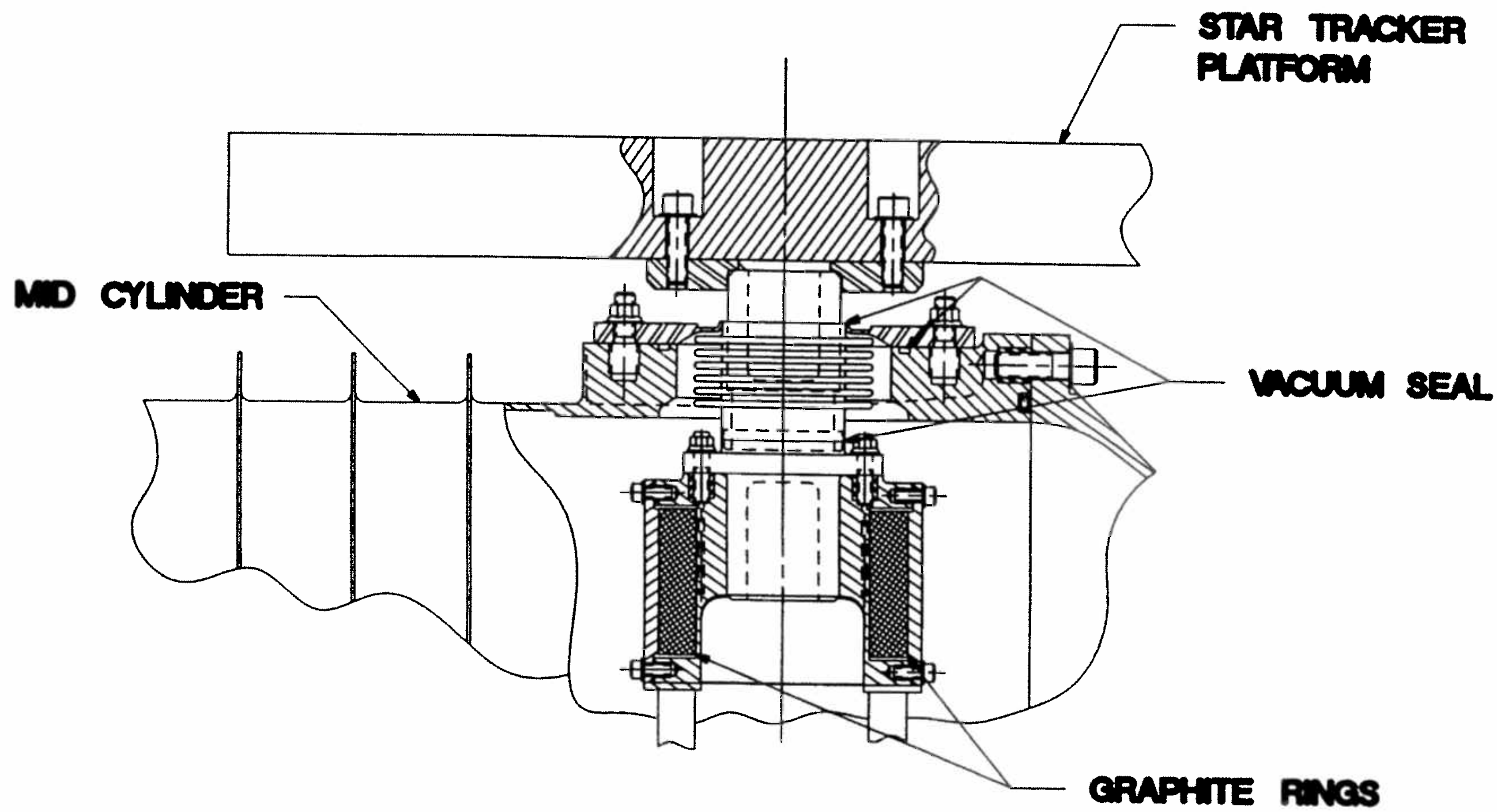


VIEWING -X*



VIEWING +X*

STAR TRACKER PEDESTAL



VACUUM SHELL RISKS AND RISK REDUCTIONS

RISKS	RISK REDUCTIONS
VACUUM SHELL PARTS ARE COMPLICATED MACHININGS, FORGINGS ARE EXPENSIVE	C/O NC PROGRAM ON LOW COST MATERIAL
HIGH COST/SCHEDULE IMPACT IF VACUUM SHELL DOME AND CONE WELDS ARE NOT SATISFACTORY	WELD DEVELOPMENT, LEAK CHECKS, BONDED DOUBLER
LEAKAGE OF INSTRUMENTATION FEED THRUS	THERMALLY CYCLE TO 180 K AND LEAK CHECK FEED THRUS
LEAKAGE OF LARGE NUMBER OF SEALS	SMALL SEALS HAVE BEEN QUALIFIED. (SEE SECTION DT) LARGE SEALS LEAK CHECKED AT ASSEMBLY

VS - 20

VACUUM SHELL STATUS

- DESIGN STATUS
  - TOP PLATE ASSEMBLY COMPLETE
  - FORWARD CONE IN PROGRESS
  - MID-CYLINDER COMPLETE
  - SUPPORT RING COMPLETE
  - AFT DOME ASSEMBLY IN PROGRESS
- CHEMTRONICS SELECTED TO BUILD VACUUM SHELL
- FORGING STATUS
  - RECEIVED
    - » SUPPORT RING
  - ON ORDER
    - » TOP PLATE
    - » CYLINDER
- MACHINING IN PROGRESS
  - SUPPORT RING

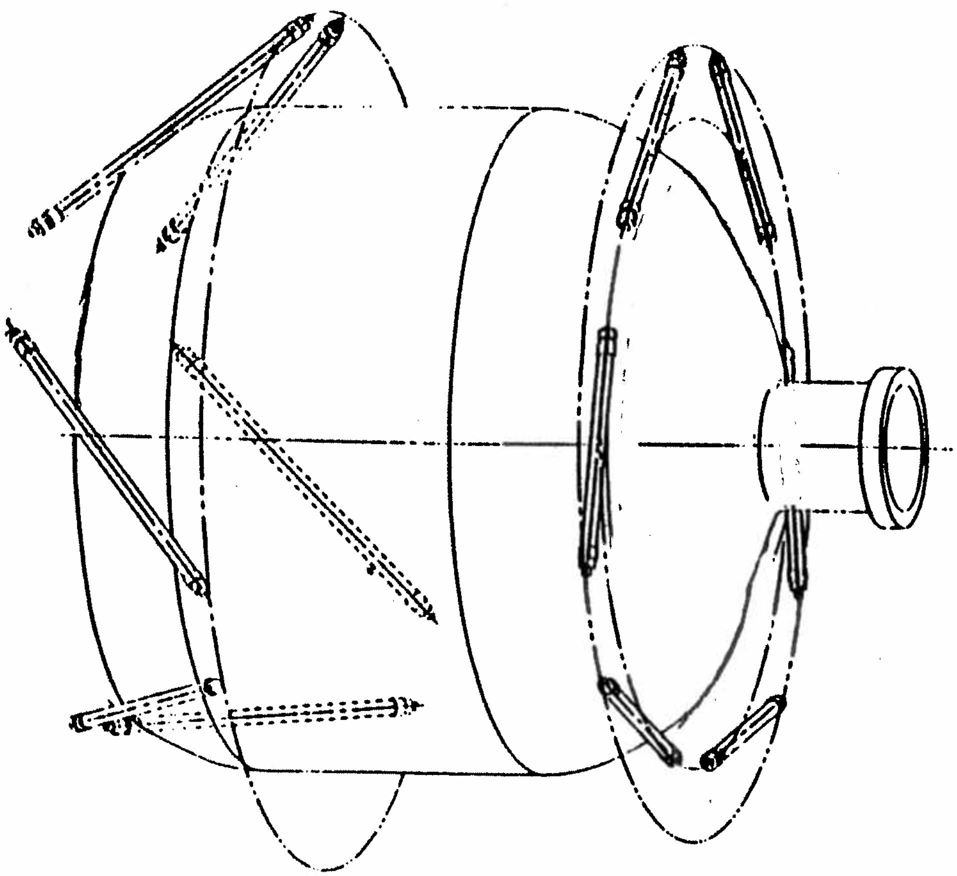
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

PASSIVE ORBITAL DISCONNECT STRUTS

RICHARD PARMLEY

PODS-V SUPPORTS, 12 EA.

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

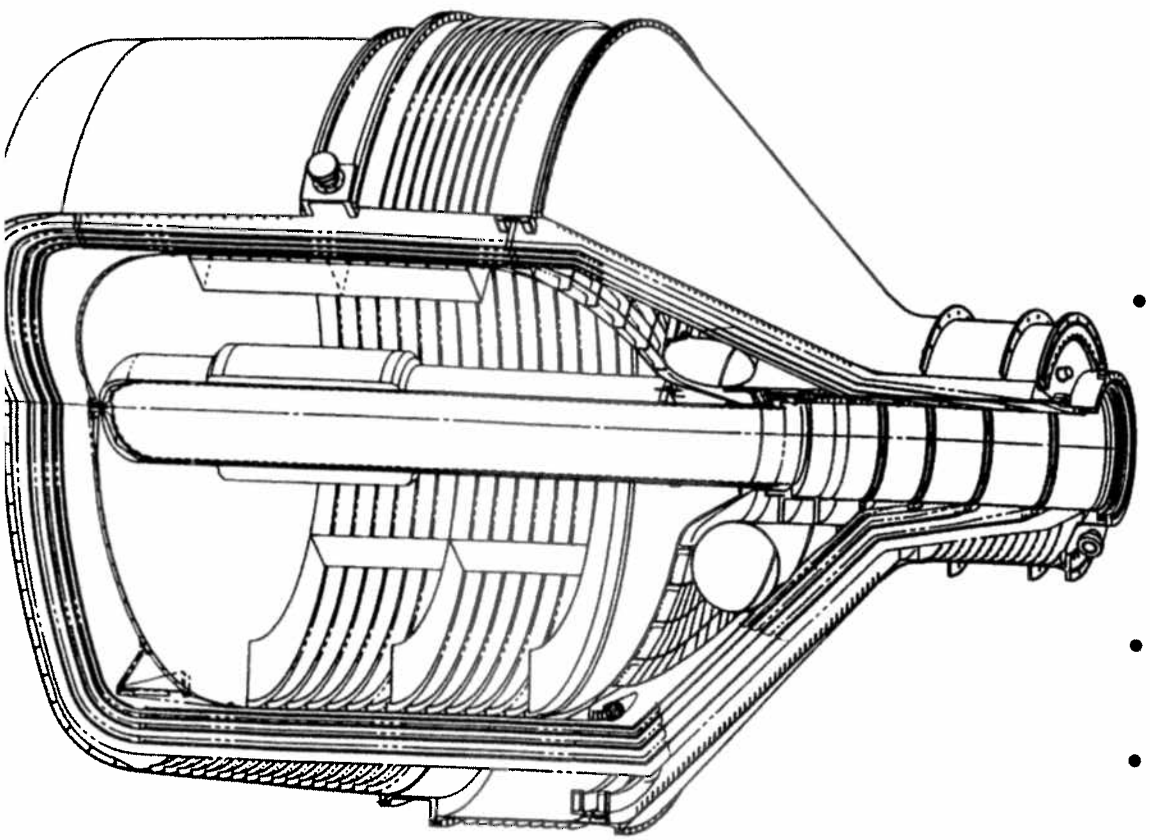


FUNCTIONS

- SUPPORTS 918.7 kg (2025 lb)
  - MAIN TANK 287.9
  - GUARD TANK 16.4
  - VCS's PLUS MLI 118.7
  - CNT ASSY 13.6
  - COLD PLUMBING 16.1
  - LHe (337 + 3.8)
  - PROBE 84.2
  - SIA 41.0
- DOES NOT SHORT OUT ON THE GROUND OR IN ORBIT
- MINIMIZES PARASITIC HEAT LOAD TO MAIN TANK
- STIFFNESS MEETS LAUNCH AND ORBIT RESONANCE REQUIREMENTS

PODS-V SUPPORTS VERIFICATION

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



VERIFICATION

- QUALIFICATION LOADS TEST (COMP & TENSION) TO DESTRUCTION ON TWO AFT AND TWO FORWARD PODS IN TENSILE TEST MACHINE
- TENSION & COMPRESSION SHORTING AND PROOF LOADS; SPRING RATE MEASUREMENTS IN TENSILE TEST MACHINE (12 PODS, EACH TESTED SEPARATELY)
- SIDE LOAD SHORTING TEST (EA OF 12 PODS)
- COLD VIBRATION TEST OF SMD / PROBE-B

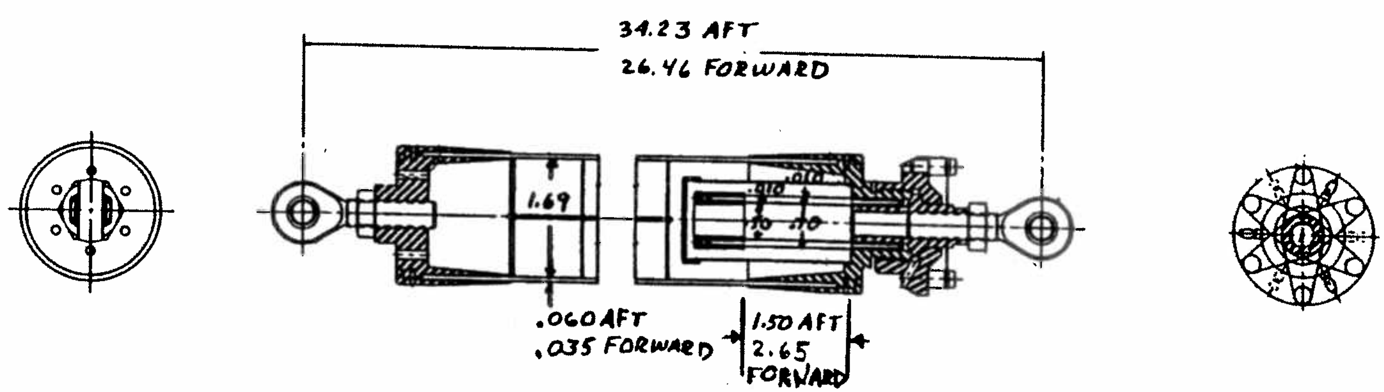
PODS V DESIGN

MATERIALS

- LAUNCH TUBE: ± 10° γ ALUMINA FIBER/SCI REZ 081 EPOXY
- ORBIT TUBES: ± 10° γ ALUMINA FIBER/SCI REZ 081 EPOXY
  (T300 GRAPHITE/SCI REZ 081 EPOXY*)
- METAL END FITTINGS: 303 CRES(INVAR*)
- ROD END FITTINGS: INCONEL 718

PODS GAP, MILS

	NO LOAD		FULL TANK, COLD			
			GROUND (VERT)		ORBIT	
	TENSION	COMP	TENSION	COMP	TENSION	COMP
FORWARD	4.6	4.6	0.9	8.3	4.5	4.7
AFT	4.6	4.6	0.7	8.5	4.6	4.6



* PDR MATERIALS

PODS RISKS AND RISK REDUCTION

RISKS	RISK REDUCTION
PODS SHORTING, STRUCTURAL FAILURE	WELL DEVELOPED TECHNOLOGY, EACH POD WILL BE STRUCTURALLY TESTED PRIOR TO INSTALLATION, STRUTS LIGHTLY LOADED IN TENSION (242% MARGIN), NO FATIGUE PROBLEMS

PODS STATUS

- FINAL DESIGN COMPLETE
- ASSEMBLY SEQUENCE DEFINED
- PARTS FABRICATION IN PROGRESS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

COMPOSITE NECK TUBE ASSEMBLY AND TOP PLATE

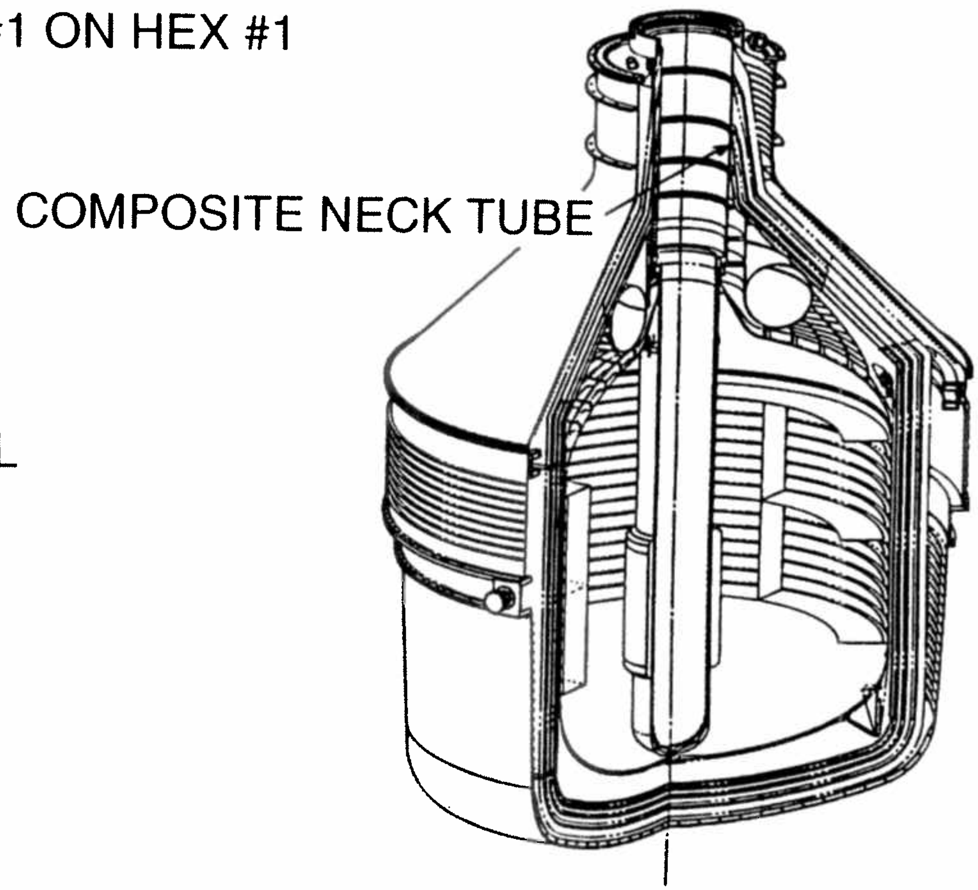
DAVID DONEGAN

FUNCTIONS OF COMPOSITE NECK TUBE / HEAT EXCHANGER ASSEMBLY

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

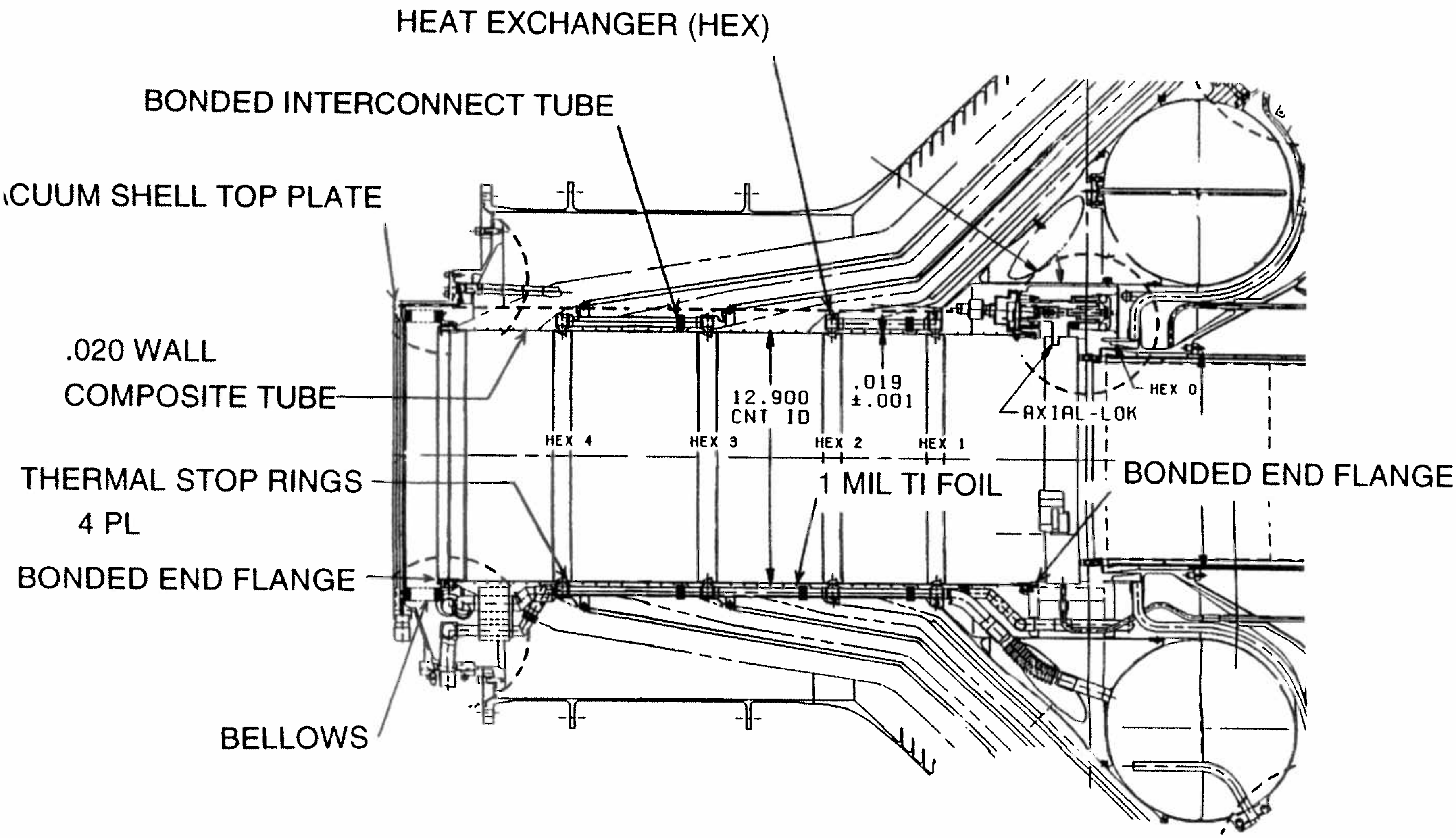
- ISOLATE DEWAR VACUUM SPACE FROM WELL
- INTERFACE FOR COOLING OF PROBE THROUGH TSRS
- THERMAL INTERFACE / STRUCTURAL SUPPORT FOR VAPOR COOLED SHIELDS AND GUARD TANK ON O.D. OF HEX
- SUPPORT OF GUARD TANK AND VCS#1 ON HEX #1
- SUPPORT OF VCS #2 ON HEX #2
- THERMAL INTERFACE ONLY FOR VCS #3 & #4 ON HEX #3 & #4
- HEX PROVIDE PARALLEL TANK VENT PATH
- HEX PROVIDE THERMAL GROUND 4 PL FOR SEPARATE GUARD TANK VENT
- OPTIMIZE THERMAL PERFORMANCE



LAYOUT- COMPOSITE NECK TUBE / HEAT EXCHANGER

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94



CN - 4

COMPOSITE NECK TUBE / HEAT EXCHANGER ASSY. SPECIFICATION REQUIREMENTS

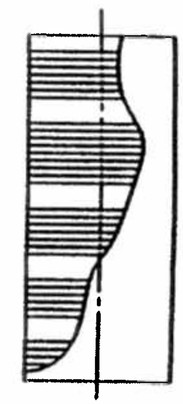
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

ITEM	REQUIREMENT	VERIFICATION
CNT INTERNAL PRESSURE	.13 MPA,(19 PSID), FOS 4.0 ULTIMATE	EM 219 ANALYSIS / PROOF TEST
CNT EXTERNAL PRESSURE	.13 MPA,(19 PSID), FOS 2.0 ULTIMATE	EM 219 ANALYSIS / PROOF TEST
HEX INTERNAL PRESSURE	.26 MPA,(38 PSID), FOS 4.0 ULTIMATE	EM 245 ANALYSIS / PROOF TEST
HEX EXTERNAL PRESSURE	.13 MPA,(19 PSID), FOS 2.0 ULTIMATE	EM 245 ANALYSIS / PROOF TEST
ACCELERATION LOADS	SEE EM 310	ANALYSIS / TEST
END TO END ELECTRICAL RESISTANCE	1 TO 10 OHMS CNT & HEX	DESIGN / TEST

COMPOSITE NECK TUBE ASSY DESIGN FEATURES

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

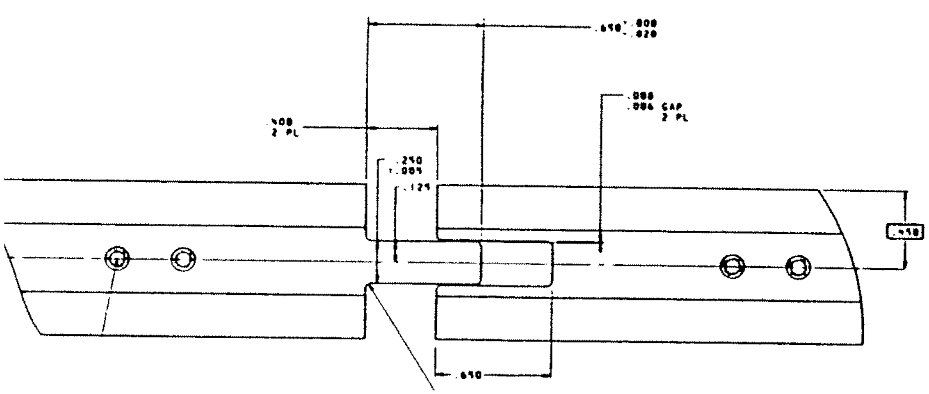
- COMPOSITE TUBE/ HEX ASSY MODULAR DESIGN
  - END FLANGES AND HEX BONDED ON TUBE, ASSY. ACCEPTANCE TESTED BEFORE BONDING TO TONGUE AND GROOVE JOINTS ON DEWAR - MINOR CHANGES FROM EDD
- COMPOSITE TUBE
  - .020 WALL CYLINDER (EDD WAS .080)
  - GAMMA ALUMINA FIBER / SCI REZ 081 RESIN PREPREGGED UNIDIRECTIONAL TAPE
  - 4-PLY BALANCED LAYUP, +/- 40 DEG WIND ANGLE TO MATCH CTE OF COPPER TSR, HEX
  - RING STIFFENED BY FILAMENT WINDING, .030 THICK,.125 HIGH, 33PL
  - PERMEATION BARRIER: 1 MIL TITANIUM FOIL (15V-3AL-3CR-3SN)
  - SAME FABRICATION TECHNIQUE / VENDOR AS PROBE CNT
  - DEVELOPMENT TUBE FABRICATION AND TEST SUCCESSFUL

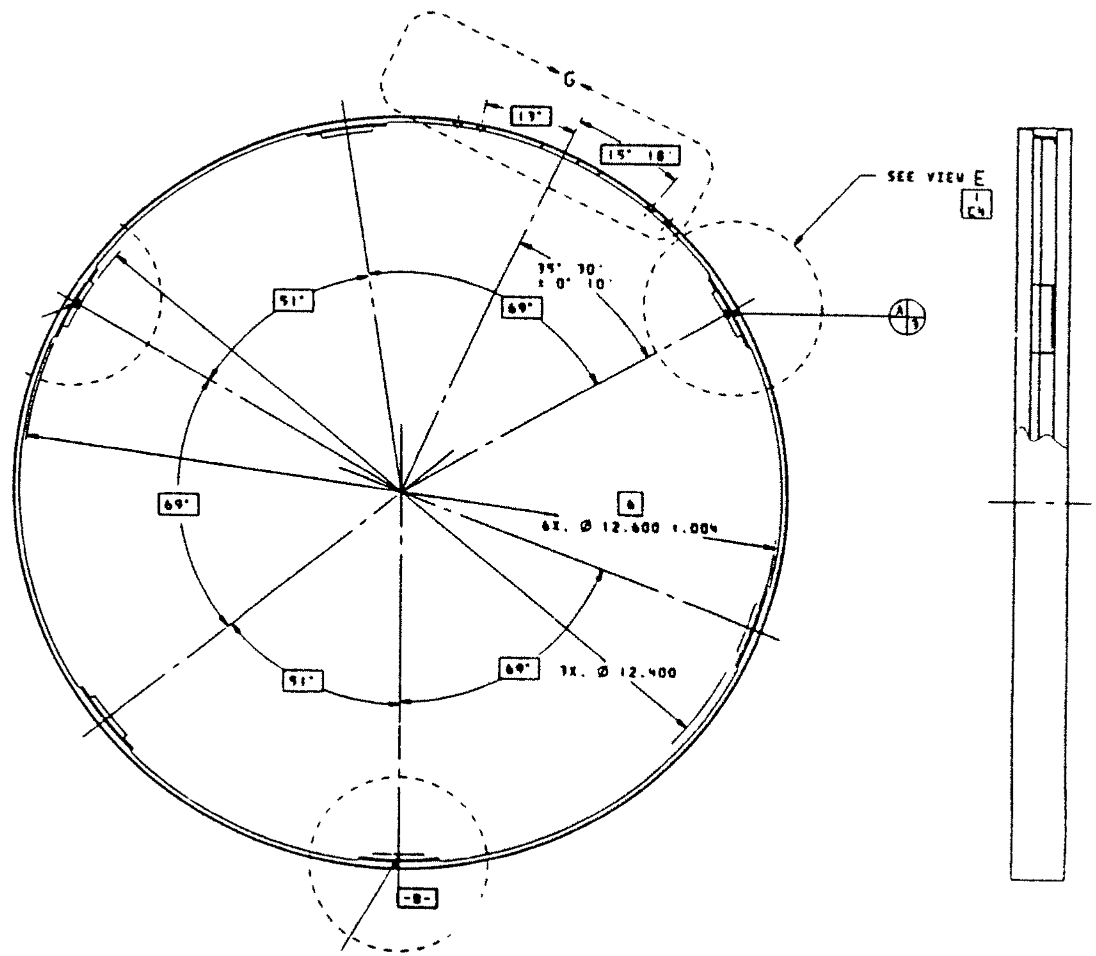


COMPOSITE NECK TUBE ASSY DESIGN FEATURES

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- THERMAL STOP RINGS (TSRs)
  - OFHC COPPER WITH RHODIUM OVER GOLD STRIKE PLATED TABS
  - CIRCUMFERENTIALLY COLLAPSIBLE DESIGN ALLOWS INSTALLATION AT ROOM TEMP. WITH "BLUE DEATH " EPOXY
  - IDENTICAL TO EDD

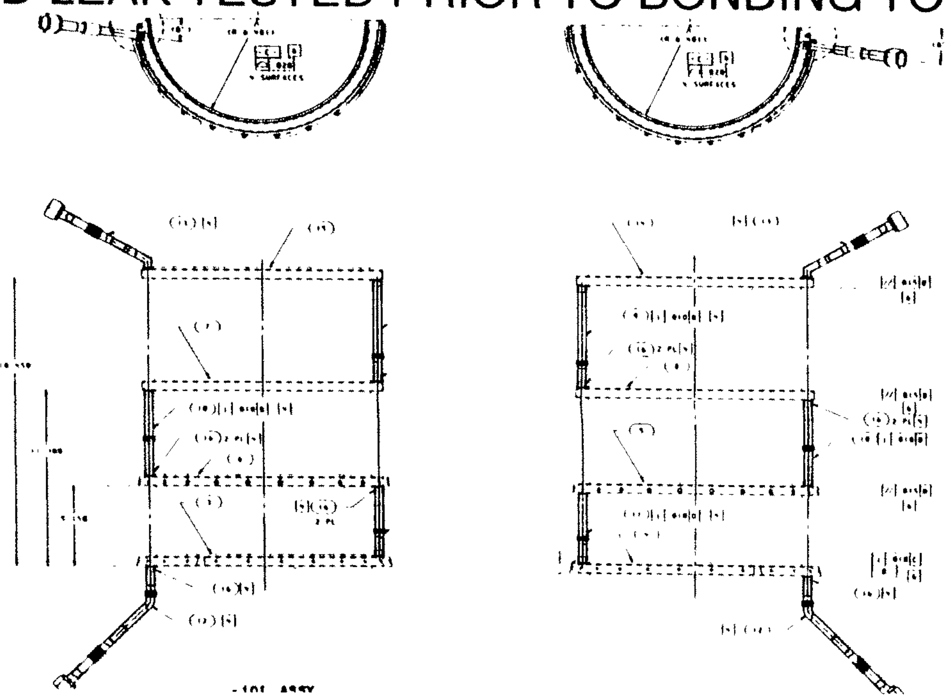




COMPOSITE NECK TUBE ASSY
DESIGN FEATURES

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- HEAT EXCHANGERS
  - DUAL FLOW PATH - MIRROR IMAGES
  - OFHC COPPER HALF-RINGS JOINED BY .005 WALL 321 S.S. INTERCONNECT TUBING / BELLOWS BONDED IN PLACE
  - HALF-RINGS ALL BRAZED CONSTRUCTION-2 STEP HYDROGEN FURNACE BRAZE
  - "CLAMSHELL" DESIGN - EPOXY BONDED TO COMPOSITE TUBE
  - "MODULAR DESIGN"- THERMAL CYCLED, PROOF PRESSURE TESTED,AND LEAK TESTED PRIOR TO BONDING TO COMPOSITE TUBE



CN - 8

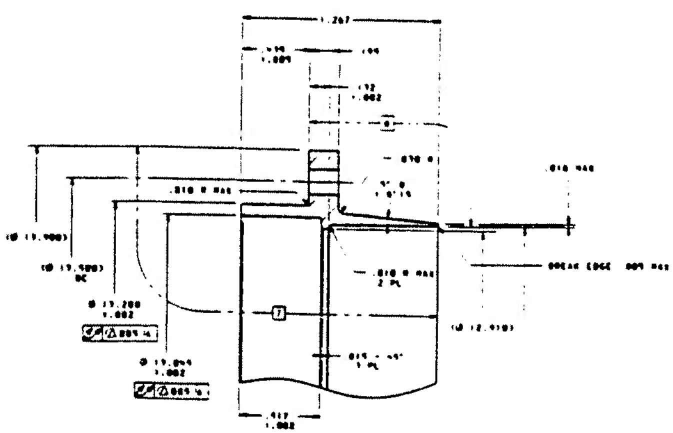
COMPOSITE NECK TUBE ASSY DESIGN FEATURES

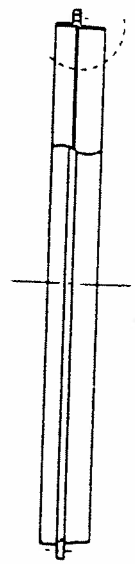
STANFORD

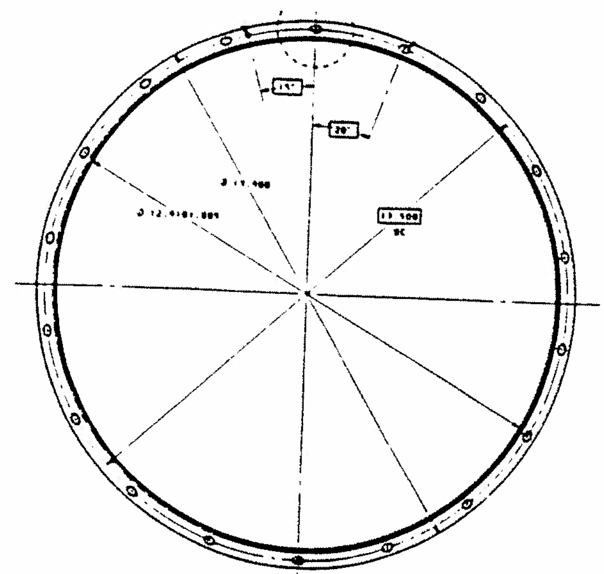
Lockheed

LMSC-P088357
2,3 MAR 94

- END FLANGES
  - CONTINUOUS INTERLOCKING RINGS ON I.D. & O.D. OF EACH END OF TUBE (ALUM ON COLD END, S.S. ON WARM END)
  - OUTER RING FLANGED WITH BOLT PATTERN
  - CLOCKED TO TSRs AND TO EACH OTHER, "BLUE DEATH" EPOXY BONDED W/ WIRE SPACERS AND GLASS BEADS

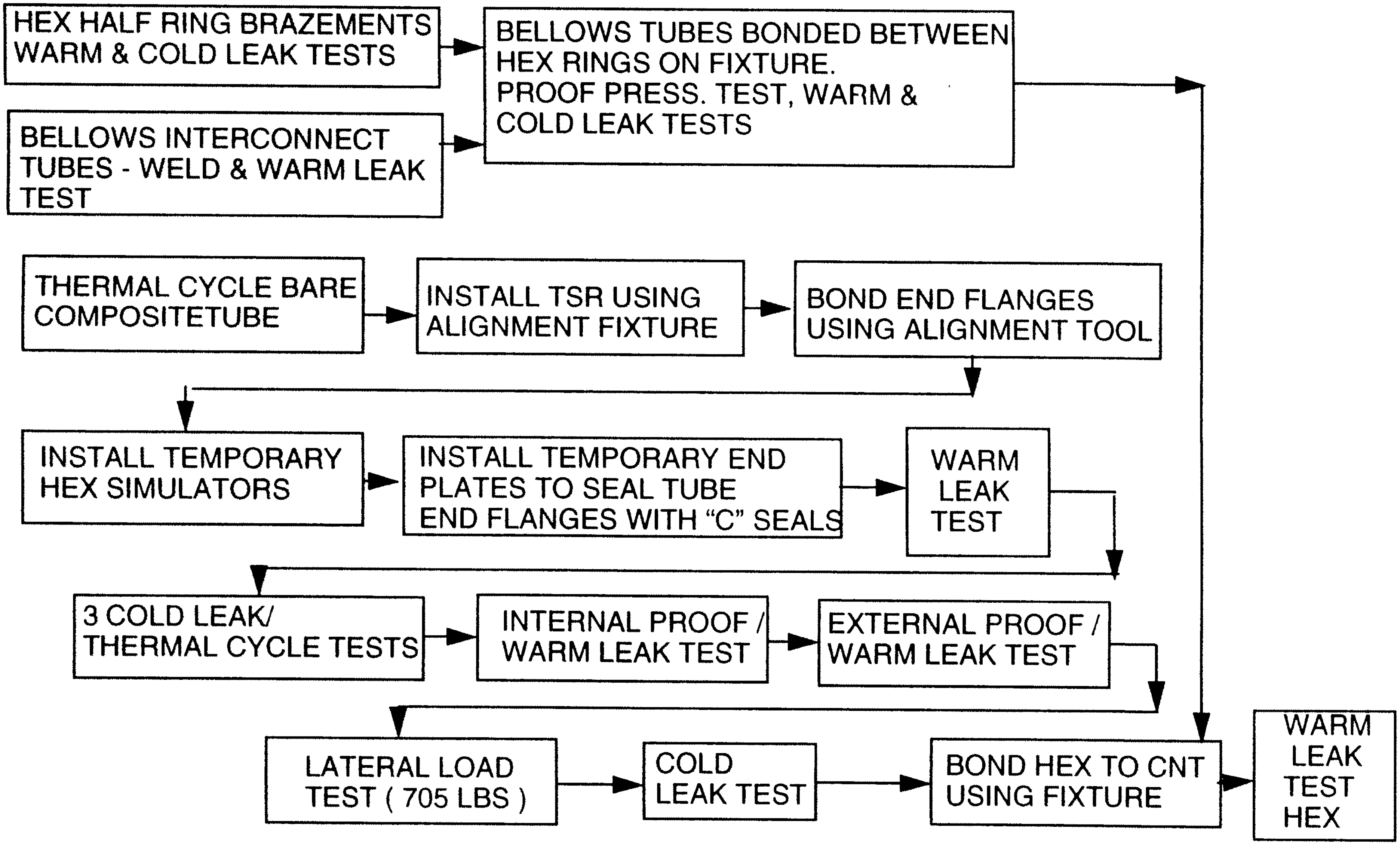






COMPOSITE NECK TUBE / HEAT EXCHANGER ASSEMBLY AND TEST FLOW

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



STATUS OF COMPOSITE NECK TUBE / HEAT EXCHANGER ASSY.

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- MANY SUCCESSFUL DEVELOPMENTS INCORPORATED FOR SMD
  - PROBE RESIN SELECTION, TUBE FAB., DEV TESTING
  - EDD HEAT EXCHANGER BRAZEMENTS, TSRs, END FLANGE CONCEPTS
  - MODULAR DESIGN,FABRICATION, ASSEMBLY AND TEST CONCEPT DEVELOPED FOR EDD
    - » END FLANGES AND HEX BONDED ON TUBE, ASSY. ACCEPTANCE TESTED BEFORE BONDING TO TONGUE AND GROOVE JOINTS ON DEWAR - MINOR CHANGES FROM EDD
- COMPOSITE NECK TUBE DEVELOPMENT TESTING COMPLETE
  - DEMONSTRATED STRUCTURAL CAPABILITY,VACUUM INTEGRITY OF NEW PROTOTYPE THIN WALL TUBE
    - » WARM AND COLD LEAK TESTS
    - » 37.4 PSID EXTERNAL PRESSURE
    - » 705 LBS LATERAL LOAD AT TOP PLATE
    - » NO BUCKLING OR LEAKAGE
    - » AXIAL LOAD TO FAILURE - 9311 LBS
  - VALIDATED DESIGN,FABRICATION,ASSY. AND TEST PROCEDURES

STATUS OF COMPOSITE NECK TUBE / HEAT EXCHANGER ASSY.

- ALL DRAWINGS RELEASED

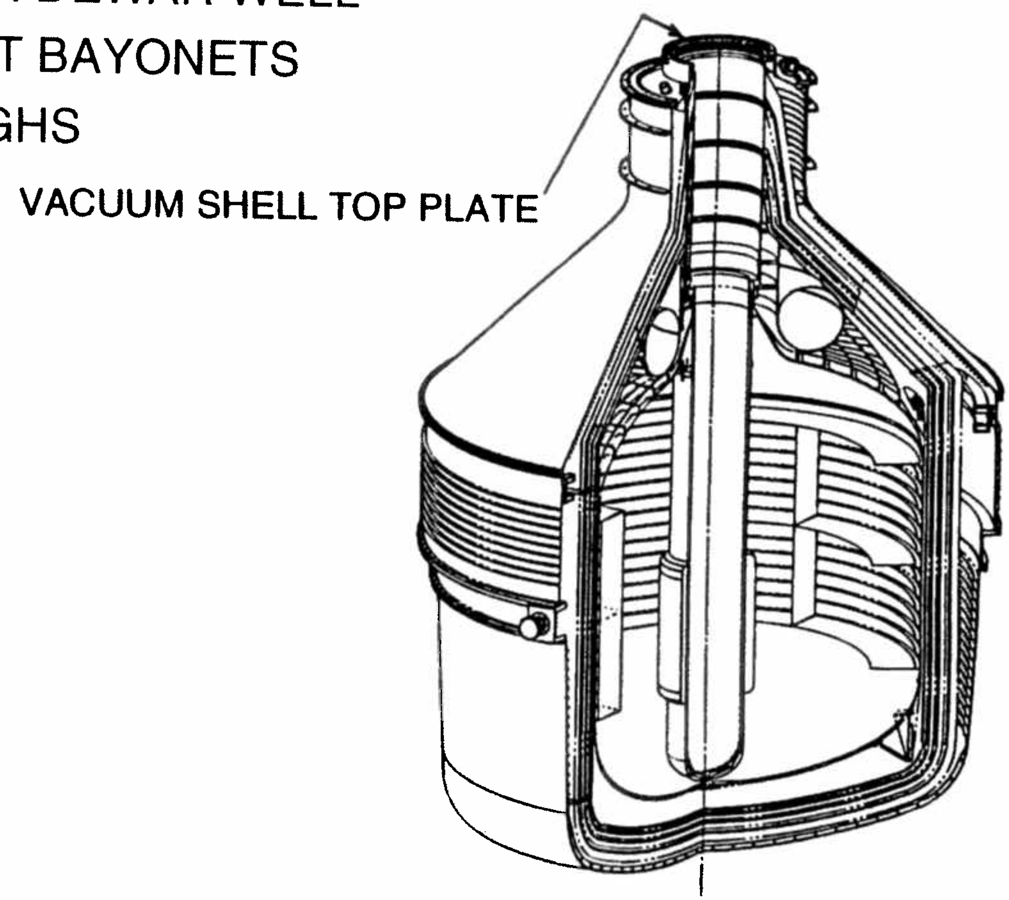
- CHANGES FROM PDR
  - 1 MIL Ti 15-3-3-3 FOIL LINER - WAS 1/2 MIL
    (TO EASE FABRICATION AND HANDLING)
  - LONGER BELLOWS , SHORTENED COMPOSITE NECK TUBE
    (LONGER BELLOWS TO MEET LATERAL STIFFNESS REQUIREMENT)
  - HEX INTERCONNECT TUBES BONDED IN PLACE - WAS BRAZED
    (BONDING INCREASES END TO END ELECTRICAL RESISTANCE)

VACUUM SHELL TOP PLATE COMPONENT FUNCTIONS

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

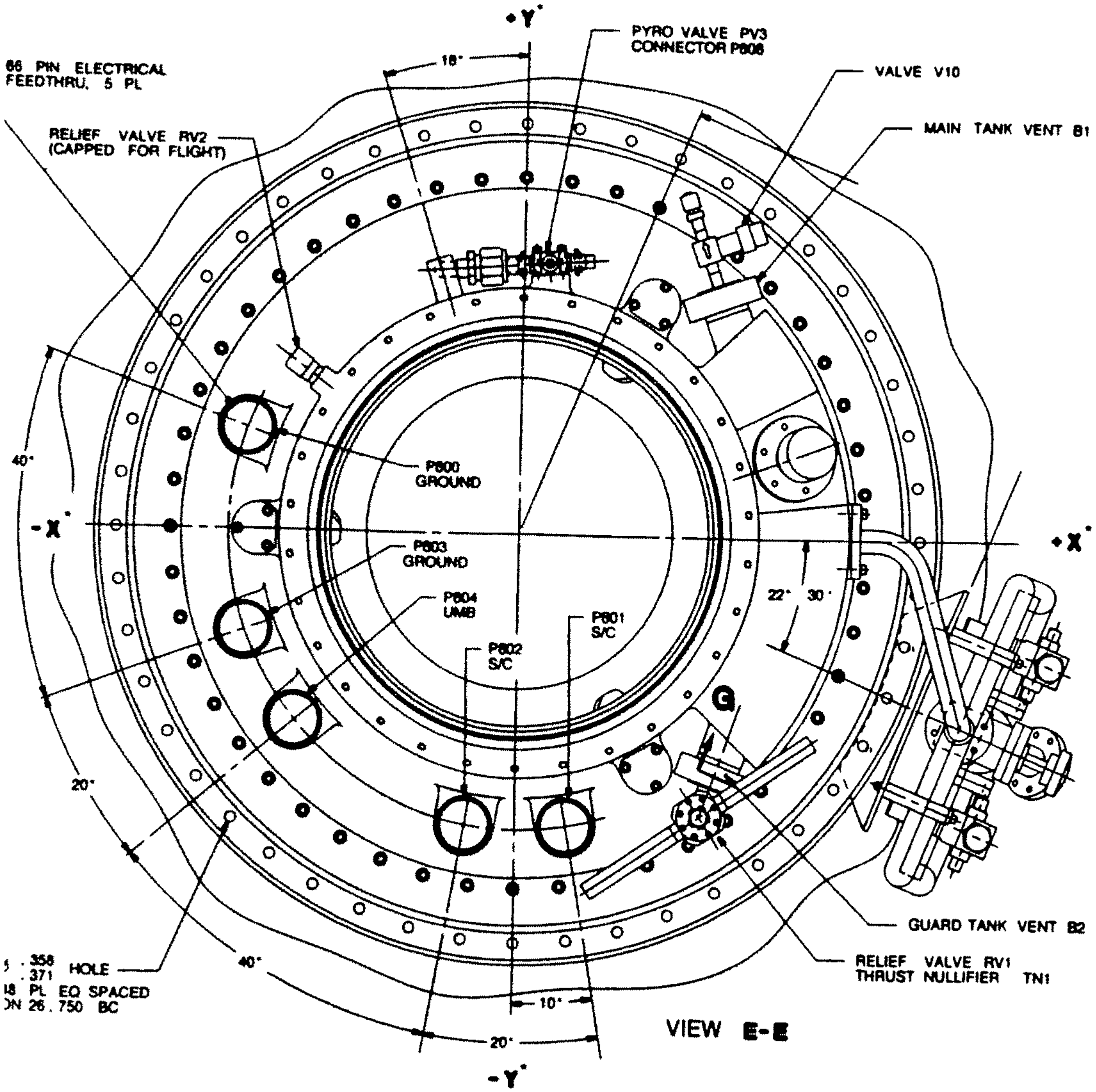
- INTERFACE WITH PROBE
- VACUUM SEAL JOINT WITH LOWER PORTION OF VACUUM SHELL
- FACILITATE DIFFERENTIAL THERMAL CONTRACTION BETWEEN TANK AND VACUUM SHELL WITH BELLOWS JOINT AT TOP OF NECK TUBE
- OVERPRESSURE PROTECTION FOR DEWAR WELL
- MAIN TANK AND GUARD TANK VENT BAYONETS
- DEWAR ELECTRICAL FEEDTHROUGHS
- GSE INTERFACES
  - TOP PLATE HEATERS
  - LEAD BAG
  - PROBE INSTALLATION



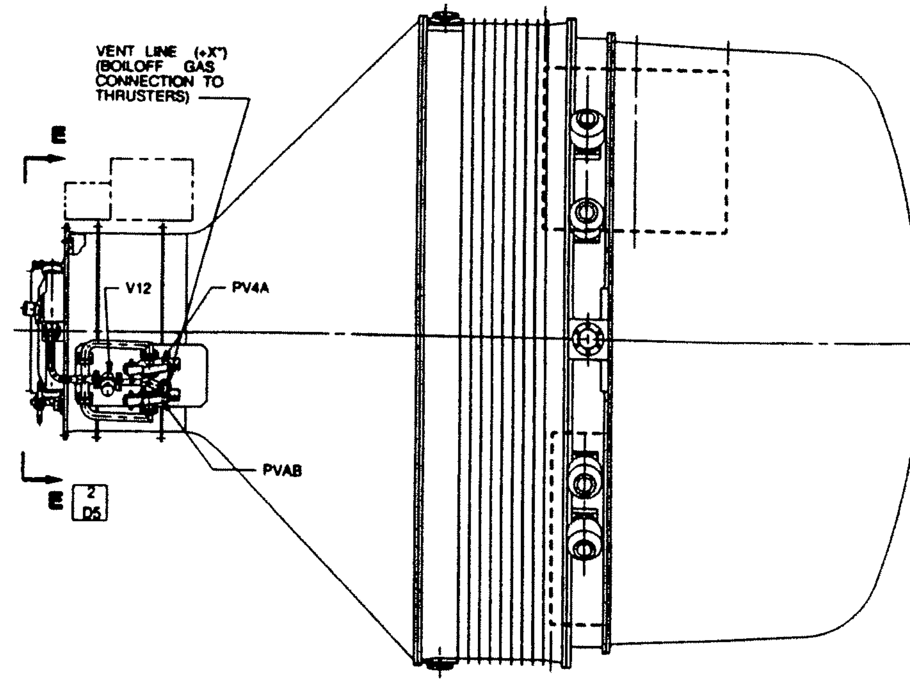
VACUUM SHELL TOP PLATE LAYOUT

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

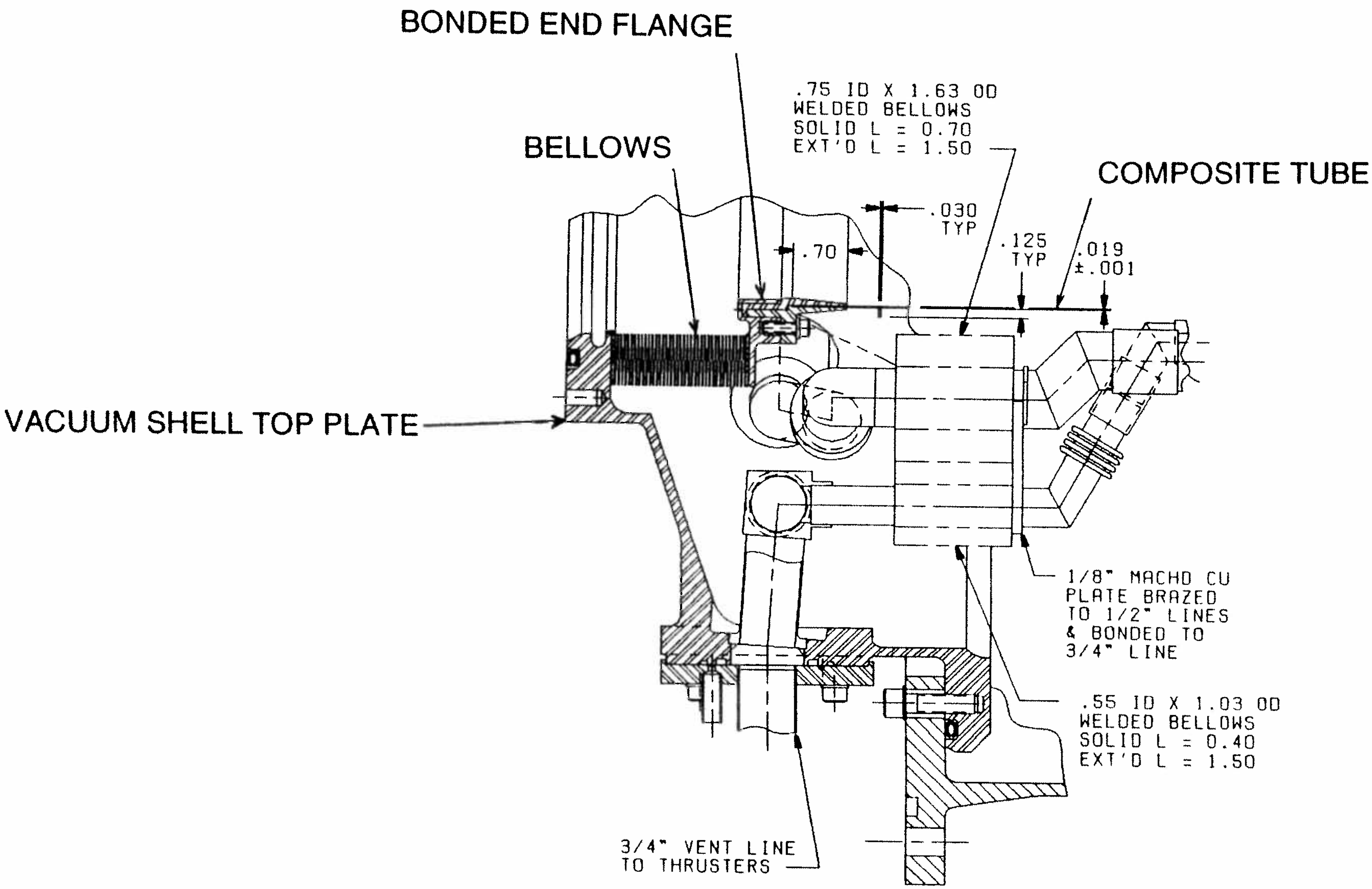


VIEW E-E



VACUUM SHELL TOP PLATE / NECK TUBE JOINT LAYOUT

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



VACUUM SHELL TOP PLATE REQUIREMENTS

ITEM	REQUIREMENT	VERIFICATION
LEAK RATE FOR ALL PENETRATIONS AND SEALS	<1X10E-9 SCC/SEC	TEST
SUPPORTED WEIGHT	121 Kg EST	ANALYSIS
LAUNCH LOADS	ACCELERATION (G'S) Z*: 9.8, RADIAL: 8.9	DYNAMICS LOAD MODEL
INTERNAL LIMIT WORKING PRESSURE MPa (PSID)	BELLOWS / TOP PLATE .13 (19) / .06 (8)	TEST
EXTERNAL LIMIT WORKING PRESSURE MPa (PSID)	BELLOWS / TOP PLATE .13 (19) / .10 (15)	TEST

VACUUM SHELL TOP PLATE REQUIREMENTS (CONTINUED)

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

ITEM	REQUIREMENT	VERIFICATION
BELLOWS STROKE	> + .375 IN.	TEST
BELLOWS AXIAL SPRING RATE	< 9 Kg/CM (50 LB/IN.)	TEST
BELLOWS RADIAL SPRING RATE	< 1800 Kg/CM (10K LB/IN.)	TEST

STATUS OF VACUUM SHELL TOP PLATE

- DESIGN STATUS
  - TOP PLATE ASSEMBLY COMPLETE
  - DETAILS IN PROGRESS
  - ELECTRICAL FEEDTHROUGH DESIGN COMPLETE, VENDOR QUOTING
- 304 STAINLESS STEEL FORGING ON ORDER
- CHANGES SINCE PDR
  - POSITION AND ANGLE OF ELECTRICAL CONNECTORS
  - SINGLE MAIN TANK VENT BAYONET - WAS DUAL
    (WEIGHT REDUCTION)
  - ADDED SEPARATE GUARD TANK VENT BAYONET - MAIN TANK USED TO VENT THROUGH GUARD TANK (ELIMINATE POSSIBLE TAOs)
  - ADDED BOSS FOR MOUNTING ASSEMBLY OF PAIR OF PYRO VALVES TO OPEN MAIN TANK VENT TO THRUSTERS (FLIGHT INSTALLATION ONLY)
  - MANUAL VALVE ADDED TO ISOLATE MAIN TANK GROUND VENT BAYONET FOR FLIGHT

PLUMBING

DAVID FRANK

PLUMBING FUNCTIONS

- MAIN TANK
  - FILL AND TOP-OFF WITH He-I
  - CONDITION TO He-II
  - PRE-COOLING OF FILL LINE
  - PROVISIONS FOR NON-VENTED OR VENTED
  - PRESSURE DRAIN
- GUARD TANK
  - FILL AND TOP-OFF WITH NBP He
  - CONTINUOUS VENT
  - EMPTY WITH HEATER
- WELL
  - FILL AND TOP-OFF WITH NBP He
    - » FROM EXTERNAL SOURCE OR MAIN TANK
  - FILL WITH HE-II FROM MAIN TANK
- EVACUATE VACUUM SPACES
  - GUARD VACUUM, WELL, PLUMBING LINES
- PROVIDE PRESSURE RELIEF OF TRAPPED VOLUMES

DESIGN PHILOSOPHY

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- REDUNDANT PYRO VALVES(PV4A &4B) ARE TO INSURE PROPER VENTING OF TANK AFTER LAUNCH
- NO REDUNDANCY FOR ON-ORBIT VENTING OF FILL PLUMBING
  - NOT CRITICAL TO LIFETIME
- NO REDUNDANCY FOR GROUND OPERATIONS EXCEPT FOR CLOSURE OF FOUNTAIN EFFECT PUMP VALVE (RAV6A & 6B)
  - REDUNDANCY INCLUDED BECAUSE VALVES CAN'T BE LEAK CHECKED PRIOR TO LAUNCH
- PLUMBING COMPONENTS ARE REMOVABLE BY USE OF HELICOFLEX SEAL
- DESIGNING FOR MAXIMIZING ACCESS TO PLUMBING COMPONENTS THRU THERMAL PROTECTION SYSTEM
- ACCEPTANCE LEAK TESTING OF COLD COMPONENTS ARE PERFORMED AT LIQUID NITROGEN TEMPERATURE
- TESTING OF MOTORIZED VALVES ARE PERFORMED BELOW 20K
- ALL PLUMBING LINES ARE METALLIC (CRES OR AL)

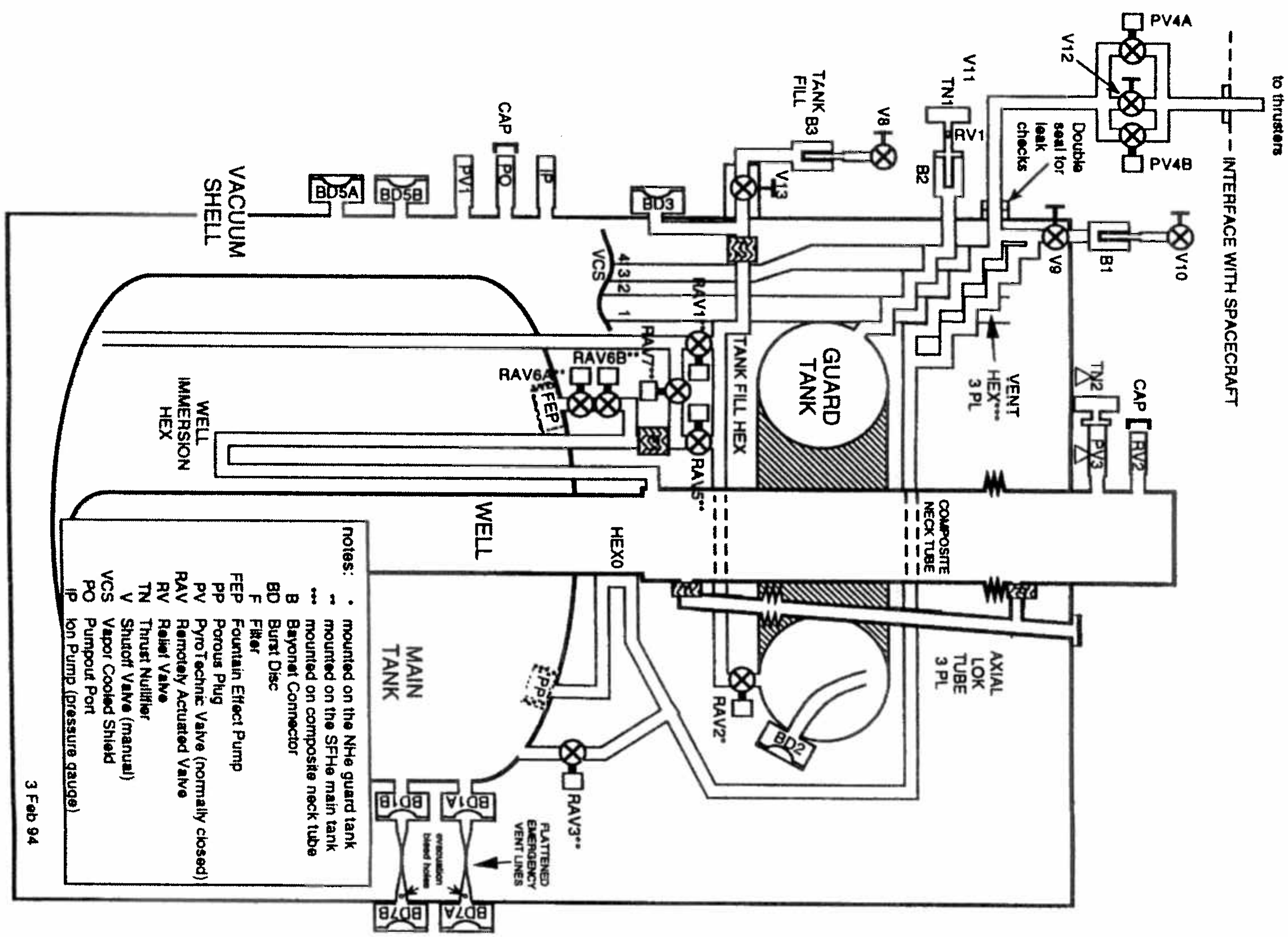
PL - 4

PLUMBING SCHEMATIC

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94



CHANGES SINCE PDR

- INTERFACE WITH THE SPACECRAFT CHANGED SUCH THAT PAYLOAD HAS COMPLETE CONTROL OVER CRYOGEN SERVICING PLUMBING
- MAIN TANK
  - VENT BYPASSES THE GUARD TANK
  - POST LAUNCH ACTIVATION OF VENTING CHANGED FROM OPERATING COLD VALVES TO FIRING OF PYROTECHNIC VALVES
- GUARD TANK
  - SEPARATE VENT FOR THE GUARD TANK
  - ELIMINATION OF ONE COLD BURST DISC
  - ELIMINATION OF SEPARATE EMERGENCY VENT LINES
    - » NORMAL VENT LINE IS USED
- FOUNTAIN EFFECT PUMP
  - FLOW DOWNSTREAM OF PUMP GOES THRU THE HEAT EXCHANGER WITH THE MAIN (SUPPLY) TANK

LAUNCH CONFIGURATION OPERATIONS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- GUARD TANK NEEDS TO BE SERVICED EVERY 7 DAYS
  - DRAINED TO 30 LITERS PRIOR TO LAUNCH WHICH IS SUFFICIENT TO ACCOMMODATE 2 LAUNCH ABORTS

- MAIN TANK NEEDS TO BE SERVICED EVERY 90 DAYS
  - DESIGN IS SUCH THAT THERE ARE NO REQUIREMENTS FOR SERVICING ON LAUNCH PAD

- LAUNCH PAD OPERATIONS:
  - REQUIRES OPERATING OF PAYLOAD AND SPACECRAFT ELECTRONICS
  - REQUIRES USE OF UMBILICAL
  - REQUIRES ACCESS THRU PAYLOAD SHROUD

- ASCENT OPERATIONS:
  - REQUIRES FIRING OF THREE PYROTECHNIC VALVES (PV3, PV4A, PV4B) vent to thrusters well

- ON-ORBIT OPERATIONS:
  - REQUIRES OPERATION OF RAV2 ← vent fill valve
  - REQUIRES FIRING OF ONE PYROTECHNIC VALVE (PV1) guard ~~[illegible]~~ tank.

GROUND OPERATIONS

- VERTICAL
  - NORMAL BOILING POINT FOR LEAD BAG AND PROBE INSERTION
  - CONDITION MAIN TANK AND WELL (OPTION) FOR FLIGHT
  - SERVICING OF GUARD TANK
  - NO LIMITATIONS ON FILLING/CONDITIONING OF TANK, WELL, AND GUARD TANK

- VERTICAL TO 57.5 DEGREES OFF VERTICAL
  - PROBE OPERATIONS
  - NO LIMITATION ON FILLING/CONDITIONING OF TANK

- HORIZONTAL
  - GYRO TESTING (+X, +Y AXIS UP)
    - » FILLING CAPABILITY
  - CAGING (-X, -Y AXIS UP)
    - » NO FILLING OF TANK

HORIZONTAL OPERATING TEMPERATURE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- DURING GROUND TESTING, THE MAIN TANK FLOWRATE IS APPROXIMATELLY 9 mg/s

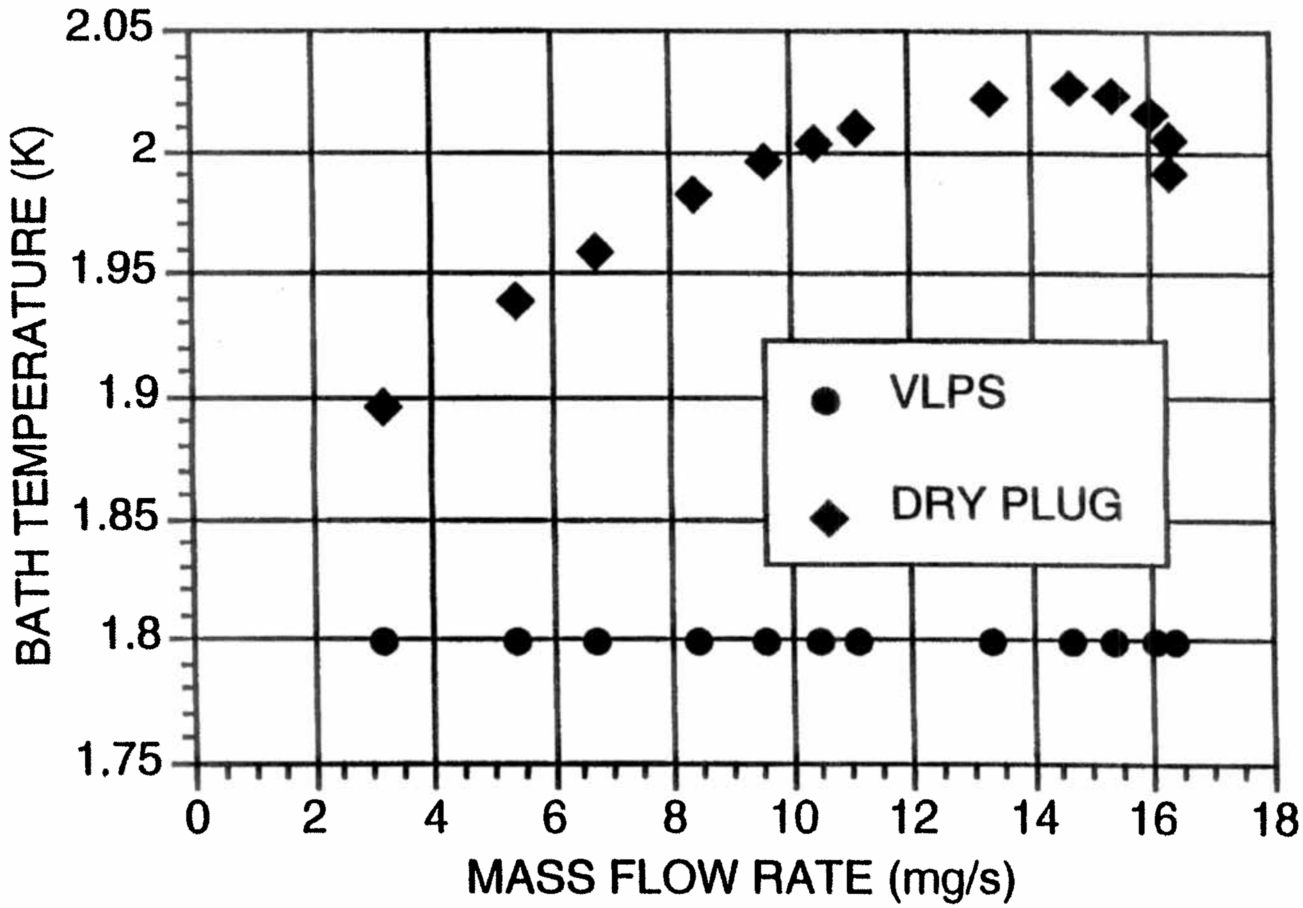
- +Y, -Y, -X AXIS UP:
  - VENT THRU POROUS PLUG BYPASS VALVE RAV3
  - CAN OPERATE TO 1.8 K

- +X AXIS UP:
  - VENT THRU POROUS PLUG (BYPASS IS SUBMERGED)
  - PLUG PRESSURE DROP REQUIRES THE BATH PRESSURE (i.e. TEMPERATURE) TO INCREASE
    - » MINIMUM TEMPERATURE APPROXIMATELY 2 K

TEMPERATURE DURING GROUND VENTING THRU POROUS PLUG

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- THE POROUS PLUG MAY BE DRY DURING HORIZONTAL OPERATIONS WITH THE +X AXIS UP
  - VENTING THRU PLUG WILL CAUSE THE BATH TEMPERATURE TO RISE



HORIZONTAL FILL OPERATIONS

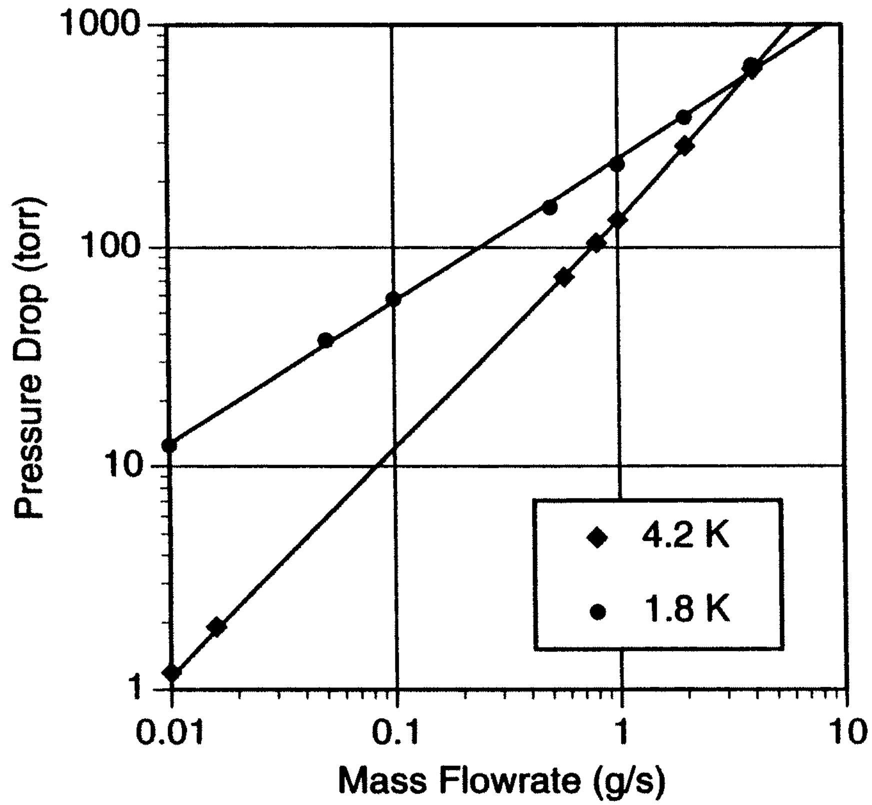
- +X AXIS UP:
  - VENT THRU POROUS PLUG (BYPASS IS SUBMERGED)
  - MAXIMUM FILL LEVEL IS 90%
  - MINIMUM OPERATIONAL LEVEL IS 38%
  - LIMITED FILL RATE DUE TO POROUS PLUG PRESSURE DROP
    - » BATH TEMPERATURE WILL RISE

- +Y AXIS UP:
  - VENT THRU POROUS PLUG BYPASS VALVE RAV3
  - MAXIMUM FILL LEVEL IS 50 %
  - MINIMUM OPERATIONAL LEVEL IS 38%

TEMPERATURE DURING HORIZONTAL FILL OPERATIONS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- HIGH VENT RATES (MANY GRAMS PER SECOND) DURING FILL OPERATIONS RESULT IN A LARGE PRESSURE DROP ACROSS THE POROUS PLUG WITH THE +X AXIS UP
  - RESULTS IN A HIGHER BATH TEMPERATURE

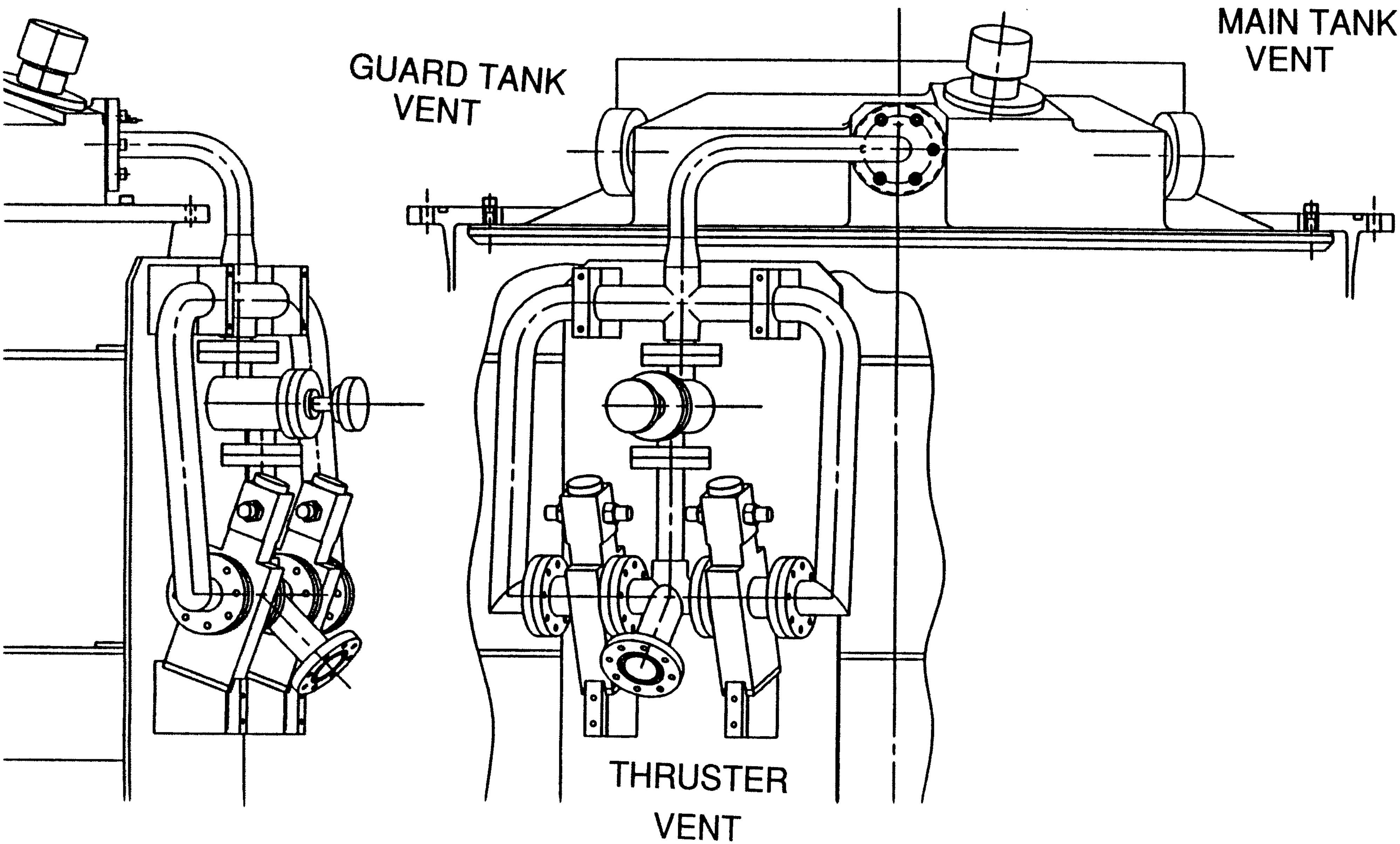


LOCATION OF PLUMBING ON TOP PLATE

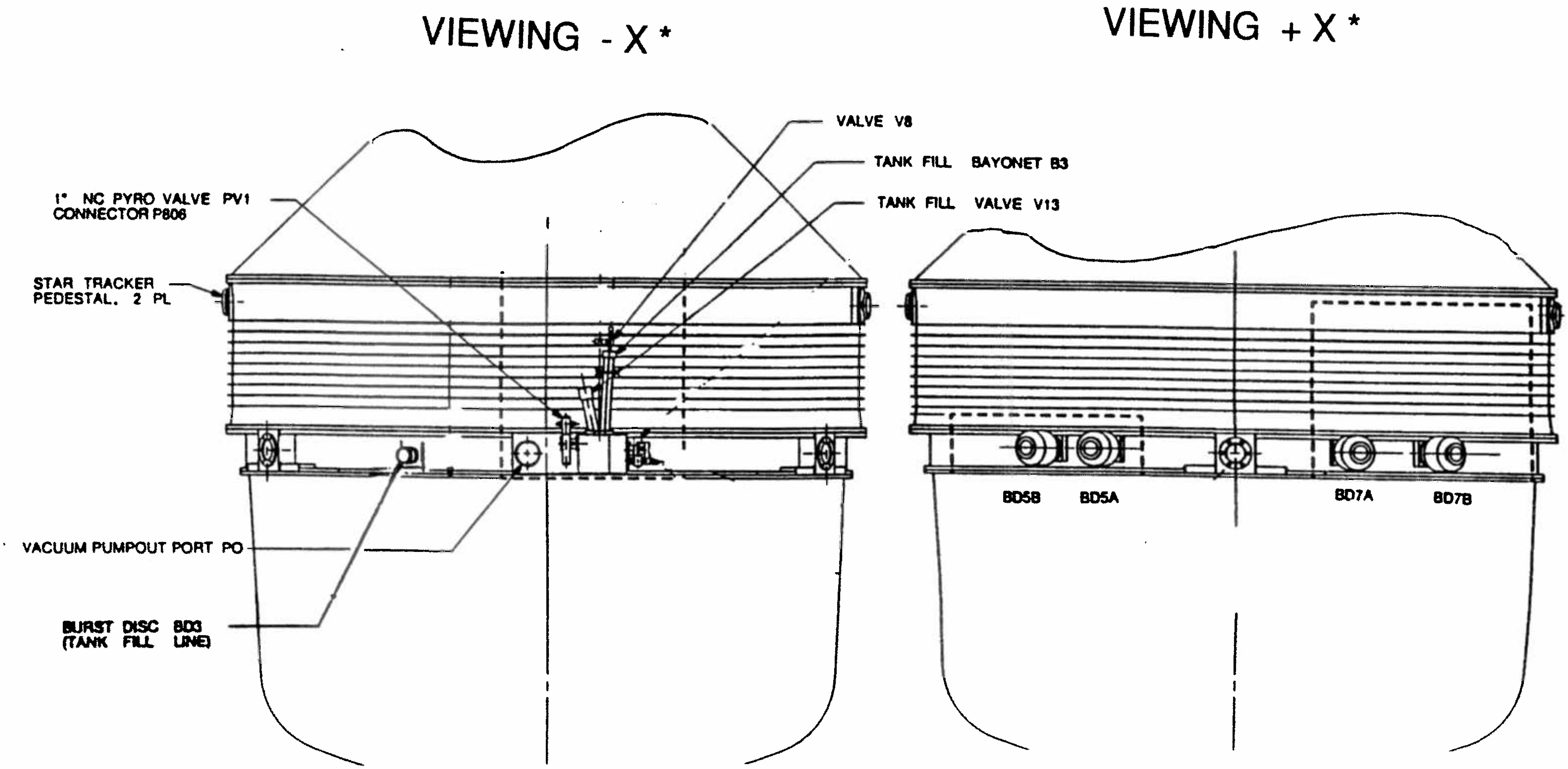
STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

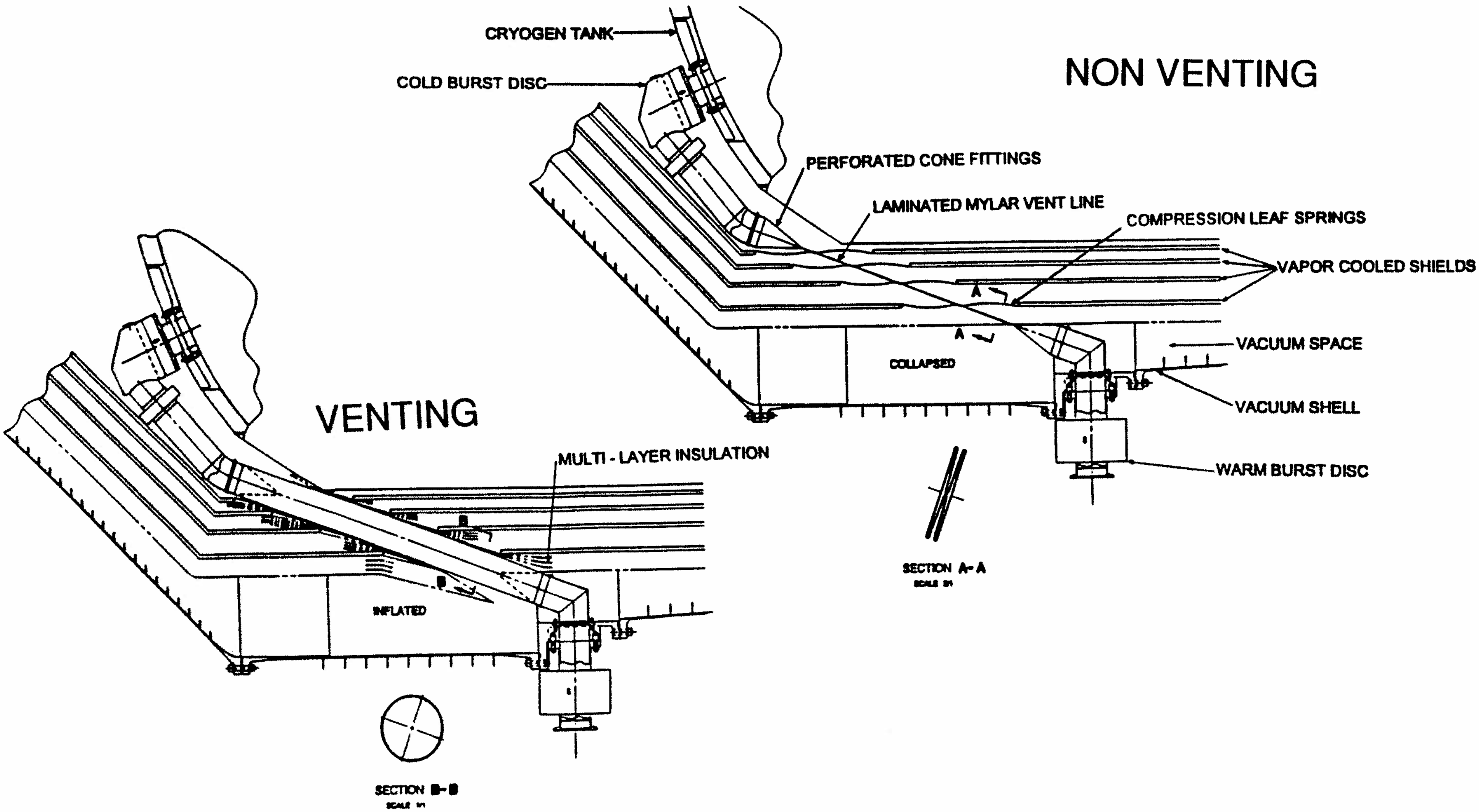


LOCATION OF PLUMBING ON SUPPORT RING



MAIN TANK EMERGENCY VENT LINE

- USED TO PREVENT OVER PRESSURIZATION OF VACUUM SPACE DURING EMERGENCY VENT OF MAIN TANK



COLD VALVES

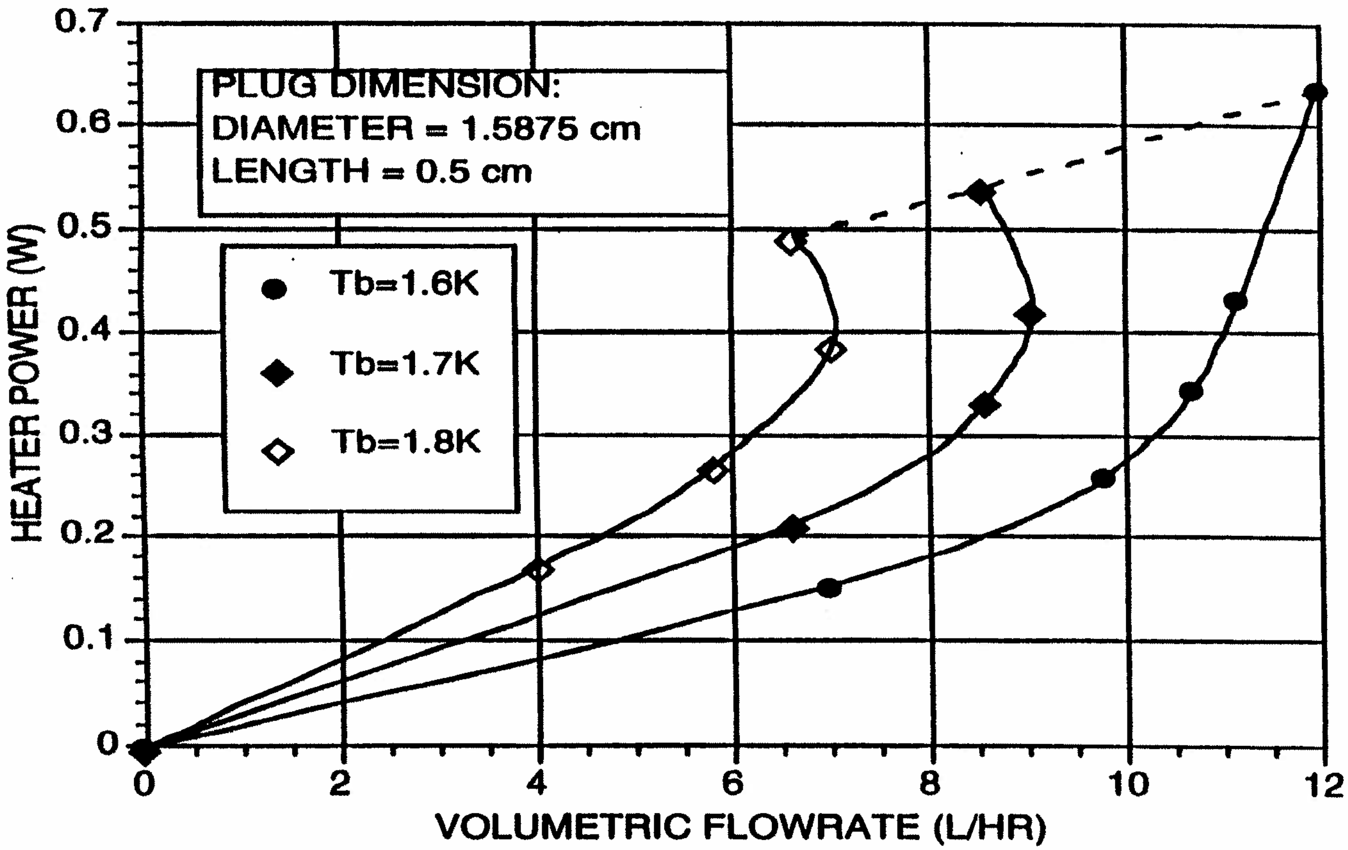
- 0.5" STEPPER MOTOR-DRIVEN VALVE (7 RAVs)
- VENDOR: MISSION RESEARCH CORPERATION
- BASIC VALVE DESIGN HAS BEEN USED FOR NUMEROUS APPLICATIONS.
- NUMBER OF IMPROVEMENTS ARE BEING INCORPORATED:
  - HIGH RELIABILITY MICROSWITCHES
  - WIRING OF MICROSWITCHES
    - » IMPROVE RELIABILITY AND DIAGNOSTIC TESTING
  - MANUFACTURING OF BALL SCREW AND NUT
  - DRY LUBRICATION OF MISC. PARTS
  - INCREASE TORQUE MARGIN TO FOUR
- TESTING:
  - EACH VALVE IS SUBJECTED TO AN ACCEPTANCE TEST
    - » MOTOR AND DRIVE TRAIN CHARACTERIZATION
    - » THERMAL CYCLING AND LEAK CHECK
    - » VIBRATION
  - TWO VALVES ARE SUBJECTED TO QUALIFICATION TEST
    - » SIMILAR TO ACCEPTANCE
    - » MORE EXTENSIVE MOTOR TESTING
    - » 1000 OPEN/CLOSE CYCLES

COLD BURST DISCS

- MAIN TANK (BD1A, BD1B) - 2 INCH ORIFICE, 38PSID
- GUARD TANK (BD2) - 0.46 INCH ORIFICE, 54 PSID
- VENDOR: FIKE CORP.
- ALL WELDED DESIGN
- TESTING:
  - EACH BURST DISC IS SUBJECTED TO AN ACCEPTANCE TEST
    - » THERMAL CYCLING AND COLD LEAK CHECK
    - » VIBRATION
  - TWO BURST DISCS ARE SUBJECTED TO QUALIFICATION TEST
    - » SIMILAR TO ACCEPTANCE
    - » COLD RUPTURE OF BURST DIAPHRAGM

FOUNTAIN EFFECT PUMP PERFORMANCE

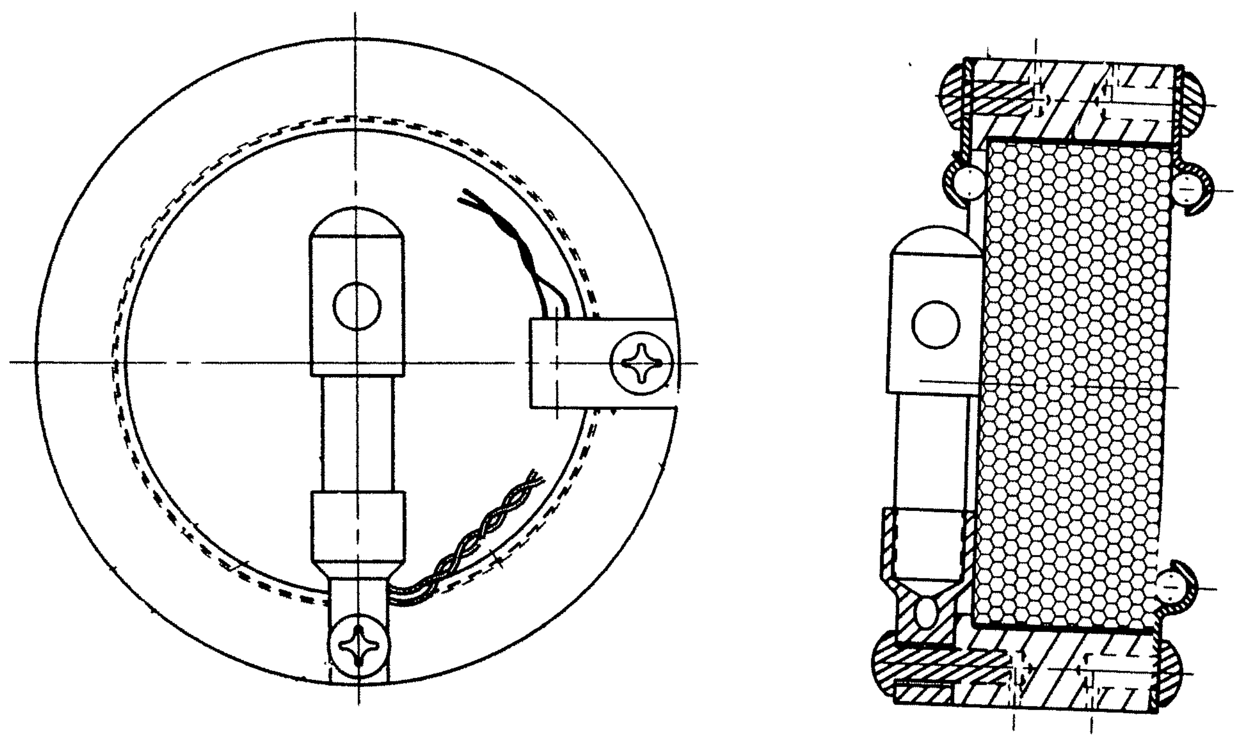
- USED FOR TRANSFERING SFHe TO WELL PRIOR TO LAUNCH (IF REQUIRED)
- DESIGN
  - 0.5 MICRON S.S. MOTT PLUG
  - 1 WATT HEATER



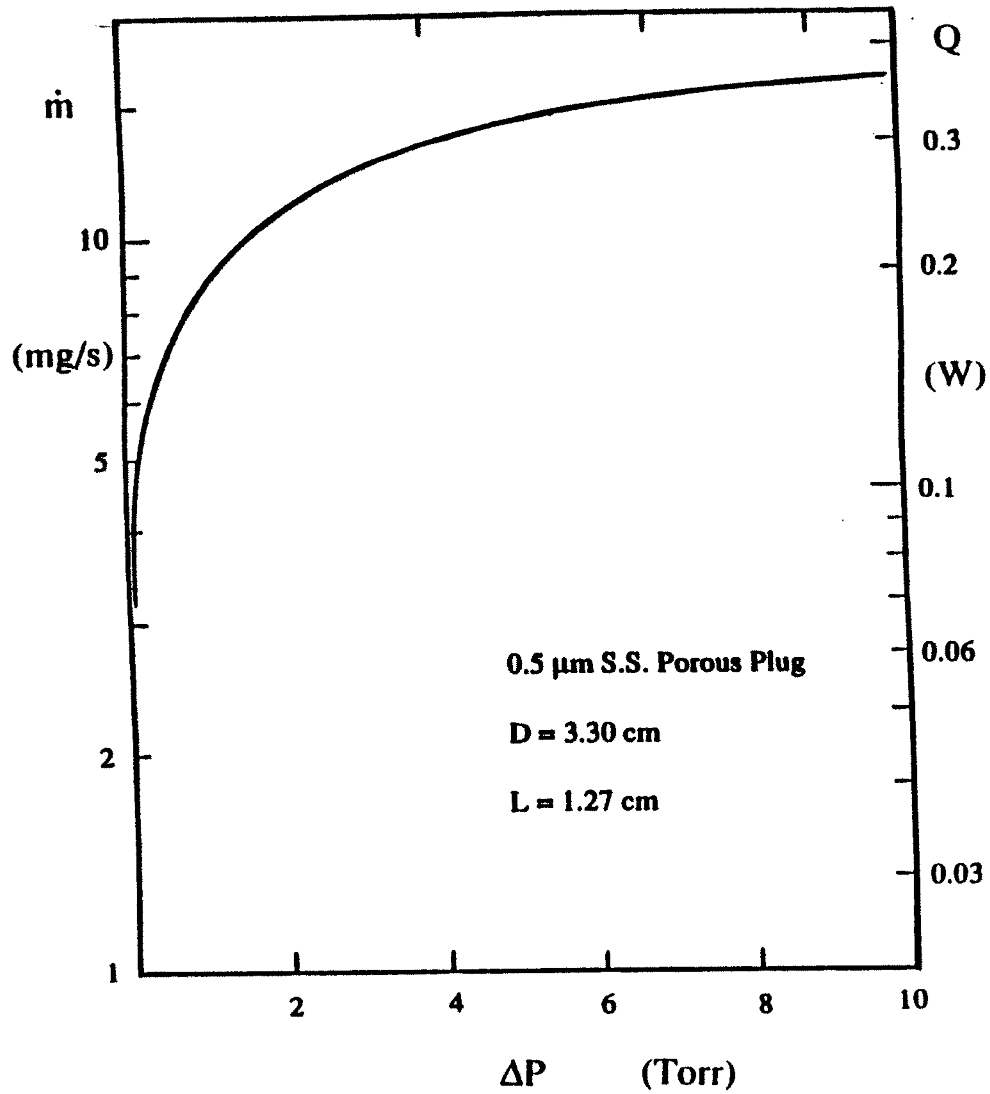
LIQUID/VAPOR PHASE SEPARATOR

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- USED FOR VENTING OF SFHe TANK
  - PHASE SEPARATION IS ACHIEVED 12 SECONDS AFTER INITIATION OF VENTING OF THE MAIN TANK DURING ASCENT
- INSTRUMENTATION
  - REDUNDANT UPSTREAM THERMOMETERS
  - DOWNSTREAM THERMOMETER
  - DOWNSTREAM LIQUID DETECTOR



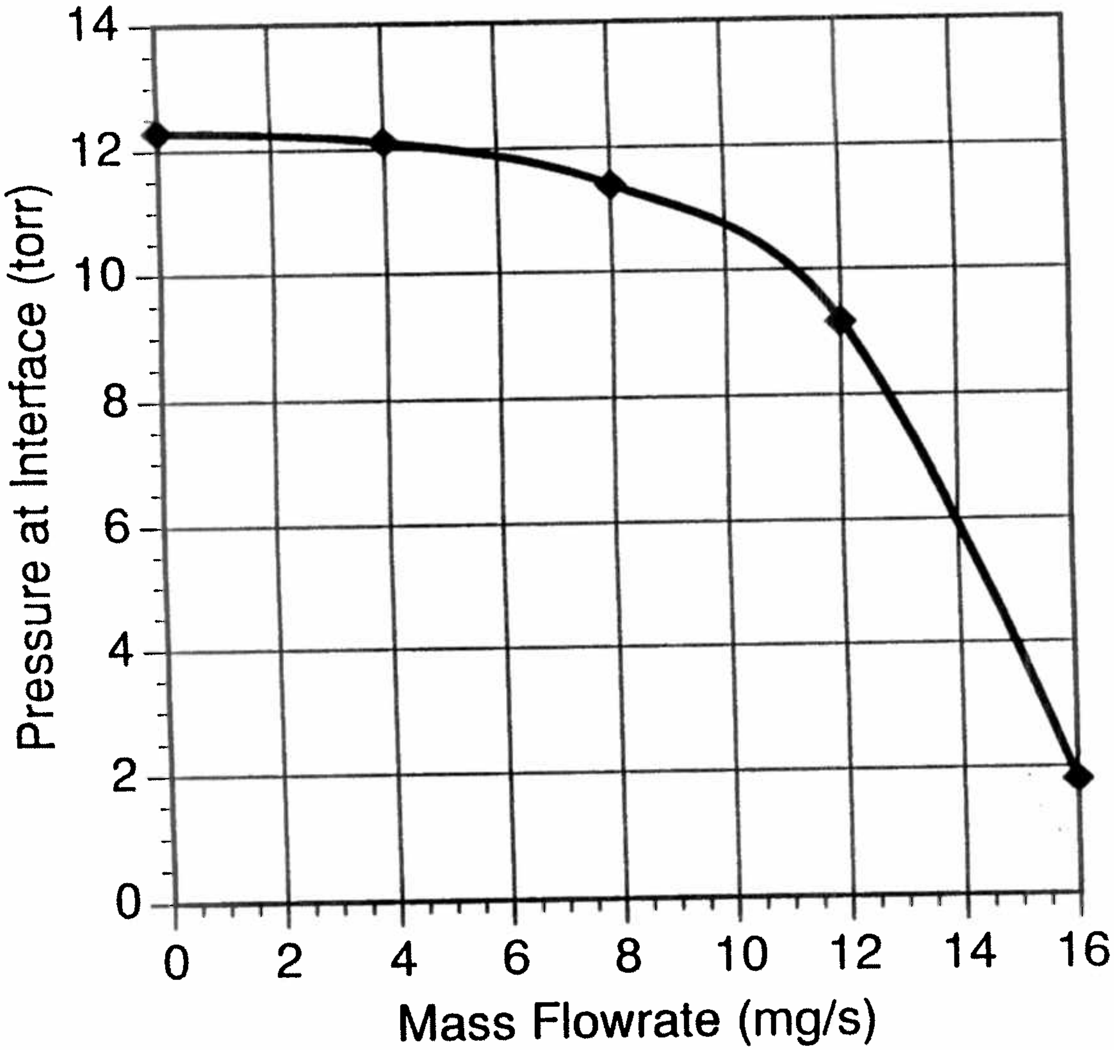
PERFORMANCE OF THE PHASE SEPARATOR



SPACECRAFT PLUMBING INTERFACE

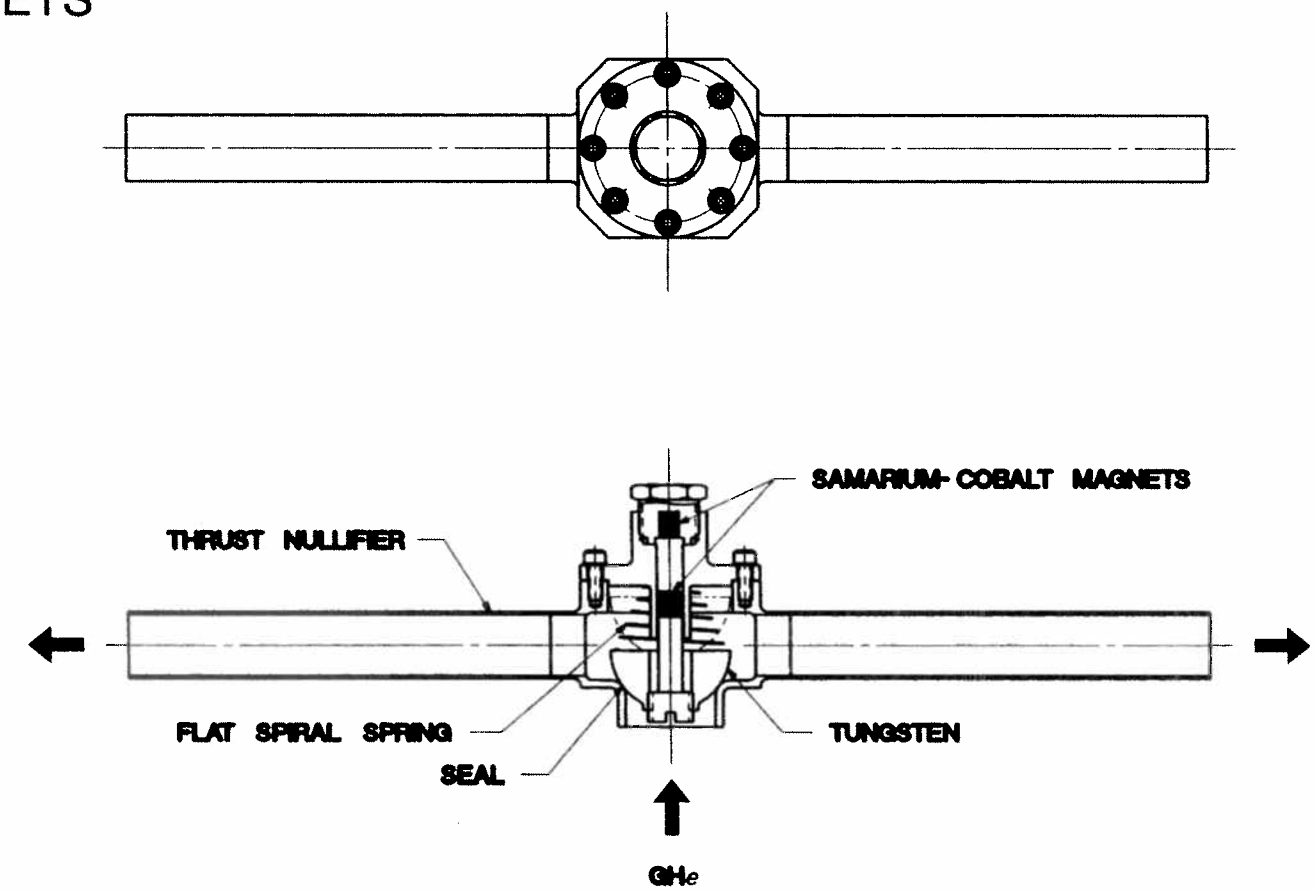
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- THE FOLLOWING GRAPH SHOWS THE INTERFACE PRESSURE AS A FUNCTION OF THE MASS FLOWRATE



GUARD TANK RELIEF

- USED FOR PREVENTING BACKFLOW OF AIR INTO VENT LINE AND FOR EVACUATION DURING ASCENT AND ON-ORBIT
- WEIGHT OF TUNGSTEN EXCEEDS SUM OF SPRING, MAGNET, AND 1/3 PSID FORCES FOR GROUND OPERATIONS
- TUNGSTEN RETRACTS IN ORBIT AND IS HELD OPEN BY SPRING AND MAGNETS



GUARD TANK FLOWRATE FOLLOWING LAUNCH

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- FOLLOWING LAUNCH, THE GUARD TANK WILL BLOWDOWN
- THERE WILL BE UP TO 30 LITERS REMAINING AT LAUNCH
- FLOWRATES WERE CALCULATED BASED ON DEPRESSURIZING THE REMAINING LIQUID
  - DOES NOT ACCOUNT FOR ANY FLASHING OF LIQUID IN WARM SECTION OF PLUMBING FOLLOWING ORBIT INSERTION
- AT ONE HOUR FOLLOWING LAUNCH THE VENT RATE WILL BE 6-15 mg/s WITH 9 LITERS OF LIQUID REMAINING IN THE TANK
  - VENTING RATE DEPENDS ON THE PARASITIC HEAT LOAD TO THE GUARD TANK
- BASED ON THESE FLOWRATES, THE VENT RATE WILL PERSIST FOR 24 - 60 HOURS
- GAS IS VENTED THRU A THRUST NULIFIER

MISC. COMPONENTS (1 OF 3)

- PLUMBING SEALS:
  - TOTAL OF 23 SEALS INTERNAL TO VACUUM SHELL
    - » ON-ORBIT SEALING: 12 SFHe, 1 GHe, 10 VACUUM
  - TOTAL OF 4 SEALS ON MAIN TANK VENT LINE EXTERNAL TO VACUUM SHELL

- WARM BURST DISCS:
  - FILL LINE (BD3) - 0.46 INCH ORIFICE, 18 PSID
  - VACUUM SHELL (BD5A, BD5B) - 2.0 INCH ORIFICE, 4 PSID
  - MAIN TANK VENT LINE (BD7A,BD7B) - 2.0 INCH ORIFICE, 4 PSID

- PYROTECHNIC VALVES:
  - VACUUM SHELL (PV1) - 1.0 INCH ORIFICE
  - WELL (PV3) - 1/2 INCH ORIFICE
  - MAIN TANK VENT (PV4A, PV4B) - 1.0 INCH ORIFICE

MISC. COMPONENTS (2 OF 3)

- THRUST NULIFIERS:
  - GUARD TANK (TN1)
  - WELL (TN2)

- BAYONETS:
  - MAIN TANK GROUND VENT (B1) - 3/4 INCH
  - GUARD TANK VENT (B2) - 3/4 INCH
  - FILL BAYONET (B3) - 1/4 INCH

- MANUAL VALVES:
  - TANK FILL VALVE (V13) - 1/4 INCH
  - MAIN TANK GROUND VENT - THRUSTERS (V12) - 3/4 INCH - MDC
  - MAIN TANK GROUND VENT - CRYOGEN SERVICING (V9) - 1/2 INCH
  - FILL AND VENT BAYONET SEAL-OFF (V8, V10) - 1/4 INCH - NUPRO

MISC. COMPONENTS (3 OF 3)

- PUMP-OUT PORT:
  - VACUUM SHELL (PO) - 2.0 INCH - SAES PURE GAS
- PUMP-OUT PORT/RELIEF:
  - WELL (RV2) - 1/4 INCH
- INTERNAL 2 MICRON LIQUID LINE FILTERS:
  - INTERNAL TANK TO WELL X-FER (F1) - NUPRO
    - » 10 torr DP @ 30 L/hr
  - EXTERNAL FILL (F2) - ERBE ENGINEERING
    - » 50 torr DP @ 600 L/hr

RISK/CONCERN AREAS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

RISK	RISK REDUCTION
• RELIABILITY OF COLD VALVES	INCORPORATE LESSONS LEARNED FROM VALVE DEVELOPMENT PROGRAMS FOR SHOOT, GPB, AND ISO
• POROUS PLUG	DEVELOPMENT TESTING
• SEAL LEAKAGE FOR REMOVABLE PLUMBING	DEVELOPMENT TESTING
• BLOWDOWN OF GUARD TANK AFFECTS S/C ATTITUDE CONTROL	PROVIDING THRUST NULIFIER TO MINIMIZE IMPACT
• BLOWDOWN OF WELL (IF USED) AFFECTS S/C ATTITUDE CONTROL	PROVIDING THRUST NULIFIER TO MINIMIZE IMPACT
• LHe REMAINING IN WELL FLASHING IN WARM REGIONS	BURST DISC ON PROBE WILL AUGMENT PRESSURE RELIEF

MASS GAUGING

DAVID FRANK

OVERVIEW

- TWO METHODS OF PERFORMING MASS GAUGING ARE BEING IMPLEMENTED:
  - HEAT PULSE METER
    - » MEASURES THE REMAINING QUANTITY OF HELIUM
  - THERMAL FLOW METER
    - » MEASURES THE FLOWRATE

- BOTH METHODS ARE BEING UTILIZED TO GET MEASUREMENTS WITH BETTER THEN 5 PERCENT ACCURACY
  - FLOW METER REQUIRES CALIBRATION THAT CAN BE PERFORMED WITH GROUND TESTING

HEAT PULSE METER

- THE HEAT PULSE METER UTILIZES A HEATER AND TEMPERATURE THERMOMETRY
  - BOTH ARE IN GOOD CONTACT WITH THE LIQUID
    - » HEATER IS LOCATED ON THE SLOSH BAFFLE INSIDE THE TANK
    - » THERMOMETER IS LOCATED ON THE INLET TO THE POROUS PLUG
- UTILIZING THE TEMPERATURE RESPONSE TO A KNOWN AMOUNT OF HEAT INPUT AND LAWS OF CONSERVATION OF ENERGY AND MASS, THE QUANTITY OF FLUID REMAINING CAN BE DETERMINED
  - HEAT RAISES THE TEMPERATURE OF THE LIQUID AND VAPOR
  - HEAT IS ABSORBED IN VAPORIZING LIQUID
- THE INCREASE IN LIQUID TEMPERATURE IS LIMITED TO 5 mK

HEAT PULSE METER OPERATION

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- OPERATING AT 28 V dc AND A MAXIMUM CURRENT OF 1.2 amp TO A 33 WATT HEATER
  - HEAT FLUX IS MAINTAINED BELOW 0.2 W/cm2
- FULL TANK REQUIRES 5000 W-S OF HEAT
  - A 5 mK RISE LEADS TO A PULSE DURATION OF 151 SECONDS WHEN THE TANK IS FULL
- DATA BEFORE AND AFTER SHOULD BE RECORDED FOR A DURATION OF TIME EQUAL TO THE PULSE DURATION
  - THIS DATA IS USED TO ESTABLISH BEFORE AND AFTER DRIFTS
- ANALYSIS CAN BE PERFORMED BY ANALYZING THE ABSOLUTE CHANGE IN TEMPERAURE OR THE RATE OF TEMPERATURE RISE
- OPERATION OF THE DRAG-FREE CONTROL SYSTEM MUST BE REVIEWED SUCH THAT THAT IT'S OPERATION DOES NOT INTERFERE

ACCURACY (1 of 2)

- THE SHORTER THE HEAT PULSE, THE SMALLER ARE THE ERRORS DUE TO CHANGES IN VENTING AND PARASITIC HEAT LOAD

- THE LARGER THE HEATER POWER IN RELATIONSHIP TO THE PARASITIC LOAD, THE SMALLER ARE CORRECTIONS NEEDED TO BE MADE TO THE CALCULATIONS

- ERRORS IN THE THERMOMETRY, READOUT, HEAT DISSIPATION, AND OTHERS (SEE NEXT CHART)

- ASSUMING PREFLIGHT ASSUMPTIONS THAT THERE ARE NO CHANGES IN VENTING RATE AND NO CORRECTIONS DUE TO TEMPERATURE DRIFT, THE ERROR IN THE HEAT PULSE READING WILL BE LESS THAN 5 PERCENT

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

ACCURACY (2 of 2)

ITEM	VALUE	COMMENTS
SENSOR CALIBRATION (GR-200-1500) @1.8K:		
- ABSOLUTE ACCURACY(dTabs1)	5mK	BASED ON TYPICAL CALIBRATION
- REPRODUCIBILITY (dTabs2)	0.5 mK	BASED ON RECOMMENDED SENSOR CHARACTERISTIC
- STABILITY (dTabs3)	0.28 mK	DRIFT OF 0.05%
- RESISTANCE (R)	13810 OHM	VENDOR CALIBRATION DATA
- SENSITIVITY (dR/dT)	24821 ohm/k	VENDOR CALIBRATION DATA
- DERIVATIVE OF SENSITIVITY (dR/dT**2)	68115 ohm/K**2	EXTRAPOLATED FROM CALIBRATION DATA
THERMOMETER READOUT UNCERTAINTY:		
- ABSOLUTE REMPERATURE (%R)	13.8 OHM	0.1 % IN ABSOLUTE RESISTANCE
- RESOLUTION (DR)	2.5 OHM	0.1 mK RESOLUTION
CALCULATED TEMPERATURE UNCERTAINTY:		
- ABSOLUTE TEMPERATURE (dTabs4)	5.1 mK	RMS OF dTabs 1,2,3 and [%R/(dR/dT)]
- CHANGE IN TEMPERATURE	0.12 mK	RMS OF ERROR IN DETERMINATION OF dR/dT [((dR/dT**2)*dTabs4/(dR/dT))*dThpm] and [DR/(dR/dT)]
HEATER POWER DISSAPATION UNCERTAINTY:	0-5 Ws	0.1 - 0.2 % OF ACTUAL HEAT DEPENDING ON PULSE DURATION
TANK VOLUME UNCERTAINTY:	23 LITERS	1 % OF MEASURED VOLUME

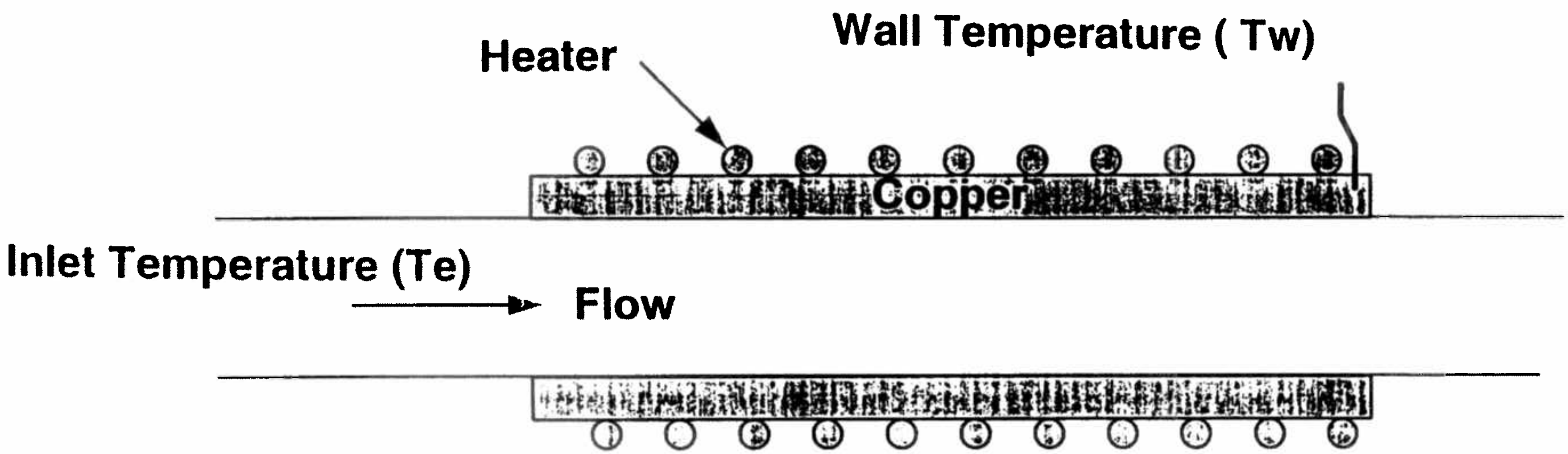
MASS FLOWMETER

- FLOWMETER APPROACH
  - MEASURE THE RESPONSE OF THE FLOW STREAM WALL TEMPERATURE TO A KNOWN HEAT INPUT
  - BASED ON FULLY DEVELOPED LAMINAR FLOW WITH A CONSTANT TEMPERATURE BOUNDARY

- DEVELOPED MODELS TO PREDICT PERFORMANCE
  - CLOSED FORM SOLUTION USED TO PERFORM PARAMETRIC STUDIES TO SIZE THE FLOWMETER
    - » ASSUMES CONSTANT PROPERTIES AND NO HEAT LOSSES
  - CFD AND SINDA MODELS TO PERFORM DETAILED ANALYSIS ON FINAL DESIGN
    - » USES VARIABLE PROPERTIES
    - » CALCULATE HEAT LOSSES (RADIATION AND CONDUCTION IN TUBING)

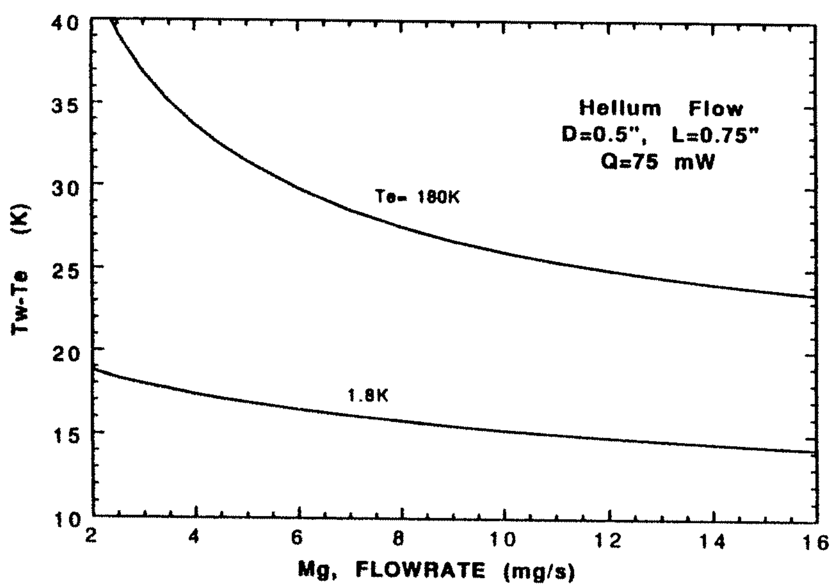
FLOWMETER SCHEMATIC

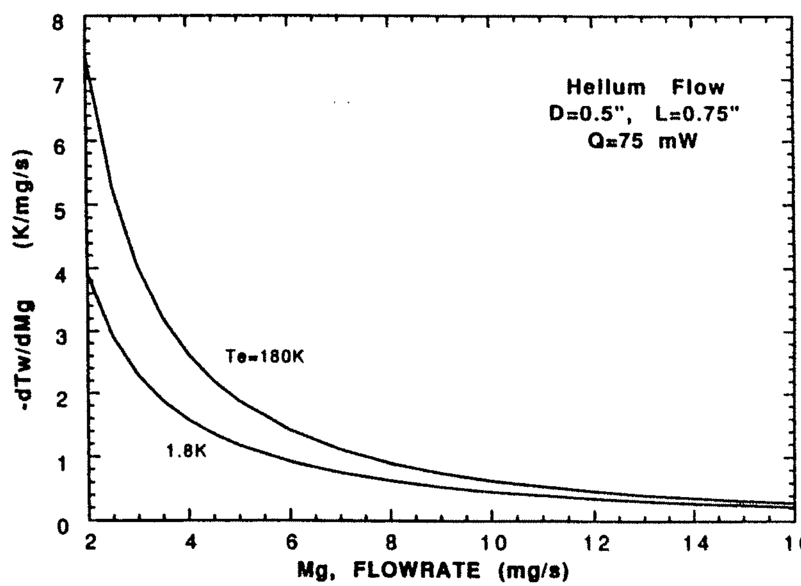
- DESIGN IS 0.75 INCH IN LENGTH WITH A HEAT INPUT OF 75 mW
- COPPER SLEEVE USED TO ACHIEVE AN ISOTHERMAL WALL



FLOWMETER PERFORMANCE

- THE FOLLOWING CURVES SHOW THE RESPONSE AND SENSITIVITY OF THE FLOWMETER
  - RESULTS SHOW THAT THE METER CAN BE LOCATED IN THE WARM OR COLD SECTION OF THE DEWAR
    - » COLD - LOCATED BETWEEN Hx-0 AND Hx-1
    - » WARM - DOWNSTREAM OF Hx-4





FLOWMETER SUMMARY

- AN ERROR ANALYSIS SHOWS THAT THE ACCURACY CAN BE BETTER THEN FIVE PERCENT
  - PRIMARY ERROR IS IN THE ASSUMPTION OF THE ENTRANCE TEMPERATURE OF THE FLOWSTREAM WHICH IS NOT MEASURED
- COLD LOCATION WAS SELECTED
- FLOWMETER MUST BE ACTIVATED FOR FIVE MINUTES IN ORDER TO ACHIEVE STEADY STATE
  - 100% DUTY CYCLE RESULTS IN A 3/4 MONTH DECREASE IN LIFE
- WALL TEMPERATURE NEEDS TO BE RECORDED FOR FIVE MINUTES BEFORE HEAT IS APPLIED
  - WALL TEMPERATURE DURING THIS TIME WILL BE REPRESENTATIVE OF THE ENTRANCE FLOWSTREAM TEMPERATURE
- CALIBRATION OF THE FLOWMETER SHOULD BE PERFORMED DURING TESTS WHEN THE GUARD TANK IS FILLED
  - ACHIEVE OPERATIONAL FLOWRATES WITH USE OF THE MAIN TANK HEATER
- EVALUATION OF A WARM LOCATION OF THE METER IS STILL ON GOING

INSTRUMENTATION

PAUL DINEEN

IS - 2

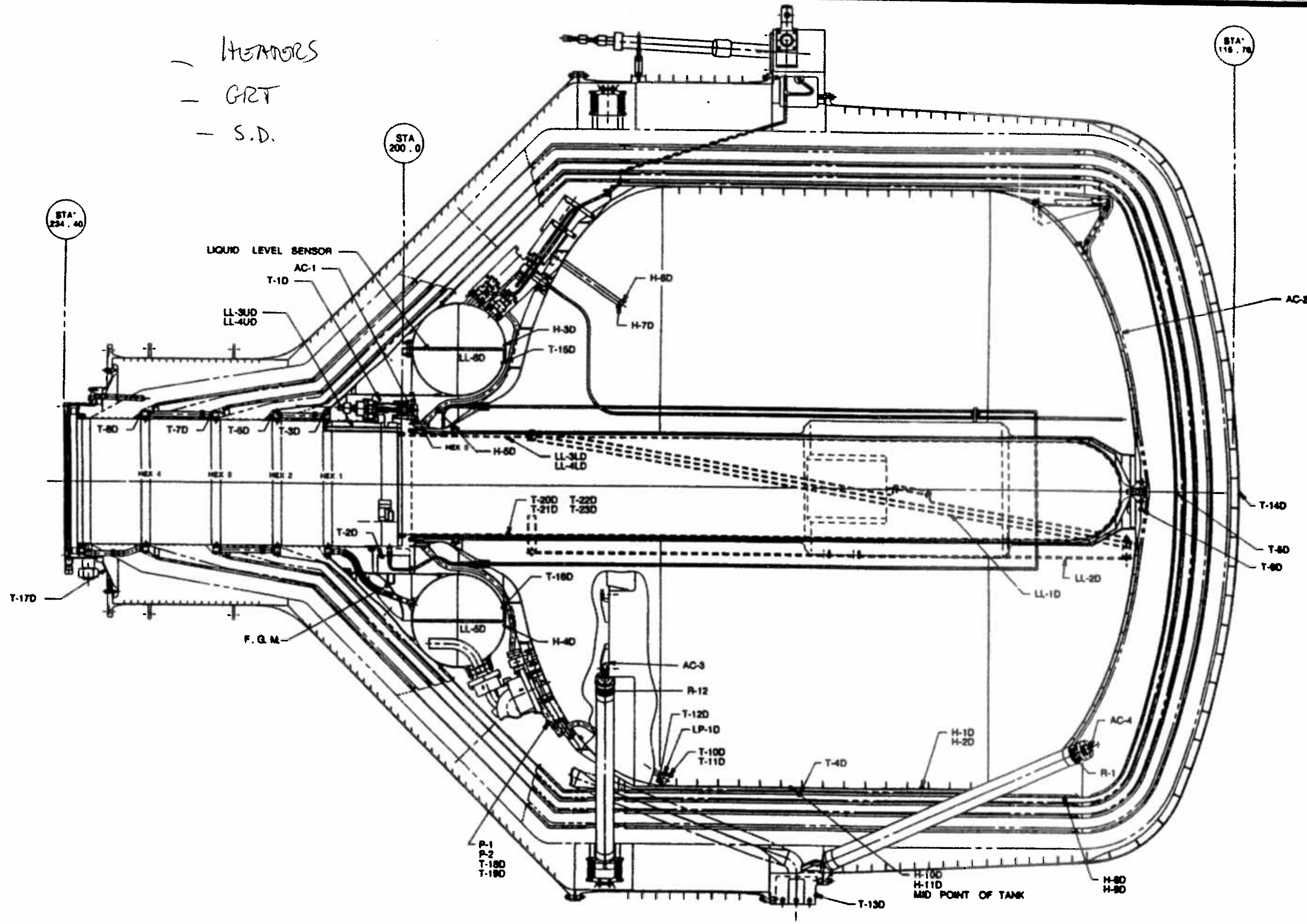
INSTRUMENTATION LOCATIONS

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

– HEATERS
– GRT
– S.D.



INSTRUMENTATION REQUIREMENTS

- LEAD BAG TEMPERATURE - 3.7.5.4.3 OF PAYLOAD SPEC F277277
  - PROVIDE INSTRUMENTATION TO INSURE CAPABILITY TO MAINTAIN TEMPERATURE AT < 6.5K AFTER INITIAL COOLDOWN.
    - » LIQUID LEVEL SENSORS LL-3L, LL-3U, LL-4L AND LL-4U; GRT'S T-20D, T-21D, T-22D AND T-23D VERIFY COMPLIANCE.
- WELL FILL CAPABILITY - 3.7.5.4.4 OF PAYLOAD SPEC F277277
  - PROVIDE TANK TO WELL LIQUID HELIUM TRANSFER (NORMAL/ SUPERFLUID)
    - » HEATERS H-6D AND H-7D ALLOW TRANSFER OF SUPERFLUID HELIUM THROUGH FOUNTAIN EFFECT PUMP
    - » HEATERS H-8D AND H-9D ALLOW TRANSFER OF NORMAL HELIUM THROUGH RAV7

INSTRUMENTATION REQUIREMENTS

- HELIUM BOIL-OFF - 3.7.5.5 OF PAYLOAD SPEC F277277
  - PROVIDE HELIUM BOILOFF GAS AND THE CAPABILITY TO MONITOR BOILOFF GAS FOR SPACECRAFT OPERATIONS
    - » HEATERS H-5D MONITORS FLOW OF GAS
    - » HEATERS H-10D AND H-11D ALLOW THE FLOW RATE TO BE INCREASED ON ORBIT

HEATERS DESIGN

- SEE EM#339, P065938 FOR HEATER WATTAGE SIZING
- HEATERS RESISTANCE SIZED USING HEATER WATTAGE AND NOMINAL 28 VDC
- HEATER CURRENT BASED ON 35 VDC MAX
  - * H8 & 9 SIZED USING 52 VDC POWER SOURCE
- HEATER FUNCTIONS REDUNDANT
- MANUFACTURER: TAYCO ENGINEERING (SAME AS PROBE B)
- CONSTRUCTION: KAPTON INSULATION W/COPPER LEAD WIRES
- ACCEPTANCE TEST: 70VDC BURN-IN TEST, 77K- 5 CYCLE THERMAL SHOCK TEST AND 100V INSULATION RESISTANCE TEST
- QUALIFICATION TEST: BY SIMILARITY TO OTHER COOLER PROGRAMS AND FLIGHT DESIGNS USED IN SPACE SYSTEM DIVISION

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

HEATERS DEFINITION

TOP PLATE FEEDTHRU	PIN NO.S	DEVICE NO	FUNCTION	LOCATION	POWER (W)	CURRENT (A)	WIRE SIZE, TYPE	COLD FEEDTHRU	PIN NO.S
P802 (FLIGHT)	1,4,5,6	H-1D	HEAT PULSE METER, MEASURE TANK RESIDUAL	INSIDE SFHE TANK, MOUNTED ON BAFFLES	33	1.47	.040 DIA MANGANIN	P824	1,2,3, 4
P802	10,11,1 7,18	H-2D	HEAT PULSE METER, MEASURE TANK RESIDUAL	INSIDE SFHE TANK, MOUNTED ON BAFFLES	33	1.47	.040 DIA MANGANIN	P824	5,6,7, 8
P804 (UMBILLICAL)	49,50	H-3D	GUARD TANK DEPLETION	GUARD TANK, OUTSIDE	4	.18	.010 DIA MANGANIN	N/A	N/A
P804	43,51	H-4D	GUARD TANK DEPLETION	GUARD TANK, OUTSIDE	4	.18	.010 DIA MANGANIN	N/A	N/A
P802	2,3,7,8	H-5D	MEASURE FLOW RATE	VENT LINE	.2	.01	.005 DIA MANGANIN	N/A	N/A
P804	59,60	H-6D	WELL TRANSFER, SUPER FLUID HELIUM	FOUNTAIN EFFECT PUMP	1	.05	.005 DIA MANGANIN	N/A	N/A
P804	55,56	H-7D	WELL TRANSFER, SUPER FLUID HELIUM	FOUNTAIN EFFECT PUMP	1	.05	.005 DIA MANGANIN	N/A	N/A
P803 (GROUND)	15,22	H-8D	WELL TRANSFER, NORMAL BOILING PT HELIUM	SFHE TANK, OUTSIDE	67.5 *	1.3	.040 DIA MANGANIN	N/A	N/A
P803	13,14	H-9D	WELL TRANSFER, NORMAL BOILING PT HELIUM	SFHE TANK, OUTSIDE	67.5 *	1.3	.040 DIA MANGANIN	N/A	N/A
P802	9,15,16 ,23	H-10D	FLOW CONTROL, INCREASE ON ORBIT FLOWRATE	SFHE TANK, OUTSIDE	.4	.18	.010 DIA MANGANIN	N/A	N/A
P802	12,13,1 9,20	H-11D	FLOW CONTROL, INCREASE ON ORBIT FLOWRATE	SFHE TANK, OUTSIDE	.4	.18	.010 DIA MANGANIN	N/A	N/A

TEMPERATURE SENSORS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

TOP PLATE FEEDTHRU	PIN NO.S	DEVICE NO	DEVICE DESCRIPTION	SUPPLIERS PART NO REF	LOCATION	WIRE SIZE, TYPE	COLD FEEDTHRU	PIN NO.S
P801 (FLIGHT)	34,42,43,51	T-1D	GRT *	GR-200B-1500-1.4B	HEX0	.005 DIA, MANGANIN	N/A	N/A
P801	23,24,32,33	T-2D	GRT	""	HEX0	""	N/A	N/A
P801	9,15,16,22	T-3D	SILICON DIODE **	DT470-SD-11-1-.4LS	HEX1	""	N/A	N/A
P801	3,7,8,14	T-4D	SD	""	VCS1, MIDDLE	""	N/A	N/A
P801	1,2,5,6	T-5D	SD	""	VCS1, BOTTOM	""	N/A	N/A
P801	4,10,11,17	T-6D	SD	""	HEX2	""	N/A	N/A
P801	18,25,26,27	T-7D	SD	""	HEX3	""	N/A	N/A
P801	35,36,44,45	T-8D	SD	""	HEX4	""	N/A	N/A
P800 (GROUND)	1,4,5,6	T-9D	SD	""	SFHE TANK OUTSIDE, BOTTOM	""	N/A	N/A
P801	61,62,65,66	T-10D	GRT	SEE ABOVE	PP, UPSTREAM	""	P821	4,5,6,7
P801	21,30,31,40	T-11D	GRT	SEE ABOVE	PP, UPSTREAM	""	P821	8,9,10,11
P801	12,13,19,20	T-12D	GRT	SEE ABOVE	PP, DOWNSTREAM	""	P821	12,13,14, 15
P805	1,2	T-13D	SD	SEE ABOVE	SUPPORT RING VAC SHELL	""	N/A	N/A
P805	3,4	T-14D	SD	SEE ABOVE	BOTTOM VACUUM SHELL	""	N/A	N/A
P804 (UMBILLICAL)	10,17,18,27	T-15D	SD	SEE ABOVE	GUARD TANK, OUTSIDE	""	N/A	N/A

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

TEMPERATURE SENSORS

TOP PLATE FEEDTHRU	PIN NO.S	DEVICE NO	DEVICE DESCRIPTION	SUPPLIERS PART NO REF	LOCATION	WIRE SIZE, TYPE	COLD FEEDTHRU	PIN NO.S
P801	28,29,37,38	T-16D	SD	SEE ABOVE	GUARD TANK, OUTSIDE	""	N/A	N/A
P805	5,6	T-17D	SD	SEE ABOVE	TOP PLATE	""	N/A	N/A
P801	46,47,54,55	T-18D	GRT	SEE ABOVE	VENT LINE	""	N/A	N/A
P801	52,53,59,60	T-19D	GRT	SEE ABOVE	VENT LINE	""	N/A	N/A
P800	10,11,17,18	T-20D	GRT	SEE ABOVE	ID OF WELL	""	P823	1,2,3,4
P804	1,2,3,6	T-21D	GRT	SEE ABOVE	ID OF WELL	""	P823	21,22,23 ,24
P800	12,13,19,20	T-22D	GRT	SEE ABOVE	ID OF WELL	""	P823	5,6,7,8
P800	14,15,21,22	T-23D	GRT	SEE ABOVE	ID OF WELL	""	P823	9,10,11, 12

* GERMANIUM RESISTANCE THERMOMETER (GRT)
** SILICON DIODE (SD)

- MANUFACTURER: LAKESHORE CRYOTRONICS
- ACCEPTANCE TEST: THERMAL CYCLING AT VENDOR
- CALIBRATION: AT VENDOR
- CONCERNS: CALIBRATION WILL NEED TO BE REPEATED USING FLIGHT ELECTRONICS

STANFORD
Lockheed

LIQUID LEVEL SENSORS

LMSC-P088357
2,3 MAR 94

TOP PLATE FEEDTHRU	PIN NO.S	DEVICE NO	DEVICE DESCRIPTION	LOCATION	FUNCTION	WIRE SIZE, TYPE	COLD FEEDTHRU	PIN NO.S
P803 (GROUND)	9,16,23,24	LL-1	LIQUID LEVEL SENSOR	SFHE, TANK	VERIFY 95% FILL LEVEL,MONITOR FILL LEVEL DURING TESTING	.012 DIA CU ON SENSOR, .005 DIA MANGANIN FROM TOP PLATE TO SENSOR	P824	1,2,3,4
P803	2,3,7,8	LL-2	""	SFHE, TANK	""	""	P824	5,6,7,8
P804 (UMBILLICAL)	44,45,52,53	LL-3L	""	WELL	MONITOR WELL FILL LEVEL DURING PROBE INSERTION	""	P823	25,26,27 ,28
P804	54,55,61,62	LL-3U	""	WELL	""	""	P823	29,30,31 ,32
P803	1,4,5,6	LL-4U	""	WELL	""	""	P823	13,14,15 ,16
P803	17,25,26,27	LL-4L	""	WELL	""	""	P823	17,18,19 ,20
P804	56,57,58,64	LL-5	""	GUARD TANK	MONITOR GUARD TANK FILL LEVEL	""	P811	1,2,3,4
P804	25,26,35,36	LL-6	""	GUARD TANK	""	""	P812	1,2,3,4

- MANUFACTURER: AMERICAN MAGNETIC INC. SELECTED OVER KELLER PSI SENSOR
- CONSTRUCTION : SUPERCONDUCTING MEASUREMENT WIRE ENCASED IN 1/4" DIAMETER FIBERGLASS SUPPORT TUBE.
- ACCEPTANCE TEST: THERMAL CYCLING AT VENDOR

ACCELEROMETERS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

TOP PLATE FEEDTHRU	PIN NO.S	DEVICE NO	DEVICE DESCRIPTION	LOCATION	FUNCTION	WIRE SIZE, TYPE
P800 (GROUND)	35,36,37, 44,45,46	AC-1	TRIAXIAL ACCELEROMETER	SFHE TANK, HEX0	MONITOR LOADS AT STA 200*	.005 DIA MANGANIN
P800	38,39,40,47, 48,49	AC-2	""	SFHE TANK, AFT	MONITOR OVERALL TANK LOADS	""
P800	41,42,50,51, 57,58	AC-3	""	SFHE TANK, NEAR FWD POD SUPPORT	MONITOR LOADS NEAR POD SUPPORTS	""
P800	16,23,24,32, 33,34	AC-4	""	SFHE TANK, NEAR AFT POD SUPPORT	MONITOR LOADS NEAR POD SUPPORTS	""

- MANUFACTURER: KISTLER MODEL 8614A-500
- CONSTRUCTION:
  - THREE KISTLER MODEL 8614A-500 ACCELEROMETERS MOUNTED ON ALUMINUM CUBE
  - CONNECTION: SOLDER
- ACCEPTANCE TEST/CALIBRATION TEST: AT TEMPERATURE AT UTAH STATE
- QUALIFICATION: SPIRIT III

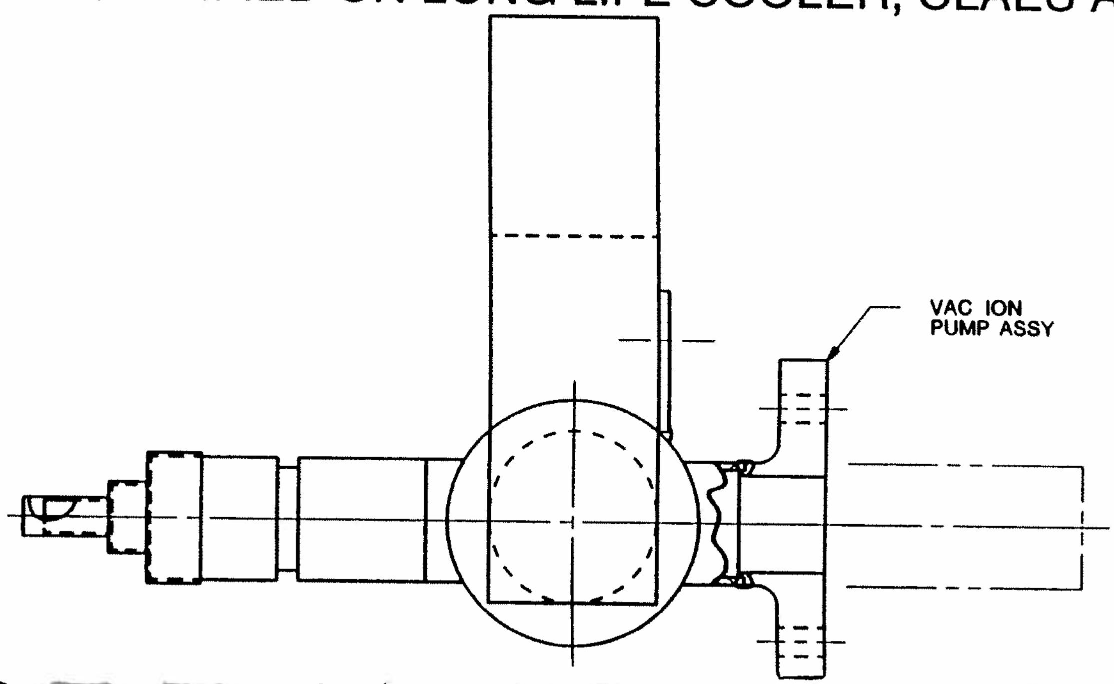
hit on orbit.

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

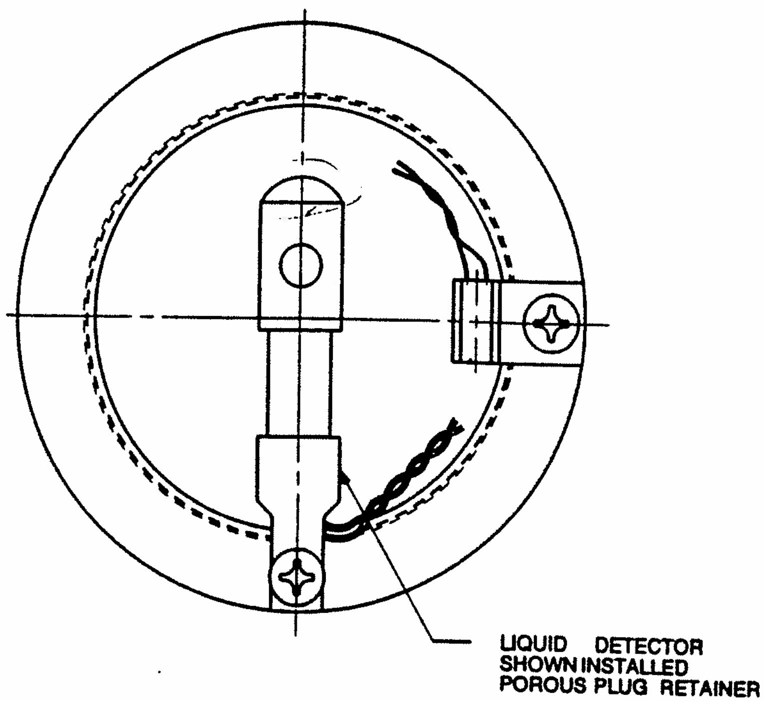
PRESSURE SENSORS

- VAC-ION PUMP (GROUND TEST ONLY)
  - FUNCTION: MEASURE A 10^{-7} TO 10^{-8} TORR VACUUM BETWEEN THE DEWAR MAIN TANK AND VACUUM SHELL
  - PUMP MAGNET TO BE REMOVED BEFORE FLIGHT TO REDUCE WEIGHT
  - VARIAN MODEL: 913-0032; PUMPING RATE: 2 LITER/SEC
  - INTERFACE: CONNECTOR P811, SEE VIEW C-C OF ICD 5833115
  - ACCEPTANCE TEST: LEAK TEST
  - FLIGHT QUALIFIED ON LONG LIFE COOLER, CLAES AND SPIRIT III



LIQUID POINT SENSOR

- LIQUID POINT SENSOR — DIAGNOSTIC - DECISION SENSOR
  - FUNCTION: MEASURE THE PRESENCE OF LIQUID HELIUM DOWN STREAM OF THE POROUS PLUG. VERIFIES THAT THE POROUS PLUG IS FUNCTIONING CORRECTLY BY INDICATING THAT NO LIQUID HELIUM IS PRESENT.
  - AMERICAN MAGNETICS INC MODEL: LHE-PT25
  - ACCEPTANCE TEST: THERMAL CYCLE TO LN2
  - QUALIFICATION: VIBRATION TEST PLANNED AT POROUS PLUG ASSEMBLY LEVEL



IS - 13

PODS DISCONNECT SENSOR

TOP PLATE FEEDTHRU	PIN NO.S	DEVICE NO	DEVICE DESCRIPTION	LOCATION	WIRE SIZE, TYPE
P801 (FLIGHT)	24	R-0	PODS DISCONNECT COMMON RETURN	TANK	.005" DIA MANGANIN
P802 (FLIGHT)	34	R-1	PODS DISCONNECT	PODS#1	""
P802	33	R-2	""	PODS#2	""
P802	43	R-3	""	PODS#3	""
P802	51	R-4	""	PODS#4	""
P802	50	R-5	""	PODS#5	""
P802	59	R-6	""	PODS#5	""
P802	52	R-7	""	PODS#7	""
P802	44	R-8	""	PODS#8	""
P802	35	R-9	""	PODS#9	""
P802	26	R-10	""	PODS#10	""
P802	25	R-11	""	PODS#11	""
P802	27	R-12	""	PODS#12	""

- FUNCTION: VERIFY THERMAL ISOLATION BETWEEN TANK AND VACUUM SHELL
- READINGS SHOULD NORMALLY BE OPEN UNLESS PODS SHORT OUT
- R-0 COMMON RETURN FOR R-1 THRU R-12
- ACCEPTANCE TEST: CONTINUITY CHECK AT INSTALLATION USING JUMPER TO SHORT POD

VALVE WIRING

Heater valve.

TOP PLATE FEEDTHRU	PIN NO.S	DEVICE NO	DEVICE DESCRIPTION	LOCATION	CURRENT (A)	WIRE SIZE, TYPE
P800 (GROUND)	52,53,54,55,56, 59,60,61,62,65, 66	RAV-1	REMOTE ACTUATED VALVE	SFHE TANK FILL	1 @ 1.5 4 @ 0.7 6 @ >.001	1 @ .040 DIA 4 @ .020 DIA 6 @ .005 DIA
P802 (FLIGHT)	55,56,57,58,60, 61,62,63,64,65, 66	RAV-2	""	GUARD TANK FILL	""	""
P803 (GROUND)	35,36,37,38,39, 40,44,45,46,47, 48	RAV-3	""	POROUS PLUG BYPASS	""	""
P804 (UMBILLICAL)	4,5,7,8,11,12,13 ,14,19,20,21	RAV-5	""	WELL FILL	""	""
P804	9,15,16,22,23,24 ,32,33,34,41,42	RAV-6A	""	FOUNTAIN EFFECT PUMP	""	""
P804	28,29,30,31,37, 38,39,40,46,47, 48,	RAV-6B	""	FOUNTAIN EFFECT PUMP	""	""
P803	33,34,41,42,43, 49,50,51,57,58, 64	RAV-7	""	TANK TO WELL TRANSFER	""	""
P806	1,2,3,4	PV-1	PYRO VALVE	EXTERNAL VACUUM SHELL	TBD	4 @ TBD
P808	1,2,3,4	PV-3	""	EXTERNAL WELL	""	""
P809	1,2,3,4	PV-4A	""	SFHE ON ORBIT VENT	""	""
P810	1,2,3,4	PV-4B	""	SFHE ON ORBIT VENT	""	""

FEEDTHROUGH CONNECTORS

- TOP PLATE FEEDTHROUGH CONNECTORS
  - MANUFACTURER: PACIFIC COAST TECHNOLOGIES
  - TYPE: 66 PIN MIL-C-38999 TYPE III CONNECTORS
  - ACCEPTANCE TEST AT VENDOR: THERMAL CYCLE TO 220K, ROOM TEMPERATURE DC ISOLATION AND LEAK TEST
  - QUALIFICATION TEST: SMD VIBRATION TEST
- COLD FEEDTHROUGH CONNECTORS
  - MANUFACTURER: PACIFIC COAST TECHNOLOGIES
  - CONSTRUCTION: STAINLESS STEEL BODY, INCONEL PINS, CRYOFLEX SEAL, SOLDER CONNECTION BOTH ENDS
  - DEVELOPMENT TEST: SEE DEVELOPMENT TEST SECTION
  - ACCEPTANCE TEST AT VENDOR: THERMAL CYCLE TO LN2, ROOM TEMPERATURE DC ISOLATION AND LEAK TEST
  - LMSC ACCEPTANCE TEST (AFTER WELDING INTO FLANGE) : THERMAL CYCLE/LEAK TEST AT LN2, ROOM TEMPERATURE 83PSI PRESSURE TEST
  - QUALIFICATION TEST: SMD VIBRATION TEST

INTERFACES

- DEWAR INTERFACE TO PROBE -ICD DWG 5833117
  - REVISION WILL SHOW INSTALLATION OF LIQUID LEVEL SENSORS LL-3U, LL-3L, LL4U AND LL4L IN WELL AND NECK REGIONS
  - REVISION WILL SHOW INSTALLATION OF GRTS T-20D, T-21D, T-22D AND T-23D IN WELL REGION
- PAYLOAD - TO - SPACECRAFT INTERFACE - ICD DWG 5833115
  - UPDATE IN PROCESS
  - UPDATE WILL SHOW T-13D, T-14D AND T-17D INSTALLATION LOCATIONS AND WIRE ROUTING TO CONNECTOR P805

INSTRUMENTATION STATUS

- INTERNAL TANK: DETAILED DRAWINGS
  - HEATER, GRT, FEEDTHRU, FLANGE, AND WIRE DWGS COMPLETE
  - LIQUID LEVEL SENSOR AND BRACKET DRAWINGS IN PROCESS, REVISED FOR +X AND +Y HORIZONTAL FILL ORIENTATIONS
- INTERNAL TANK INSTALLATION DRAWINGS: IN PROCESS
- EXTERNAL TANK DRAWINGS/LAYOUT
  - WIRES SORTED BY DEVICE TYPE, GROUND, FLIGHT AND UMBILLICAL FUNCTIONS AND ASSIGNED PIN NUMBERS
  - TOP HAT CONNECTORS INCREASED FROM 55 PINS TO 66 PINS BECAUSE OF WIRE SORTING AND AVAILABILITY OF OFF-THE-SHELF MATING CONNECTORS
  - OFF THE SHELF BENDIX CONNECTOR SELECTED AS TOP PLATE FEEDTHROUGH MATE. PREVIOUS CONCEPT SOLDER CONNECTION
  - WIRES SIZED FOR CURRENT LOADS, REF EM#338 -REV A, P065937
  - DETERMINED THAT WIRES WILL NOT NEED TO BE SHIELDED WITHIN DEWAR. TEMPERATURE SENSORS TO BE ROUTED SEPARATE FROM REMOTE ACTUATED VALVES
  - FINAL WIRE ROUTING IN PROCESS

CHANGES SINCE PDR

- TANK LIQUID LEVEL SENSOR ORIENTATION REVISED TO MONTIOR TANK FILL LEVEL WITH +X AXIS AND +Y AXIS POINTING UP
- SELECTION OF AMI AS MAIN TANK AND GUARD TANK LIQUID LEVEL SENSOR VENDOR
- DEFINITION OF NUMBER OF WIRES NEEDED FOR REMOTE ACTUATED VALVES AND FINAL NUMBER OF REMOTE ACTUATED VALVES
  - ALLOWED FINAL SORTING OF WIRES BY CONNECTOR FUNCTION (I.E. GROUND, FLIGHT AND UMBILLICAL)
- SELECTION OF PACIFIC COAST TECHNOLOGIES AS COLD FEEDTHROUGH VENDOR
  - ALLOWED FINALIZATION OF TANK AND AXIAL LOK FEEDTHROUGH OPENINGS

INSTRUMENTATION RISKS AND RISK REDUCTIONS

RISK	RISK REDUCTION
• COLD FEEDTHRU LEAKAGE	• THERMAL CYCLED & LEAK TESTED AT VENDOR AND LMSC PRIOR TO INSTALLATION. WELDED TO REMOVABLE FLANGES IF REPLACEMENT REQUIRED
• FAILURE OF GRTS AND SILICON DIODES	• THERMAL CYCLING AT VENDOR AND LMSC PRIOR TO INSTALLATION. REDUNDANT FUNCTIONS INSTALLED
• FAILURE OF HEATERS	• THERMAL SHOCK TEST PERFORMED AT VENDOR. REDUNDANT HEATER INSTALLED.
• WIRE BREAKING	• HEAVIEST POSSIBLE COATING OF POLYIMIDE INSULATION USED ON WIRES.

SUMMARY AND CONCLUSION

- INSTRUMENTATION MEETS REQUIREMENTS
- DETAILED DESIGN IN PROGRESS
- DEWAR INTERNAL INTERFACES CLEARLY DEFINED
- RISK AREAS CLEARLY IDENTIFIED AND BEING ADDRESSED

GROUND SUPPORT EQUIPMENT

DAVID PICKETT

GROUND SUPPORT EQUIPMENT

- LEAD BAG AND RETAINER INSTALLATION
- PROBE/DEWAR INTEGRATION EQUIPMENT
- DEWAR HANDLING EQUIPMENT
- CRYOGENIC SERVICE EQUIPMENT
- DEWAR GROUND SUPPORT EQUIPMENT

GROUND SUPPORT EQUIPMENT DESIGN PHILOSOPHY

- EDD/SMD COMMON INTERFACE DESIGN AND OPERATIONS APPROACH TO CAPITALIZE ON EDD SUCCESSES AND MAXIMIZE COMMONALITY OF EQUIPMENT, PROCEDURES, AND EXPERIENCE

- SUCCESFUL LEAD BAG WORK AND COLD PROBE INSERTION SHOWS UTILITY OF MAJOR PORTION OF ALL GSE NEEDED FOR SMD

LEAD BAG AND RETAINER INSTALLATION EQUIPMENT

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

EQUIPMENT DESCRIPTION	COMMENTS
• GLOVEBOX	EXISTING EDD EQUIPMENT
• RADIATION BAFFLES	EXISTING EDD EQUIPMENT
• RADIATION COVER PLATE	EXISTING EDD EQUIPMENT
• MAGNETOMETERS	EXISTING EDD EQUIPMENT
• EXPANSION TOOLS	EXISTING EDD EQUIPMENT
• SHUTTER	EXISTING EDD EQUIPMENT
• DEWAR ADAPTER	NEW DESIGN FOR SMD
• REMOVABLE MAGNETIC SHIELD	NEW SMD DESIGN, EDD 'BUCKING COIL' CAN 'T BE USED

LEAD BAG AND RETAINER INSTALLATION EQUIPMENT

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- DEWAR ADAPTER
  - SMD TOP PLATE DESIGN IS SIGNIFICANTLY DIFFERENT FROM EDD
  - PROVIDES INTERFACE BETWEEN TOP PLATE & LEAD BAG GSE

- REMOVABLE MAGNETIC SHIELD
  - CYLINDER Mu METAL MATERIAL WHICH MATES WITH STATION 200 AND EXTENDS UP INTO THE DEWAR NECK TUBE
  - EXTENDS MAGNETIC SHIELD FURTHER UP THE NECK DURING INITIAL COOLDOWN THROUGH THE INSTALLATION OF THE 10 INCH LEAD BAG

PROBE/DEWAR INTEGRATION EQUIPMENT

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

EQUIPMENT DESCRIPTION	COMMENTS
• PROBE AIRLOCK	MODIFICATION REQUIRED FOR PROBE B/EDD INTEGRATION
• PROBE AIRLOCK SUPPORT PLATE	CLAMSHELL DESIGN REQUIRED FOR SMD
• AIRLOCK BARREL LIFTING MECHANISM	LIMITED HOOK HEIGHT REQUIRES NEW DESIGN FOR PROBE-B/EDD
• SHORT LOAD CELL/LIFTING DEVICE	LIMITED HOOK HEIGHT REQUIRES NEW DESIGN FOR PROBE/EDD
• DIAL INDICATOR PROBE CENTERING DEVICE	EXISTING EDD EQUIPMENT

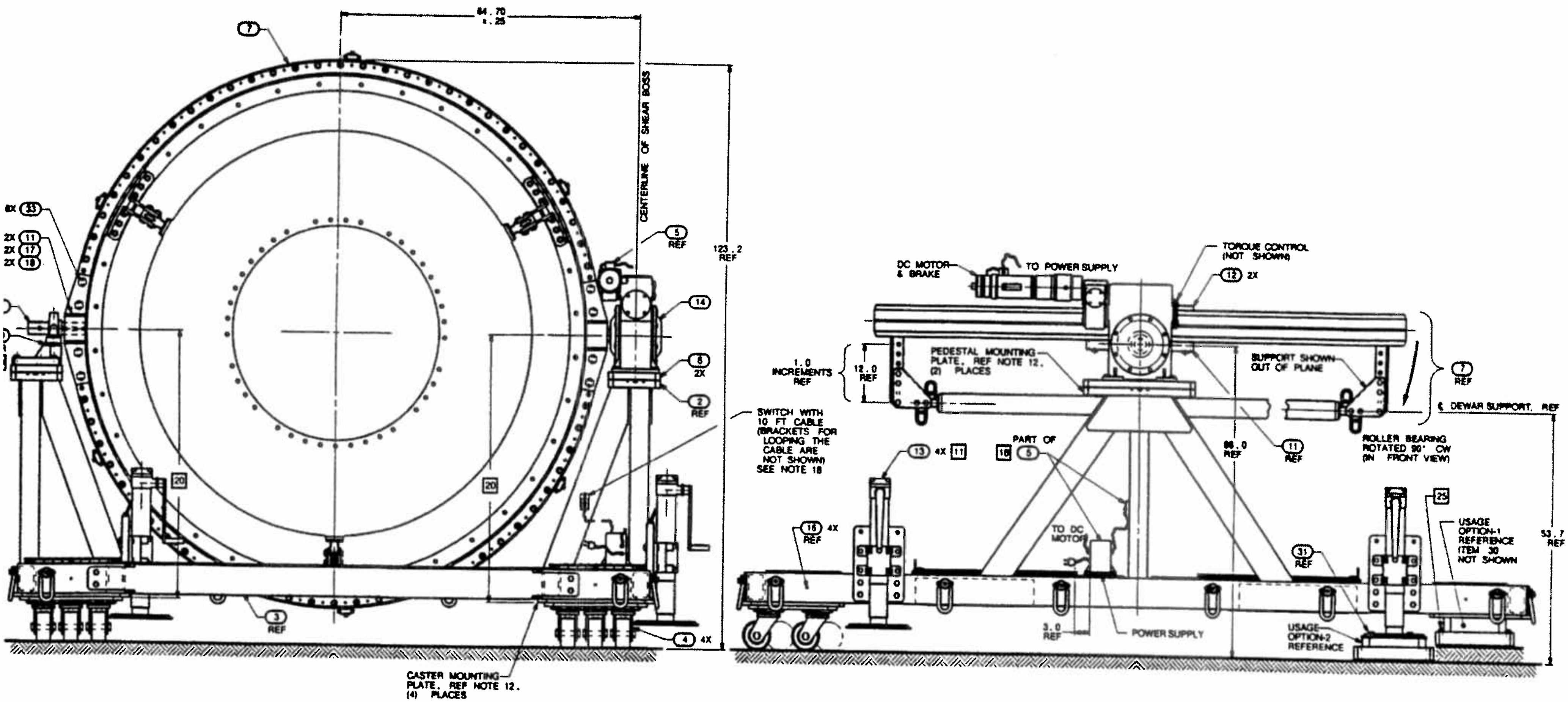
SMD HANDLING EQUIPMENT

EQUIPMENT DESCRIPTION	COMMENTS
• ASSEMBLY STAND	180° TILT CAPABILITY, 5°ROLL POSITIONING, LOCKS IN PLACE FOR TILT OPERATIONS
• INTEGRATION AND TEST STAND	ASSEMBLY STAND MODIFIED FOR MOTORIZED ROLL & DITHER
• LIFTING SLING	LIFTING DEVICE TO HOIST TANK AND DEWAR INTO AND OUT OF THE ASSEMBLY/TEST STAND (5000 LB CAPABILITY)

GS - 8

SMD ASSEMBLY STAND

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



SMD ASSEMBLY STAND REQUIREMENTS

- DESIGN REQUIREMENTS
  - WEIGHT CAPACITY =2000 KG (FULLY LOADED DEWAR WITH PROBE)
  - INTERFACE WITH VACUUM SHELL SUPPORT RING AT SPACECRAFT ATTACH POINTS

- FUNCTIONAL REQUIREMENTS
  - STAND CAN BE ROLLED AROUND LAB
  - STAND CAN BE JACKED UP OFF WHEELS AND FIRMLY BOLTED TO THE LAB FLOOR
  - STAND SHOULD MAXIMIZE ASSEMBLY ACCESS
  - DEWAR CAN BE SECURED TO THE STAND EVERY FIVE DEGEES IN THE ROLL ORIENTATION
  - DEWAR CAN BE TILTED UPSIDE DOWN
  - STAND CAN BE USED FOR SHIPPING

- CAN BE MODIFIED FOR USE AS TEST AND INTEGRATION STAND

TEST AND INTEGRATION STAND REQUIREMENTS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

ITEM	REQUIREMENT (STANFORD) S0130 5/2/90	BASELINE PERFORMANCE	VERIF
LOAD CAPABILITY	3700 LBS. (MAX AT PROBE INTEGRATION) @ FOS 5.0	MEETS REQ. (18500 LBS)	AN/TEST
TILT CAPABILITY	DEWAR VERTICAL TO HORIZ.	MEETS REQ.	DES/TEST
TILT VELOCITY PROFILE	TBD	TBD	
ROLL CAPABILITY	360 DEG. (30 MIN/REV)	MEETS REQ.	DES/TEST
ROLL MECHANISM	STEPPER MOTOR , CONTROL: MANUAL OR COMPUTER	MEETS REQ.	DES/TEST
ROLL VELOCITY PROFILE	TBD	TBD	
ROLL REFERENCE MARKS	DETERMINE QBA ROLL TO +/- 1 DEG	MEETS REQ. SEE EM 229	DES/INSP
LEVELING ADJUST	SET TRUNNION HORIZONTAL	JACKS @ 4 PLCS	DES/INSP
LEVELING CHECK	TBD (CHECK AT DEWAR TOP)	CLINOMETER	INSP

TEST AND INTEGRATION STAND REQUIREMENTS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

ITEM	REQUIREMENT (STANFORD SO130 5/2/90)	BASELINE PERFORMANCE	VERIF
DITHER RANGE/ TOLERANCE	200 ARC SECONDS +/- 10 ARC SECONDS	MEETS REQ.	DES/TEST
ANGULAR VELOCITY VELOCITY PROFILE	200 ARC SEC / 5 SEC TBD	50 +/- 10 ARC SEC/SEC TBD	DES/TEST
CALIBRATION/ READOUT	MANUAL / DIAL INDICATOR	MEETS REQ.	DES/TEST
MECHANISM	STEPPER MOTOR	MEETS REQ.	DES/TEST
DITHER PIVOT POINT LOCATION	INTERSECTION PROBE C. L. & SIDE MOUNT GATE VALVE FLANGE	MEETS REQ.	DES/TEST
DITHER PIVOT REF	LOCATION: WITHIN .25 DEG. OF TILT PLANE	MEETS REQ.	DES/INSP

CRYOGENIC SERVICE EQUIPMENT

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

EQUIPMENT DESCRIPTION	COMMENTS
• LIQUID HELIUM SUPPLY DEWAR (2 EACH)	1000 L CAPACITY, WITH MODIFICATIONS FOR SUB-ATMOSPHERIC FLUID TRANSFER AND LEVEL SENSORS
• SUPPLY DEWAR SIPHON	FEMALE LINDE TYPE BAYONETS. NEED TO REVIEW LAUNCH PAD HEIGHT RESTRICTION
• TANK FILL TRANSFER LINE	9" RIGHT ANGLE MALE BAYONET AT DEWAR. 0.5 MICRON FILTER. TRANSFER LINE LENGTHS REQUIRED IS TBD
• TANK EXHAUST LINE	MALE LINDE TYPE BAYONETS, EACH END. INTERFACES WITH MAIN TANK OR GUARD TANK AND EXHAUST MODULE

DEWAR GROUND SUPPORT EQUIPMENT

FUNCTIONAL REQUIREMENTS

- CAPABLE OF OPERATING AT REMOTE FACILITIES
- CAPABLE OF CONTINGENCY OPERATIONS AT THE LAUNCH PAD
- VACUUM PUMPING ON DEWAR VACUUM SPACE, TANKS, WELL, & PLUMBING
- MONITOR DEWAR STATUS (TEMPERATURE, PRESSURE, FILL LEVEL)
- SUPPORT HELIUM (NORMAL & SUPER FLUID) FILL/VENT OPERATIONS

DEWAR GROUND SUPPORT EQUIPMENT

EQUIPMENT DESCRIPTION	COMMENTS
• VACUUM MODULE	PUMPS THE DEWAR VACUUM SPACE TO A HARD VACUUM
• GAS MODULE	PROVIDES A CONTROLLED EVACUATION AND BACKFILL OF THE MAIN TANK AND GUARD TANK; SUPPORTS HELIUM FILL OPERATIONS
• EXHAUST MODULE	PROVIDES HIGH CAPACITY PUMPING TO CONDITION SFHE; PROVIDES HEAT EXCHANGER TO WARM EXHAUST GAS DURING FILL OPERATIONS

DEWAR GROUND SUPPORT EQUIPMENT

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

EQUIPMENT DESCRIPTION	COMMENTS
• ELECTRICAL MODULE	CONTAINS MONITORS AND CONTROLS FOR GAS, VACUUM, AND EXHAUST MODULES. INCLUDES LIQUID LEVEL R/O, POWER SUPPLIES FOR ALL HEATERS AND CONTROL FOR CRYOVALVES. SUPPLIES POWER TO ALL MODULE GSE EXCEPT SFHE CONDITIONING PUMPS
• DATA AQUISITION SYSTEM	COMPUTER, PRINTER, PLOTTER, VOLTMETER AND SCANNER FOR DISPLAYING, REDUCING, AND STORING TEST DATA
• TEMPERATURE, MONITOR AND ALARM (TMA)	MONITOR AND DISPLAY CRITICAL TEMPS. 115 VAC OR SELF CONTAINED BATTERIES. PORTABLE (CAN BE CARRIED). AUDIBLE ALARM FEATURES.

GS - 16

CRYOGENIC GSE REQUIRED FOR PLANNED OPERATIONS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

OPERATION	HELIUM SUPPLY DEWAR	FILL/VENTTRANSFER LINES AND SIPHON	VACUUM MODULE	GAS MODULE	EXHAUST MODULE	ELECTRICAL MODULE	TEMP MONITOR & ALARM	LEAK DETECTOR	ELECT CABLES & PNEUMATIC LINES	DATA ACQ SYSTEM	
EVACUATE VACUUM SPACE			•			•			•		
EVACUATE/BACKFILL MAIN TANK, GUARD TANK, WELL, & PLUMBING				•		•			•		
SYSTEM LEAK CHECKS			•	•		•		•	•		
SYSTEM BAKEOUT			•	•		•			•	•	
MAIN TANK FILL (NBHE)	•	•	•		•	•		•	•	•	
MAIN TANK FILL (SFHE)	•	•	•		•	•		•	•	•	
MAIN TANK VENTING		•			•				•	•	
GUARD TANK FILL	•	•	•		•	•		•	•	•	
GUARD TANK VENTING		•			•				•	•	
MONITOR AND OPERATE INSTRUMENTATION						•	•		•	•	

PRELIMINARY GSE FACILITY REQUIREMENTS

EQUIPMENT	APPROXIMATE ENVELOPE (In.)	APPROXIMATE WEIGHT (lb)	POWER	COMPRESSION AIR (80 psi)
VACUUM MODULE	(L) (W) (H) 30 X 36 X 60	600	N/R	YES
GAS MODULE	30 x 36 x 60	600	N/R	YES
EXHAUST MODULE 2 (UNITS)	30 X 72 X 80	800	208V, 3 Ø 30A	YES
ELECTRICAL MODULE	30 X 36 X 60	800	208 V, 3 Ø, 30 A	YES
TM&A	10 x 26 x 18	30	110 V, 10 A (OR) BATTERIES	N/R
DATA SYSTEM	36 x 72 x 36	800	110 V, 10, 20 A	N/R
LEAK DETECTOR	36 x 36 x 36	600	110 v, 10, 30 A	N/R

FABRICATION AND ASSEMBLY

DAVID PICKETT

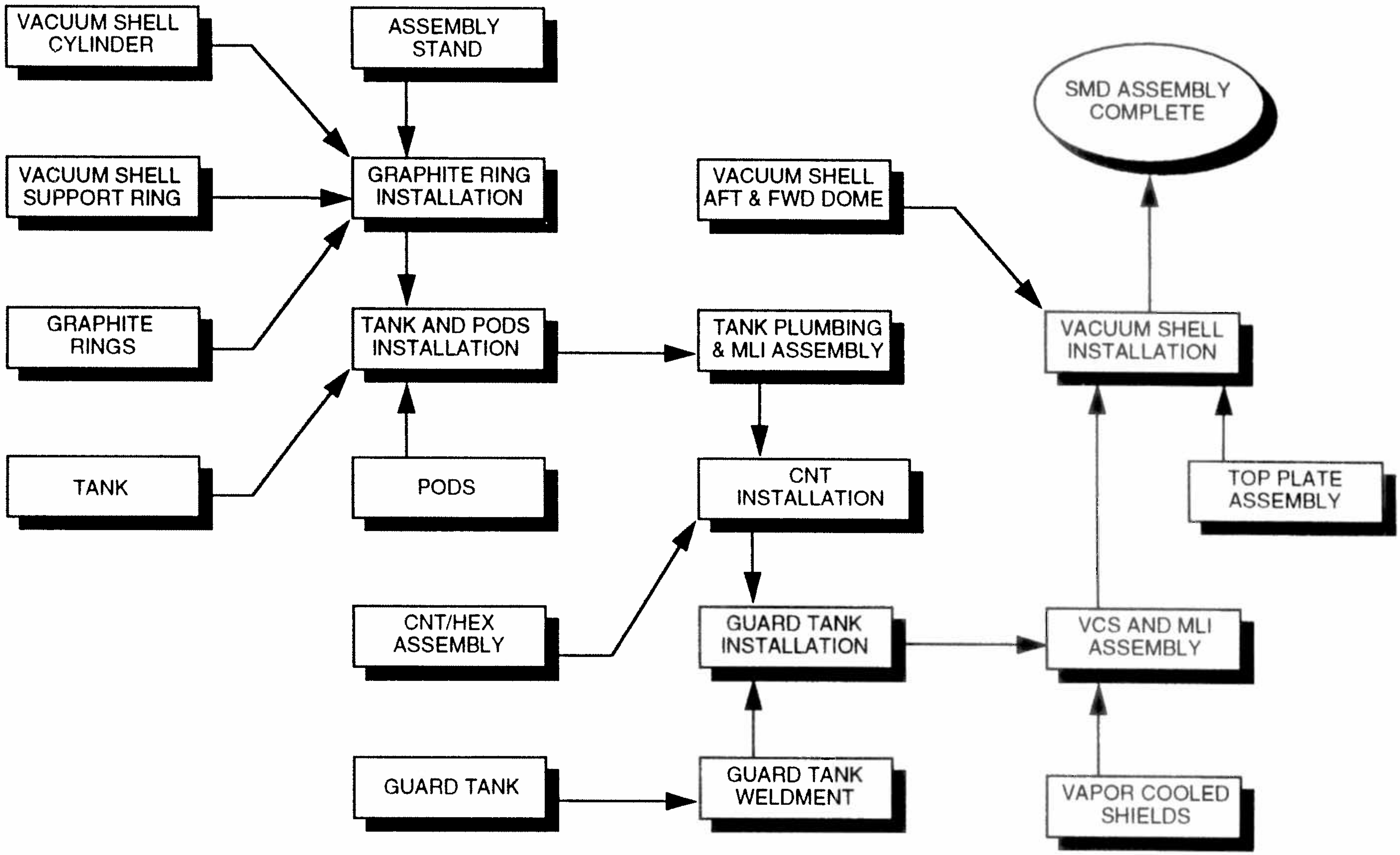
FA - 2

SMD ASSEMBLY FLOW

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94



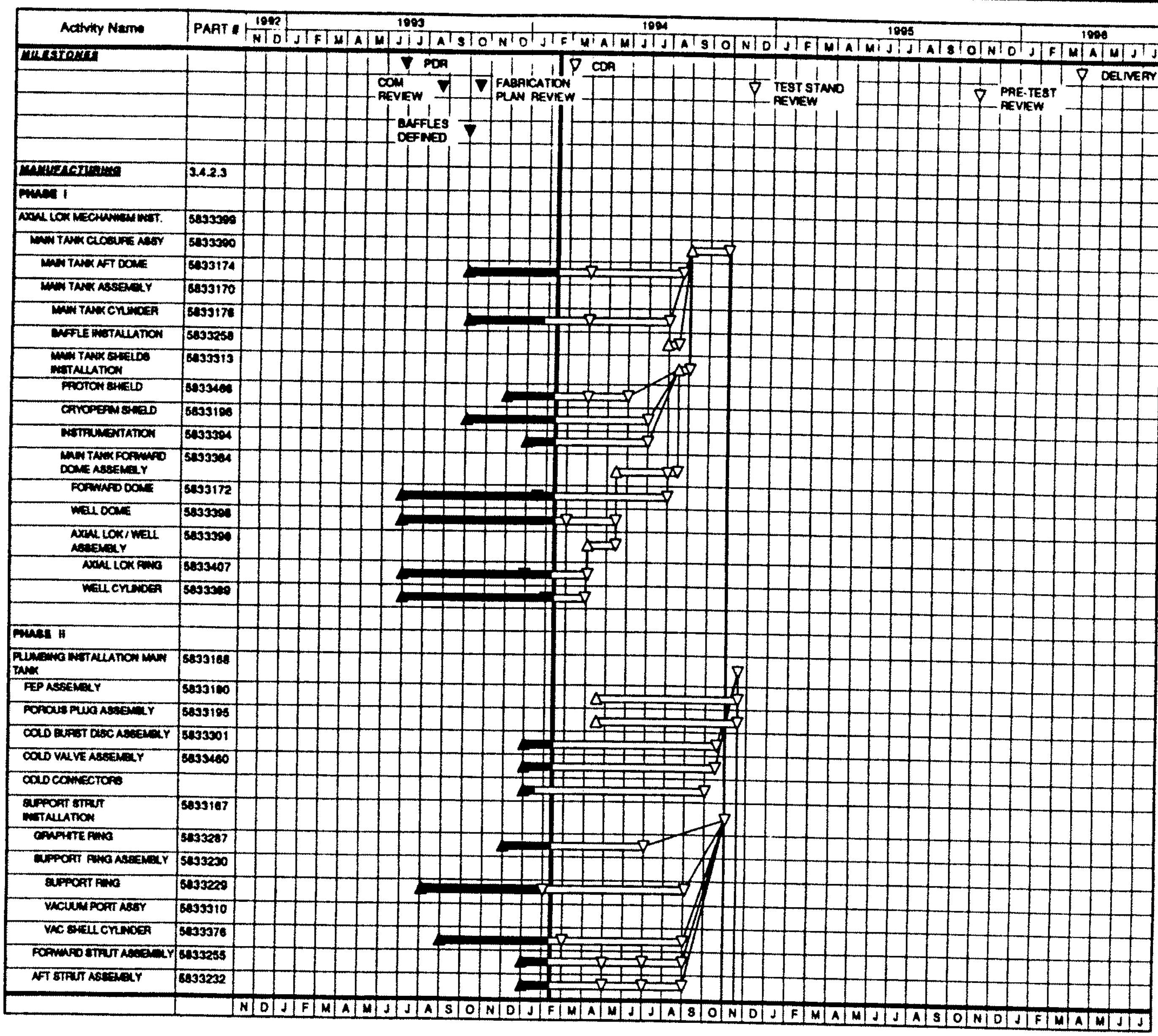
STANFORD

Lockheed

SMD FABRICATION SCHEDULE

PAGE 1 OF 3

LMSC-P088357
2,3 MAR 94



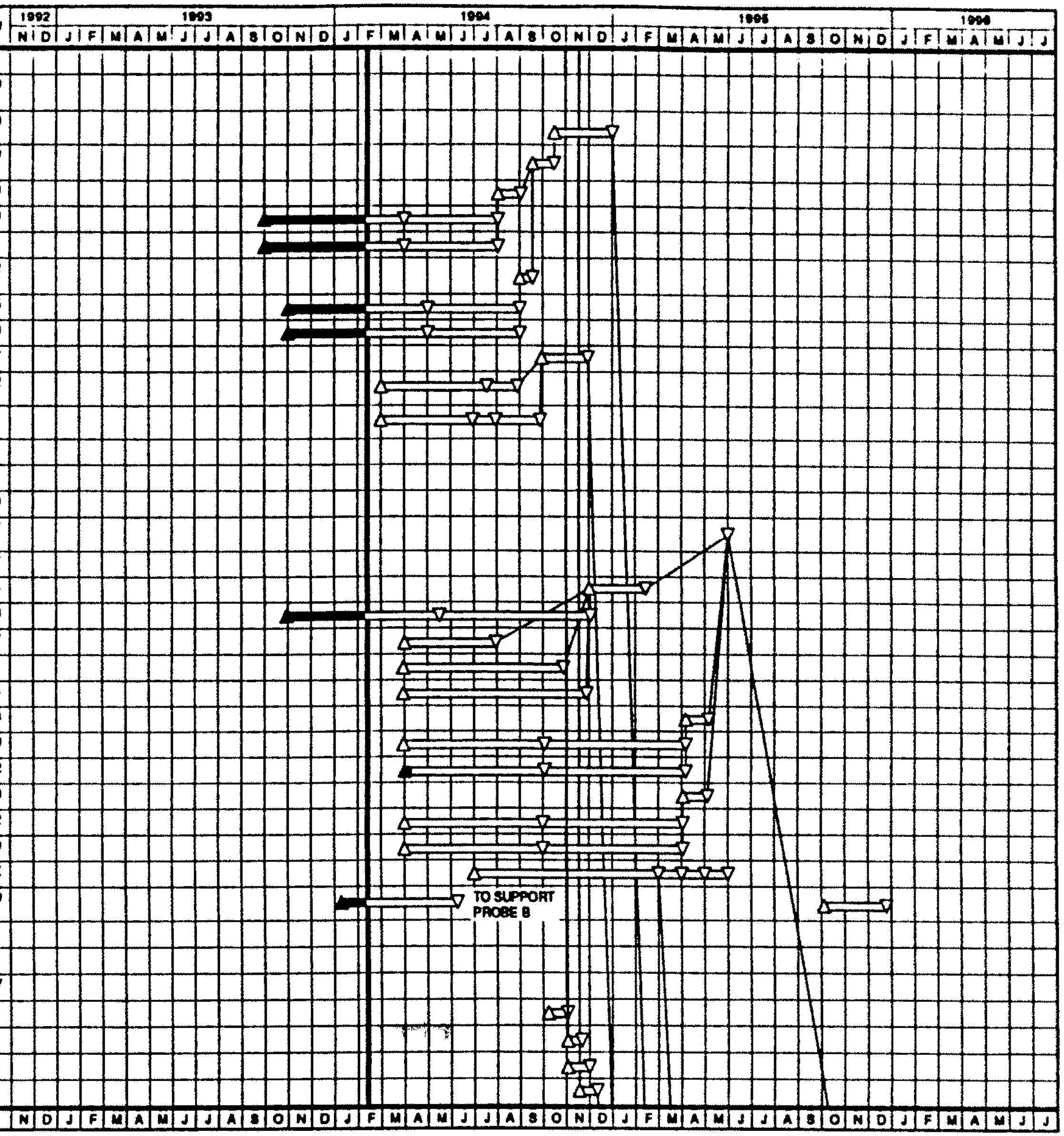
SMD FABRICATION SCHEDULE

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

Activity Name	PART #
PHASE III	
INTERCONNECT PLUMBING, TANKS TO RING	5833480
CNT/GUARD TANK ASSEMBLY SEQUENCE	5833223
GUARD TANK PLUMBING INSTALLATION	5833300
GUARD TANK WELDMENT	5833279
FWD TOROIDAL	5833280
AFT TOROIDAL	5833281
GUARD TANK SUPPORT WELDMENT	5833282
CYLINDER	5833285
CONE SECTION	5833283
CNT/HEX ASSEMBLY	5833197
HEAT EXCHANGER BRAZEMENT	5833202
CNT FLANGE INSTALLATION	5833201
PHASE IV	
DEWAR FINAL ASSEMBLY	5833500
VACUUM SHELL CLOSURE ASSEMBLY	5833377
TOP PLATE ASSEMBLY	5833257
TOP PLATE WELDMENT	5833454
TOP PLATE MACHINED	5833216
BELLOWS	5833217
VENT LINE BAYONET	5833221
CONNECTORS	5833334
FWD CONE WELDMENT	5833378
FWD CONE	5833380
FWD CYLINDER	5833382
AFT DOME WELDMENT	5833369
AFT CONE	5833372
AFT DOME	5833370
VCS #1, #2, #3, #4	58333XX
LEAD BAG RETAINER ASSEMBLY	5833430
ASSEMBLY	
TANK AND SUPPORTS	5833187
INSTALL GRAPHITE RINGS	
INSTALL TANK	
INSTALL PODS	
INSTALL PLUMBING	



FA - 5

SMD FABRICATION SCHEDULE

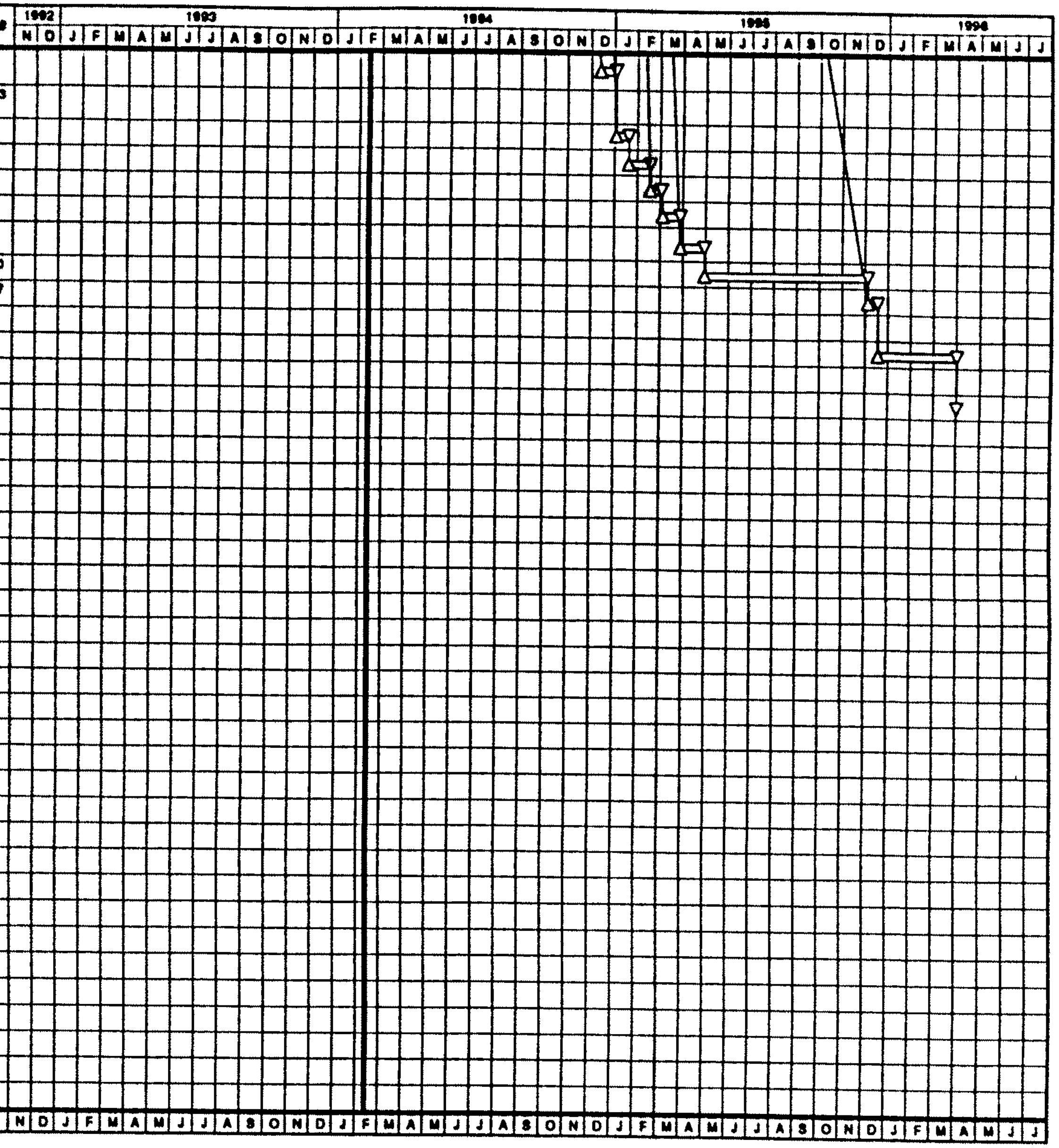
PAGE 3 OF 3

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

Activity Name	PART #
INSTALL INSTRUMENTATION	
INSTALL CNT ASSY/GUARD TANK/TOP PLATE ASSY	5833223
BOND CNT TO MAIN TANK	
INSTALL FLIGHT MLI	
BOND GUARD TANK	
INSTALL PLUMBING	
INSTALL INSTRUMENTATION	
INSTALL VCS AND MLI	5833350
INSTALL VAC SHELL	5833377
SMD SUBSYSTEM TESTS	3.4.2.6
SMD DELIVERY	



SMD FABRICATION STATUS

LMSC-P088357
2,3 MAR 94

PHASE I (MAIN TANK ASSEMBLY)

- AXIAL LOK MACHINING - IN PROGRESS
- WELL CYLINDER MACHINING - IN PROGRESS
- WELL DOME FORGING - COMPLETE
- UPPER DOME FORGING - COMPLETE
- UPPER DOME TOOL TRIAL MACHINING - IN PROGRESS
- CRYOPERM SHIELD PROCUREMENT - IN PROGRESS
- TANK CYLINDER FORGING - IN PROGRESS
- LOWER DOME FORGING - IN PROGRESS

SMD FABRICATION STATUS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

PHASE II (SUPPORT RING, PODS, & PLUMBING INSTALLATION)

- PODS PIECE PART PROCUREMENT - IN PROGRESS
- VACUUM SHELL SUPPORT RING FORGING - COMPLETE
- VACUUM SHELL MID-CYLINDER FORGING - COMPLETE
- GRAPHITE RING PROCUREMENT - IN PROGRESS
- AXIAL LOK PIECE PART PROCUREMENT - COMPLETE
- COLD VALVE PROCUREMENT - IN PROGRESS
- COLD BURST DISC PROCUREMENT - IN PROGRESS

STANFORD

Lockheed

SMD FABRICATION STATUS

LMSC-P088357
2,3 MAR 94

PHASE III (COMPOSITE NECK TUBE & GUARD TANK ASSEMBLIES)

- COMPOSITE NECK TUBE PROCUREMENT - INITIATE IN MARCH
- HEAT EXCHANGER PROCUREMENT - INITIATE IN MARCH
- GUARD TANK FORGING PROCUREMENT - IN PROGRESS

PHASE IV (VAPOR COOLED SHIELDS, MLI, & VACUUM SHELL ASSEMBLIES)

- VAPOR COOLED SHIELDS PROCUREMENT - INITIATE IN APRIL
- VACUUM SHELL NECK CYLINDER FORGING - IN PROGRESS
- FIXED ASSET PROCUREMENT OF CUTTING TABLE - INITIATE IN MARCH

CHEMTRONICS

PROCESS DEVELOPMENT

- AXIAL LOK TOOL FABRICATION COMPLETE
- FORWARD DOME TOOL TRIAL - IN PROGRESS
- WELD SCHEDULE DEVELOPMENT - IN PROGRESS

MAIN TANK FABRICATION

- AXIAL LOK FABRICATION - IN PROGRESS
- WELL CYLINDER FABRICATION - IN PROGRESS
- FORWARD DOME BASKET FIXTURE AND VACUUM CHUCK FIXTURE - COMPLETE
- CENTER CYLINDER TOOL FABRICATION - IN PROGRESS

VACUUM SHELL FABRICATION

- SUPPORT RING FABRICATION - IN PROGRESS

WELD REQUIREMENTS

<u>WELL, AXIAL LOK, PROTON SHIELD, & GUARD TANK SUPPORT (6063 AL)</u>

- LOCKHEED LAC SPECIFICATION 3853-020101
  - PROCESS QUALIFICATION REQUIRED
  - X-RAY, VISUAL, PENETRANT, AND HELIUM LEAK INSPECTION REQUIRED
  - WELD FILLER MATERIAL CONTROL REQUIRED

<u>MAIN TANK, GUARD TANK, & VACUUM SHELL (2219 AL)</u>

- LOCKHEED LAC SPECIFICATION 3861-010000
  - PROCESS QUALIFICATION REQUIRED
  - X-RAY, VISUAL, PENETRANT, AND HELIUM LEAK INSPECTION REQUIRED

WELD PROCESS QUALIFICATION

DEVELOP WELD PARAMETERS

- PREPARE WELD COUPONS
  - FLAT PLATE AT THICKNESS OF JOINT
  - FLAT PLATE WITH PROPOSED JOINT GEOMETRY
- WELD "BEAD ON PLATE" AND MACHINED JOINTS TO DEVELOP PARAMETER WINDOWS
  - CLEANING PROCEDURE
  - MACHINE PARAMETERS
  - FIT-UP REQUIREMENTS
  - BEAD SHAPE

WELD PROCESS QUALIFICATION

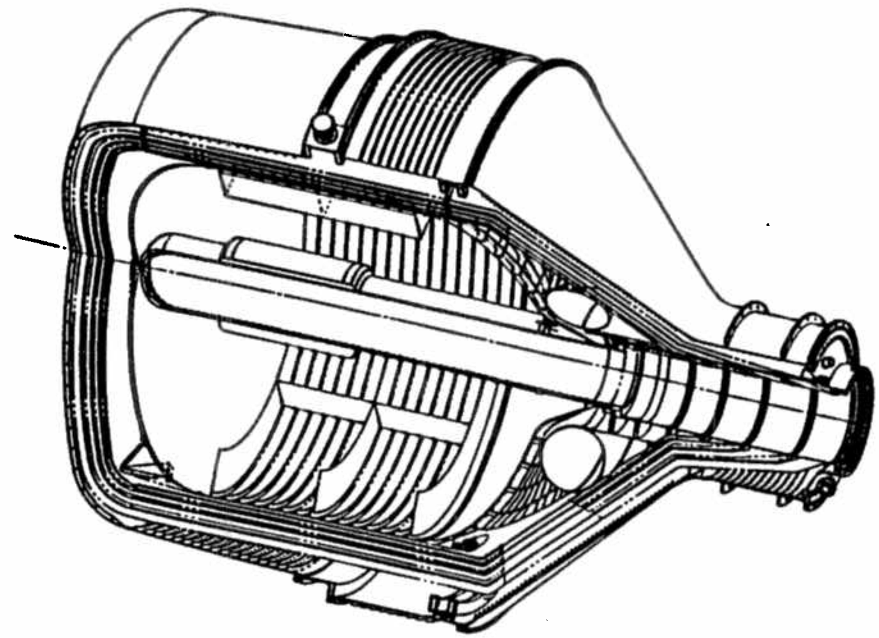
WELD PARAMETERS QUALIFICATION

- MACHINE ADDITIONAL FLAT PLATE TO CONFIRMED JOINT GEOMETRY
- GTAW OR EB WELD
- GRIND WELD FLUSH
- VISUAL INSPECT, X-RAY INSPECT, HELIUM LEAK CHECK, PENETRANT INSPECT
- SECTION AND IDENTIFY
- METALLURGICAL EXAM
- MECHANICAL TESTING
- MACHINE FULL SIZE JOINTS FROM EXTRA FORGING MATERIAL
  - REPEAT WELDING AND THE WELD INSPECTION/TESTING ABOVE

FA - 13

HELIUM TANK COMPONENTS

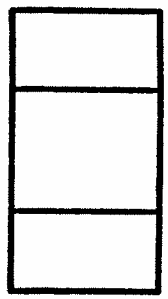
- MAIN TANK AND WELL
- CRYOPERM
- PROTON SHIELDING
- INSTRUMENTATION AND HEATERS
- INTERNAL PLUMBING
- SLOSH BAFFLES



TANK FABRICATION SEQUENCE

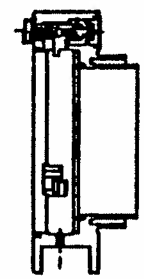
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

5833408-101
AXIAL LOK RING
FORGING (6063-T452)

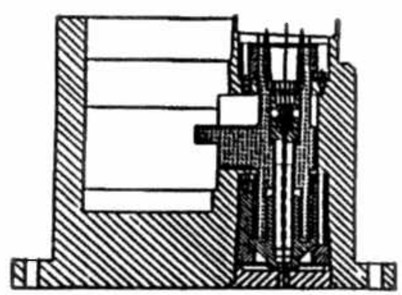


DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, ULTRASONIC
INSPECTED, MAGNETIC
INSPECTED

5833407-101
AXIAL LOK RING
MACHINED



AXIAL LOK RING
DEVELOPMENT TEST
FIXTURE

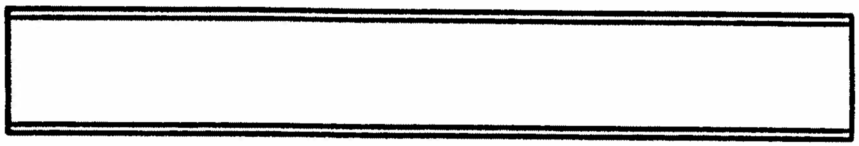


MACHINING TRIAL FOR
COMPLEX BORE AREA

TANK FABRICATION SEQUENCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

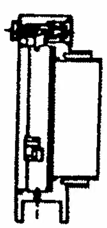
5833381-101
WELL CYLINDER
FORGING (6063-T452)



DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, ULTRASONIC
INSPECTED, MAGNETIC
INSPECTED

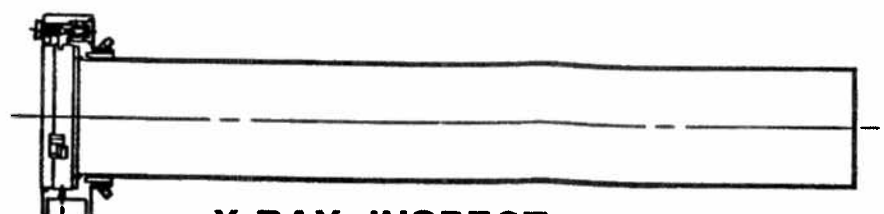
5833389-101
WELL CYLINDER
MACHINED

5833407-101
AXIAL LOK RING
MACHINED



REMOVE FROM STORES

5833396-101
AXIAL LOK/WELL
WELDMENT

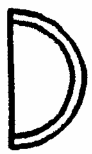


X-RAY INSPECT,
HELIUM LEAK CHECK,
PENETRANT INSPECT

TANK FABRICATION SEQUENCE

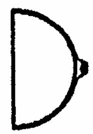
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

5833464-101
WELL DOME
FORGING (6063-T652)

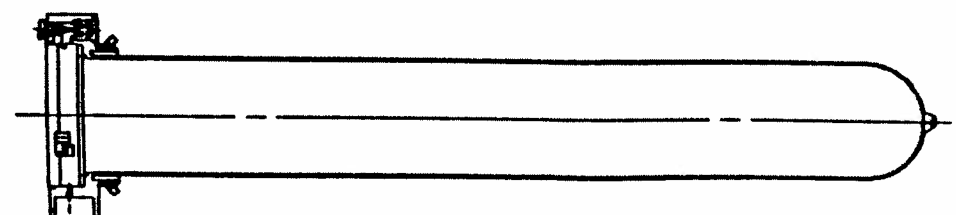


DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, ULTRASONIC
INSPECTED, MAGNETIC
INSPECTED

5833398-101
WELL DOME
MACHINED

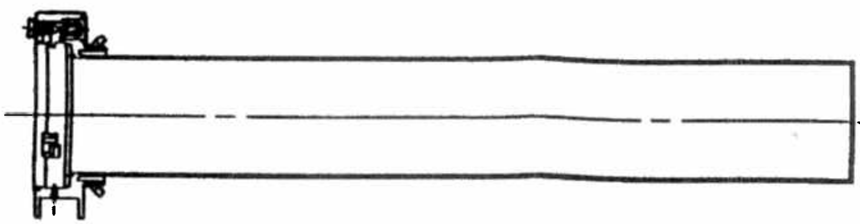


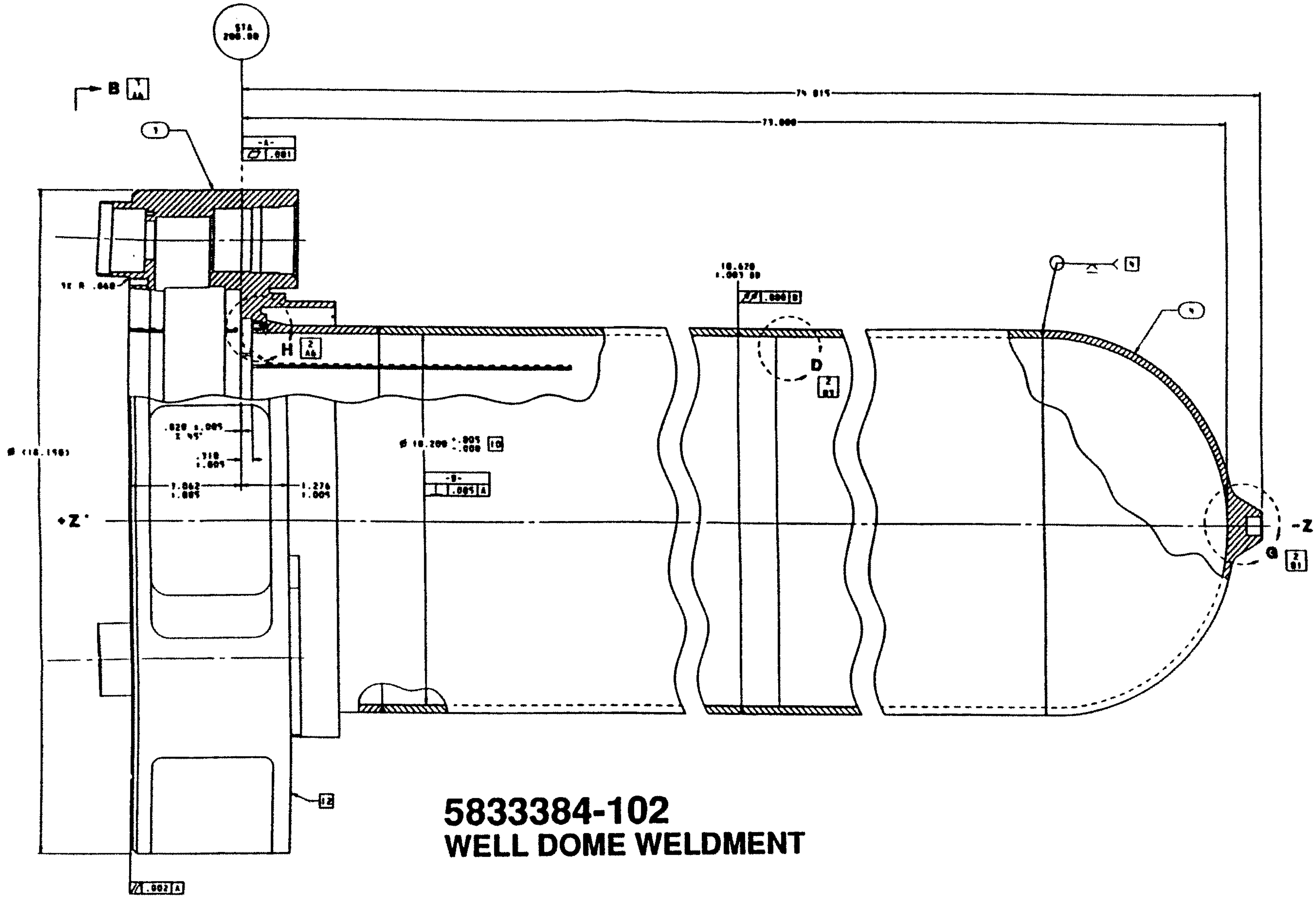
5833384-102
WELL DOME WELDMENT



X-RAY INSPECT,
HELIUM LEAK CHECK,
PENETRANT INSPECT

5833396-101
AXIAL LOK/WELL
WELDMENT

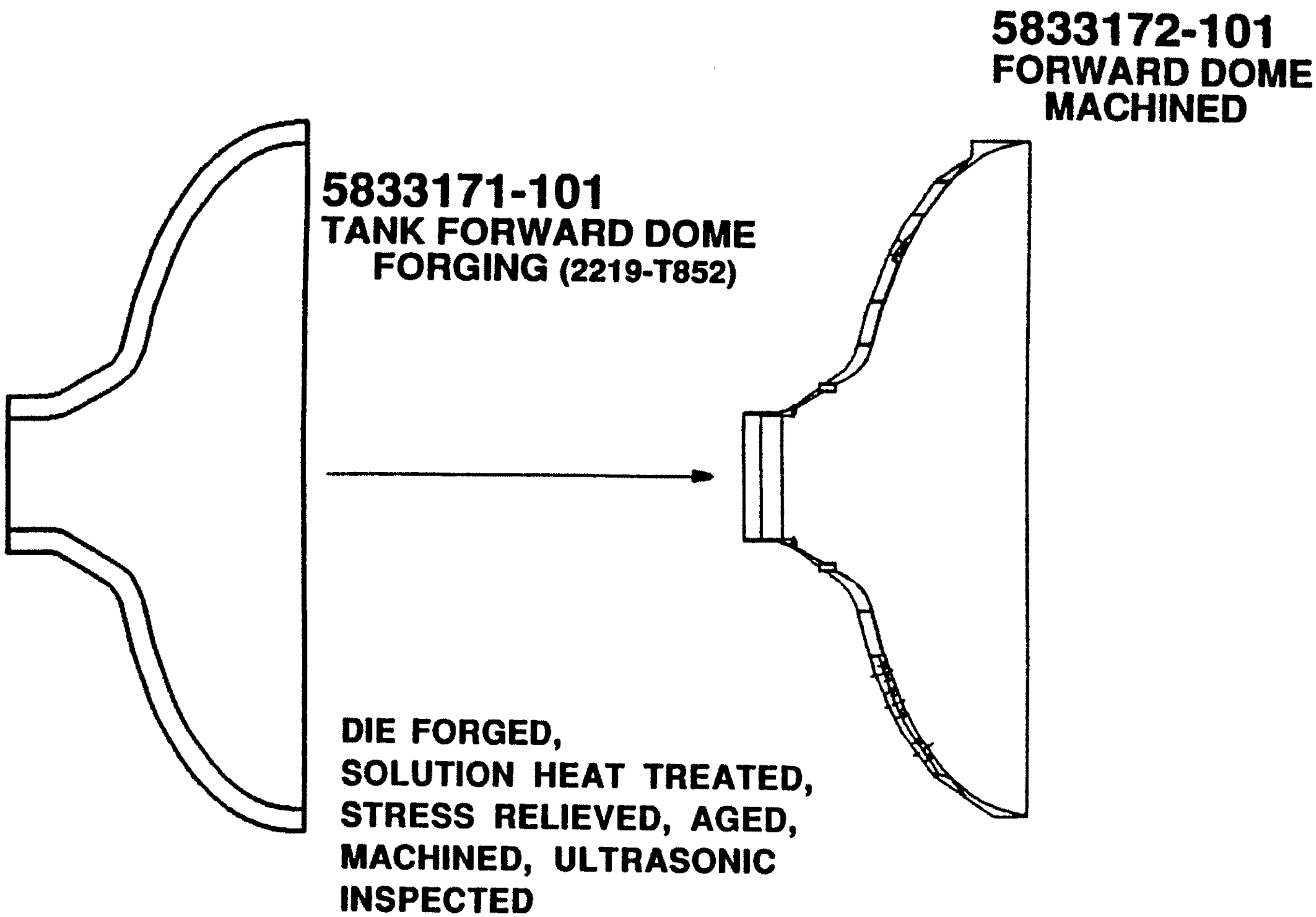




5833384-102
WELL DOME WELDMENT

TANK FABRICATION SEQUENCE

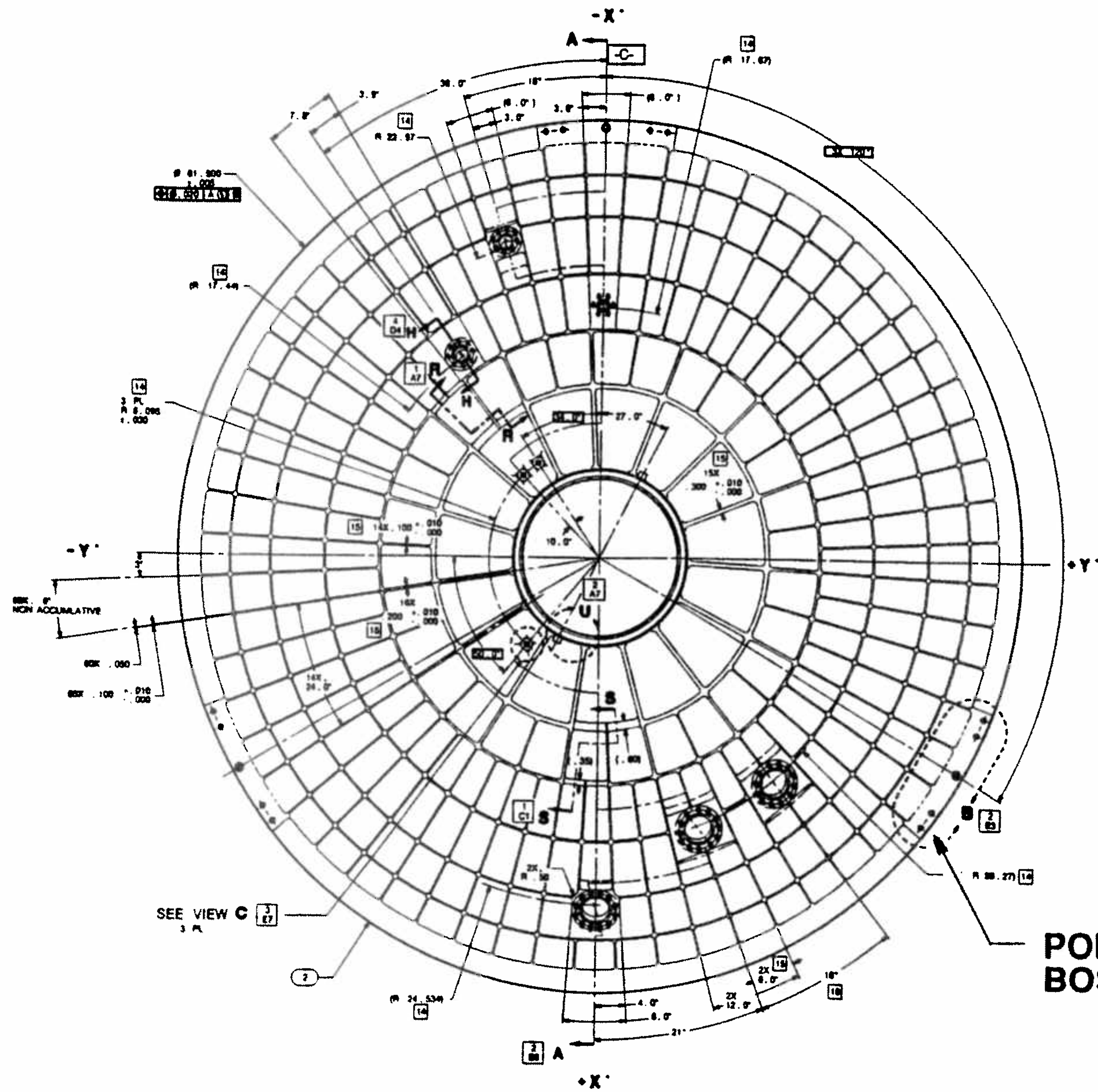
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



TANK FABRICATION SEQUENCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

5833172-101
FORWARD DOME MACHINED

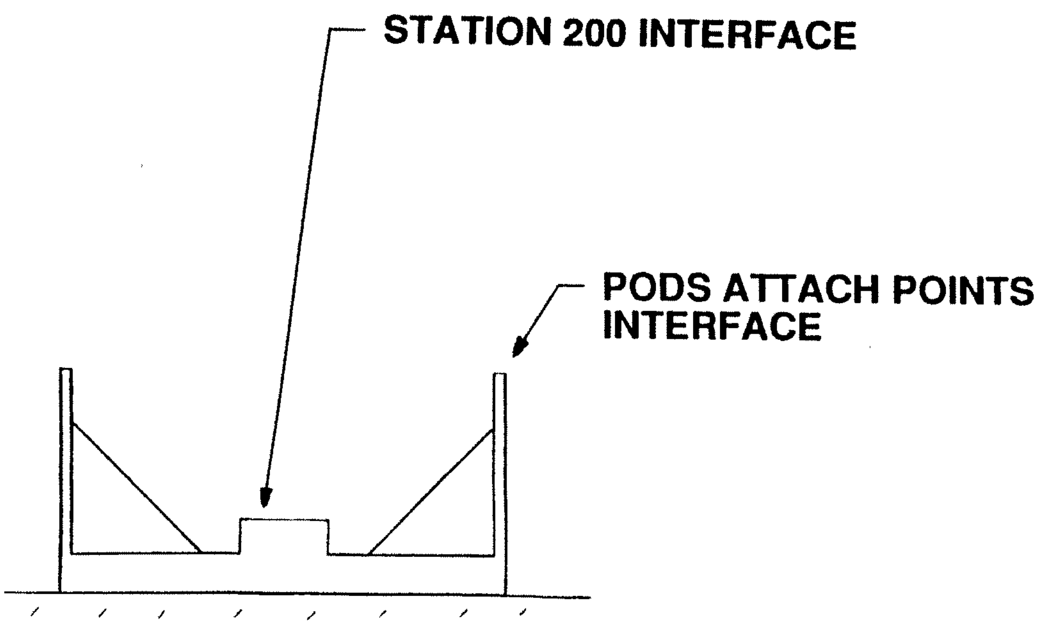


PODS ATTACH POINTS PROVIDE BOSSES FOR THREE POINT LIFT

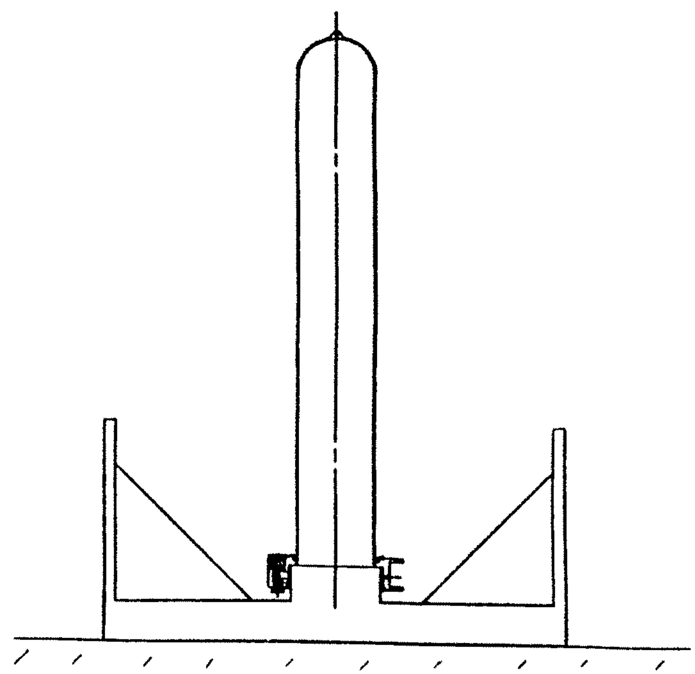
TANK FABRICATION SEQUENCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

UPPER DOME BONDING/ALIGNMENT FIXTURE



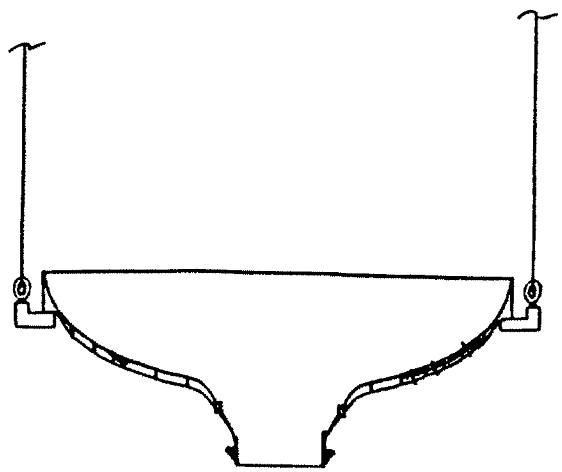
INSTALL WELL DOME WELDMENT (5833384-102)



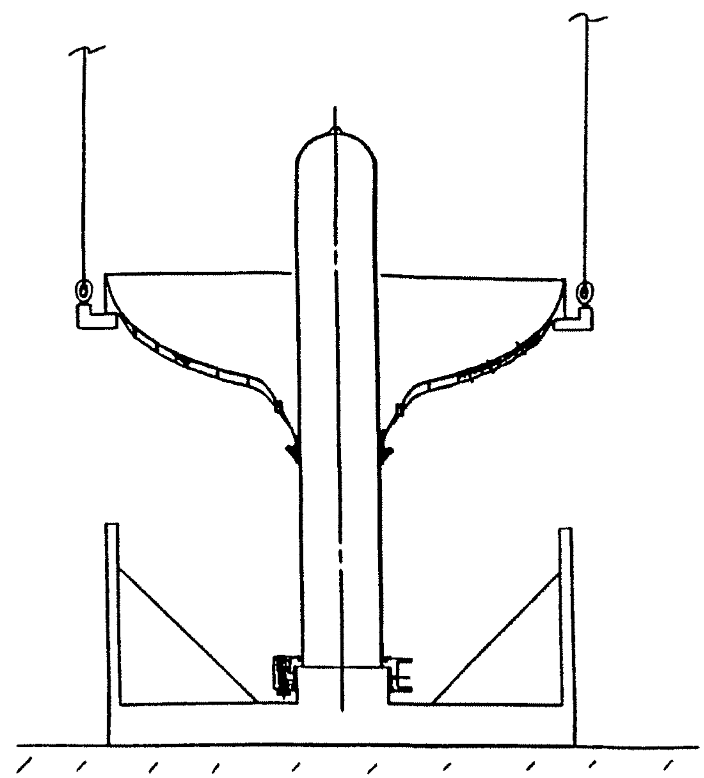
TANK FABRICATION SEQUENCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

ATTACH UPPER DOME
TO LIFTING FIXTURE



LOWER UPPER DOME
OVER WELL TO BOND



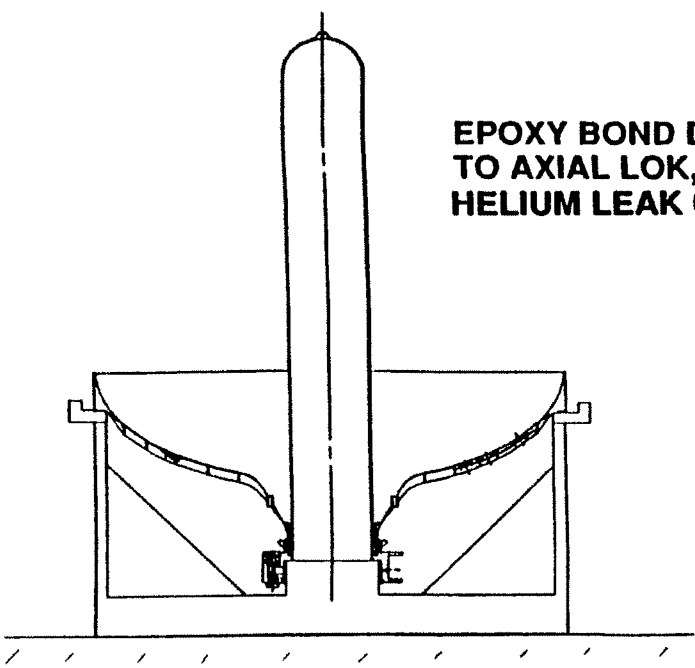
TANK FABRICATION SEQUENCE

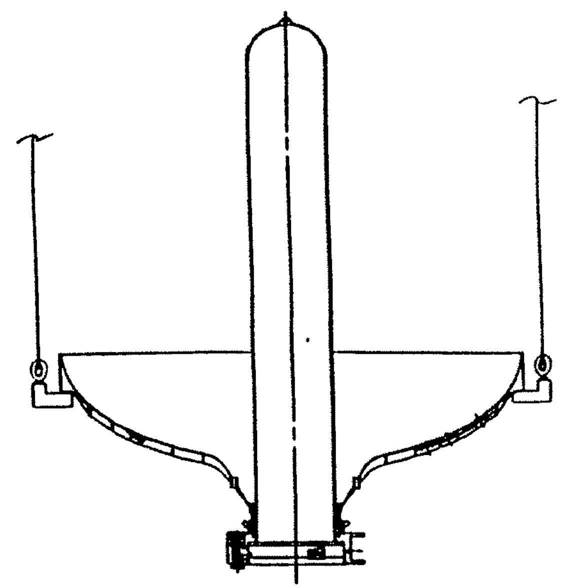
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

5833384-101
FORWARD DOME ASSEMBLY

FORWARD DOME ASSEMBLY CAN BE REMOVED FROM FIXTURE FOR PRECISION CLEANING PRIOR TO NEXT ASSEMBLY

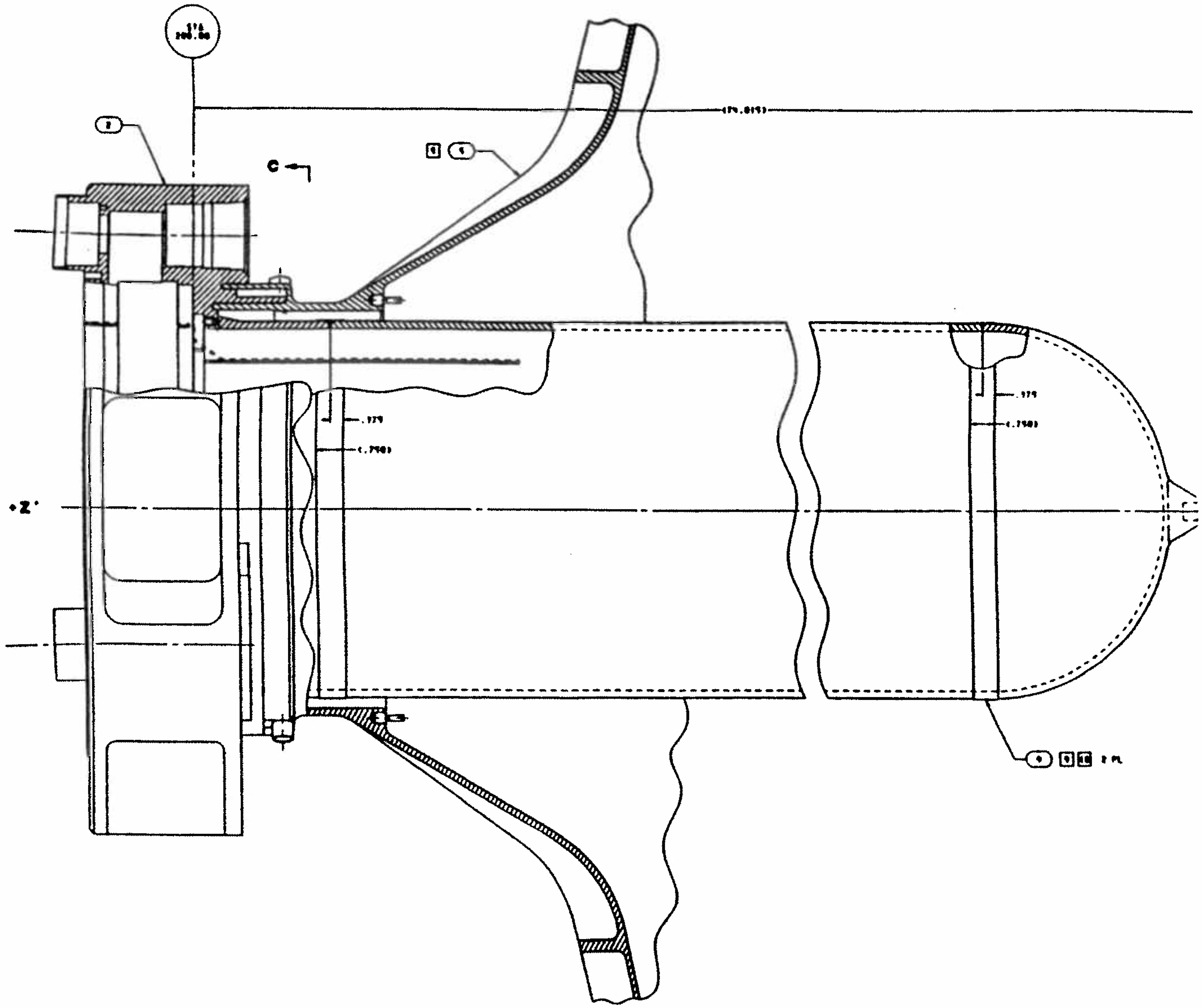
EPOXY BOND DOME TO AXIAL LOK, THEN HELIUM LEAK CHECK





TANK FABRICATION SEQUENCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



5833384-101
FORWARD DOME ASSEMBLY

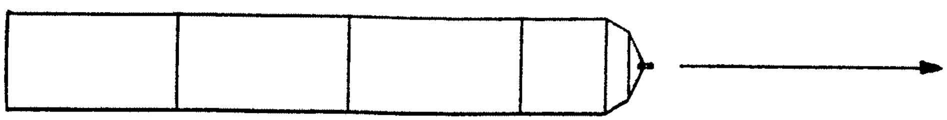
TANK FABRICATION SEQUENCE

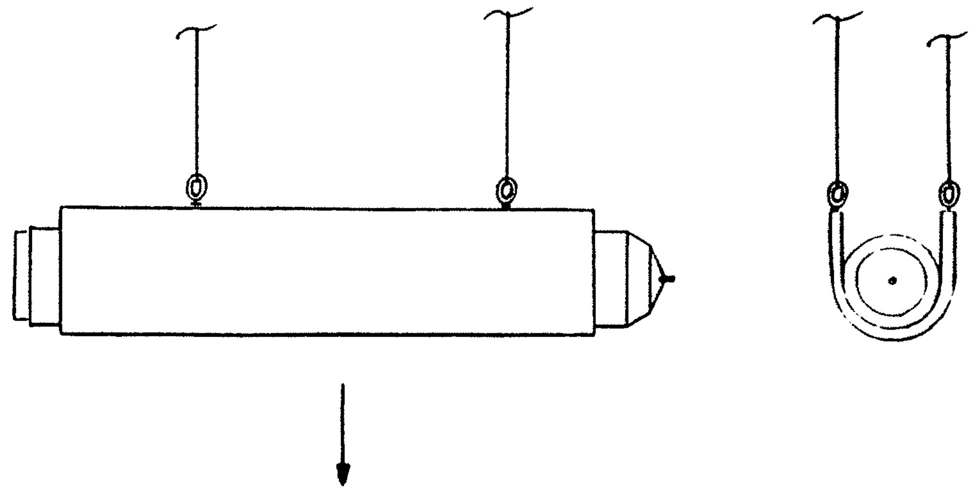
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

5833196-101
MAGNETIC SHIELD ASSEMBLY

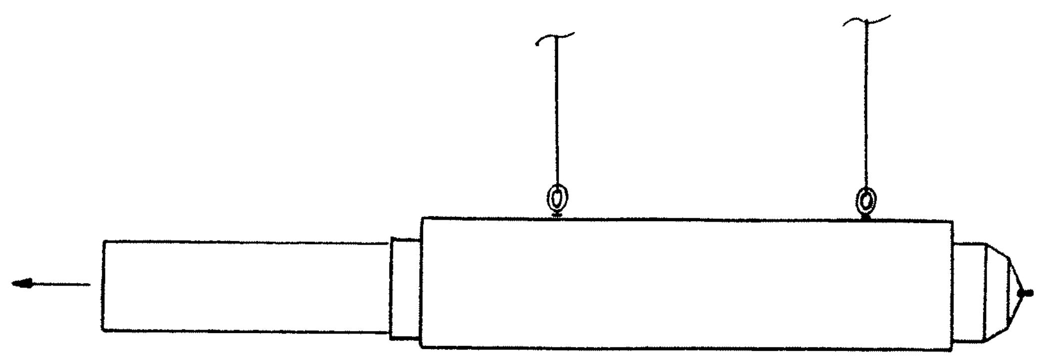
INSTALL MAGNETIC SHIELD IN SUPPORT CRADLE

WELD PER DRAWING,
STRAIN RELIEVE,
MAGNETIC TEST





REMOVE INNER SUPPORT
PLUG FROM MAGNETIC SHIELD



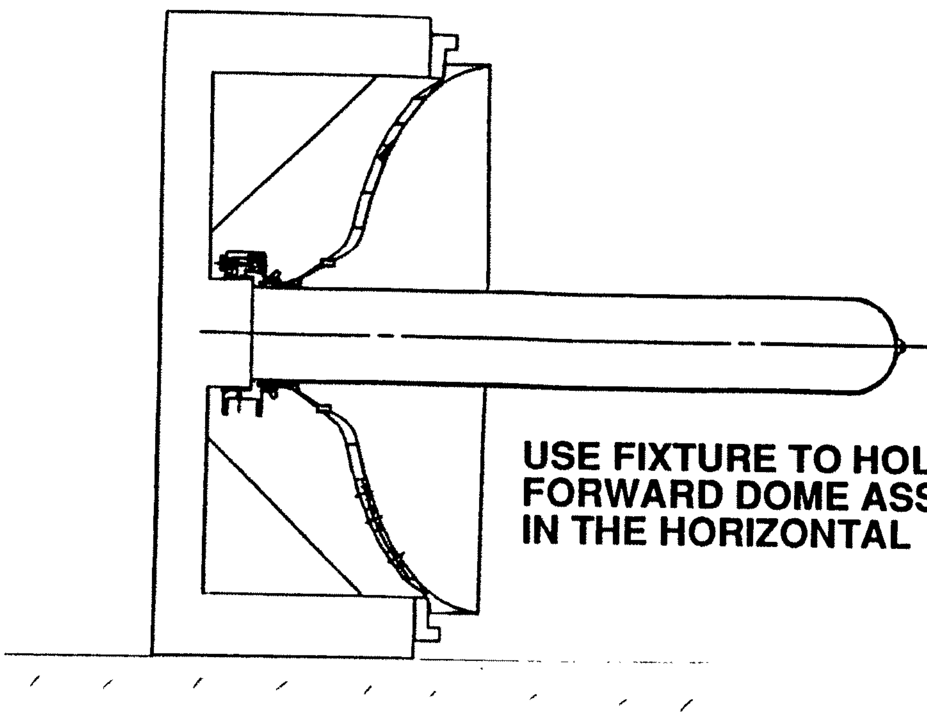
TANK FABRICATION SEQUENCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

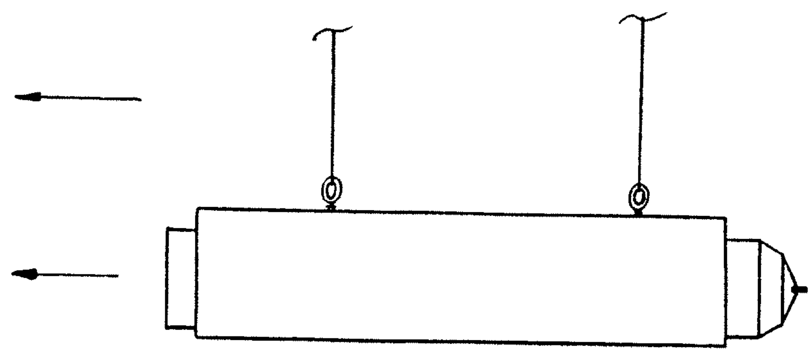
5833313-101
MAIN TANK SHIELDS INSTALLATION

ALL MAIN TANK SHIELDS AND PLUMBING ASSEMBLY OPERATIONS SHALL BE PERFORMED IN A CLASS 100 CLEAN ROOM ENVIRONMENT

ALL 5833313-101 COMPONENTS SHALL BE PRECISIONED CLEANED PRIOR TO ASSEMBLY

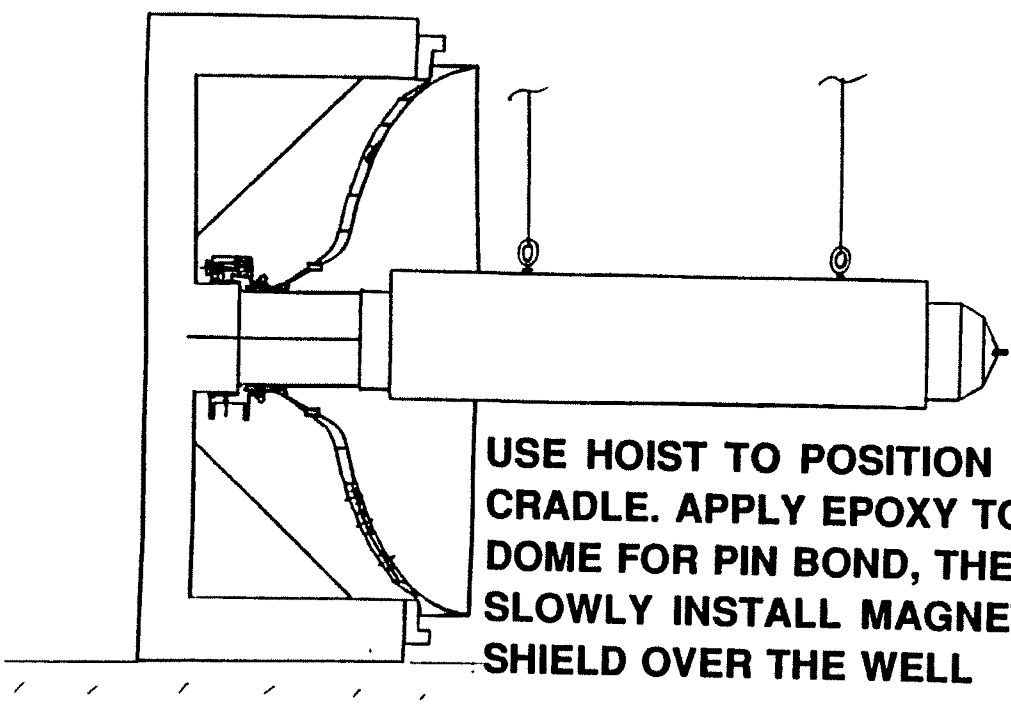


USE FIXTURE TO HOLD FORWARD DOME ASSEMBLY IN THE HORIZONTAL

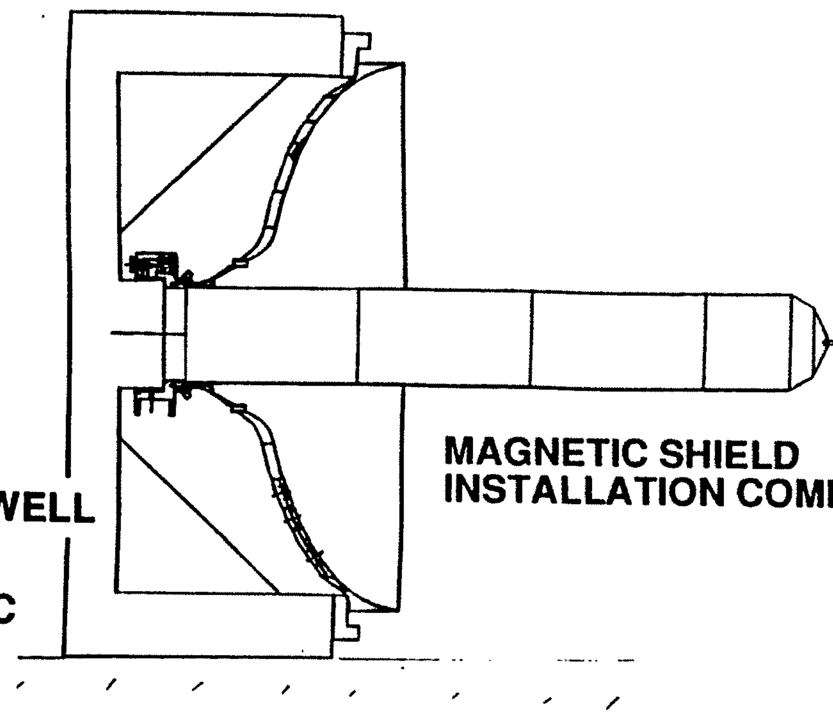


USE HOIST TO POSITION CRADLE

5833313-101
MAIN TANK SHIELDS INSTALLATION



USE HOIST TO POSITION CRADLE. APPLY EPOXY TO WELL DOME FOR PIN BOND, THEN SLOWLY INSTALL MAGNETIC SHIELD OVER THE WELL



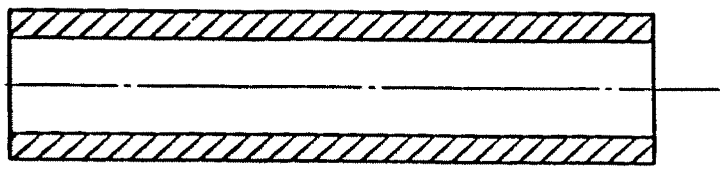
MAGNETIC SHIELD INSTALLATION COMPLETE

TANK FABRICATION SEQUENCE

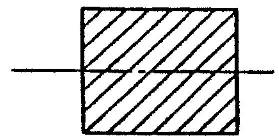
STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

5833465-101
PROTON SHIELD
FORGING (6063-T452)

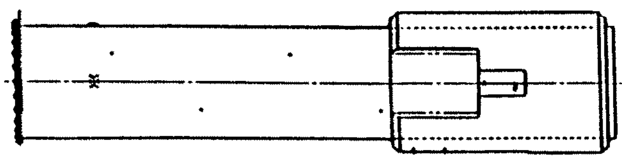


5833465-102
PROTON SHIELD
FORGING

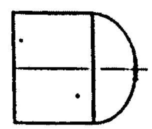


DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, UTRASONIC
INSPECTED, MAGNETIC
INSPECTED

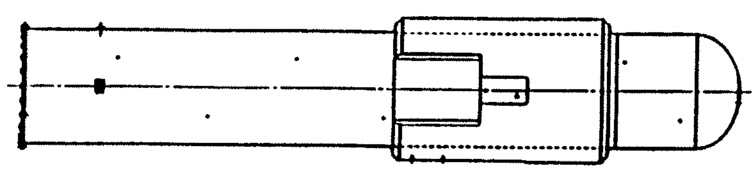
5833466-102
PROTON SHIELD
CYLINDER



5833466-104
PROTON SHIELD
DOME



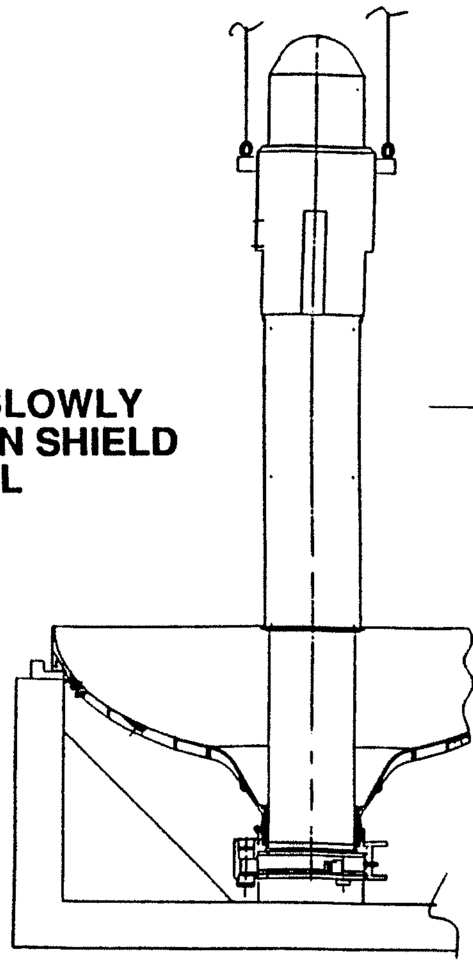
5833466-101
PROTON SHIELD
ASSEMBLY



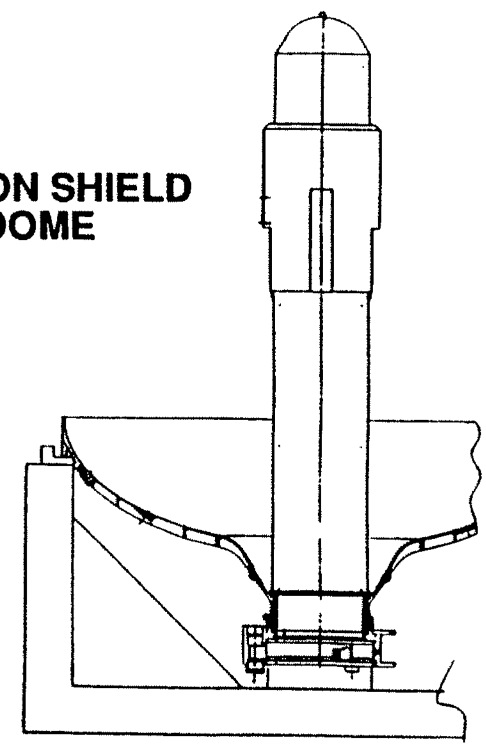
X-RAY INSPECT,
PENETRANT INSPECT

5833313-101
MAIN TANK SHIELDS INSTALLATION

USING HOIST, SLOWLY LOWER PROTON SHIELD OVER THE WELL



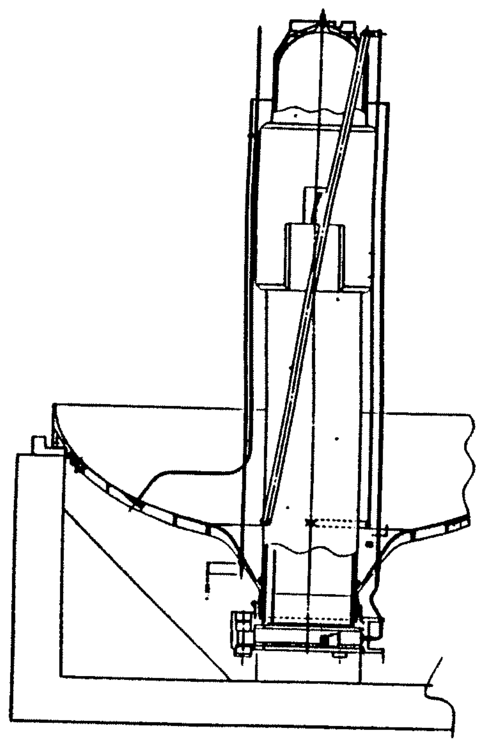
SECURE PROTON SHIELD TO FORWARD DOME



TANK FABRICATION SEQUENCE

INSTALL INTERNAL PLUMBING, LEAK CHECK AND THERMAL CYCLE BOND JOINTS

INSTALL LIQUID LEVEL SENSOR AND HEATERS



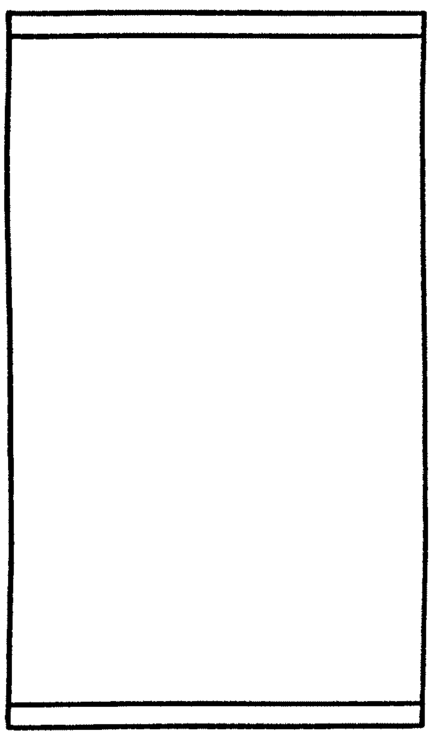
5833313-101
MAIN TANK SHIELDS INSTALLATION COMPLETE

TANK FABRICATION SEQUENCE

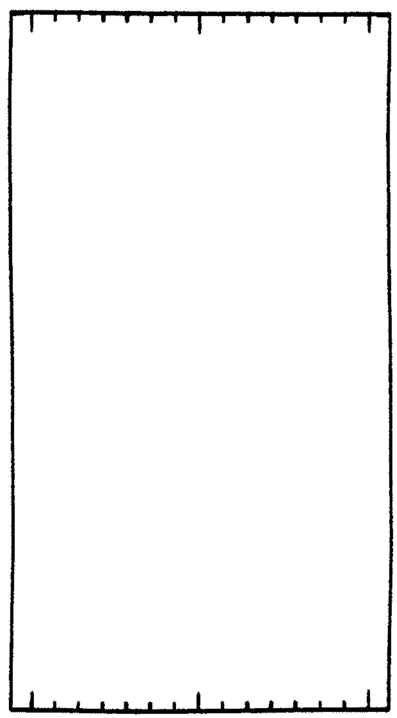
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

5833175-101
TANK CYLINDER FORGING (2219-T851)

DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, ULTRASONIC
INSPECTED



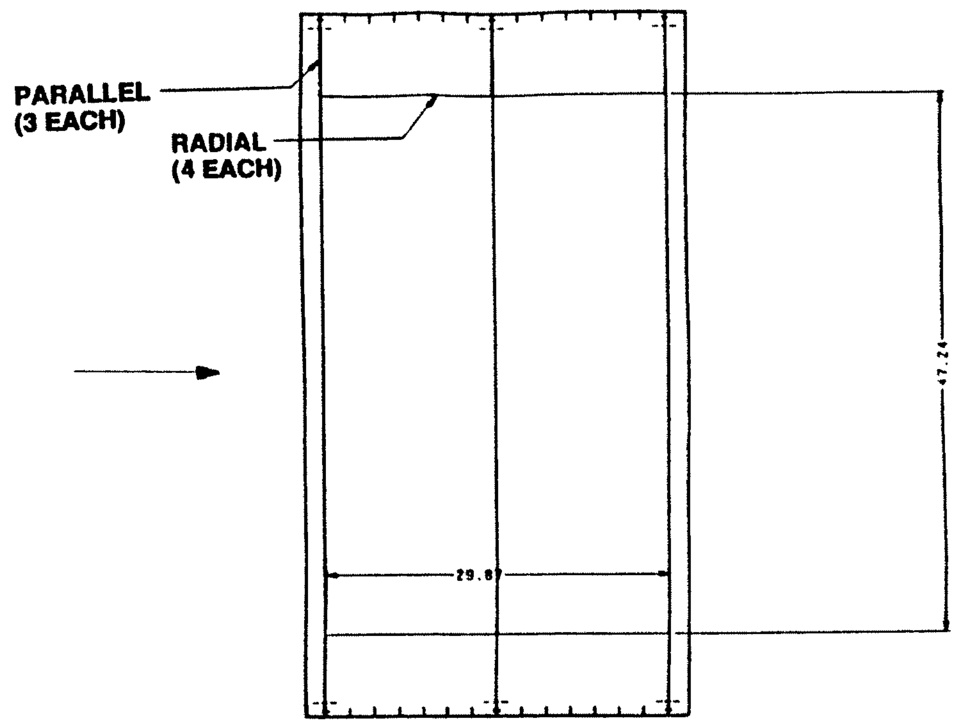
5833176-101
TANK CYLINDER MACHINED



5833170-101
MAIN TANK ASSEMBLY

PRECISION CLEAN

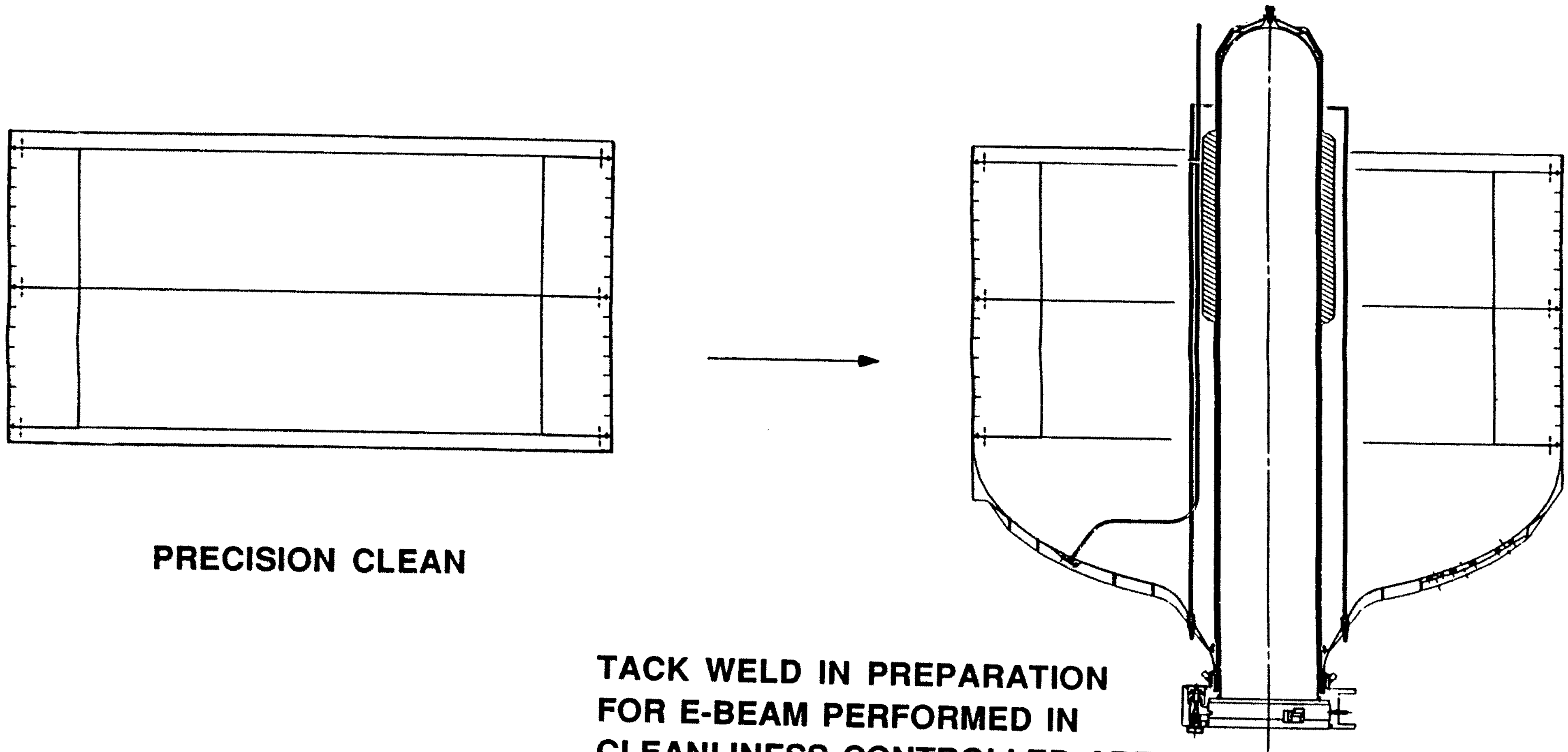
SPOT WELD SLOSH
BAFFLES INTO CYLINDER



TANK FABRICATION SEQUENCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

5833170-101
MAIN TANK
ASSEMBLY

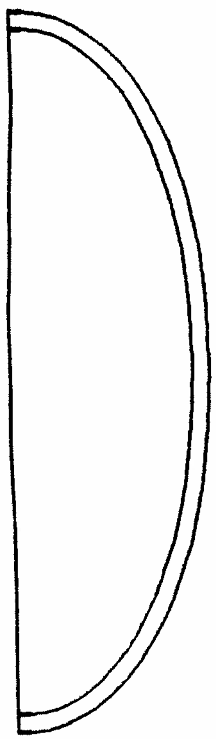


PRECISION CLEAN

TACK WELD IN PREPARATION
FOR E-BEAM PERFORMED IN
CLEANLINESS CONTROLLED AREA

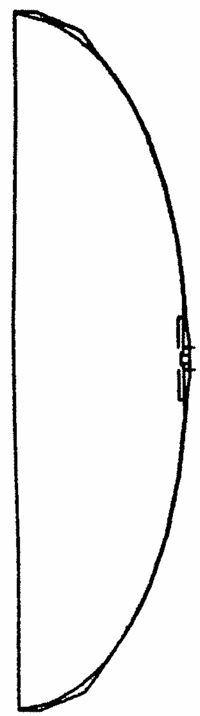
TANK FABRICATION SEQUENCE

5833173-101
TANK AFT DOME FORGING (2219-T852)



DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, ULTRASONIC
INSPECTED

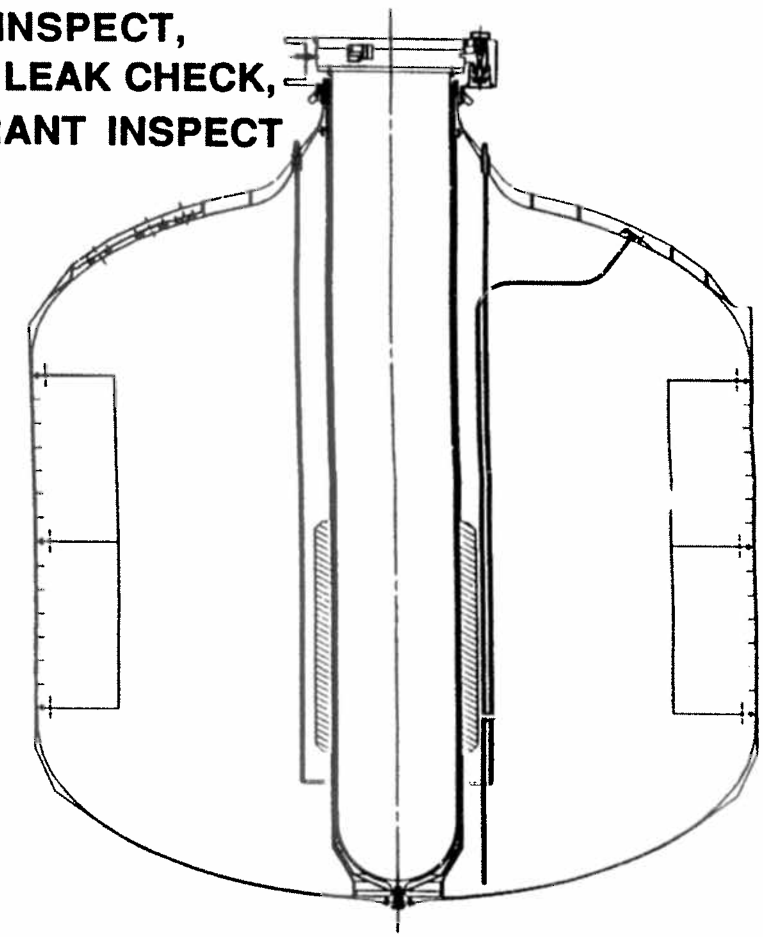
5833174-101
TANK AFT DOME MACHINED



PRECISION CLEAN
THEN TACK WELD
DOME TO CYLINDER

5833390-101
MAIN TANK CLOSURE ASSEMBLY

E-BEAM WELD
X-RAY INSPECT,
HELIUM LEAK CHECK,
PENETRANT INSPECT



COMPONENT TEST/INSPECTION REQUIRED PRIOR TO DEWAR ASSEMBLY

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- MAIN TANK
  - TESTS COMPLETED
    - » TANK PROOF PRESSURE TEST
    - » HELIUM LEAK TEST
- PODS
  - TESTS COMPLETED
    - » LOADS TEST
- GRAPHITE RING
  - COUPON TESTS COMPLETED
    - » MATERIAL TEST
    - » LOADS TEST

COMPONENT TEST/INSPECTION REQUIRED PRIOR TO DEWAR ASSEMBLY

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- GUARD TANK
  - COMPONENTS INSTALLED
    - » LIQUID LEVEL SENSOR
  - TESTS COMPLETED
    - » TANK PROOF PRESSURE
    - » HELIUM LEAK TEST

- COMPOSITE NECK TUBE ASSEMBLY
  - COMPONENTS INSTALLED
    - » COMPOSITE NECK TUBE
    - » TSR, HEX, AND END FLANGES
  - TESTS COMPLETED
    - » PROOF PRESURE TEST (INTERNAL & EXTERNAL)
    - » THERMAL CYCLE/HELIUM LEAK TEST
    - » BUCKLING TEST

COMPONENT TEST/INSPECTION REQUIRED PRIOR TO DEWAR ASSEMBLY

- COLD VALVES AND COLD BURST DISCS
  - ACCEPTANCE TEST PERFORMED ON EACH COMPONENT
    - » PERFORMANCE AND ENVIRONMENT TESTS
- VAPOR COOLED SHIELDS
  - PIECE PARTS INSPECTED FOR DIMENSIONAL VERIFICATION
- CRYOPERM SHIELD ASSEMBLY
  - MAGNETIC TESTING
- VACUUM SHELL
  - TESTS COMPLETE
    - » HELIUM LEAK TESTS
    - » COMPONENT PROOF PRESSURE TESTS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

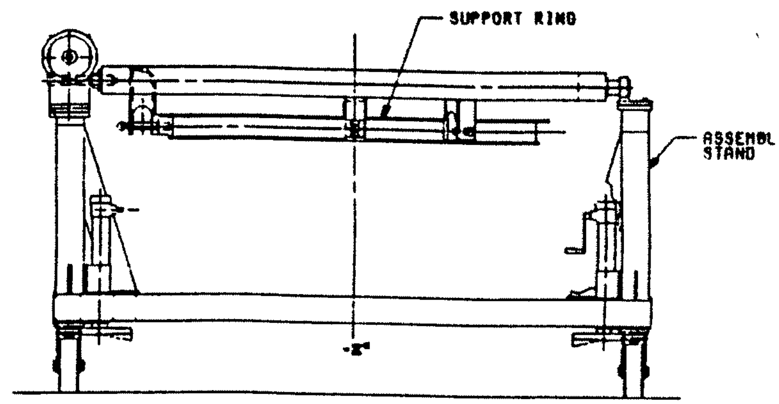
DEWAR ASSEMBLY SEQUENCE

STEP 1

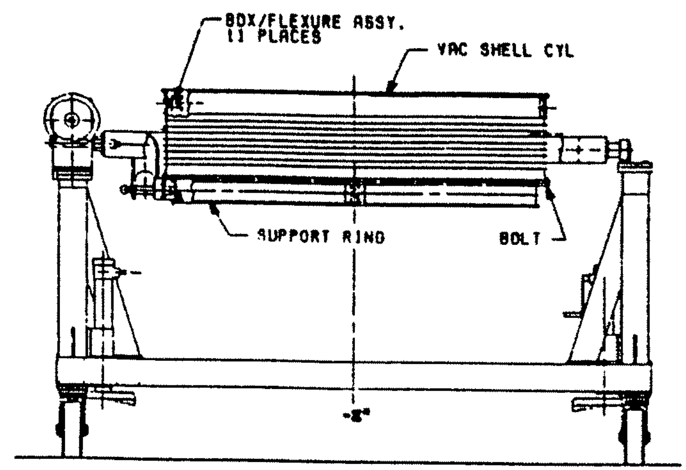
- INSTALL VACUUM SHELL SUPPORT RING IN ASSEMBLY STAND

STEP 2

- BOLT VACUUM SHELL TO SUPPORT RING (WITH ALIGNMENT PINS)
- SLIP LOWER GRAPHITE RING THRU VACUUM SHELL CYLINDER; TEMPORARILY TAPE GRAPHITE RING TO SUPPORT RING
- BOLT BOX/FLEXURE ASSY'S TO ID OF VACUUM SHELL CYLINDER



STEP 1



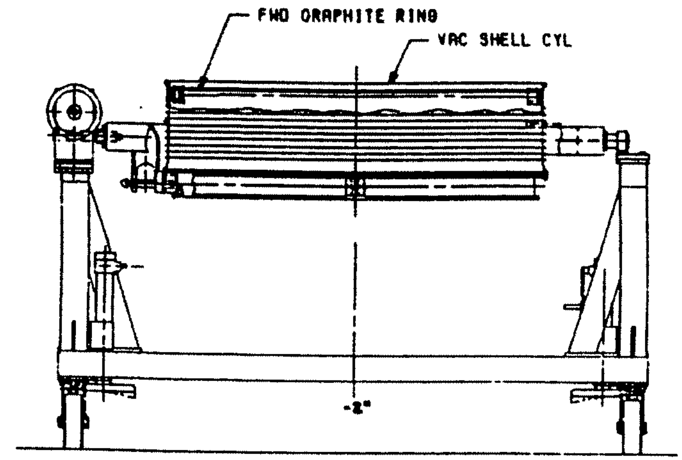
STEP 2

DEWAR ASSEMBLY SEQUENCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

STEP 3

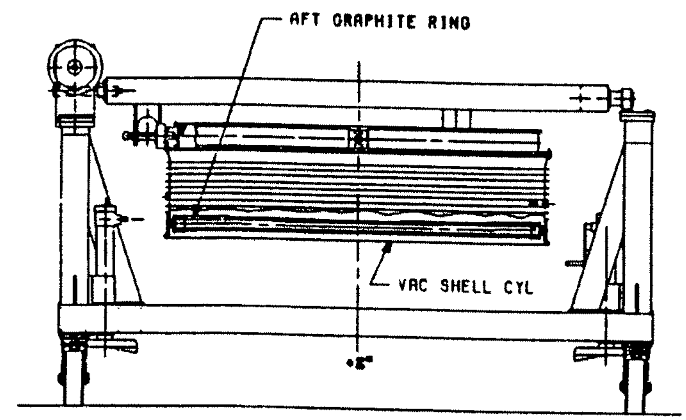
- FIT CHECK FWD GRAPHITE RING
- SAND, BOND, AND BOLT IN GRAPHITE RING TO ELEVEN BOX STRUCTURES



STEP 3

STEP 4

- ROTATE VACUUM SHELL CYLINDER UPSIDE DOWN USING FIXTURE
- REPEAT STEP 3 FOR AFT GRAPHITE RING



STEP 4

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

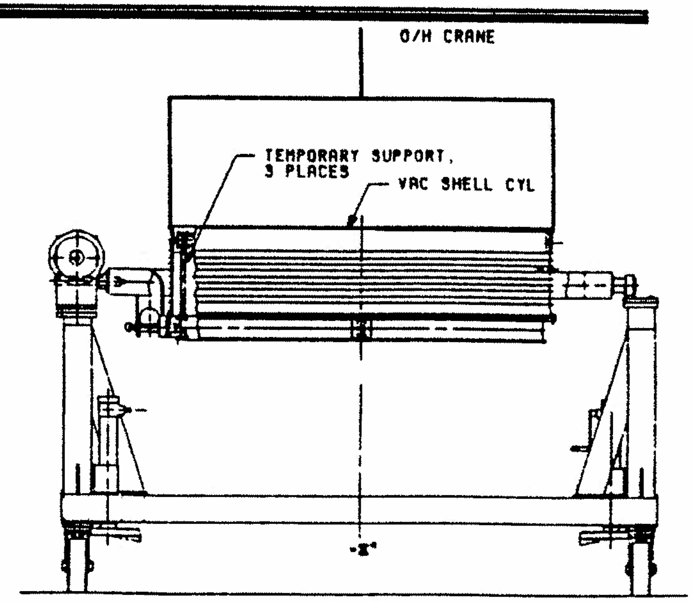
DEWAR ASSEMBLY SEQUENCE

STEP 5

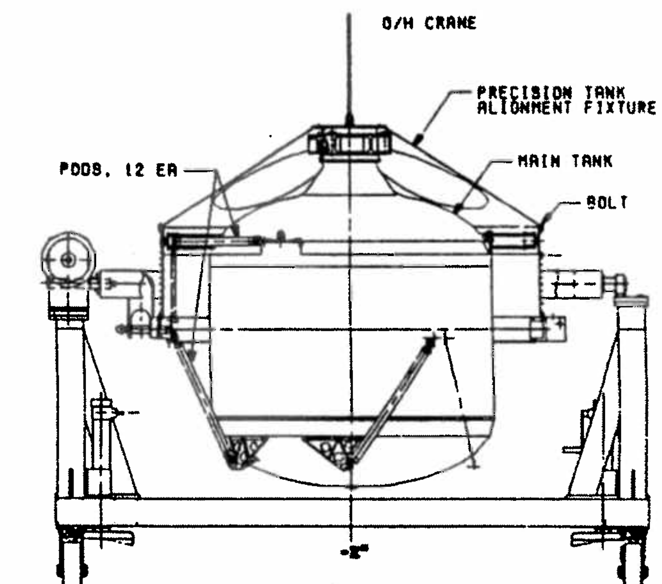
- ROTATE VACUUM SHELL CYLINDER RIGHT SIDE UP USING FIXTURE
- INSTALL 3 TEMPORARY SUPPORTS BETWEEN BOX ASSY'S ON AFT GRAPHITE RING AND SUPPORT RING

STEP 6

- BOLT PRECISION ALIGNMENT TOOL TO MAIN TANK AT AXIAL LOK
- LIFT TANK/TOOL WITH CRANE AND LOWER INTO THE VACUUM SHELL CYLINDER (BOLT ALIGNMENT TOOL TO VACUUM SHELL CYLINDER)
- INSTALL 12 PODS STRUTS



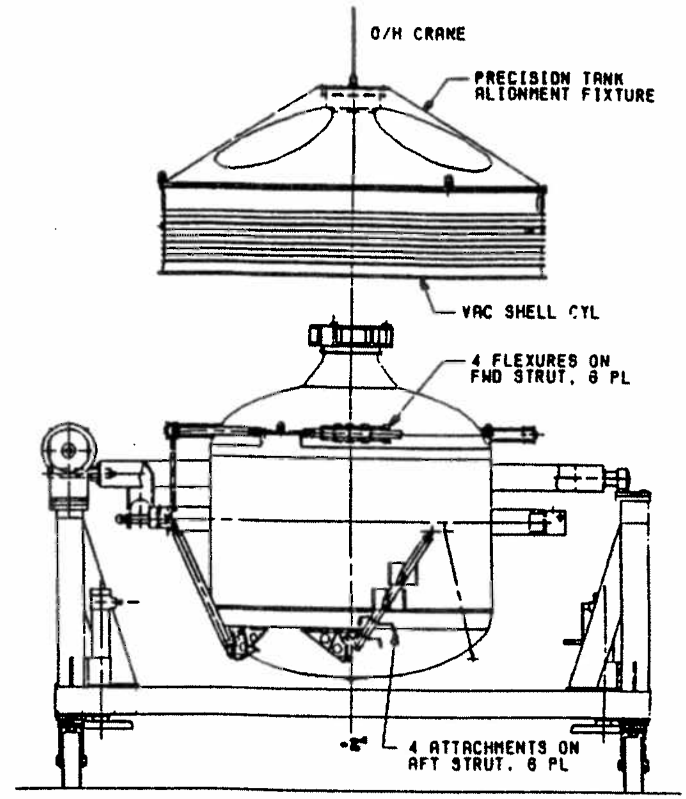
STEP 5



STEP 6

STEP 7

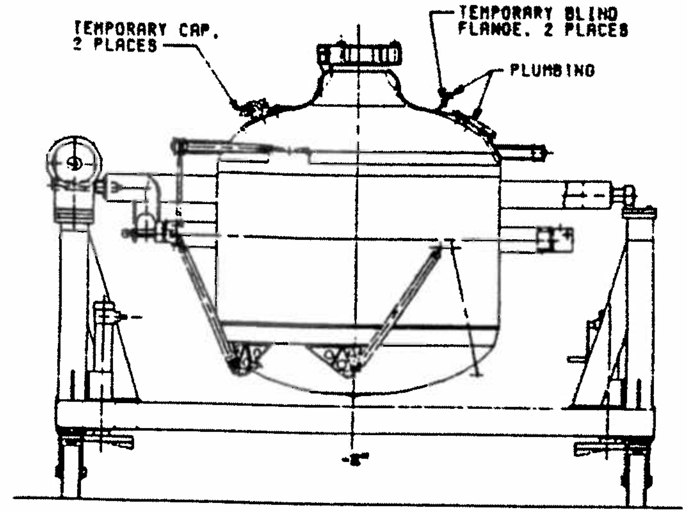
- UNBOLT FLEXURES FROM VACUUM SHELL
- UNBOLT FIXTURE FROM MAIN TANK
- UNBOLT VACUUM SHELL CYLINDER FROM SUPPORT RING
- REMOVE 9 FLEXURES FROM BOXES
- BOLT ALL VCS ATTACHMENTS TO PODS
- MEASURE, ADJUST, AND MARK VCS ATTACHMENT LOCATIONS AND CLOCKING ON PODS
- REMOVE ALL VCS ATTACHMENTS



STEP 7

STEP 8

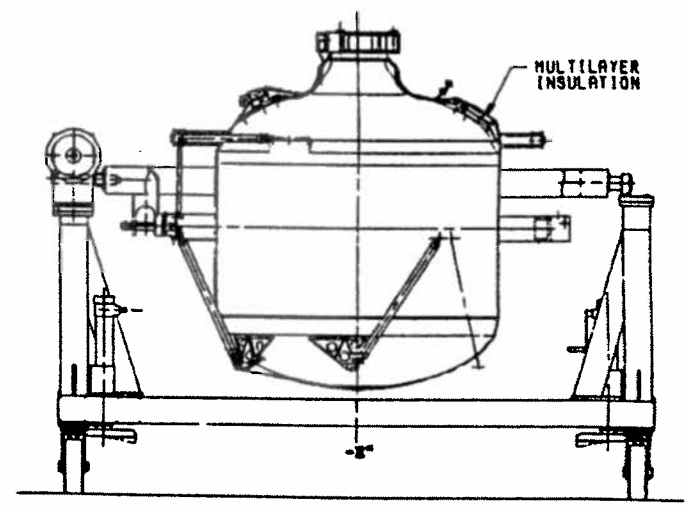
- INSTALL VALVE AND PLUMBING MOUNTING BRACKETS
- INSTALL FEP AND POROUS PLUG
- INSTALL INSTRUMENTATION, VALVE CABLING, AND HEATER WIRES; BRING WIRE LEADS TO STATION 200
- INSTALL FLIGHT MLI ON TANK



STEP 8

STEP 9

- INSTALL COLD VALVES, COLD BURST DISCS, AND , MISC. PLUMBING
- LEAK CHECK PLUMBING A/R



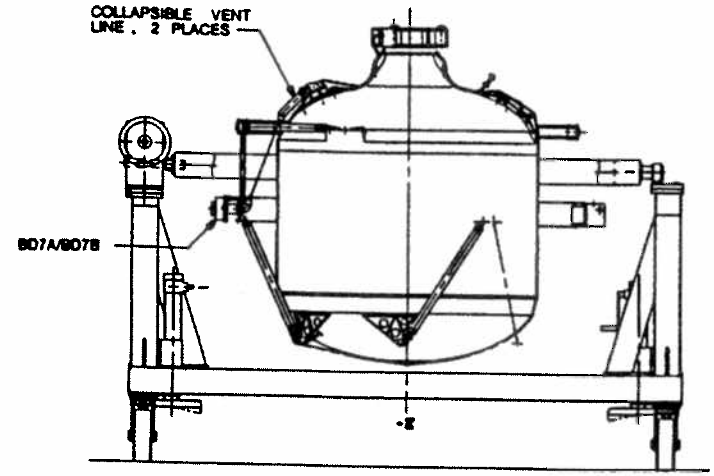
STEP 9

DEWAR ASSEMBLY SEQUENCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

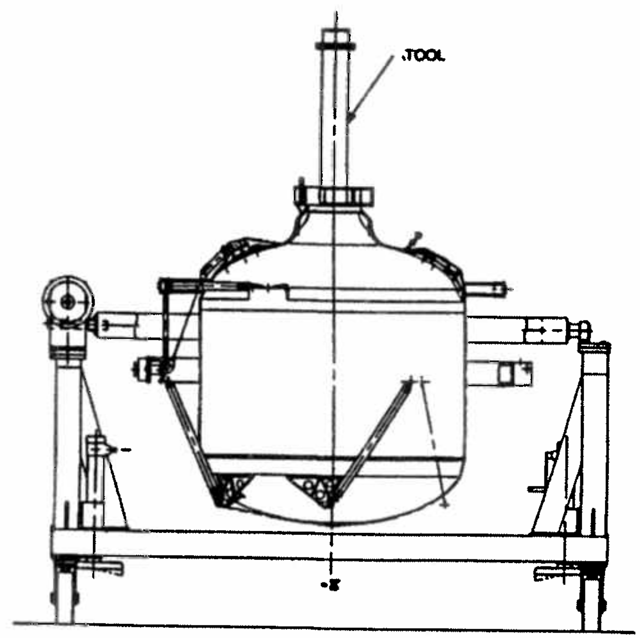
- INSTALL TANK BURST DISC CHECK VALVE ASSEMBLIES ON VACUUM SHELL SUPPORT RING

- CONNECT COLLAPSIBLE VENT LINES FROM MAIN TANK TO VACUUM SHELL



STEP 10

- CLAMP ALIGNMENT/SUPPORT TOOL TO STATION 200 WITH 3 DOGS

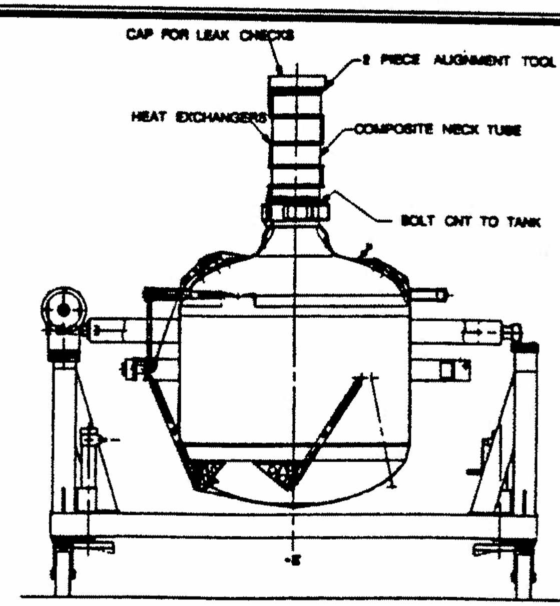


STEP 11

DEWAR ASSEMBLY SEQUENCE

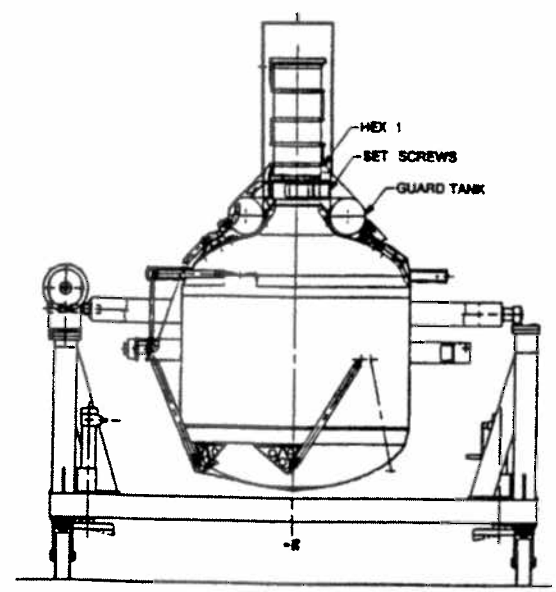
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- EPOXY BOND CNT ASSEMBLY TO TANK USING ALIGNMENT TOOL TO ASSURE POSITIONING
- EPOXY BOND DOUBLER
- LEAK CHECK BOND JOINT
- BOND AXIAL LOK TUBES TO TANK AND HEAT EXCHANGERS.
- LEAK CHECK BOND JOINTS



STEP 12

- EPOXY BOND GUARD TANK ASSEMBLY TO HEX 1
- INSTALL ALL FILL AND VENT INTERCONNECT PLUMBING. COVER ALL EXPOSED PLUMBING W/ DAM
- INSTALL INSTRUMENTATION AND ROUTE LEAD WIRES UP CNT, HEAT SINKING THEM TO EACH HEX



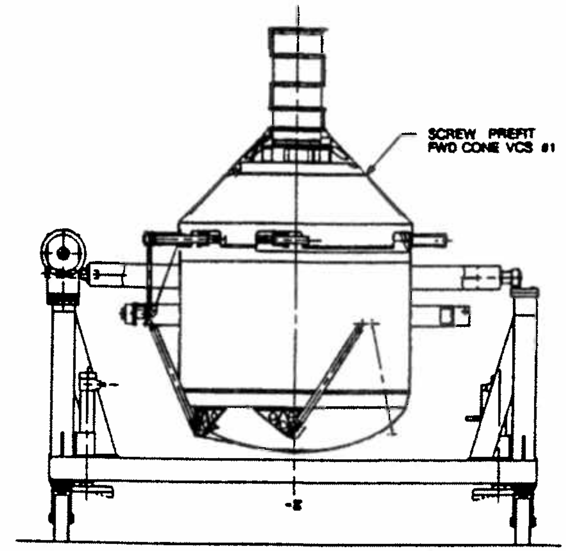
STANFORD

Lockheed

DEWAR ASSEMBLY SEQUENCE

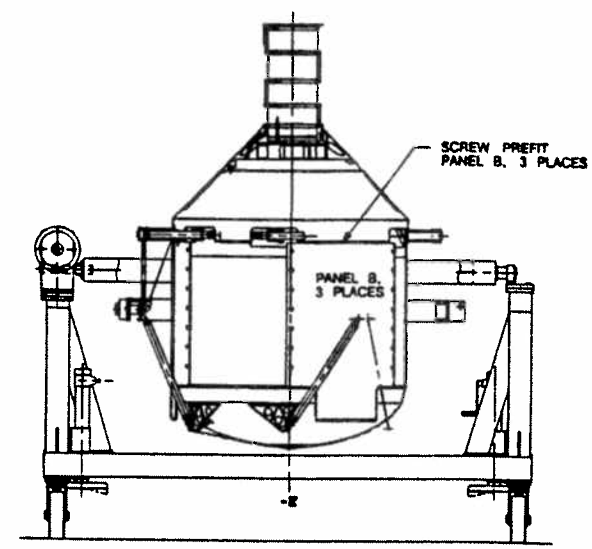
LMSC-P088357
2,3 MAR 94

- REATTACH VCS #1 ATTACHMENTS ON ALL 12 PODS
- HAND LIFT VCS # 1 CONE ON TO THE GUARD TANK
- SCREW CONE TO GUARD TANK



STEP 14

- SCREW VCS #1 "B" PANELS TO VCS #1 CONE

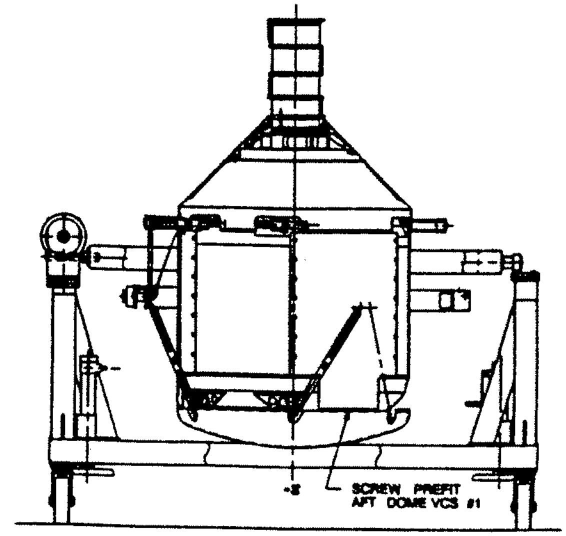


STEP 15

DEWAR ASSEMBLY SEQUENCE

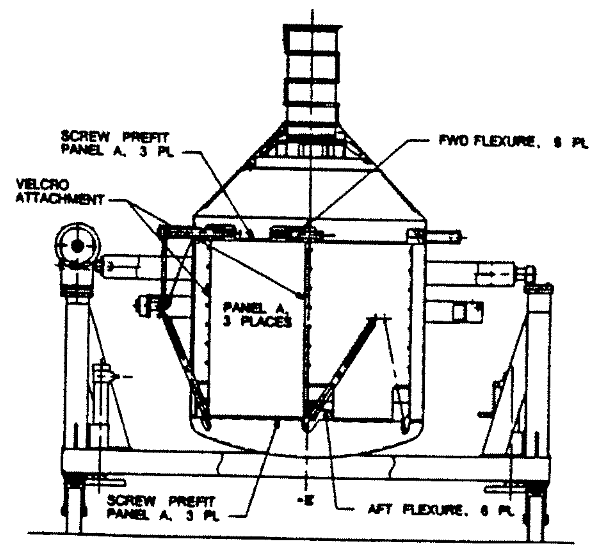
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- HAND LIFT LOWER DOME IN PLACE AND BOLT TO 'B' PANELS



STEP 16

- BOLT VCS #1 'A' PANEL TO CONE AND DOME
- CHECK SPACING
- MATCH DRILL PODS ATTACHMENTS TO VCS FLANGES



STEP 17

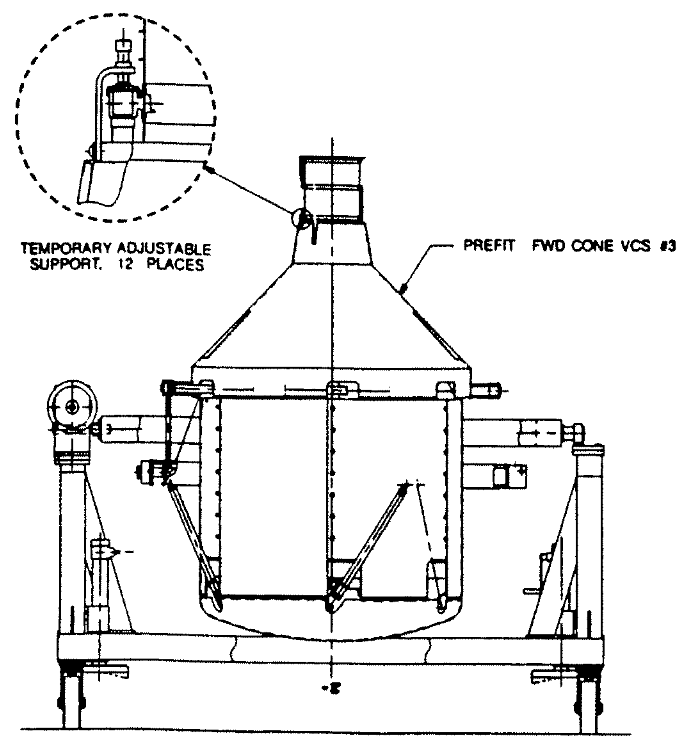
DEWAR ASSEMBLY SEQUENCE

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

- MATCH DRILLING OPERATIONS 18 19, 20, & 21 FOR SHIELD # 2 ARE SIMILAR TO STEPS 14, 15, 16, & 17

- BOLT VCS #3 ATTACHMENTS ON ALL PODS
- PLACE 12 ADJUSTABLE SUPPORTS ON HEX-3
- HAND LIFT AND HOLD CONE OVER TANK
- SCREW CONE TO TEMPORARY SUPPORTS (12 PLACES)

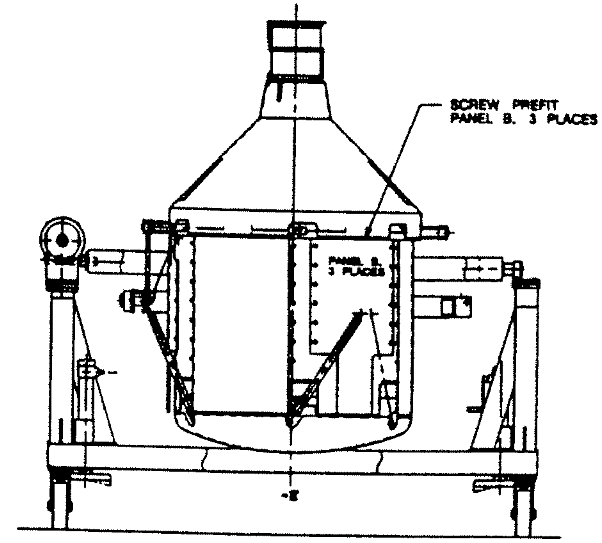


STEP 22

DEWAR ASSEMBLY SEQUENCE

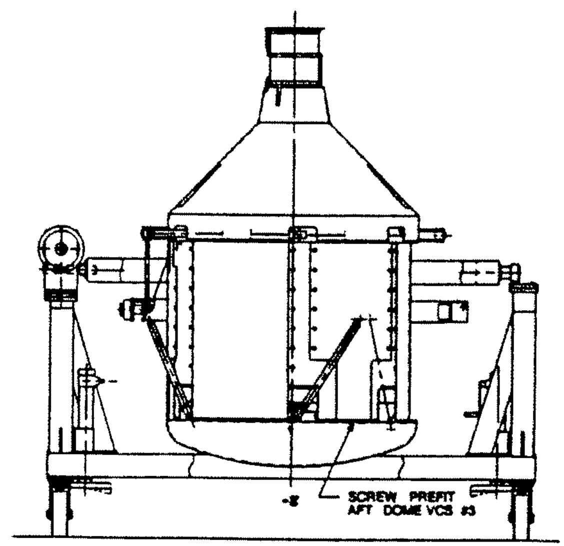
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- SCREW VCS #3 "B" PANELS TO VCS #3 CONE



STEP 23

- HAND LIFT LOWER DOME IN PLACE AND BOLT TO 'B' PANELS



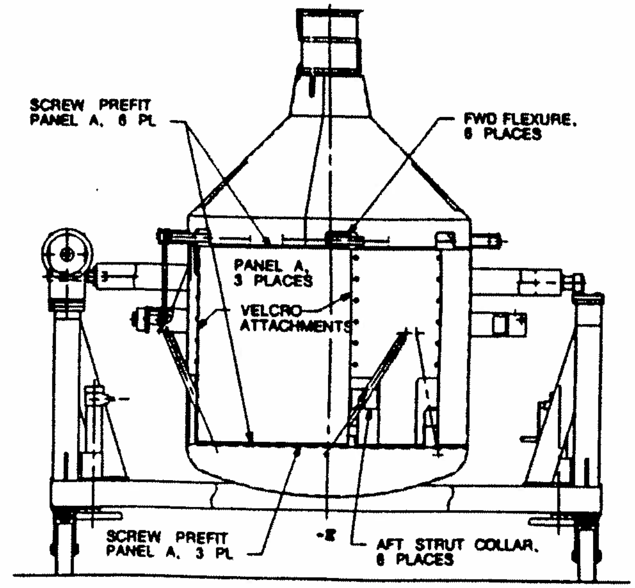
STEP 24

DEWAR ASSEMBLY SEQUENCE

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- SCREW VCS #3 "A" PANELS TO VCS #3 CONE AND DOME

- MATCH DRILL PODS ATTACHMENTS



- MATCH DRILLING OPERATIONS 26, 27, 28, & 29 FOR SHIELD # 4 ARE SIMILAR TO STEPS 22, 23, 24, & 25

STANFORD

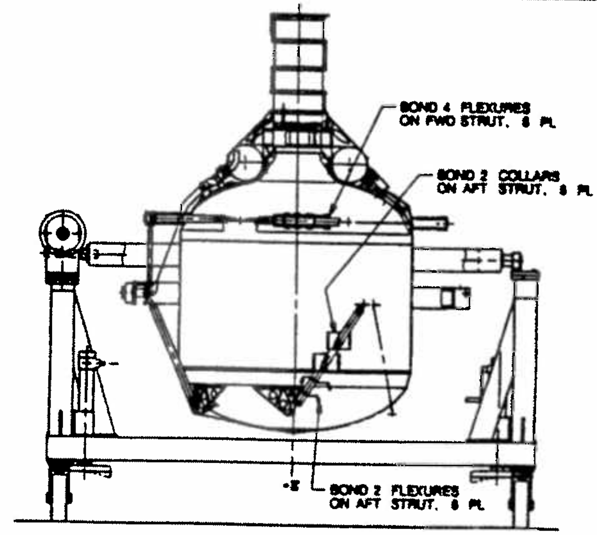
Lockheed

LMSC-P088357

2,3 MAR 94

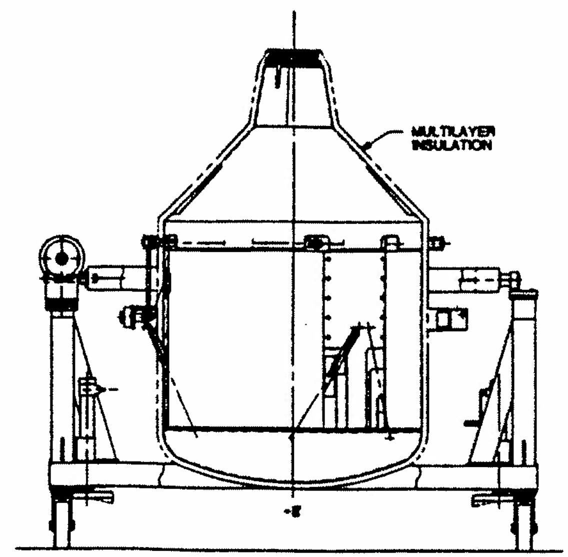
DEWAR ASSEMBLY SEQUENCE

- REMOVE ALL VCS USING SPECIAL TOOLS TO SEPARATE VECRO FASTENERS
- ADD NUT PLATES TO ALL FLEXURE (EACH ATTACHMENT CUSTOM MARKED TO PODS LOCATION)
- EPOXY BOND ALL (48) FLEXURES TO PODS



STEP 30

- REINSTALL ALL VCS'S PER STEPS 14 THROUGH 29. EPOXY BOND ALL BOLTED JOINTS
- INSTALL MLI AND INSTRUMENTATION ON EACH VCS, AS REQUIRED
- REBOLT FLEXURES TO BOX STRUCTURE

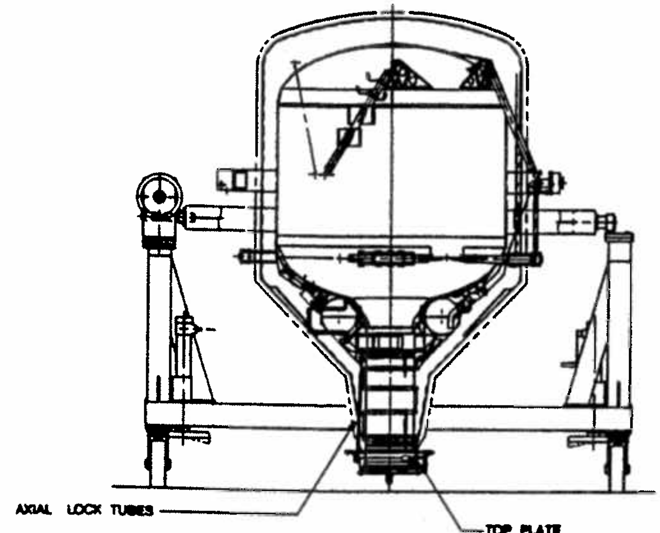


STEP 31

DEWAR ASSEMBLY SEQUENCE

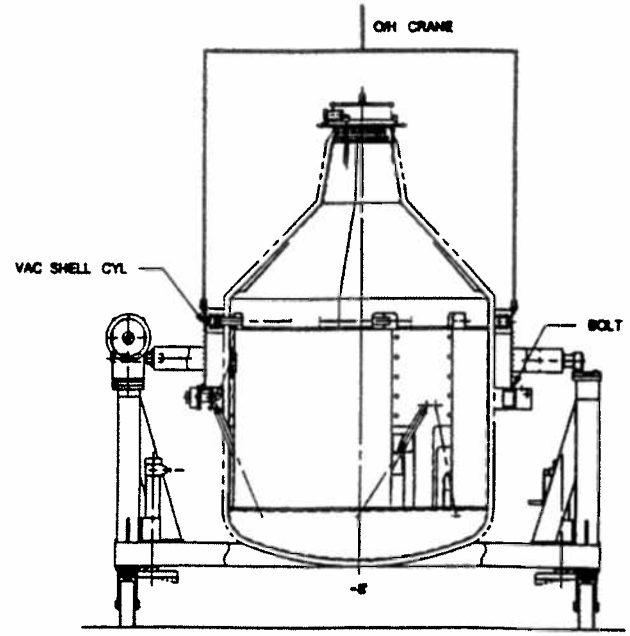
STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- ROTATE DEWAR UPSIDE DOWN
- REMOVE ATTACHMENT BETWEEN CNT FLANGE AND SUPPORT TOOL
- EPOXY BOND TOP PLATE TO CNT AND AXIAL LOK TUBES
- LEAK CHECK BOND JOINT
- BOND DOUBLERS TO AXIAL LOK TUBE JOINTS, LEAK CHECK
- ROTATE DEWAR UPRIGHT



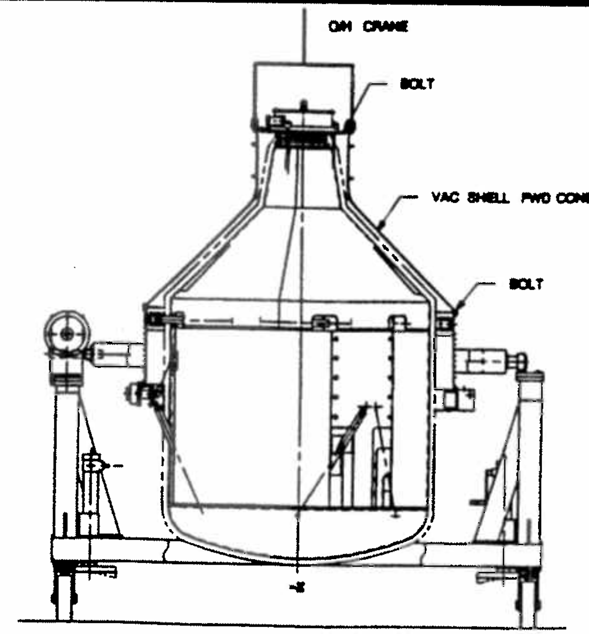
STEP 32

- PLACE HELICOFLEX SEAL INTO SUPPORT RING GROOVE
- LOWER VACUUM SHELL CYLINDER ON TO SUPPORT RING AND BOLT
- BOLT NINE FLEXURES TO I.D. OF VACUUM SHELL CYLINDER
- REMOVE TEMPORARY STRUTS



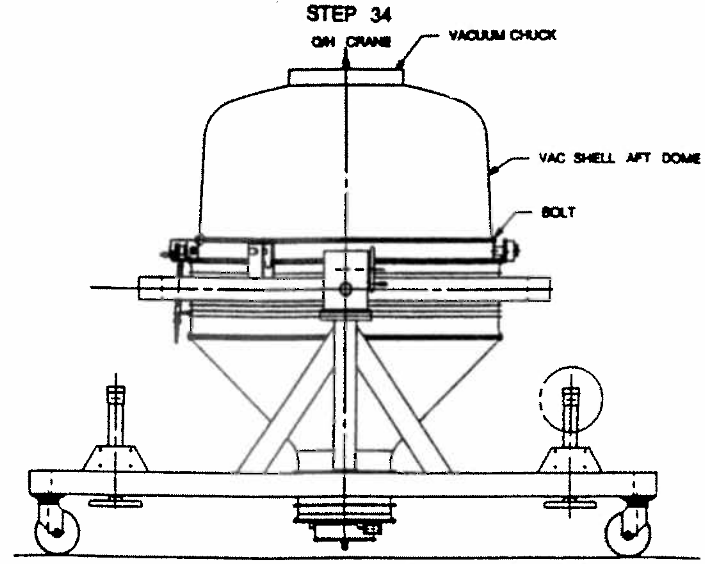
STEP

- PLACE HELICOFLEX SEAL INTO VACUUM SHELL CYLINDER GROOVE AND TOP PLATE GROOVE
- REMOVE ALIGNMENT TOOL FROM INSIDE CNT
- USING O/H CRANE, LOWER FORWARD VACUUM SHELL WELDMENT ON TO VACUUM SHELL CYLINDER AND TOP PLATE AND BOLT AT BOTH LOCATIONS



STEP 34

- ROTATE DEWAR UPSIDE DOWN
- PLACE HELICOFLEX SEAL IN SUPPORT RING
- USING O/H CRANE AND VACUUM CHUCK, LOWER AFT VACUUM SHELL WELDMENT ON TO SUPPORT RING AND BOLT



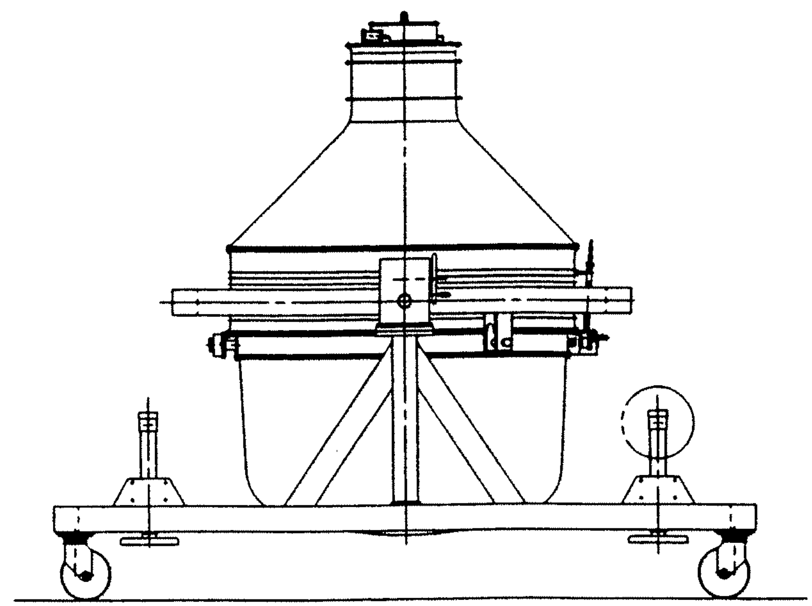
STANFORD

Lockheed

DEWAR ASSEMBLY SEQUENCE

LMSC-P088357
2,3 MAR 94

- ROTATE DEWAR UPRIGHT
- INSTALL EXTERNAL VALVES AND BURST DISCS ON VACUUM SHELL SUPPORT RING AND TOP PLATE
- DEWAR READY FOR SMD SUBSYSTEM TESTING



STEP 36

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

SMD MASS PROPERTIES

RICHARD WHELAN

MP - 2

DEWAR
MASS PROPERTIES SUMMARY

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

DRAWING NUMBER	ITEM	BASIC WT (KG)	CONT. %	PREDICTED WT (KG)
5833454	TOP PLATE WELDMENT	20.61	6	21.94
5833377	VACUUM SHELL ASSEMBLY	308.13	6	327.58
5833170	MAIN TANK ASSEMBLY	262.15	10	288.69
5833278	GUARD TANK ASSEMBLY	12.81	10	14.13
5833350	VAPOR COOLED SHIELDS	57.20	15	65.78
5833197	NECK TUBE ASSEMBLY	12.72	4	13.27
5833393	INSULATION	44.09	20	52.91
5933167	STRUTS	14.48	5	15.20
	PLUMBING	34.08	11	37.87
	ELECTRICAL & INST.	9.16	37	12.58
5833500	DEWAR - DRY	775.43	10	849.95
	HELIUM	341.50	0	341.50
	DEWAR - WET	1116.93	7	1191.45

DRY DEWAR CONTROL WEIGHT = 936 KG; MARGIN = +86 KG

GPB SCIENCE PAYLOAD
MASS PROPERTIES SUMMARY

MP - 3

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

ITEM	BASIC WT (KG)	CONT. %	PREDICTED WT (KG)
DEWAR - DRY	775.43	10	849.95
HELIUM	341.50	0	341.50
PROBE	176.85	5	185.69
SIA	39.05	5	41.00
SHUTTER	22.09	35	29.82
SUNSHADE	2.20	82	4.00
FORWARD ELECTRONICS	77.96	44	112.27
MAIN PAYLOAD - WET	1435.08	10	1564.23
AFT ELECTRONICS (ON S/C)	173.00	14	197.76
AFT HARDWARE (ON S/C)	106.34	37	145.22
SCIENCE PAYLOAD - WET TOTAL	1714.42	12	1907.21

SCIENCE PAYLOAD WEIGHT ALLOCATION = 2000 KG; MARGIN = +93 KG

CONTINGENCY ALLOCATION AND DEPLETION

This table is used to assess design maturity:

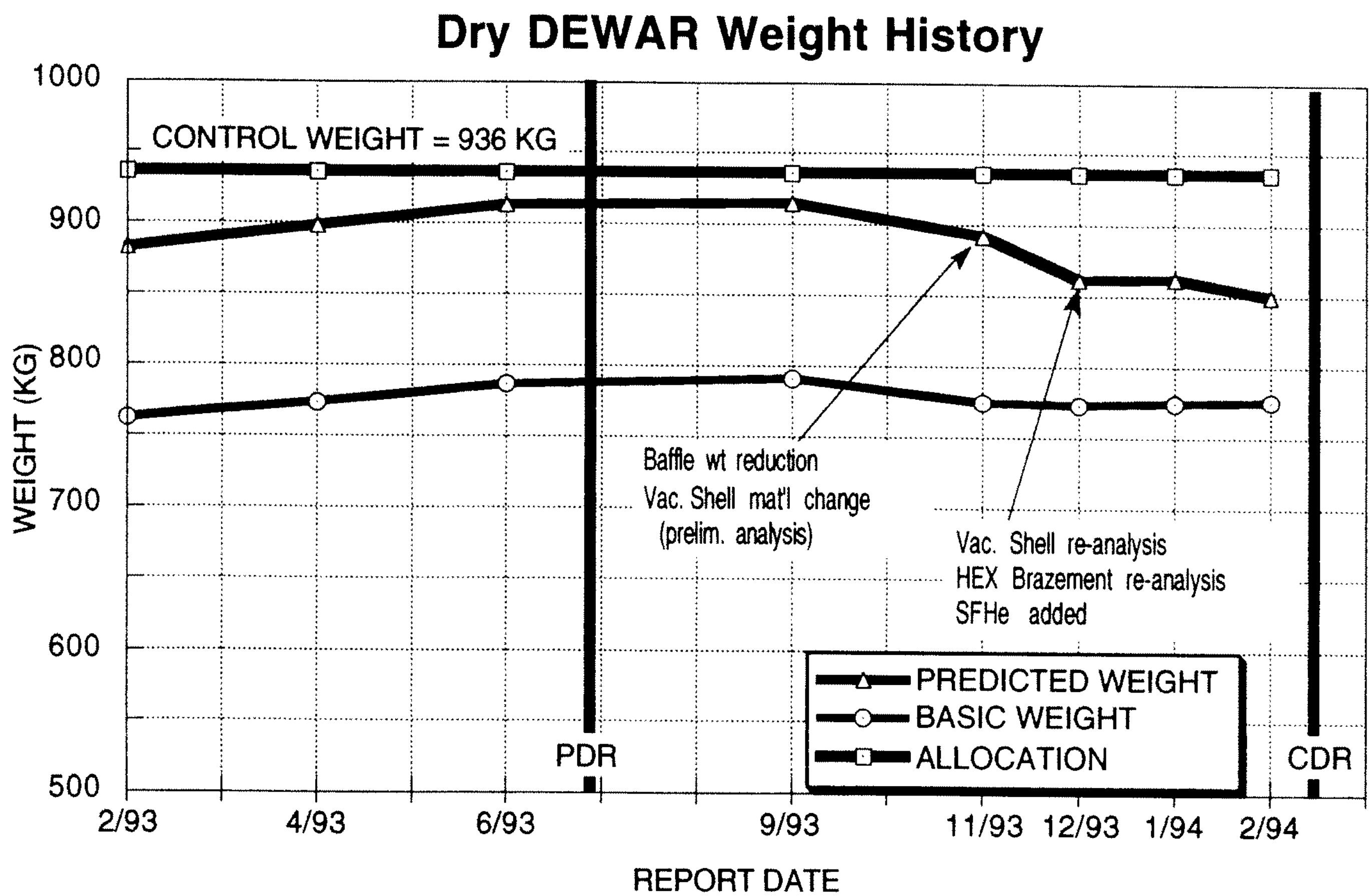
MATURITY		PERCENT CONTINGENCY									
		ELECTRICAL/ ELECTRONIC COMPONENTS			STRUCTURE	MECHANISMS	THERMAL CONTROL	PROPULSION AND PYROTECHNICS	BATTERIES	WIRING AND CABLES	INSTRUMENTATION
CODE	DESIGN DEFINITION OR EQUIVALENT	0 TO 10 LBS	11 TO 30 LBS	31 LBS AND UP							
E J	NEW DESIGN OR PRELIMINARY DESIGN (SKETCHES, DESCRIPTIONS)	30	25	20	20	20	25	20	20	50	50
L N	MAJOR MODS TO EXISTING HARDWARE OR LAYOUT CALCULATIONS	25	20	15	15	15	20	15	15	25	25
P	MINOR MODS TO EXISTING HARDWARE OR PRERELEASED DWG CALCULATIONS	20	15	10	8	8	15	8	10	15	15
C	RELEASED DWG CALCULATIONS	15	10	5	3	3	10	3	5	10	10
X	EXISTING HARDWARE ACTUAL WEIGHT	1	1	1	1	1	1	1	1	1	1
A	FLIGHT HARDWARE ACTUAL WEIGHT	0	0	0	0	0	0	0	0	0	0
S	SUBCONTRACTOR HARDWARE	(1) MAXIMUM SPECIFICATION WEIGHTS: "0" PERCENT CONTINGENCY (2) REPORTED STATUS VALUES: SUBCONTRACTOR CONTINGENCY, OR AS MUTUALLY AGREED									
G	CUSTOMER FURNISHED EQUIPMENT	"0" PERCENT CONTINGENCY, OR AS DIRECTED BY PROCURING AGENCY									

WEIGHT CHANGES

CHANGES SINCE PDR:

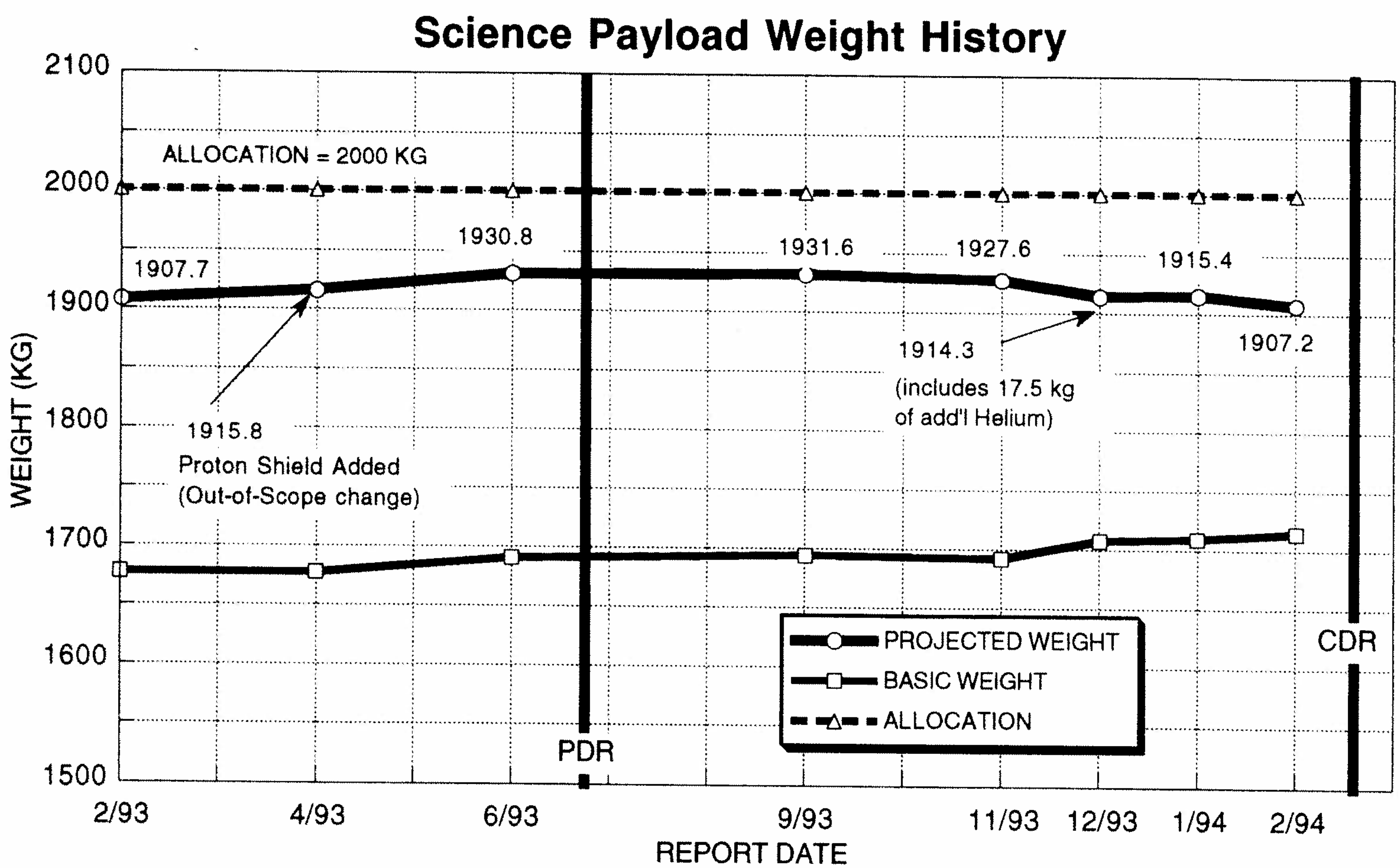
REPORT	CHANGE	Δ (KG)
SEPTEMBER 93	MISC. PROBE & DEWAR CHANGES	+1 KG
NOVEMBER 93	BAFFLE WEIGHT REDUCED	-61 KG
	VACUUM SHELL MATERIAL CHANGE	+40 KG
	OTHER MISC. CHANGES (MOSTLY PROBE SUNSHADE CHANGE - FIXED TO DEPLOYABLE)	+17 KG
DECEMBER 93	PRE-RELEASED VAC. SHELL DWGS ANALYZED	-17 KG
	HEX BRAZEMENT RE-ANALYSIS	-13 KG
	SFHe ADDED (MAIN TANK VOLUME RE-ANALYSIS)	+17 KG
JANUARY 94	BAFFLE STRESS ANALYSIS UPDATED	+6 KG
	STAR TRACKER PALTFORM -> S/C	-5 KG
	PLUMBING, MISC. CHANGES	-2 KG
	PLUMBING, INTERFACE CHANGES	+7 KG
	GUARD TANK	-3 KG
	OTHER MISC. CHANGES	-2 KG
FEBRUARY 94	VACUUM SHELL HARDWARE REANALYSIS	-10 KG
	MISC. CHANGES	+2 KG

DRY DEWAR WEIGHT HISTORY



SCIENCE PAYLOAD - WET WEIGHT HISTORY

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



MAIN PAYLOAD - WET MASS PROPERTIES REQUIREMENTS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- CENTER OF GRAVITY LIMITS:

  XCG < ±4 MM   YCG < ±4 MM

  ZCG > 4260 MM & ZCG < 4500 MM

- PRESENT STATUS:

  XCG = -4.15 MM   YCG = 4.88 MM   ZCG = 4555.87 MM

- PRODUCT OF INERTIA LIMITS:

  IXZ & IYZ < 10.50 KG-M2

- PRESENT STATUS:

  IXZ = 7.36 KG-M2

  IYZ = 6.84 KG-M2

CONTAMINATION

KARL MASON

SMD CONTAMINATION REQUIREMENTS

- GENERAL REQUIREMENT:

  CONTAMINATION (PARTICULATE AND MOLECULAR) SHALL BE CONTROLLED TO:
  - PREVENT DEWAR VALVE ASSEMBLY LEAKAGE
  - PREVENT MIGRATION OF MAGNETIC CONTAMINANTS FROM TANK TO WELL
  - PREVENT PLUGGING OF 0.5 μ POROUS PLUG
- APPROACH
  - GSE FILL LINE SHALL INCLUDE FILTER TO PROTECT AGAINST VALVE ASSEMBLY LEAKAGE
  - EACH WELL FILL LINE HAS ADDITIONAL FILTER TO PREVENT MIGRATION OF MAGNETIC PARTICLES INTO WELL
  - FILL LINES AND INTERNAL TANK SURFACES SHALL BE CLEANED TO LEVELS SPECIFIED IN THE CONTAMINATION CONTROL PLAN
  - ESTABLISH CONTAMINATION CONTROLS AT TANK(S) VENDORS

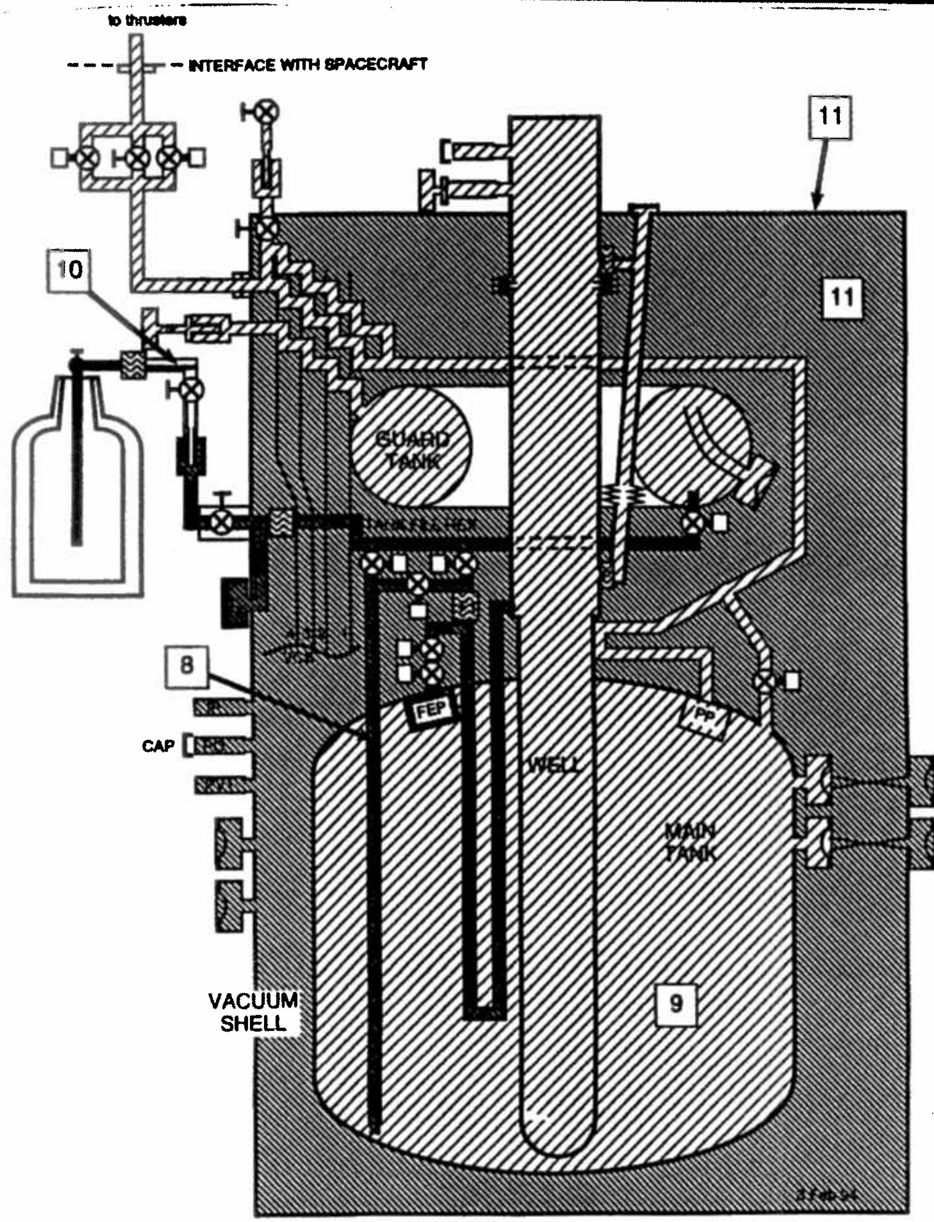
CO - 3

DEWAR CONTAMINATION ZONES

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94



DEWAR CONTAMINATION ZONES DESCRIPTIONS

ZONE	DESCRIPTION	LEVEL	RATIONALE
VIII (8)	INTERIOR OF ALL LIQUID FILL LINES, ALL COLD VALVES	100 A	PROTECT THE REMOTE VALVES, PREVENT PLUGGING WELL FILL FILTERS
IX (9)	INTERIOR OF WELL, MAIN TANK, GUARD TANK, VENT LINES, AXIAL LOK, AXIAL LOK TUBING, COMPOSITE NECK TUBE	250 A	LEVEL 250 WILL PREVENT PLUGGING OF FILTERS
X (10)	INTERIOR OF GSE FILL LINES DOWNSTREAM OF EXTERNAL FILL LINE FILTER	100 A	PROTECT THE REMOTE VALVES, PREVENT PLUGGING WELL FILL LINE FILTERS
XI (11)	INTERIOR AND EXTERIOR OF VACUUM SHELL	VISIBLY CLEAN	

FILL LINE REQUIREMENTS

- 25 μM ABSOLUTE FILTER REQUIRED IN GSE FILL LINE
- 10 μM FILTER (F-2) IN FILL LINE ON DEWAR SIDE
- WELL FILL LINE HAS 2 μm FILTER (F-1) DOWNSTREAM OF REMOTE VALVES
- FOUNTAIN EFFECT PUMP IS 0.5 μm FILTER
- FILL TUBE INTERNAL SURFACE CLEANLINESS :
  - LAC 3150 070100 / MIL-STD-1246 100A
- FILL LINE VALVES INTERNAL SURFACE CLEANLINESS:
  - LAC 3150 070100 / MIL-STD-1246 100A

LAC 3150 CLEANLINESS LEVELS

TABLE I. PARTICULATE CLEANLINESS LEVELS(a)

Particle Size Range (microns)	LAC 3150 Classes					
	-03XX00	-04XX00	-05XX00	-06XX00	-07XX00	-08XX00
5-10	(b)	(b)	(b)	(b)	(b)	120
11-25	(b)	(b)	(b)	(b)	500	55
26-50	(b)	(b)	(b)	280	65	6
51-100	(b)	(b)	340	45	10	0
101-150	(b)	700	25	4	0	0
151-250	1,230	175	7	0	0	0
251-500	170	25	0	0	0	0
501-750	5	0	0	0	0	0
Over 750	0	0	0	0	0	0
Fibers	2	2	1	1	0(c)	0(c)
Equivalent degree of cleanliness per MIL-STD-1246	750	500	250	150	100	50

(a) Sample size shall be 100 milliliters for liquid, or 10 cubic feet for gas, unless other volume is specified.

(b) Count not required (maximum particle size limits size and quantity of smaller particles).

(c) Statistical 0 (i.e., if two analyses are performed and a fiber is found in one analysis, count is 0).

TABLE III. NONVOLATILE RESIDUE (NVR)

LAC 3150 Classes	-0XX100	-0XX200	-0XX300
NVR mg/100 ml or ft^2, maximum	1.0	2.0	3.0
Equivalent MIL-STD-1246 Classes	A	B	C

MIL-STD-1246 CLEANLINESS LEVELS

CLASSIFICATION OF PRODUCT CLEANLINESS LEVELS

Table Ia
Derivation of Cleanliness Levels[1]

Cleanliness Level	Range Surface and Fluids	Quantity of Particulates
1	1	1
5	1	3
	2	2
	5	1
10	5	3
25	5	23
	15	3
	25	1
50	5	165
	15	25
	25	7
	50	1
100	15	265
	25	78
	50	11
	100	1
200	15	4190
	25	1240
	50	170
	100	16
300	25	7450
	50	1020
	100	95
	250	2
500	50	11800
	100	1100
	250	26
	500	1
750	100	8900
	250	210
	500	7
	750	1
1000	250	1020
	500	40
	750	5
	1000	1

Table Ib
Non-Volatile Residue

Level	Quantity NVR
A	Less than 1.0 mg
B	1.0 mg to 2.0 mg
C	2.0 mg to 3.0 mg
D	3.0 mg to 4.0 mg
E	4.0 mg to 5.0 mg
F	5.0 mg to 7.0 mg
G	7.0 mg to 10.0 mg
H	10.0 mg to 15.0 mg
J	15.0 mg to 25.0 mg

[1] Derivation of Cleanliness Levels. The cleanliness levels and range within each level of Table Ia were established by plotting the curves in Chart I. Chart I plot point is number of total particles above given size versus particle size.

MINIMUM PROCESS REQUIREMENTS

- CHEMICAL PRECLEAN TUBING BEFORE BENDING
- FLOW-THROUGH HIGH VELOCITY / VOLUME FLUSHING IS REQUIRED (NOT A DIP OR RINSE)

REQUIREMENTS DURING ASSEMBLY

- SPECIAL CLEANLINESS AREA REQUIRED (MINIMUM)
  - GOAL OF CLASS 300,000 AIR CLEANLINESS PER FED-STD-209
  - LMSC B/205 WILL BE CLASS 300,000 FOR DEWAR ASSEMBLY
- PROCESS REQUIREMENTS (MINIMUM)
  - CLASS 300,000 DURING OPERATION (MONITORED)
  - DEDICATED AREA
  - CLEAN ROOM GARMENTS
  - REGULAR MAINTENANCE
  - PROTECTIVE COVERS FOR HARDWARE DURING PERIODS OF NON USE. COVERS CLEAN TO LAC 3150 050100 / MIL-STD-1246 250A
- ASSEMBLY TOOLING TO BE REGULARLY DEGAUSSED AND CLEANED BEFORE USE.

FILL TUBE WELDING REQUIREMENTS

- SPECIAL CLEANLINESS AREA REQUIRED (MINIMUM)
- PROCESS REQUIREMENTS (MINIMUM)
  - INITIATE NITROGEN PURGE DURING ASSEMBLY PROCESS, CONTINUE UNTIL ALL WELDS COMPLETED
- COVER FILL TUBE ENDS WITH CLEAN COVERS. CLEAN TO LAC 3150 070100 / MIL-STD-1246 100A

MAGNETICS

RICHARD VASSAR / ERNEST IUFER

MA - 2

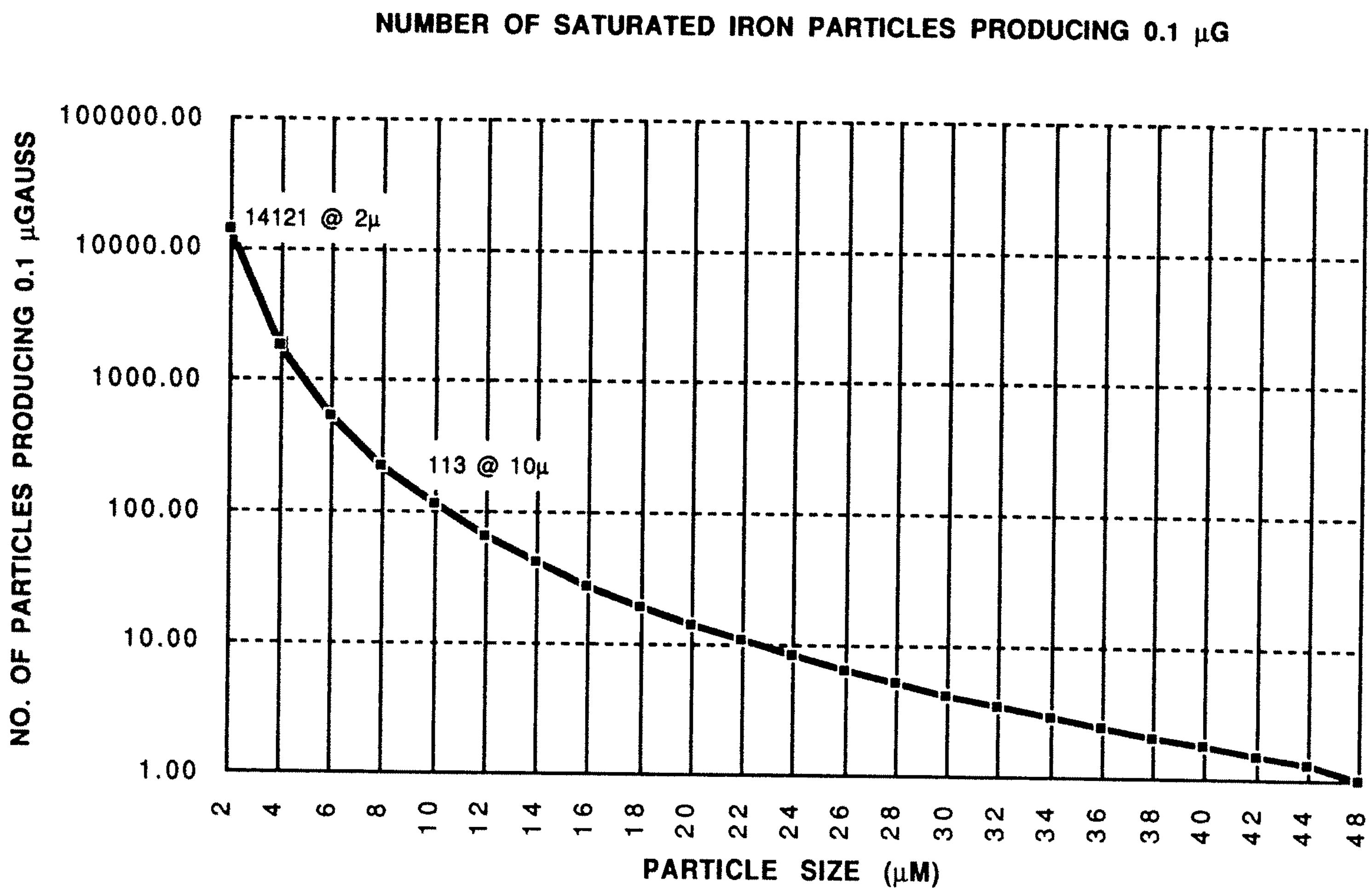
DEWAR MAGNETIC CONTROL

- DEWAR WELL, CRYOPERM SHIELD, LEAD BAGS, LEAD BAG RETAINER, AND TRANSFER LINES ARE MAGNETICALLY SCREENED TO ZONE 4.
- MAGNETIC CONTAMINATION OF WELL IS PREVENTED BY TRANSFER LINE FILTERS
  - LHE ALWAYS PASSES THROUGH 2 μ FILTER F1 BEFORE WELL ENTRY
  - A 2 μ FILTER IS ABSOLUTE FOR 10 μ PARTICLES. A SINGLE, SATURATED IRON 10 μ PARTICLE CAN PRODUCE 9×10^{-10} GAUSS AT 5 ". A SINGLE 2 μ PARTICLE CAN PRODUCE 7×10^{-13} GAUSS.
  - LHE NEVER ENTERS THE PROBE VACUUM SHELL
- USE OF FILTERS AVOIDS NEED TO SCREEN TANK

MA - 3

NO. OF PARTICLES PRODUCING 0.1 μGAUSS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



CRYOPERM SHIELD TESTING

- THE CRYOPERM FERROMAGNETIC SHIELD WILL BE TESTED FOR CONFORMANCE TO REQUIREMENTS AT NASA AMES PRIOR TO INTEGRATION.
- THE FOLLOWING KEY ELEMENTS WILL BE INCLUDED IN THE TEST PROCEDURE
  - REMOVAL OF REMANENCE UPON ARRIVAL
  - MEASUREMENT OF POST DEMAGNETIZATION REMANENCE IN ZERO AMBIENT FIELD
  - MEASUREMENT OF NET FIELD AT GYRO LOCATIONS AND AT THE SHIELD MOUTH IN ZERO FIELD AND AGAIN WHILE IN AN AXIAL AMBIENT FIELD OF 600 mG
  - MEASUREMENT OF NET FIELD AT GYRO LOCATIONS AND AT THE SHIELD MOUTH IN ZERO FIELD AND AGAIN WHILE IN A TRANSVERSE AMBIENT FIELD OF 600 mG
  - MEASURE THE EXTERIOR CHARACTERISTICS OF THE SHIELD AS REQUIRED TO DETERMINE IN-ORBIT MAGNETIC TORQUES

SAFETY

JIM CALAHANE

SAFETY OVERVIEW

- SCIENCE MISSION DEWAR SAFETY COMPLIANCE DOCUMENT, GPB-100153, REFLECTS THE ASSESSMENT OF THE DESIGN AS OF THE PRINTING OF THIS CDR PACKAGE.
  - MINOR UPDATE TO THE HAZARD REPORTS REQUIRED TO REFLECT DETAILS OF THE ENGINEERING MEMORANDUMS RELEASED SINCE THIS CDR PACKAGE WAS PRINTED.
- MOST OF THE SMD SAFETY ISSUES HAVE BEEN ADDRESSED WITHIN THE SECTIONS OF THE CDR WHERE THE REQUIREMENTS APPLY.
  - STRESS ANALYSIS PRESENTED STRUCTURAL FACTORS OF SAFETY.
  - THERMAL ANALYSIS PRESENTED MAXIMUM DESIGN PRESSURES.
  - OVERALL DESIGN PRESENTED DUAL VENTING CAPABILITY.
  - REQUIREMENTS LISTED WITHIN LMSC DOCUMENT F277277 AND TRACKED BY SYSTEMS ENGINEERING.

REQUIREMENTS CHANGE

- THE WESTERN RANGE REQUIREMENTS , WRR 127-1, JUNE 1993 HAS REPLACED WSMCR 127-1, DEC 1989.
  - DETAILED COMPARISON COMPLETED BETWEEN CHAPTER 3 OF EACH DOCUMENT.
  - ADDED A WRR 127-1 CHAPTER 3 CHECKLIST AS AN ATTACHMENT TO THE LMSC SMD SAFETY COMPLIANCE DOCUMENT.
  - INPUTS MADE TO UPDATE LMSC DESIGN REQUIREMENTS SPECIFIED IN LMSC DOCUMENT F277277.
    - » NO IMPACT TO THE FLIGHT HARDWARE
    - » CHANGES TO THE GSE REQUIREMENTS WILL NOT IMPACT THE PROGRAM AS THE GSE DESIGN AND OPERATIONS FOR THE WESTERN RANGE HAVE NOT MATURED TO THE LEVEL THAT A CHANGE IN THE REQUIREMENTS IMPACTS THE HARDWARE.
  - PRESENTATION, LMSC DOCUMENT GPB 100151, SENT TO THE WESTERN RANGE SAFETY OFFICE TO OBTAIN AGREEMENT THAT LEAK-BEFORE-BURST DESIGN FOR THE VACUUM SHELL REDUCES THE RISK TO ACCEPTABLE LEVELS.

HANDLING AND TRANSPORTATION

- DEFINED IN LMSC DESIGN DOCUMENT F277277;
  - LOADS FOR SMD DESIGN
  - TRANSPORTATION LOADS.
- ALERT TO SHIPPING HAZARDS TO THE HARDWARE;
  - X, Y, & Z AXIS FOR THE CONTAINER AND FOR THE SMD ARE COORDINATED AND APPROPRIATE ACTIONS TAKEN TO MITIGATE UNWANTED LOADING.
  - SHIPMENT OF PARTIAL ASSEMBLIES ARE REVIEWED FOR STRUCTURAL SOUNDNESS.
  - TRANSPORTATION LOADS ARE MONITORED.
- GROUND HANDLING FIXTURES REVIEWED FOR STABILITY, GIVEN MOVEMENT OF THE FIXTURE OR A SEISMIC EVENT.
- GROUND HANDLING FIXTURES WILL BE PROOF LOADED.

HELIUM SHIPMENT

- SHIPMENT OF SMD WITH NORMAL BOILING POINT LIQUID HELIUM.
  - SHIPMENT PERFORMED WITH PRESSURES LESS THAN 40 PSIA, THEREFORE THE DEWAR DOES NOT QUALIFY AS A PRESSURE VESSEL WITHIN THE DEFINITIONS OF THE DOT.
    - » COORDINATE THE TRANSPORTATION WITH A TRANSPORTATION ORGANIZATION. WITHIN CALIFORNIA THE JURISDICTION FOR ENFORCEMENT OF TRANSPORTATION REGULATIONS IS THE HIGHWAY PATROL.
  - PER DOT, LIQUID HELIUM QUALIFIES AS A CRYOGENIC GAS, HAZARDOUS CLASSIFICATION 2.2, ID # UN1963, LABELED AS A NON-FLAMMABLE GAS.
  - LIMITED TO 500 KG ON CARGO AIRCRAFT.
    - » EACH CARRIER HAS THEIR OWN RULES AND PROCEDURES.
    - » THE VENT LINES SHOULD BE ROUTED THROUGH AN ABSOLUTE PRESSURE REGULATOR.
    - » THE EMERGENCY VENT LINES NEED TO BE ROUTED OUT OF THE AIRCRAFT.

HELIUM VENTING

- ESTABLISH "KEEP OUT ZONES" AROUND BURST DISKS DURING HANDLING, KEEP MAIN TANK BURST DISKS CONNECTED TO A FACILITY VENT WHEN PRACTICAL.
  - MAIN TANK HAS CAPACITY TO REDUCE THE AIR IN A 700,000 CUBIC FOOT ROOM TO LESS THAN ACCEPTABLE OXYGEN LEVELS (19% OXYGEN).
  - THE GUARD TANK AND VACUUM SHELL CAN BE CONSIDERED EQUAL RISK TO THE 500 LITER SUPPLY DEWARS.
    - » THE OXYGEN DEFICIENCY FIGURE IS DECEPTIVE. THE VENTED GAS WILL RISE, DISPLACING THE AIR FROM THE CEILING DOWN. AT THE CEILING THE OXYGEN LEVEL COULD GO LESS THAN 5% WHILE THE GROUND LEVEL IS STILL 21%.
    - » EACH FACILITY NEEDS TO BE ASSESSED. HOW PERMEABLE IS THE CEILING, WHERE DOES THE GAS GO, ARE THEIR PEOPLE WORKING AT HEIGHTS...
      - THE LMSC HIGH BAY FACILITY, BUILDING 205, HAS AN 02 MONITOR IN THE CEILING.
      - THE LMSC ENVIRONMENTAL TEST FACILITY DETERMINED SUFFICIENTLY LARGE AND "LEAKY" BY OCCUPATIONAL SAFETY.

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

RELIABILITY - SMD INSTRUMENTATION AND PLUMBING

JIM SUTY

SMD RELIABILITY

- OBJECTIVE & APPROACH
- FMECA DESCRIPTION
- STUDIES & ACTIONS SINCE PDR
  - BURST DISK RELIABILITY ANALYSIS
  - COLD VALVE/MOTOR DURABILITY ACTIONS
- RESULTS, CONCLUSIONS, RISK AREAS

OBJECTIVE & APPROACH

- DEFINE DURABILITY REQUIREMENTS
  - DESIGN LIFE ENVIRONMENTS
    - » SERVICE LIFE
    - » TEST & VERIFICATION
    - » TRANSPORTATION AND LAUNCH

- CONDUCT FAILURE MODES, EFFECTS & CRITICALITY ANALYSIS (FMECA)

- ASSESS PLUMBING COMPONENT RELIABILITY
  - CRITICAL ITEM LIST
  - DESIGN TRADEOFFS
  - OPERATING MARGINS (PRESSURE, FORCE, TORQUE, TRAVEL)
  - RISK ASESSMENT / MITIGATION

- PLAN FOR TRENDING / VERIFICATION OF PERFORMANCE

- LIST CONCLUSIONS / RECOMMENDATIONS

FMECA DESCRIPTION (1 OF 2)

- A FMECA HAS BEEN CONDUCTED FOR EACH TYPE OF PLUMBING COMPONENT. THEY ARE:
  - VACUUM-JACKETED BAYONET CONNECTION
  - PYROTECHNIC VALVE
  - REMOTELY ACTUATED VALVE
  - MANUALLY ACTUATED VALVE
  - COLD AND WARM BURST DISCS
  - RELIEF VALVE
  - FOUNTAIN EFFECT PUMP
  - POROUS PLUG
  - EMERGENCY VENT LINE
  - FILTER
  - ELECTRICAL WIRING
  - TANK HEATERS
  - PASSIVE ORBITAL DISCONNECT STRUT
  - ELECTRICAL FEEDTHROUGH
  - VAC ION PUMP
  - HELICAL FLEX COLD SEAL

FMECA DESCRIPTION (2 OF 2)

- EACH FMECA ITEM ANALYSIS CONSISTS OF:
  - END ITEM DESCRIPTION
  - ITEM DESCRIPTION
  - FUNCTION
  - NEXT HIGHER ASSEMBLY
  - FAILURE MODE AND CAUSES
  - EFFECTS
  - HOW FAILURE IS DETECTED
  - HOW FAILURE IS ISOLATED
  - HOW FUNCTION IS RESTORED
  - TIME TO RESTORE
  - ASSESSMENT
  - CORRECTIVE DESIGN AND DEVELOPMENT ACTION
  - STATUS
  - ADDITIONAL NOTES

STUDIES & ACTIONS SINCE PDR

- BURST DISK RELIABILITY
  - ANALYSIS TO CONVERT .999 RELIABILITY INTO TEST PARAMETERS
  - INCORPORATION OF PARAMETERS INTO BURST DISK SPECIFICATION

COLD VALVE/MOTOR DURABILITY ACTIONS
  - REVIEW OF PREVIOUS FAILURES IN SIMILAR HARDWARE
  - REVIEW OF PREVIOUS FAILURE ANALYSIS AND DESIGN FIXES
  - FORMULATION OF DESIGN AND FABRICATION GUIDELINES
  - INTERCHANGE WITH VALVE/MOTOR SUPPLIER

RESULTS, CONCLUSIONS, RISK AREAS

- BURST DISKS
  - SPECIFICATION
    - » REQUIRES VERIFICATION OF .999 PROBABILITY THAT BURST DISKS WILL PERFORM THEIR FUNCTION BETWEEN 83% AND 117% OF NOMINAL SET POINT
    - » ALLOWS ADDITIONAL MARGIN OF SAFETY OF 17 PSID FOR MAIN TANK
    - » ALLOWS ADDITIONAL MARGIN OF SAFETY OF 24 PSID FOR GUARD TANK
  - RISK OF MULTIPLE LOT/DATE CODES FOR BURST DISK ASSEMBLIES
    - » MITIGATED BY SPECIFICATION, CERTIFICATION OF CONFORMANCE,INSPECTION

- COLD VALVES/MOTORS
  - SUPPLIERS SUBSCRIBING TO DESIGN GUIDELINES
  - SUPPLIERS ALREADY FOLLOWING FABRICATION GUIDELINES
  - RISK OF CONTAMINATION, TOOL DAMAGE, OVERPOTTING OF COILS
    - » MITIGATED BY ADHERENCE TO AGREED ASSEMBLY PRACTICES

QUALITY ASSURANCE

JIM LEPETICH

REQUIREMENTS

- IMPLEMENTATION: LMSC GP-B SAFETY, RELIABILITY, MAINTAINABILITY AND PRODUCT ASSURANCE PLAN REF: F428533 - REPRESENTS A TAILORED VERSION OF NHB5300.4(1B)
- SPECIFIC AREAS;
  - DESIGN AND BUILD
  - PROCUREMENT
  - INSPECTION
  - TESTING
  - AUDITS
  - NON-CONFORMANCES

DESIGN AND BUILD

- REVIEW AND SIGNOFF ON ALL DRAWINGS AND PROCEDURES PRIOR TO RELEASE, AND ON SUBSEQUENT REVISIONS
  - DRAWINGS / PROCEDURES ARE REVIEWED FOR INSPECT POINTS AND CONTINUITY WITH PREVIOUS DOCUMENTATION
- OPERATIONS ORDERS ARE USED FOR KITTING AND BUILD ACTIVITY; USED TO INVOKE PROCEDURES
  - OPERATIONS ORDERS ARE ALSO REVIEWED FOR INSPECT POINTS AS WELL AS BEING REVIEWED PRIOR TO FINAL CLOSURE TO VERIFY STEPS ARE COMPLETED AND TO VERIFY THAT NO ISSUES ARE LEFT UNRESOLVED

PROCUREMENT

- VENDOR CERTIFICATION
  - SURVEYED BY LMSC, PUBLISHED IN LMSC DIRECTORY OF APPROVED SOURCES (DAS)
  - BASED ON PREVIOUS R&D WORK HISTORY, VENDOR MAY BE INCLUDED IN R&D DAS
  - SPECIAL APPROVAL MAY BE GRANTED FOR A ONE - TIME PROCUREMENT BY THE QUALITY ENGINEER
- IMPOSE QUALITY REQUIREMENTS ON OUTSIDE VENDORS VIA PURCHASE ORDERS
  - IMPOSE GENERAL PROGRAM REQUIREMENTS
  - ADDITIONAL REQUIREMENTS ARE BASED ON DRAWING NOTES, STATEMENTS OF WORK, ETC.

INSPECTION

- RECEIVING INSPECTION
  - VERIFIES PROPER ITEM IDENTIFICATION AND NO SHIPPING DAMAGE
  - PERFORMS DIMENSIONAL INSPECTION; MINIMUM 100% 1 PART AND CRITICAL DIMENSIONS ON A SAMPLE BASIS OF BALANCE OF PARTS
  - VERIFIES RECEIPT OF CERTIFICATIONS (MATERIAL, PROCESS, ETC.)
  - VERIFIES RECEIPT OF SUPPLIER DOCUMENTATION (TEST DATA, FIRST ARTICLE INSPECTION REPORTS, ETC.)
- IN - PROCESS INSPECTION
  - INDEPENDENT INSPECTIONS / OPERATION VERIFICATIONS ARE PERFORMED AT KEY STEPS IDENTIFIED BY THE QE SUCH AS SOLDERING OR VERIFICATION OF CONTROLLED INTERFACE DIMENSIONS
  - UNANNOUNCED AUDITS WILL BE PERFORMED TO VERIFY CONFORMANCE TO AND MAINTENANCE OF BUILD PAPER
- SHIPPING INSPECTION
  - PACKAGING WILL BE INSPECTED TO VERIFY CONFORMANCE WITH ESTABLISHED STANDARDS

INSPECTION CONT.

- SOURCE INSPECTION
  - VERIFICATION OF DIMENSIONAL AND / OR DOCUMENTATION REQUIREMENTS AT VENDOR; EITHER IN - PROCESS, OR JUST PRIOR TO DELIVERY
    - » eg. Dewar hardware at Chemtronics

TESTING

- REVIEW AND SIGNOFF ON ALL TEST PROCEDURES PRIOR TO RELEASE, AND ON SUBSEQUENT REVISIONS
  - PROCEDURES WILL BE CHECKED AGAINST REQUIREMENTS FOR COMPLETENESS AND PROPER HANDLING OF HARDWARE
  - INSPECT / VERIFY POINTS WILL BE IDENTIFIED
- MONITORING OF IN - HOUSE TESTING
  - ACCEPTANCE TESTS WILL BE MONITORED TO ASSURE CONFORMANCE TO THE PROCEDURE
  - DATA WILL BE REVIEWED FOR CONFORMANCE TO SPECIFICATIONS
- SUPPLIER ACCEPTANCE TESTS
  - SUPPLIER ACCEPTANCE TESTS MAY BE WITNESSED AT THE DISCRETION OF THE QE AND GP - B MANAGEMENT
    - » eg: Dewar Ground Support Modules
  - ALL SUPPLIER ACCEPTANCE TEST DATA WILL BE REVIEWED

AUDIT

- HARDWARE LOGBOOKS
  - LOGBOOKS WILL BE AUDITED PERIODICALLY TO VERIFY THAT THEY ARE BEING KEPT CURRENT
  - AUDITS WILL ALSO VERIFY THAT RECORDS ARE ADEQUATE AND COMPLETE
- ASSEMBLY AREAS
  - PERIODIC AUDITS WILL BE PERFORMED TO ASSURE COMPLIANCE TO IMPOSED REQUIREMENTS (IE. CONTAMINATION CONTROL)

QA - 9

NON - CONFORMANCE CONTROL

- HARDWARE
  - DEFECTIVE HARDWARE WILL BE SUITABLY IDENTIFIED AS TO STATUS, AND IMPOUNDED AS REQUIRED
- NON - CONFORMANCE REPORTS
  - NON - CONFORMANCE REPORTS (DISCREPANCY REPORTS / DR'S) WILL BE WRITTEN TO DOCUMENT DISCREPANCIES
  - QE AND RESPONSIBLE EQUIPMENT ENGINEER DETERMINE DR DISPOSITION
  - THE QE IS RESPONSIBLE FOR MAINTAINING OPEN DR'S AND ASSURES PROPER CLOSURE ONCE OPEN ISSUES ARE RESOLVED

VERIFICATION AND SYSTEM TEST

ART NAKASHIMA

SMD VERIFICATION PROGRAM OBJECTIVES

- VERIFY SMD COMPLIANCE WITH APPLICABLE REQUIREMENTS IN PAYLOAD SPECIFICATION F277277 V2.5 AND SPACECRAFT TO PAYLOAD INTERFACE CONTROL DOCUMENT F277233 V1.8
  - ENVIRONMENTS
  - INTERFACES WITH SPACECRAFT
  - INTERFACES WITH PROBE
  - INTERFACES WITH ELECTRONICS
  - INTERFACES WITH GSE
  - OPERATIONS

SOURCES FOR PAYLOAD SYSTEM TESTS

- MIL-STD-1540B "TEST RQMTS FOR SPACE VEHICLES"
  - PROVIDES ENVIRONMENTAL TEST PROGRAM GUIDANCE FOR GP-B
- MDC H3224B, "COMMERCIAL DELTA II PAYLOAD PLANNERS GUIDE"
  - PROVIDES ENVIRONMENTAL TESTS GUIDELINES FOR DELTA II PAYLOADS
- WRR 127-1, "WESTERN RANGE SAFETY REQUIREMENTS"
  - PROVIDES RANGE SAFETY TEST REQUIREMENTS
- MIL-STD-882C, "SYSTEM SAFETY PROGRAM REQUIREMENTS"
- MIL-STD-1522A, "RQMTS FOR SAFE DESIGN AND OPERATION OF PRESSURIZED MISSILE AND SPACE SYSTEMS"
  - PROVIDES PRESSURE AND STRUCTURAL TEST GUIDELINES

VERIFICATION TESTING APPROACH

- DEVELOPMENT TESTS FOR DESIGN VERIFICATION
- QUALIFICATION TESTING OF COLD VALVES, BURST DISCS, PYROVALVES, PODS
- PROTOFLIGHT TESTING AT DEWAR SUBSYSTEM LEVEL
- SYSTEM LEVEL TESTS CONDUCTED AT DEWAR, PAYLOAD, AND SPACE VEHICLE LEVELS AT SEVERAL LOCATIONS
  - DEWAR (WITHOUT PROBE) FUNCTIONAL AND HELIUM TESTS IN LMSC B/205
  - PROBE INSERTION, LEAD BAG EXPANSIONS IN STANFORD HANSEN EXPERIMENTAL PHYSICS LAB
  - SMD / PROBE-B VIBRATION (COLD) IN LMSC B/181
  - MOST ENVIRONMENTAL TESTS AT SPACE VEHICLE LEVEL, WITH FLIGHT (SMD / PR-C) PAYLOAD
    - » S/C -P/L INTEGRATION (EXCEPT SOLAR ARRAYS) IN LMSC B/205
    - » EMC/EMI TESTING IN LMSC B/205
    - » ACOUSTIC TESTING IN LMSC B/156
    - » THERMAL VAC AND LIFETIME TESTS IN T/V CHAMBER AT LMSC
    - » INERTIA MEASURMENTS IN LMSC B/104

VERIFICATION DOCUMENTATION

- VERIFICATION AND TEST PLAN (LSE-09)
  - VERIFICATION MATRIX, INCLUDING PLAN FOR COMPLIANCE
  - SYSTEM TEST FLOW AND TEST PLAN
  - COMPONENTS AND ASSEMBLIES TEST PLAN MATRIX
  - UPDATE PRIOR TO TESTING
  - INTEGRATION INCLUDED IN LOP-01, NOT LSE-09
- TEST PROCEDURES
  - EACH SYSTEM TEST, COMPONENT TEST, AND DEVELOPMENT TEST WILL HAVE A TEST PROCEDURES DOCUMENT AND OPERATIONS ORDER DOCUMENTS
  - TEST RESULTS WILL BE DOCUMENTED IN THE WORKING COPY OF OPERATIONS ORDER
  - MAJOR TEST RESULTS WILL BE DOCUMENTED IN A TEST REPORT
- VERIFICATION REQUIREMENTS COMPLIANCE DOCUMENT (LSE-10)
  - PROVIDES REFERENCE SOURCES FOR VERIFICATION DOCUMENTATION, AND DEGREE OF COMPLIANCE
  - UPDATED AT ACCEPTANCE REVIEW

SAMPLE PAGE OF VRCD

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

TABLE 1. DEWAR SPECIFICATION (Section 3.7.5 of F277277)

Reqmt No.	Spec Section Number	Requirement	Method of Verif	Compliance Data	Nonconformance Data	Data Statement / Remarks
R-1	3.7.5	Dewar Specification reference to environments of 3.2.5.1 through 3.2.5.6, and requirements in section 3.3.	A, T	Environmental tests in (7.2), (8.1), (8.2). Loads analysis in *Integrated Payload / Spacecraft Launch Loads Analysis (Rev A) EM 310A/P030739A* .		Test 7.2 is a vibration test with Probe-B, not the flight probe. Acoustic (8.1) and thermal/vac (8.2) tests are done at the space vehicle level. Compliant. Open.
	3.7.5.1	Dewar Definition	definition			
	3.7.5.2	Physical Characteristics	header			
R-2	3.7.5.2.1	Mass Properties	A, T	*LSE-01, Mass Properties Status Report, P024612-X*, published monthly to quarterly to update the mass properties analysis. Weight and dimensions measured of the dry SMD(5.1). Inertias are verified at the space vehicle level by the spin balance test (8.3)		Compliant Open
R-3	3.7.5.2.2	Short Term Shift in Center of Gravity	A	*Gravity Probe-B Fluid Management Final Report, LMSC P088355*		Compliant. Closed
R-4	3.7.5.2.3	Dimensions	I, T	Verify dimensions to ICD drawings 5833115, 5833116, 5833117 during assembly and upon completion (5.1)		Compliant. Open
R-5	3.7.5.2.4	Probe Well	I	Inspection of Probe to Dewar Interface Drawing 5833116		Compliant Closed
	3.7.5.2.5	Structural Characteristics	header			

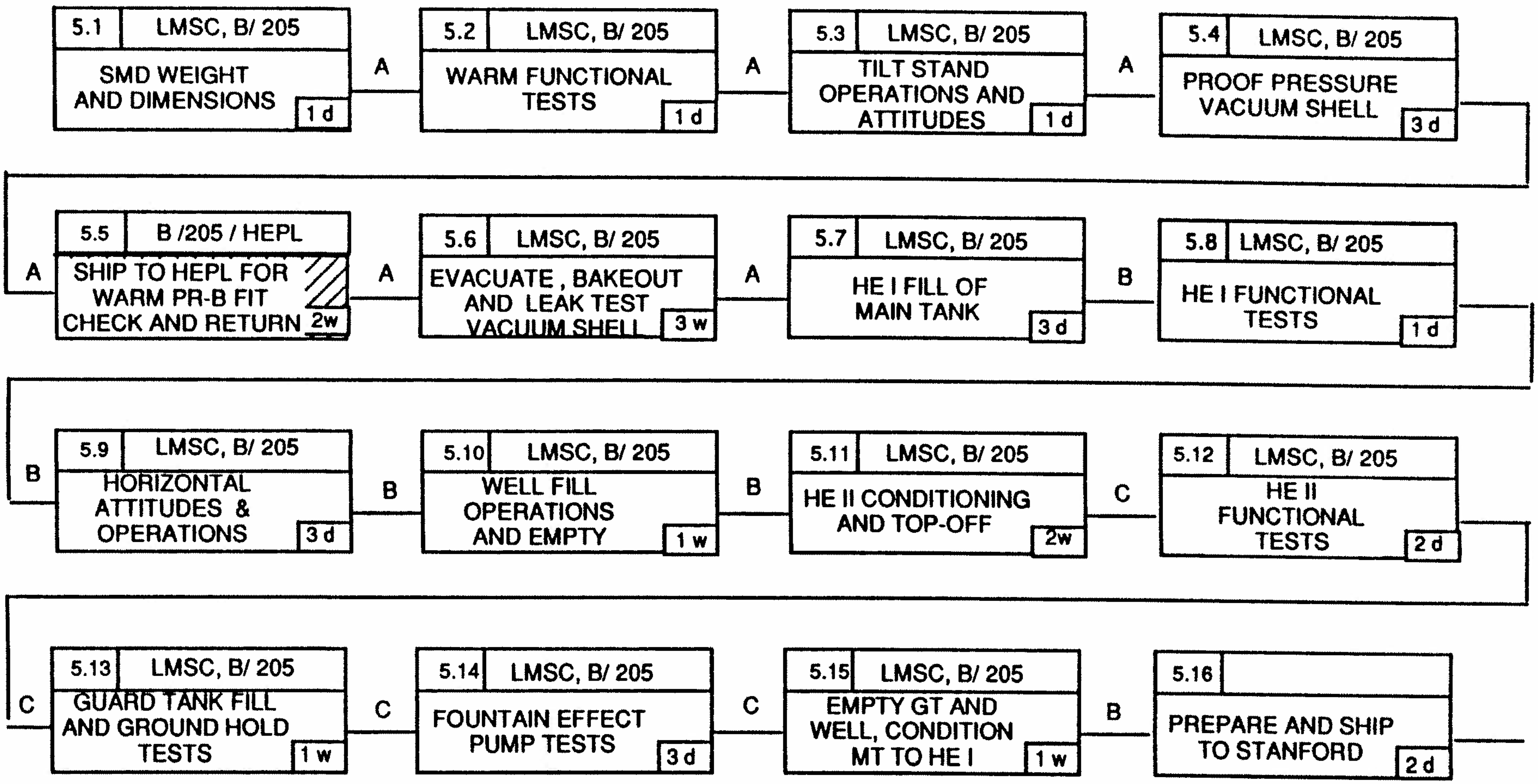
SMD / PROBE-B VIBRATION TEST

- FACILITY IN LMSC B/181 (MSD)
  - 7' BY 7' SLIP TABLE WITH HORIZONTAL SHAKER- 28,000 LB FORCE RATING
  - 54" DIAMETER TABLE WITH VERTICAL SHAKER - REQUIRES ADAPTER PLATE
- PAYLOAD MOUNTED VERTICALLY IN S/C SIMULATOR
- MODAL IDENTIFICATION TESTS PRIOR TO VIBRATION
  - LOW LEVEL SINE SWEEPS OF VARYING AMPLITUDES
  - TANK INTERNALLY INSTRUMENTED WITH 4 TRIAXIAL ACCELEROMETERS
  - PAYLOAD WILL BE TEMPORARILY INSTRUMENTED WITH MANY EXTERNAL ACC
- SIMULATE LAUNCH CONDITIONS
  - SPACECRAFT SIMULATOR WILL INTERFACE WITH SMD AND TABLE
  - MAIN TANK APPROX FULL OF HE II , GUARD TANK TO HAVE APPROX 30 L 0F HE I
  - DUMMY MASSES FOR FORWARD EQUIPMENT SECTION BOXES
  - PROBABLY NO DUMMY MASSES FOR SUNSHADE, AFT EQUIPMENT, SOLAR ARRAYS
  - GYROS CAGED
- VIBRATION IN 3 AXES - LEVELS TBD
- SHAKE WITH VACUUM IN WELL, RETURN TO STANFORD FOR LEAD BAG EVALUATION
  - OBVIATES NEED FOR SHIPPING SUSPENSION, SPINUP AND FLUX FLUSHING GSE
  - IF LEAD BAG GOES NORMAL, BASELINE WILL BE HE II IN WELL AT LAUNCH

SMD SYSTEM TEST FLOW WITHOUT PROBE

VT - 8

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



RESPONSIBILITY CODE:

LMSC P/L | SU W/ P/L SUPPORT | P/L W/ SU SUPPORT

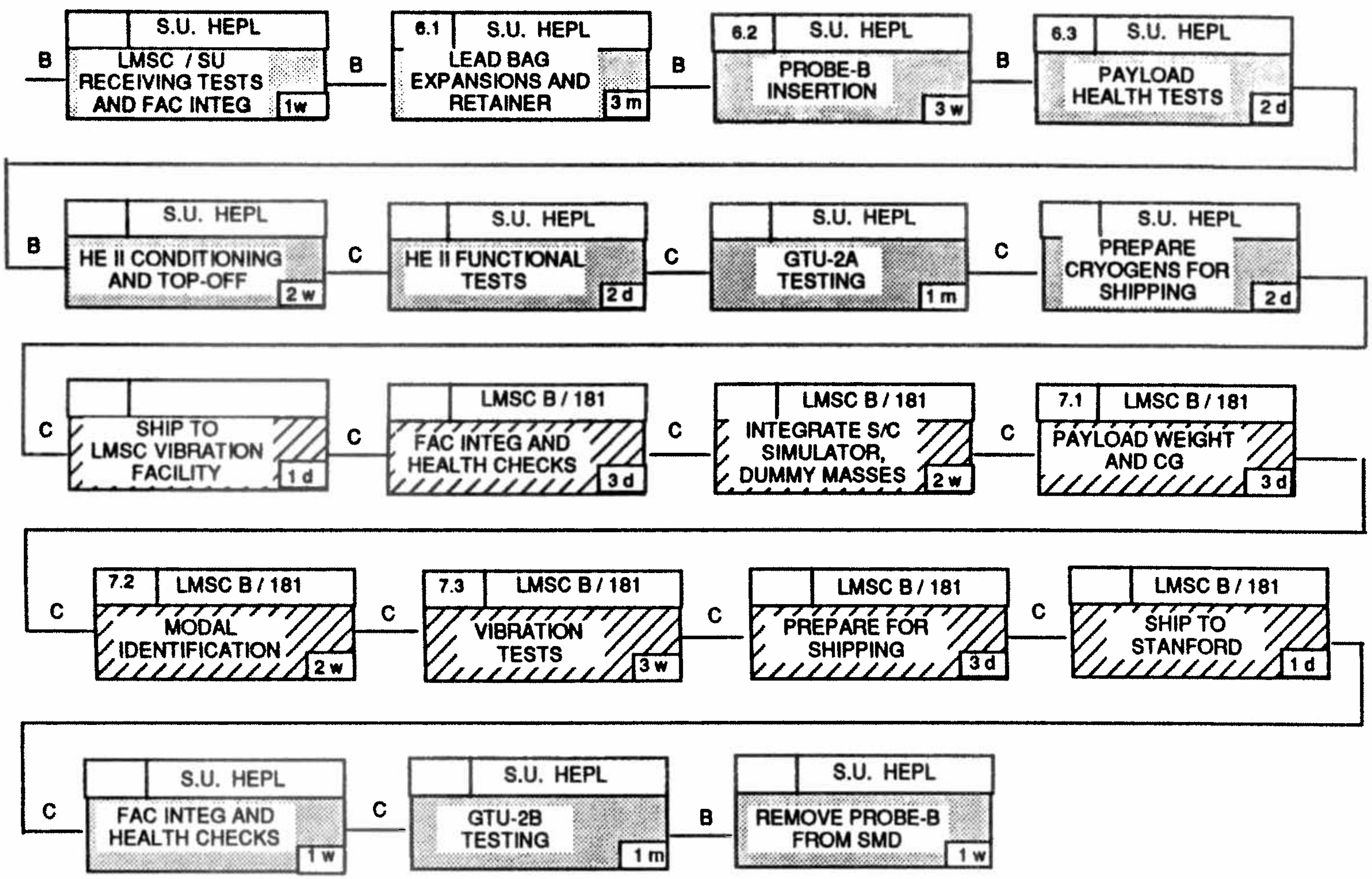
MAIN TANK TEMPERATURE INDICATED IN PATH:
A) AMBIENT TEMP; B) NHe TEMP; C) SFHe TEMP

HEADER NUMBER INDICATES SECTION DESCRIBED IN VERIFICATION PLAN

VT - 9

SMD SYSTEM TEST FLOW WITH PROBE-B

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



RESPONSIBILITY CODE:

SU W/ P/L SUPPORT

P/L W/ SU SUPPORT

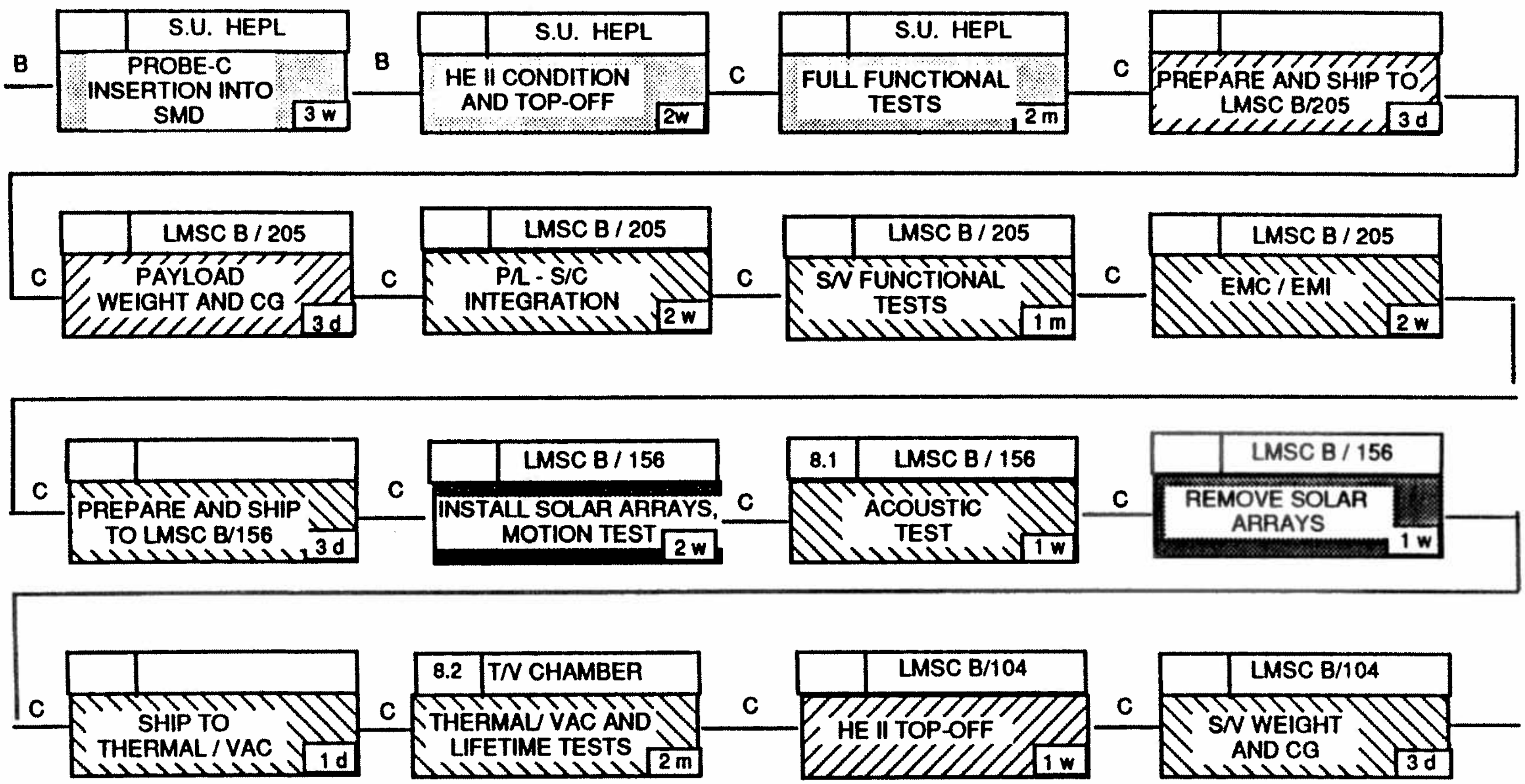
MAIN TANK TEMPERATURE INDICATED IN PATH:
A) AMBIENT TEMP; B) NHe TEMP; C) SFHe TEMP

HEADER NUMBER INDICATES SECTION DESCRIBED IN VERIFICATION PLAN

VT - 10

SMD SYSTEM TEST FLOW WITH PROBE-C (1 OF 2)

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



RESPONSIBILITY CODE:

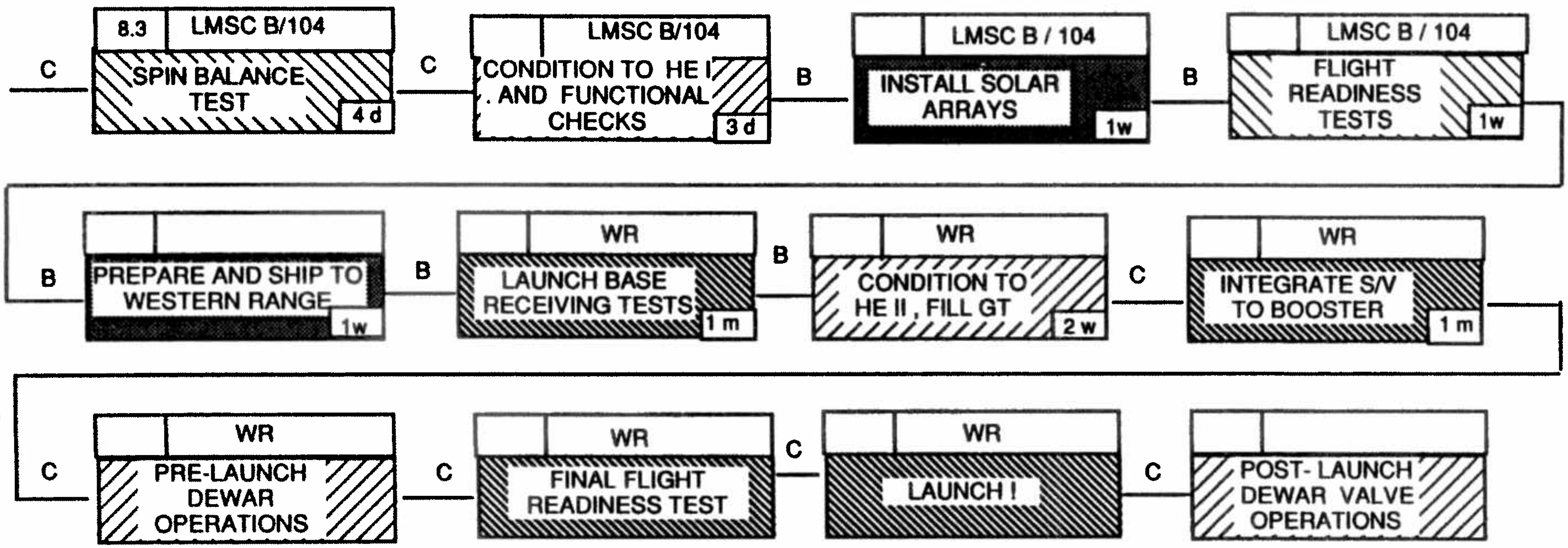
SU W/ PL SUPPORT
PL W/ SU AND S/C SUPPORT
S/C W/ SU AND PL SUPPORT
S/C

MAIN TANK TEMPERATURE INDICATED IN PATH:
A) AMBIENT TEMP; B) NHe TEMP; C) SFHe TEMP

HEADER NUMBER INDICATES SECTION DESCRIBED IN VERIFICATION PLAN

SMD SYSTEM TEST FLOW WITH PROBE-C (2 OF 2)

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94



RESPONSIBILITY CODE:

- PL W/ SU AND S/C SUPPORT
- S/C W/ SU AND PL SUPPORT
- S/C
- LAUNCH BASE W/ S/C,SU, AND LMSC SUPPORT

MAIN TANK TEMPERATURE INDICATED IN PATH:
A) AMBIENT TEMP; B) NHe TEMP; C) SFHe TEMP

HEADER NUMBER INDICATES SECTION DESCRIBED IN VERIFICATION PLAN

DEWAR CONDITIONS DURING ENVIRONMENTAL TESTS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

- HE II IN TANK DURING ACOUSTIC, THERMAL VAC AND SPIN BALANCE
  - LARGER TEMPERATURE GRADIENT PROTECTS LEAD BAG
  - MAIN TANK FULL, GUARD TANK EMPTY FOR THERMAL VAC AND SPIN BALANCE TESTS, 30 L FOR ACOUSTIC TEST
- VENTING OF MAIN TANK
  - VENT THROUGH BAYONET B1 TO VACUUM PUMP DURING ACOUSTIC, THERMAL VAC, AND SPIN BALANCE WAIT PERIODS
    - » ACCESS PORTS REQUIRED IN ACOUSTIC, THERMAL VAC CHAMBERS
  - VENT THROUGH MANUAL VALVE V12 IN VENT MODULE TO THRUSTERS DURING THERMAL VAC TESTS
  - NON-VENTED DURING ACOUSTIC AND SPIN TESTS
- FACILITY VENT LINE FROM MAIN TANK WARM BURST DISCS (BD7A&B) REQUIRED FOR SAFETY
  - ACCESS PORTS REQUIRED IN ACOUSTIC, THERMAL VAC CHAMBERS
  - WILL BE TEMPORARILY DISCONNECTED DURING ACOUSTIC AND SPIN TEST

DEWAR CONDITIONS DURING TRANSPORTATION

- FOR EARLY TRANSPORTATION OF P/L ONLY BETWEEN B/205, STANFORD, AND VIBRATION FACILITY, USE ASSEMBLY STAND WITH P/L IN VERTICAL ORIENTATION
- AFTER S/C INTEGRATION, HORIZONTAL ORIENTATION WITH S/C PROVIDED SHIPPING CONTAINER
  - VENT THROUGH POROUS PLUG BYPASS (RAV3) WITH -X UP
- IN MOST CASES, FOR SHORT TRAVEL BETWEEN PALO ALTO AND SUNNYVALE, TRAVEL WITH HE II IN MAIN TANK TO AVOID TIME CONSUMING HE II CONDITIONING
  - NON VENTED MAIN TANK, WITH PARTIALLY FILLED GUARD TANK
- FOR TRAVEL TO BASE, HE I IN MAIN TANK TO AVOID SUBATMOSPHERIC CONCERNS
  - VENT THROUGH BAYONET B1 THROUGH CHECK VALVE TO ATMOSPHERE

PAYLOAD INTEGRATION & OPERATIONS

JIM GRADY

OP-02

PAYLOAD INTEGRATION & OPERATIONS PLANNING-1

•CLOSE COOPERATION WITH GP-B SPACECRAFT CONTRACTOR

-PAYLOAD & SPACECRAFT PEOPLE CO-LOCATED, BLDG. 253

-GP-B OPERATIONS TEAM:
  -STANFORD AND NASA
  -PAYLOAD CONTRACTOR
  -SPACECRAFT CONTRACTOR

-PAYLOAD AND SPACECRAFT OPERATIONS DOCUMENTS TO BE DEVELOPED AS ONE INTEGRATED SET (OP-01 P/L, MO-01 S/C, ETC.)

-PAYLOAD AND SPACECRAFT INTEGRATION AND OPERATIONS TIMELINE DEVELOPMENT UNDERWAY

•INTERFACE CONTROL WORKING GROUP (ICWG) MEETINGS ON MISSION OPERATIONS AND DATA ANALYSIS (MO&DA)

PAYLOAD INTEGRATION & OPERATIONS PLANNING-2

•ENSURE THAT LESSONS ARE LEARNED FROM OTHER DELTA-II PROGRAMS AND PROGRAMS WITH SIMILAR MISSION REQUIREMENTS

-MSX: POLAR (SUN SYNC), '94 FIRST (?) DELTA-II WTR LAUNCH

-COBE: POLAR (90 DEG), DELTA-I WTR LAUNCH, SFHE DEWAR

-POLAR AND RADARSAT: '94 & '95 NASA DELTA-II WTR LAUNCHES

-IRIDIUM: SIX DELTA-II WTR LAUNCHES IN '96 AND '97

-OTHER PROGRAMS

•PRELIMINARY PAYLOAD OPERATIONS REQUIREMENTS DOCUMENT (OP-01), DRAFT COMPLETED.

-EMPHASIS ON SCIENCE MISSION DEWAR

-UPDATE PLANNED FOR APRIL '94 TO SUPPORT ELECTRONICS RR AND BASELINE UPDATE IN JULY '94 TO SUPPORT PROBE-C PDR

OP-O4

MISSION TIMELINE OVERVIEW-1

STANFORD

Lockheed

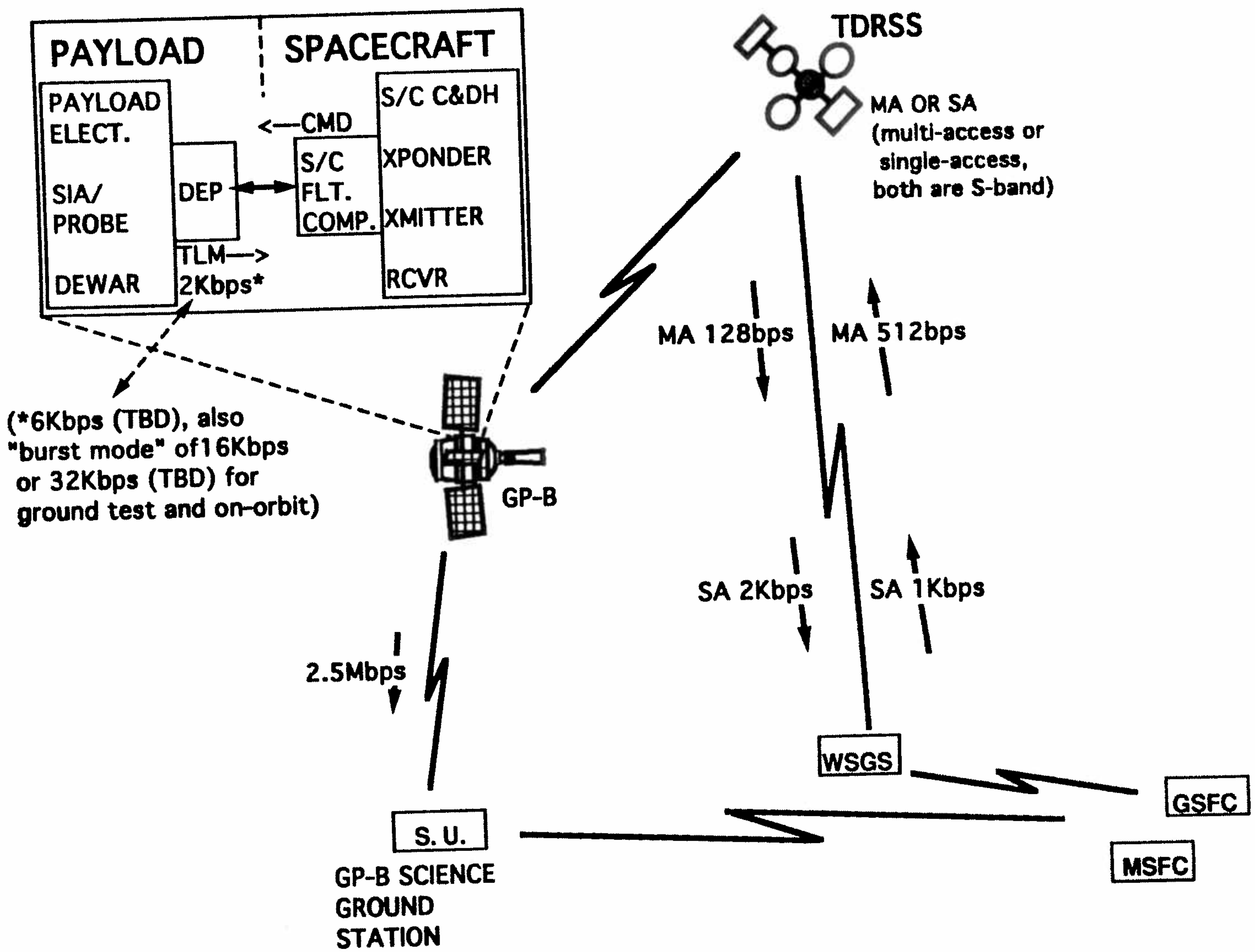
LMSC-P088357
2,3 MAR 94

Seq. no.		(Top Field)	(Bottom Field)	MET (start time)	Units (sec)	MET Time (start time)	Units	Event Duration	Units	Intervention (T, E, U, G, or GA)	Comments
		Launch		0	sec						
1	1	Delta II launch	Main engine ignition	0	sec	0	sec			n/a	(On at Launch: PDU, 10 MHz Clk Xponder Rec. Flight computer SRAM, CDU, GPS (2.2 g's)
		Vent guard tank		0		0		24-60 (from launch)	hours		
2	2	Solid motor ignition (6)		0	sec	0	sec			T - Delta	
3	3	Solid motor burnout (6)		63	sec	63	sec			T - Delta	0.6 g
4	4	Solid motor ignition (3)		66		66	sec			T - Delta	
5	5	Solid motor separation (3)		67		67	sec			T - Delta	*T=SPC time based* *E=SPC Event based*
6	6	Solid motor separation (3)		68		68	sec			T - Delta	*U=Gnd uplink with info* *G=Gnd uplink binary*
7	7	Solid motor burnout (3)		133		133	sec			T - Delta	*GA=Ground Analysis*
8	8	MECO (M)		265		265	sec			T - Delta	6.3 g's
9	9	Blow I/II separation bolts		273		273	sec			T - Delta	
10	10	Stage II ignition		278		278	sec			T - Delta	
11	11	Fairing	Separation	302	sec	302	sec			T - Delta	
12	12	Discrete to GPS rec.	(Data to Delta)	302		302	sec			E - fairing sep	
13	13	Turn on TU, SSR, and Computer		303	sec	303	sec			E - fairing sep	H & S to Recorder
14	14	Fire pyro valves 4A & 4B: allows tank to start venting through porous plug		305	sec	305	sec			E - fairing sep	4A and 4B provide He to spacecraft interface for ACS
15	15	Telemetry to SSR and COMM		310	sec	310	sec			T	
16	16	Establish TDRSS	Telemetry & Tracking	310	sec	310	sec			T	
17	17	GPS initialized (Check on time)		332	sec	332	sec			T	
18	18	SECO (S1)		620	sec	10.3	min			T - Delta	0.8 g

MISSION TIMELINE OVERVIEW-2

Seq. no.		(Top Field)	(Bottom Field)	MET (start time)	Units (sec)	MET Time (start time)	Units	Event Duration	Units	Intervention (T, E, U, G, or GA)	Comments
19	19	Stage II engine restart		3520	sec	58.7	min			T - Delta	
20	20	SECO (S2)		3576	sec	59.6	min			T - Delta	0.8 g
21	21	Turn on SV equipment		3600	sec	1.0	hours			T	
22	22	Flight computer begins ATC sensor processing (Control gyros, star trackers,and magnetometer)		3610	sec	1.0	hours			T	
23	23	Turn on DEP and Payload Electronics		3620	sec	1.0	hours			G ??	
24	24	Delta II spin up to 0.1 rpm		4000	sec	1.1	hours	TBD MDAC			
25	25	Delta cold gas orbit trim			sec		hours	TBD MDAC		T	
26	26	Deploy Arrays when at 0.1 rpm		5500	sec	1.5	hours	300.00	sec	E	
27	27	First Contact With Snapshot data dump	S.U. Ground Station to SGS using forward omni	5610	sec	1.6	hours	5	min	T	Low el. west side pass, N to S. Availability is being evaluated
28	28	Orient 2nd Stage at	Guide star (MDAC)	5800	sec	1.6	hours	8.40	min	E - arrays out	
29	29	Separate from 2nd stage		6000	sec	1.7	hours	12.00	sec	T - Delta	
30	30	Flight computer begins attitude commands		6012		1.7	hours				
31	31	Rate Capture		6012	sec	1.7	hours	2.00	hours	G	
32	32	Health and Status	Check if TDRS SA avail	13000	sec	3.6	hours	(continuing as req.)			
33	33	Three axis star processing		13212	sec	3.7	hours				
34	1	Initiate Pressure	Control @ TBD Torr	13300	sec	3.7	hours			U- pressure set point	
35	2	2nd SGS pass	(dump SSR)	39000	sec	10.8	hours	8	min		
36	2	3rd SGS pass	(dump SSR)	45000	sec	12.5	hours	10	min		

GP-B SCIENCE MISSION OPERATIONS CONCEPTUAL OVERVIEW



SMD ASCENT AND EARLY ORBIT OPERATIONS

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

PRELIMINARY TIMELINE

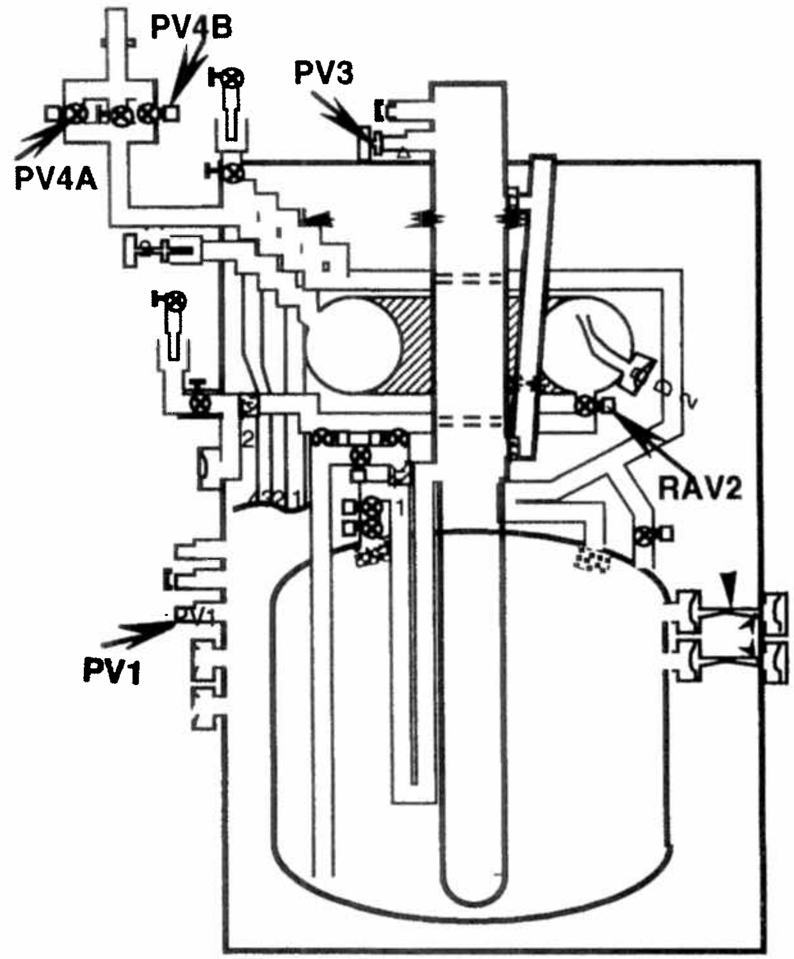
L+302 SEC.: JETTISON DELTA-II FAIRING

L+305 SEC.: FIRE PYRO VALVES 4A & 4B
(VENT MAIN TANK)

L+7 DAYS*: FIRE PV1
(VENT VACUUM SHELL)
FIRE PV3
(VENT WELL)
OPEN RAV2
(VENT FILL LINE)

*7 DAYS TO ALLOW FOR OUTGASSING AND OTHER ON-ORBIT PROCESSING

(SMD HEATH AND STATUS CHECKS ON A CONTINUAL BASIS DURING EARLY ORBIT)

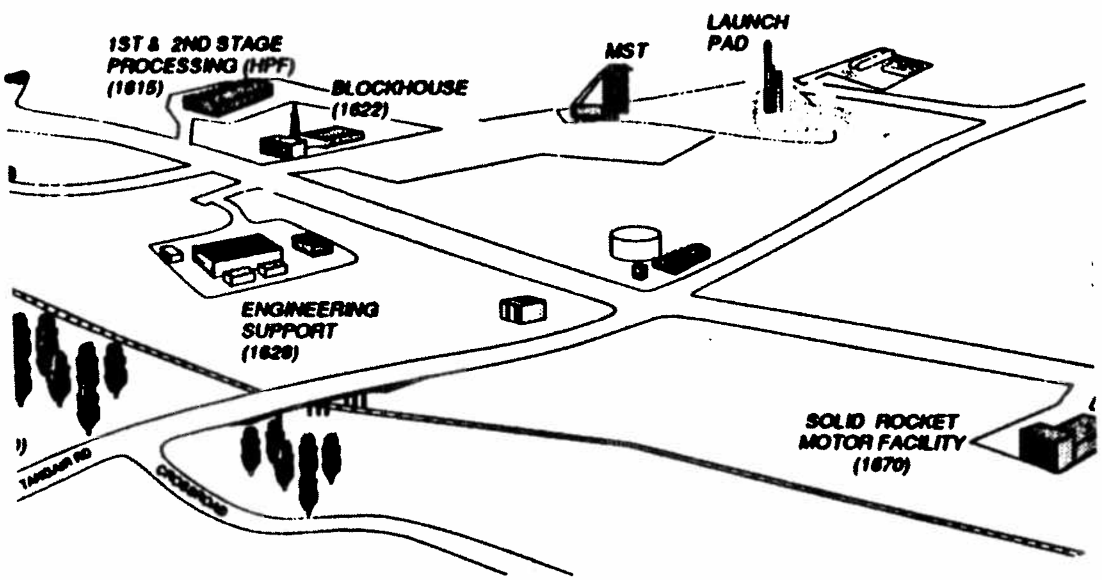


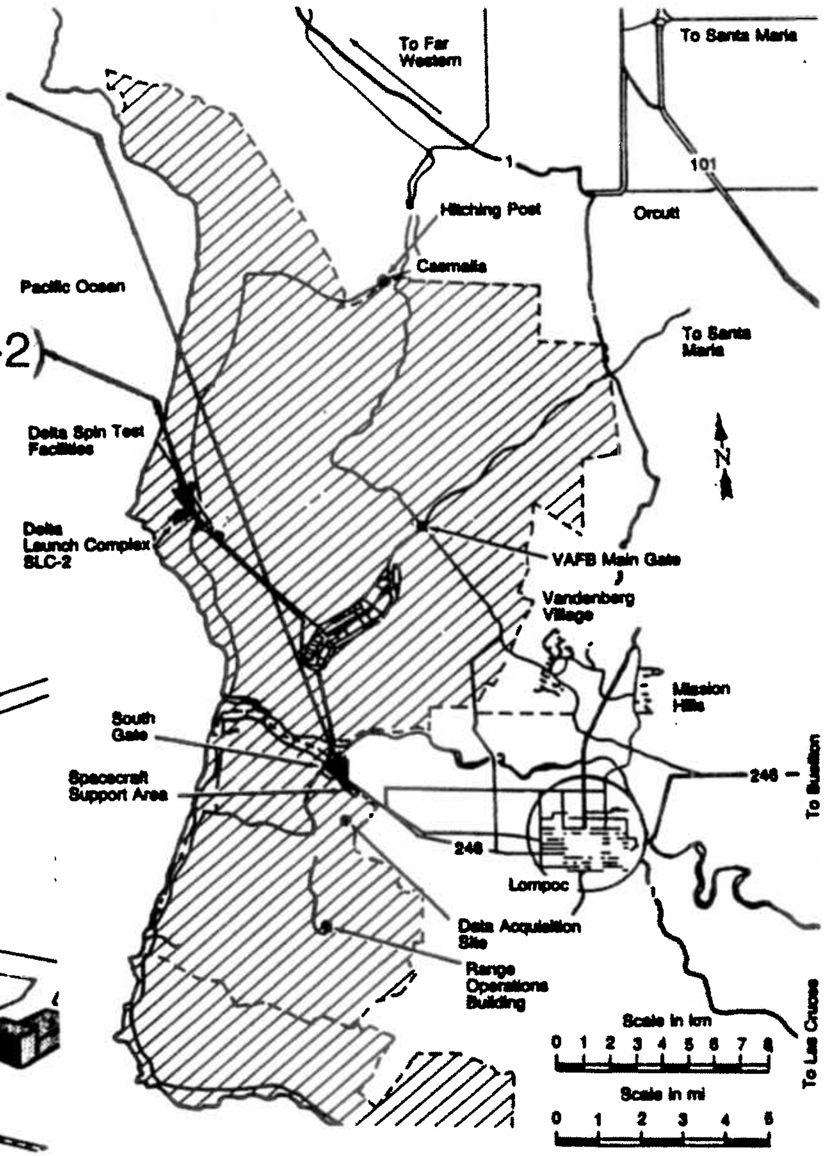
LAUNCH SITE OPERATIONS-1

STANFORD
Lockheed

LMSC-P088357
2,3 MAR 94

- TWO STOPS FOR GP-B AT VAFB
  - -(1) SPACECRAFT LAB. (BUILDING 836)
    - -POST SHIPMENT AND OTHER INTEGRATED VEHICLE TESTS
    - -CONDITION SMD TO HELIUM-II
  - -(2) SPACE LAUNCH COMPLEX-2 (SLC-2)
    - -INTEGRATION WITH DELTA-II
    - -UMBILICAL INTERFACES





STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

LAUNCH SITE OPERATIONS-2

OP-O9

•SLC-2 LAUNCH PAD OPERATIONS

-LEVEL-6 WHITE ROOM OPS
-DELTA-II INTEGRATION

-SERVICE GUARD TANK

-PAYLOAD C/O AND SERVICING, AS REQ.

-UMBILICAL INTERFACES
-66 WIRES FOR DEWAR I/F

-CONTROL OF HEATERS AND VALVES, AND MONITOR SENSORS

-TBD EXPENDABLE GSE LOCATED AT FIXED UMBILICAL TOWER (FUT)