[redacted]

N72-12777
(NASA-CR-124626) SHUTTLE CRYOGENIC SUPPLY SYSTEM OPTIMIZATION STUDY Interim Presentation (Lockheed Missiles and Space Co.) 30 Sep. 1971 179 p
CSCL 21I
G3/27
(CATEGORY)
Unclas
09395

Lockheed

MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

LMSC-A995668

SHUTTLE CRYOGENIC SUPPLY SYSTEM
OPTIMIZATION STUDY
INTERIM PRESENTATION

30 September 1971

NAS 9-11330

LOCKHEED MISSILES & SPACE COMPANY

MSP

SHUTTLE CRYOGENIC SUPPLY SYSTEM

OPTIMIZATION STUDY

NAS 9-11330

PRESENTATION COMPOSITION

- PROGRAM SUMMARY
- MAJOR CONCLUSIONS
- RESULTS OF EVALUATIONS OF SUBSYSTEMS
- RESULTS OF INTEGRATED SYSTEMS EVALUATIONS
- COMPONENT EVALUATIONS RESULTS
- TECHNOLOGY EVALUATIONS SUMMARY

SHUTTLE ORBITER CRYOGENIC SUPPLY SYSTEMS

- LIFE SUPPORT SUPPLY SYSTEM
  (INCLUDING ENVIRONMENTAL CONTROL ASPECTS)

- POWER GENERATION

  - FUEL CELL SUPPLY SYSTEM
  - AUXILIARY POWER UNIT SUPPLY SYSTEM

- PROPELLANT SUPPLY

  - ORBIT INJECTION PROPULSION (ASCENT)
  - ORBIT MANEUVER PROPULSION
  - ATTITUDE CONTROL PROPULSION
  - AIRBREATHING PROPULSION (INERTING ONLY)
  - PURGING, INERTING, AND PNEUMATIC

PROGRAM OBJECTIVE

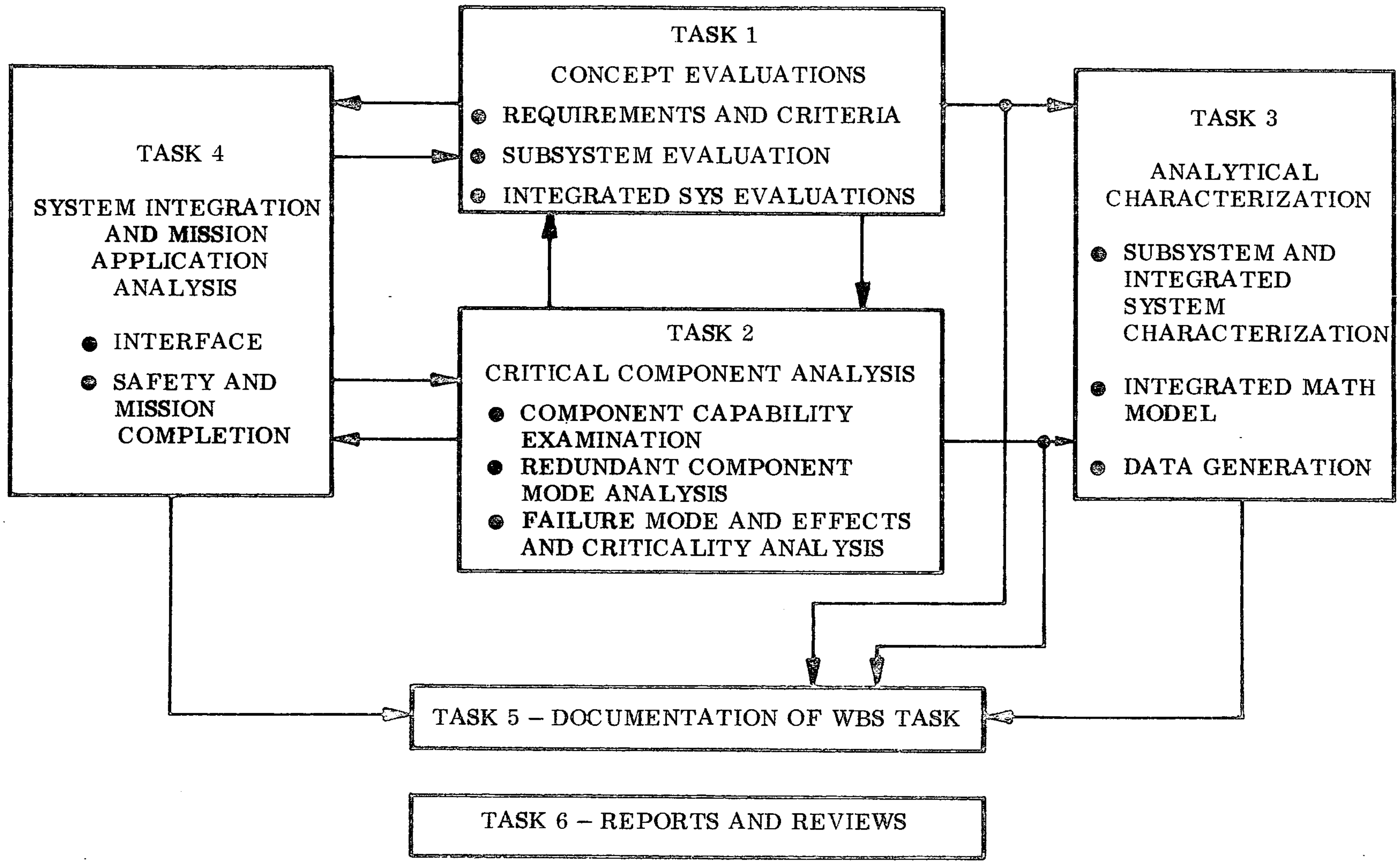
OBJECTIVE:

TO PROVIDE SUFFICIENT INFORMATION AND RECOMMENDATIONS TO ALLOW NASA TO SELECT SPACE SHUTTLE CRYOGENIC SUPPLY SYSTEMS

MAJOR OUTPUTS:

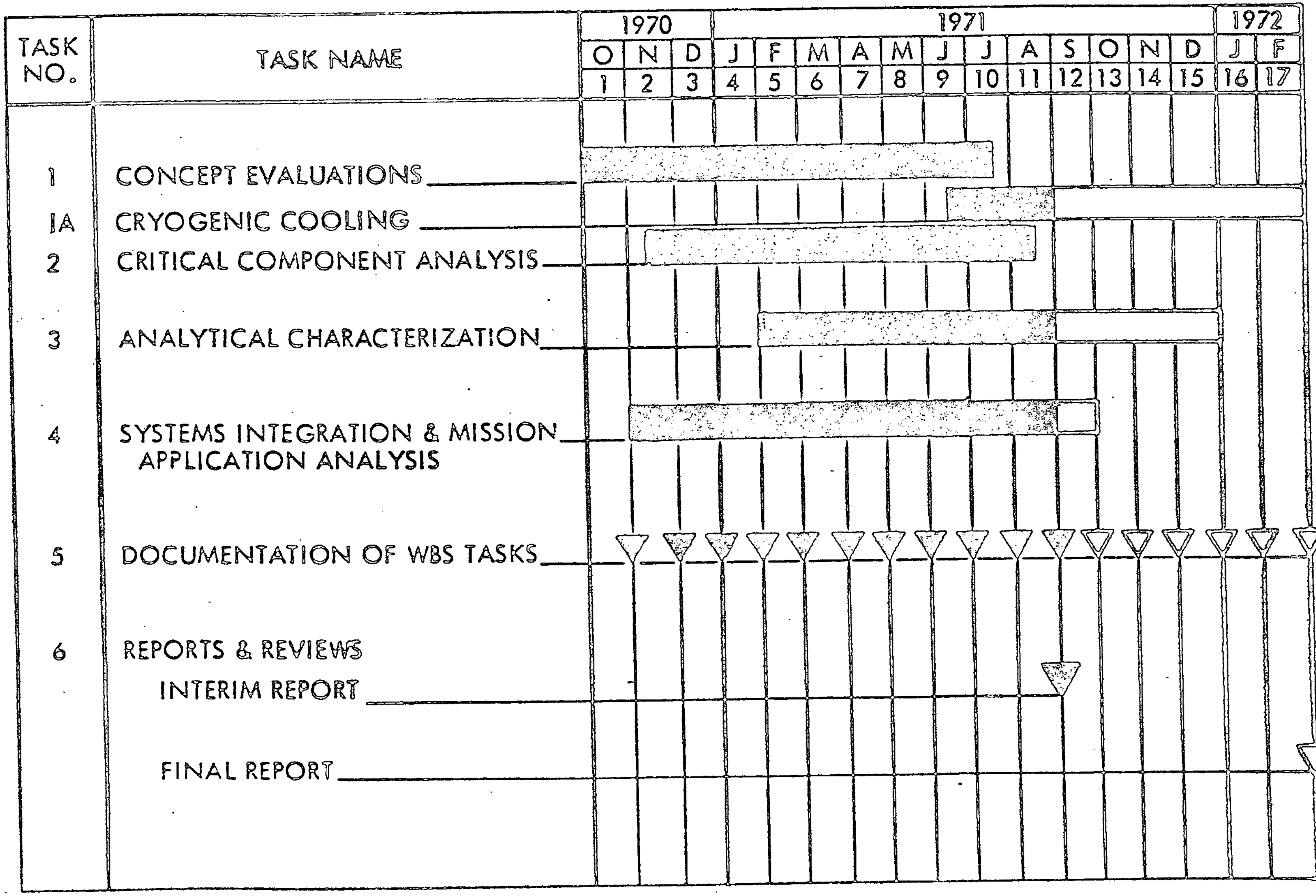
- EVALUATIONS OF CONCEPTS
- SUFFICIENT INFORMATION TO ALLOW SELECTION OF REPRESENTATIVE DESIGNS
- DOCUMENTATION AND DATA BANKS OF CRYOGENIC SUPPLY SYSTEM RELATED DATA AND INFORMATION
- DEVELOPMENT OF AN INTEGRATED MATH MODEL FOR SUPPORT OF HARDWARE PROGRAMS (COMPUTER PROGRAMS WITH REFERENCE DESIGN PARAMETRIC DATA)
- PARAMETRIC DATA AND SENSITIVITY STUDIES
- EVALUATION OF RELATED TECHNOLOGY STATUS

TASK RELATIONSHIPS



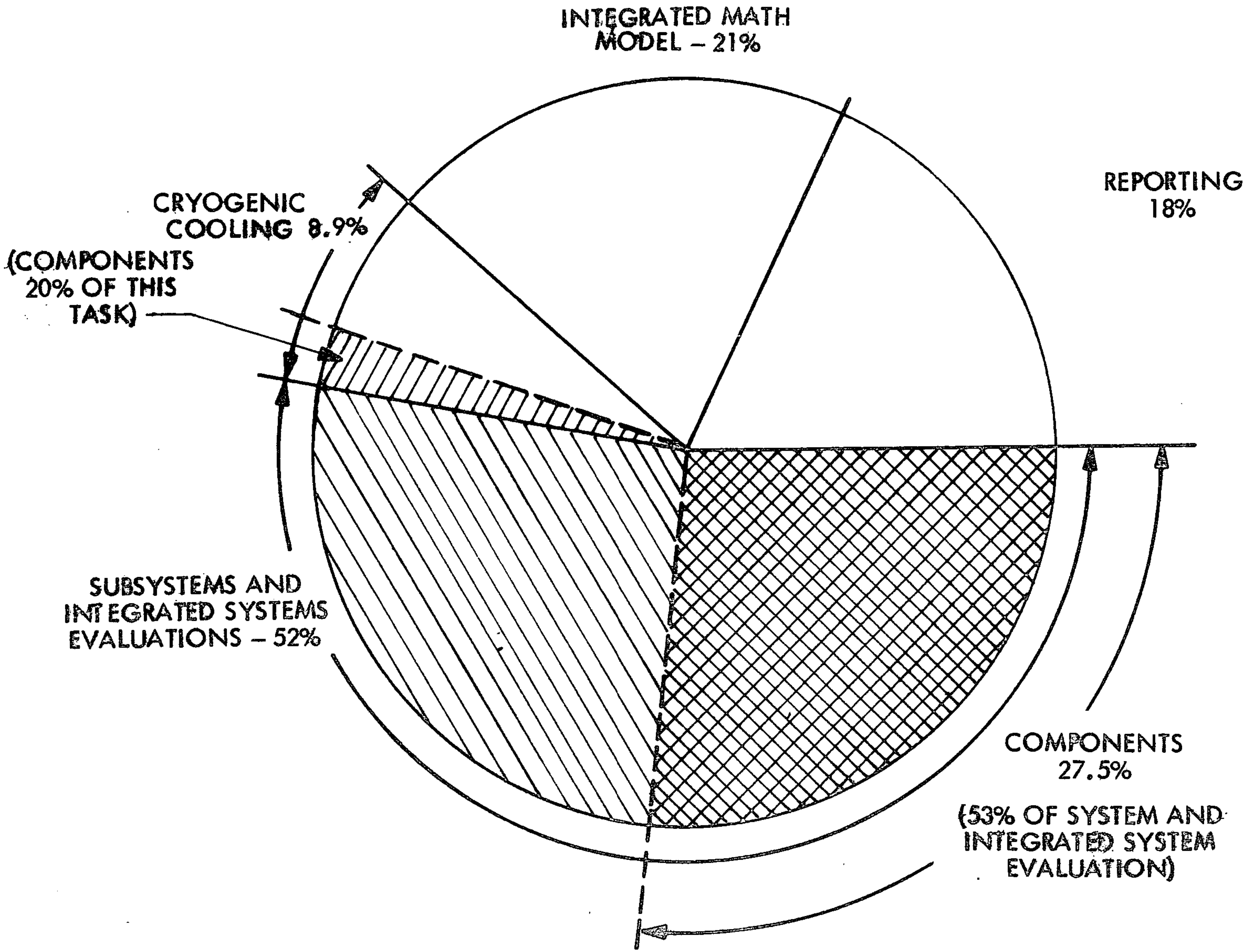
CSS

PROGRAM SCHEDULE

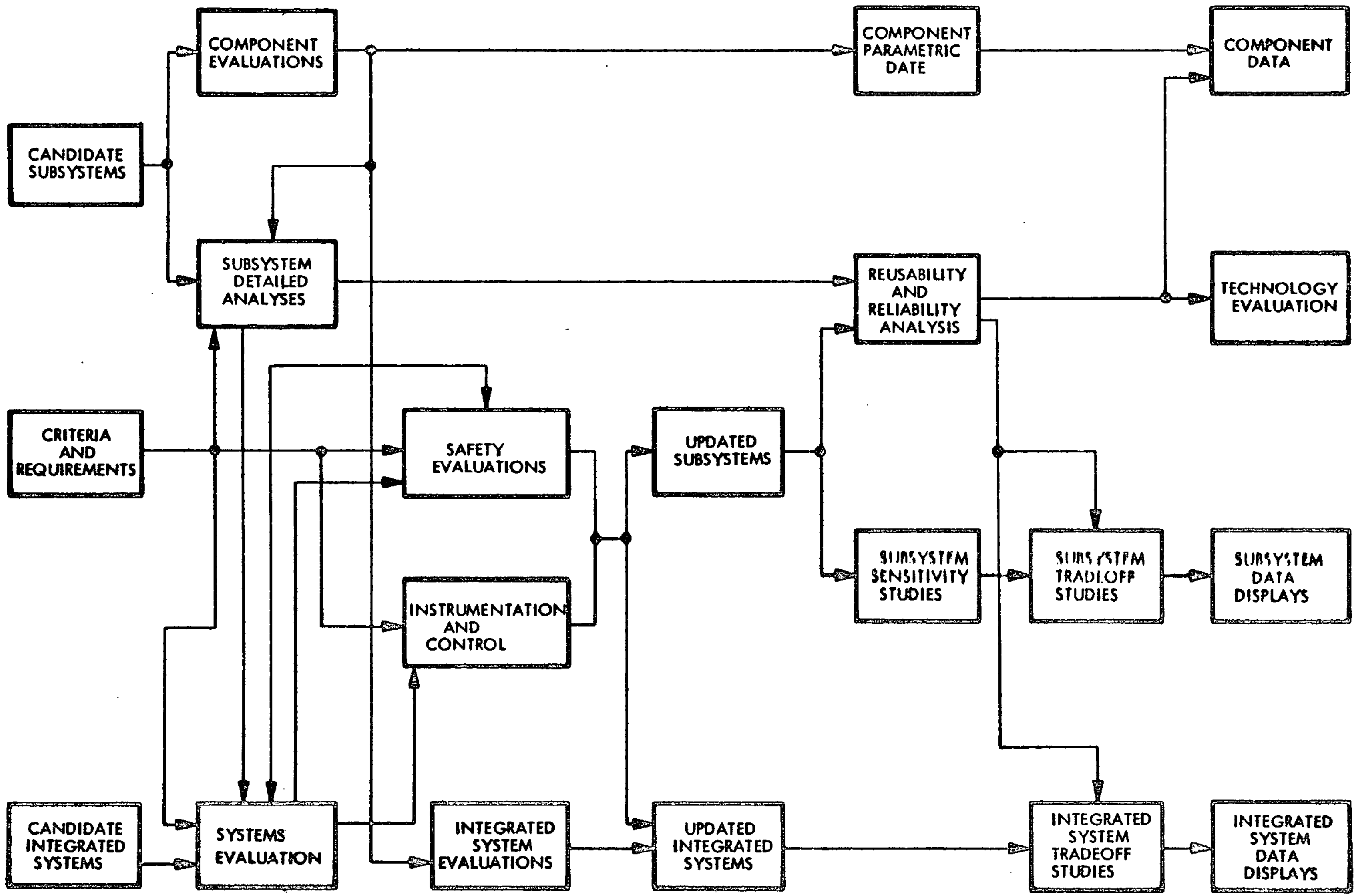


D03403
llm

APPROXIMATE STUDY EXPENDITURE BREAKDOWN



OVERALL APPROACH TO CONCEPT EVALUATIONS



D04901

llm

MAJOR STUDY CONCLUSIONS

- OPTIMIUM INTEGRATED SYSTEMS TEND TOWARDS MAXIMIZING LIQUID STORAGE
- VACUUM JACKETING OF TANKS IS A MAJOR EFFECT ON INTEGRATED SYSTEMS
- SUBCRITICAL STORAGE ADVANTAGES OVER SUPERCRITICAL STORAGE DECREASES AS THE QUANTITY OF PROPELLANT OR REACTANT DECREASES
- SHUTTLE DUTY CYCLES ARE NOT SEVERE
- OPERATIONAL MODE HAS A SIGNIFICANT EFFECT ON RELIABILITY
- COMPONENTS ARE AVAILABLE FOR MOST SUBSYSTEM APPLICATIONS
- SUBSYSTEMS AND COMPONENTS REQUIRE A MINIMUM AMOUNT OF TECHNOLOGY DEVELOPMENT

LOCKHEED

APPLICABILITY TO CURRENT SHUTTLE CONCEPTS

CRYOGENIC RELATED SUBSYSTEMS FOR CURRENT SHUTTLE CONCEPT:

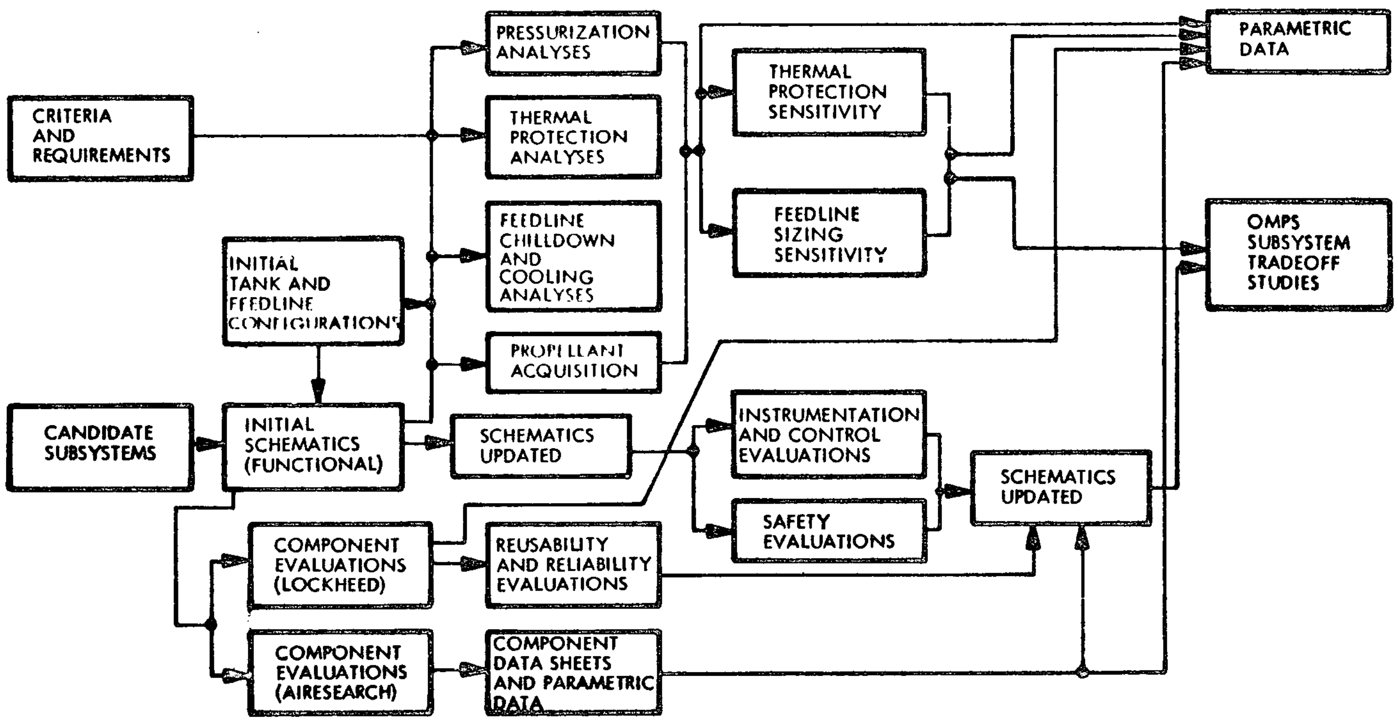
- ORBIT INJECTION SUPPLY
- FUEL CELL SUPPLY
- LIFE SUPPORT SUPPLY
- PURGING, INERTING, AND PNEUMATIC SUPPLY
- CRYOGENIC COOLING (IF IMPLEMENTED)
- CRYOGENIC HELIUM PRESSURIZATION SUPPLY FOR STORABLES

D04925

ORBIT MANEUVERING

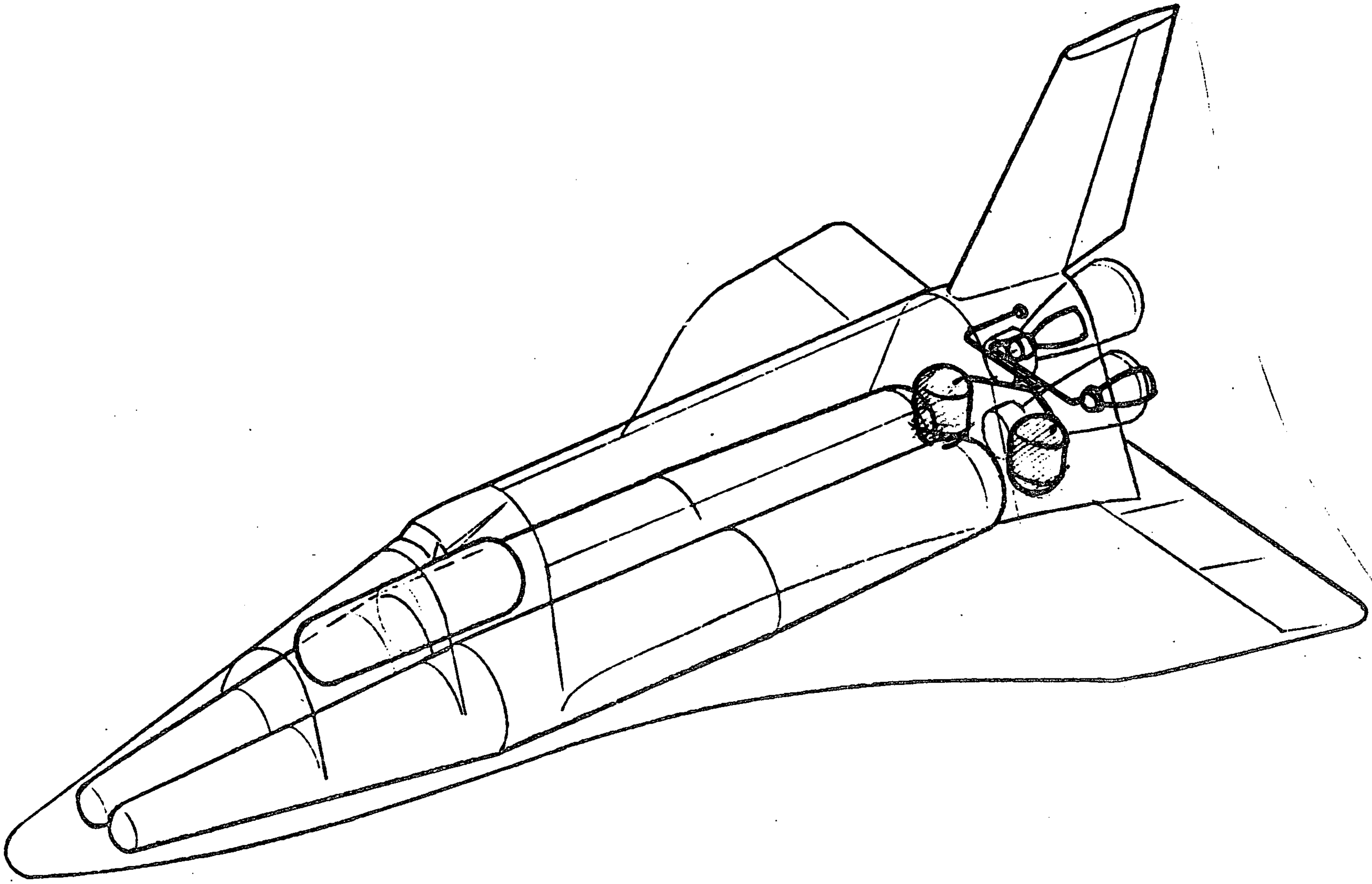
PROPELLANT SUPPLY

APPROACH TO ORBIT MANEUVERING PROPELLANT SUPPLY EVALUATIONS (NONINTEGRATED)



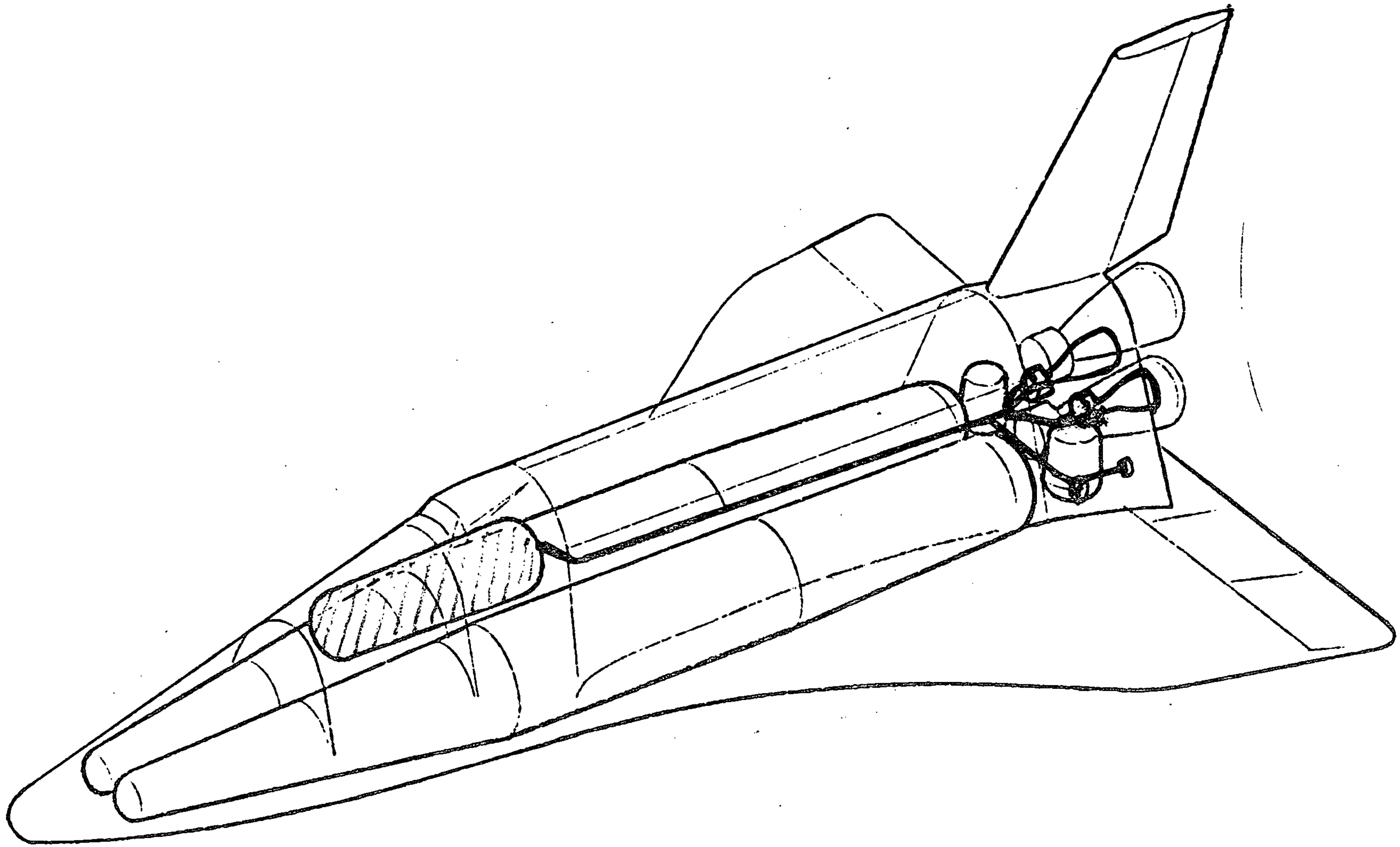
D04902

ORBIT MANEUVERING SUPPLY LO_2 FEED/FILL
MCDONNELL-DOUGLAS ORBITER



D02614
11m

ORBIT MANEUVERING SUPPLY LH_2 FEED/FILL
MCDONNELL-DOUGLAS ORBITER

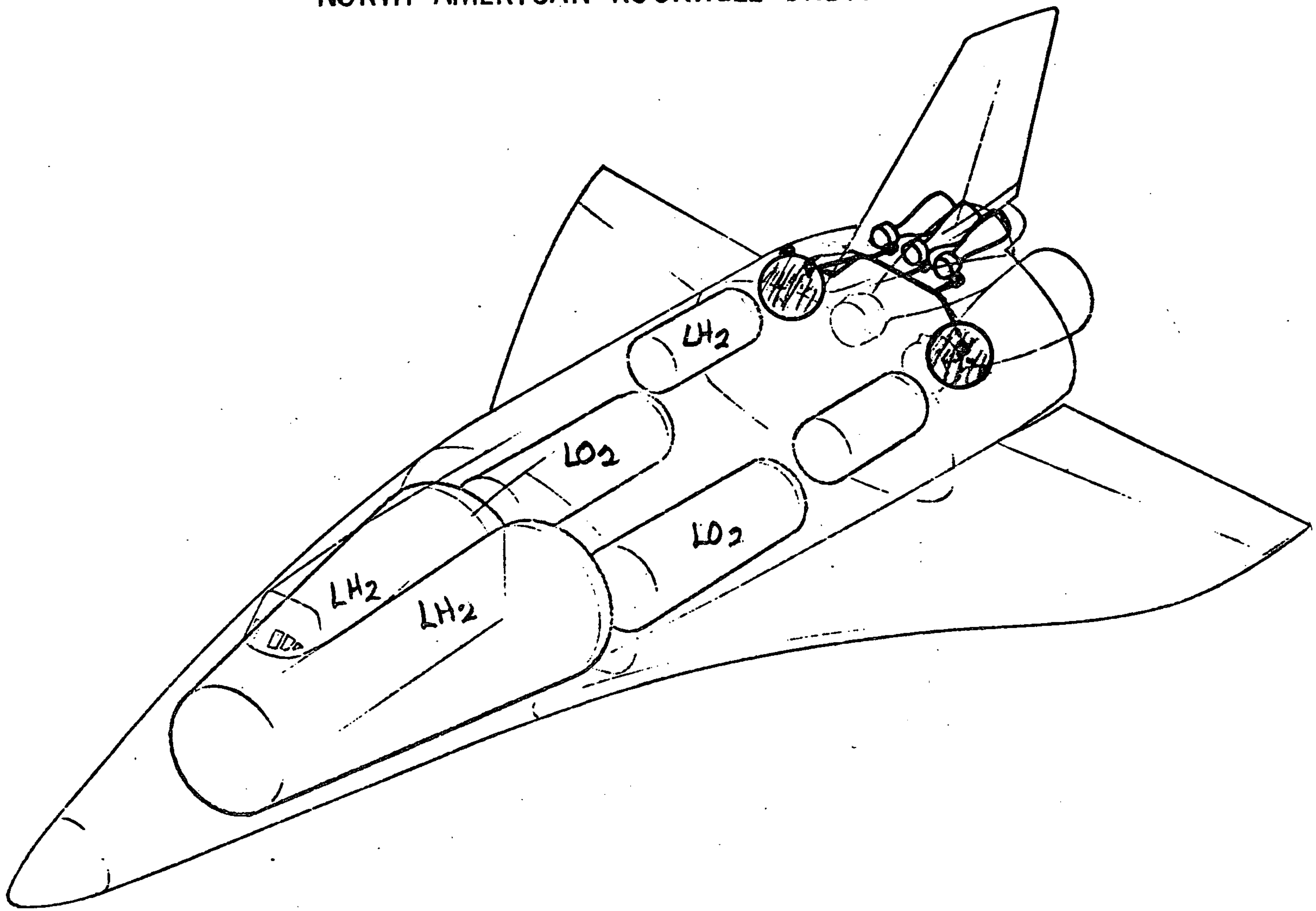


D02615
llm

LOCKHEED

ORBIT MANEUVERING SUPPLY LO_2 FEED/FILL

NORTH AMERICAN ROCKWELL ORBITER



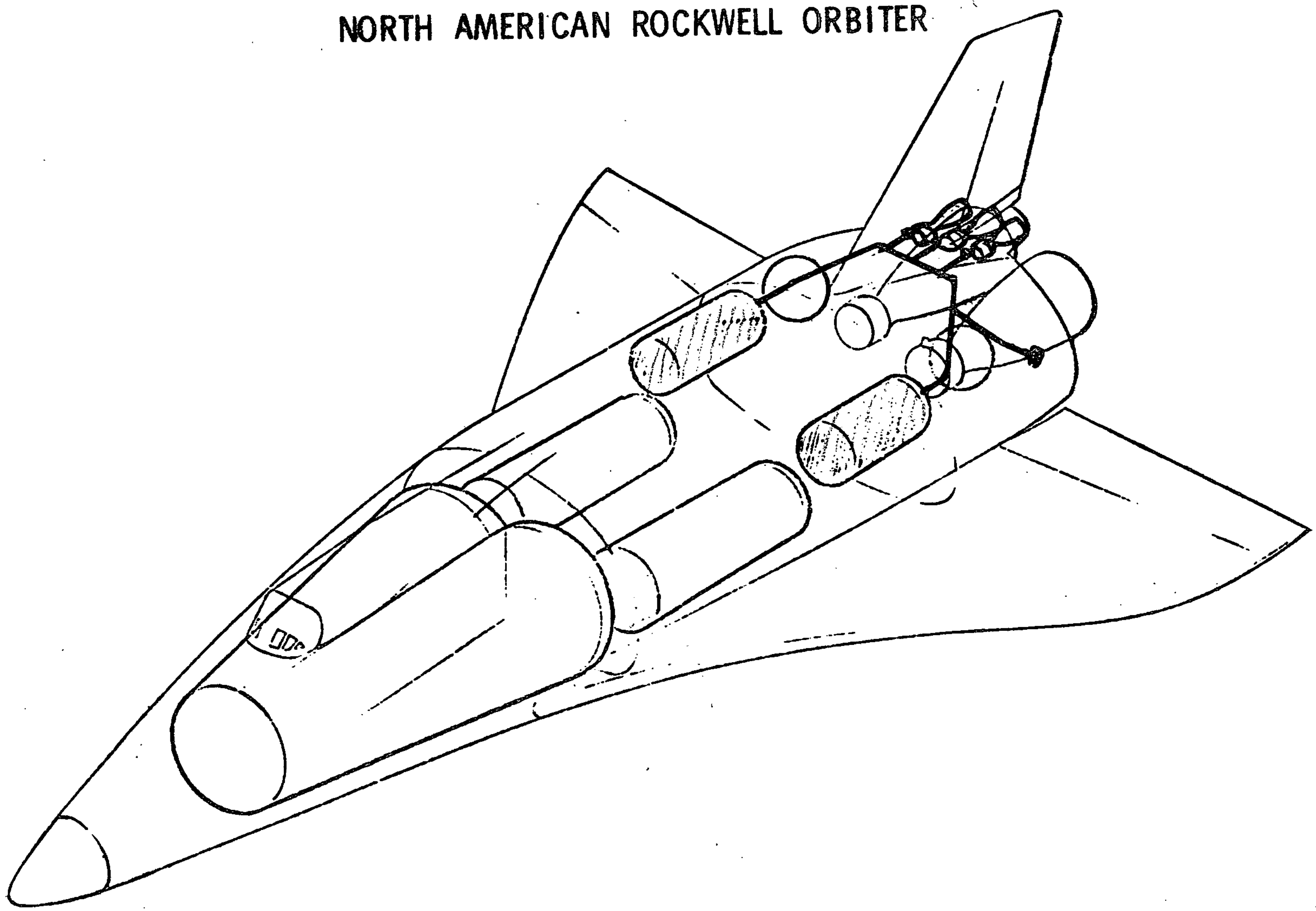
D02629

llm

LOCKHEED

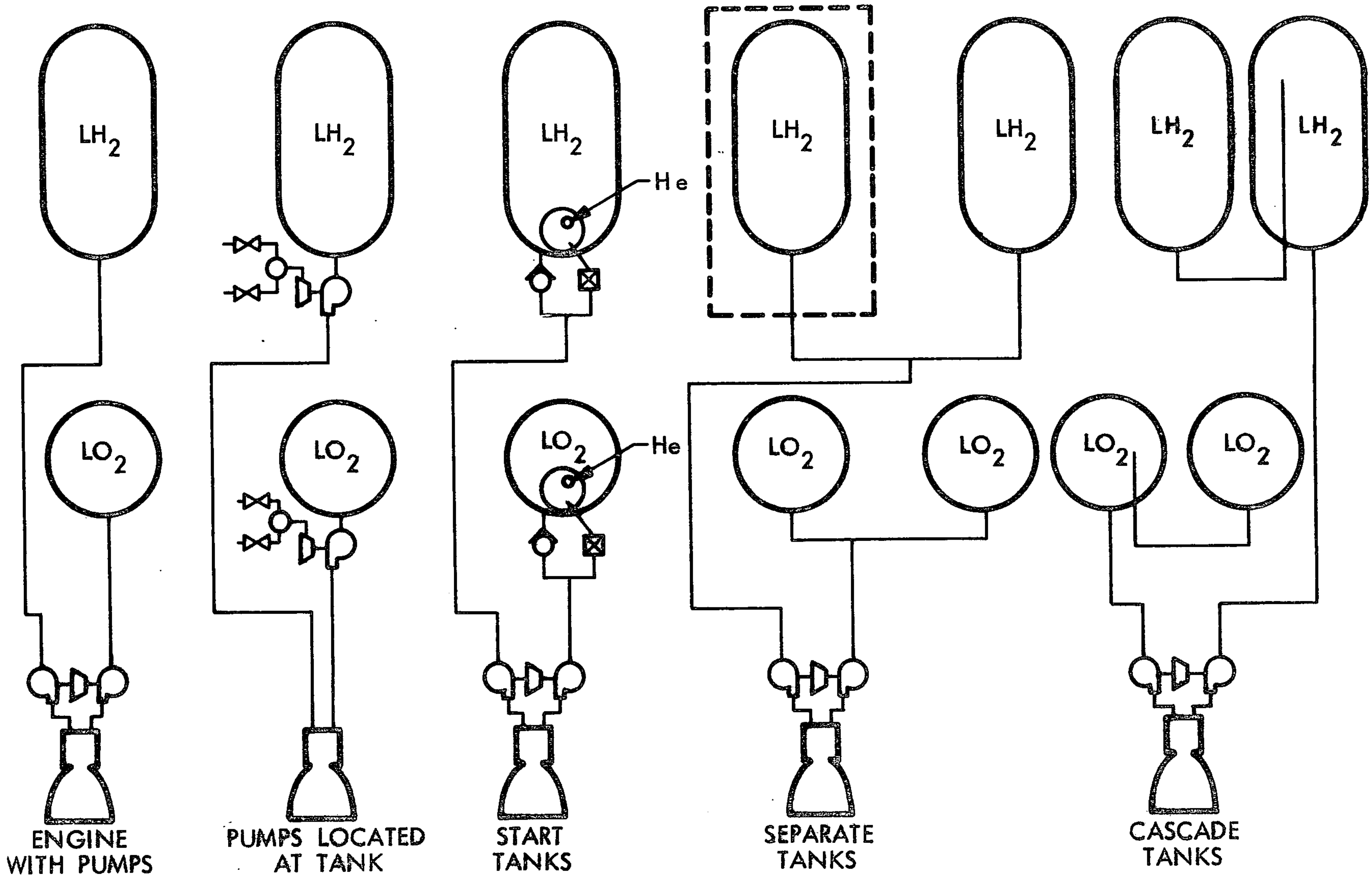
ORBIT MANEUVERING SUPPLY LH_2 FEED/FILL

NORTH AMERICAN ROCKWELL ORBITER



D02630
llm

OMPS FEED SYSTEM CONFIGURATION

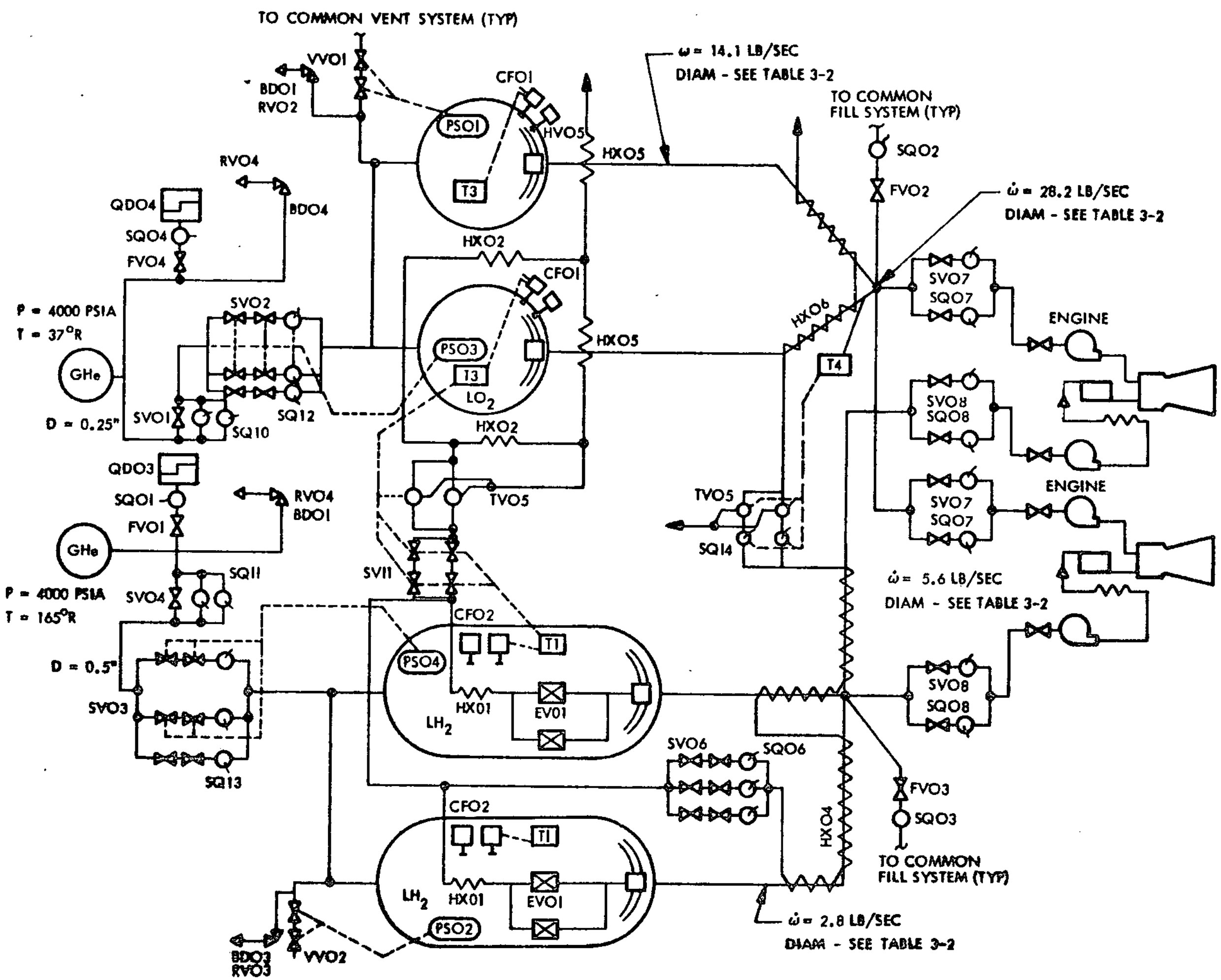


D02959(1)
llm

ORBIT MANEUVERING PROPULSION SUPPLY

GHe PRESSURIZATION - DUAL TANKS

PUMP AT ENGINE - (ONE PROPELLANT LOSS)



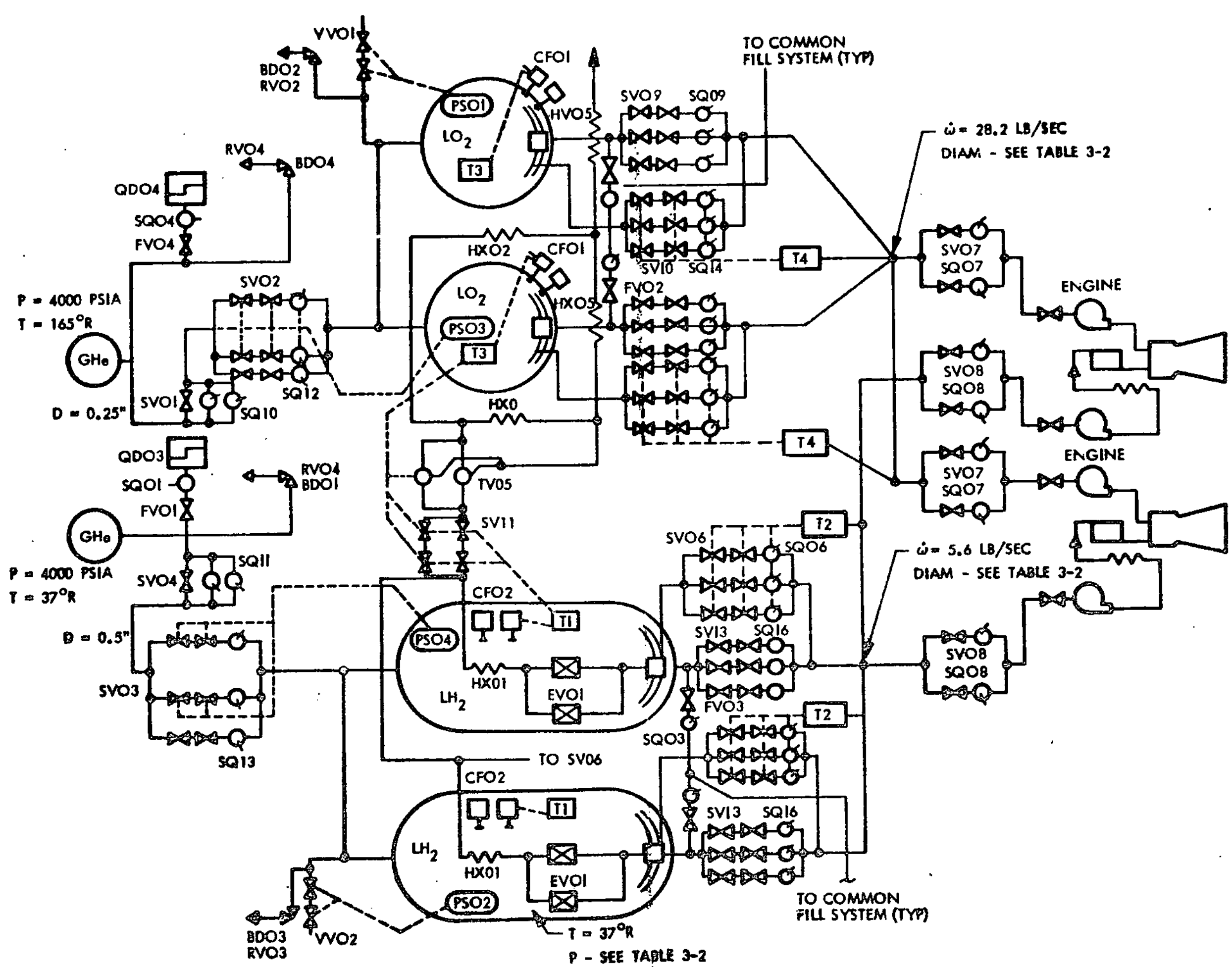
D03750

llm

ORBIT MANEUVERING PROPULSION SUPPLY

GHe PRESSURIZATION - DUAL TANKS

PUMP AT ENGINE (5 AND 12 PROPELLANT LOSSES)



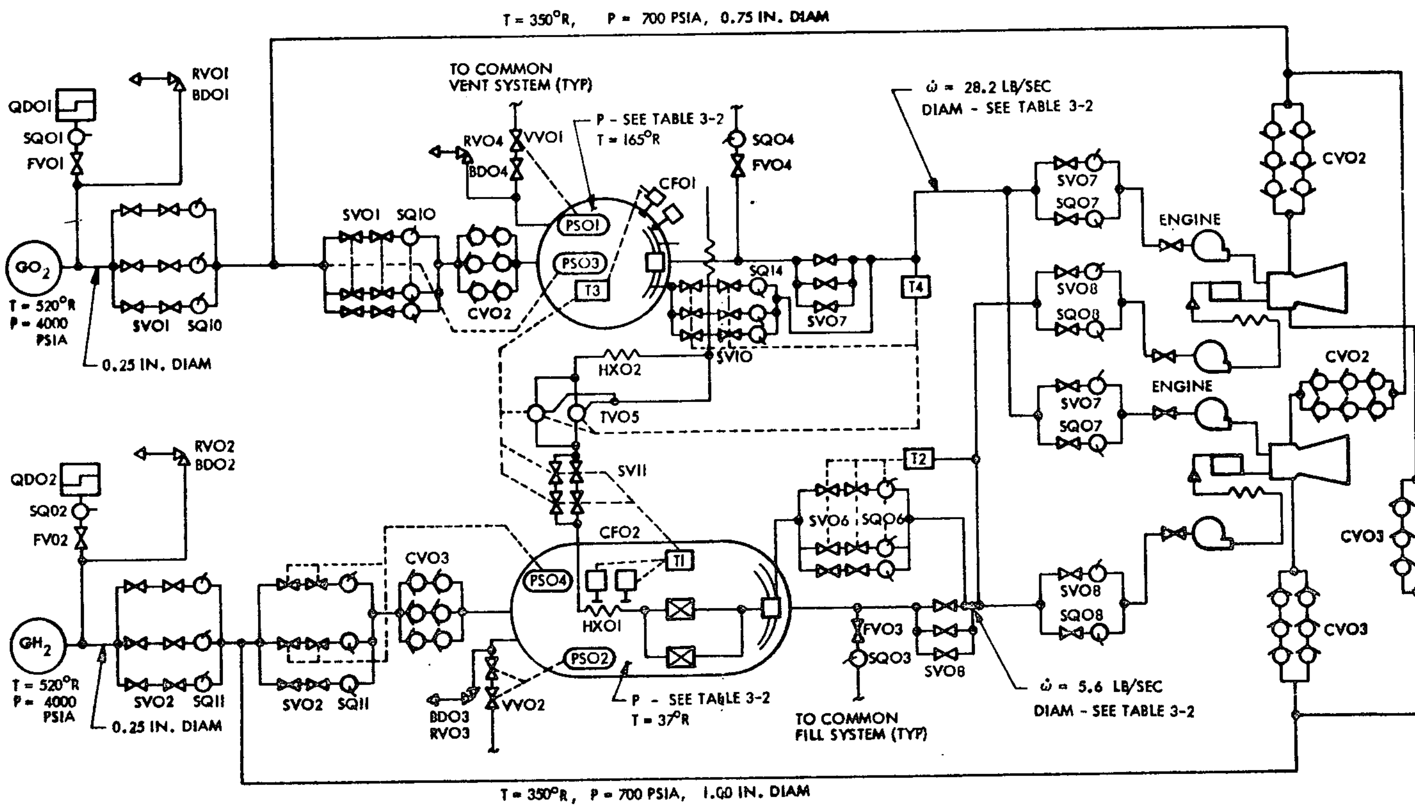
D03782

llm

ORBIT MANEUVERING PROPULSION SUPPLY

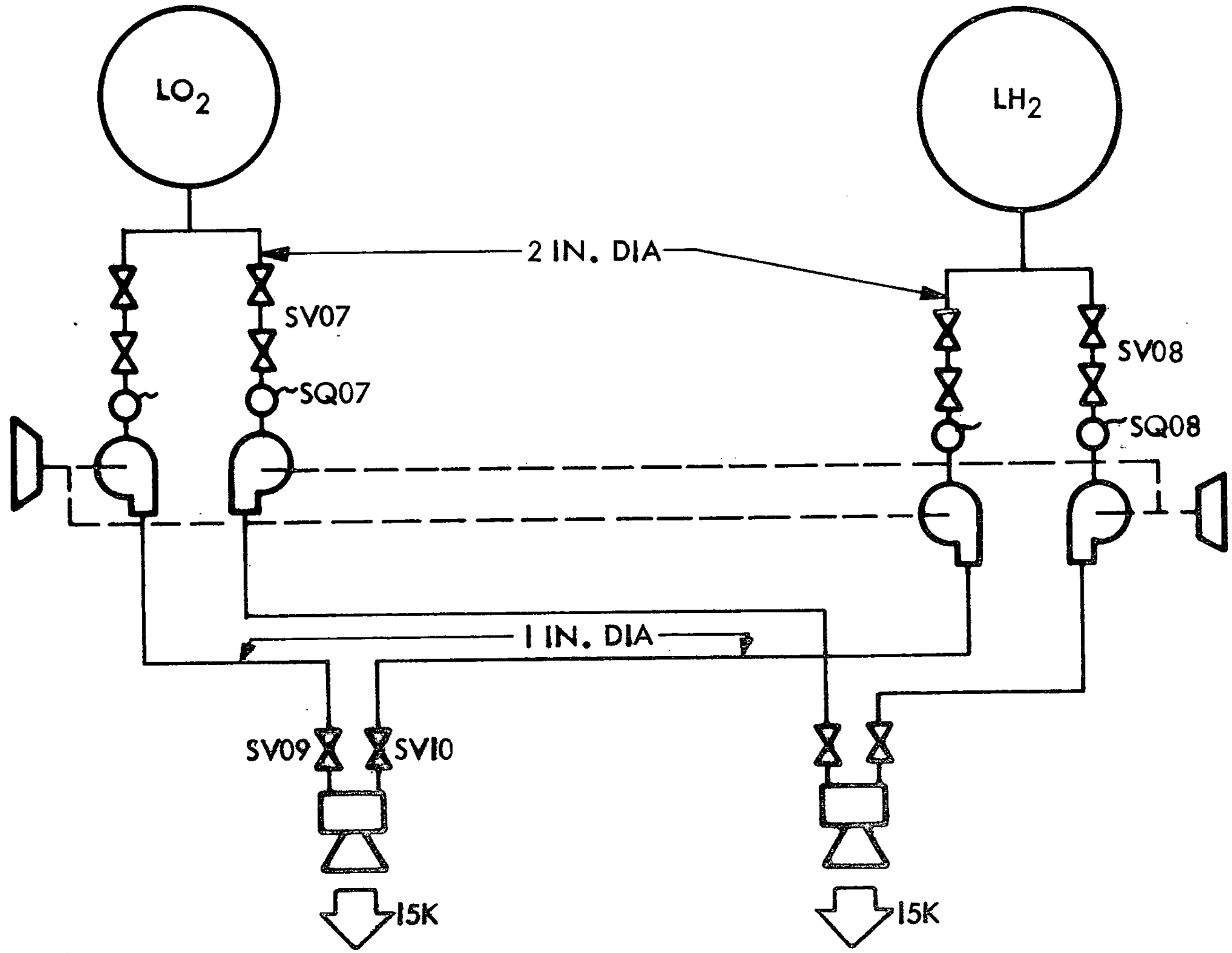
GO_2/GH_2 PRESSURIZATION – SINGLE TANKS

PUMP AT ENGINE



D03783
11m

FEEDLINE SCHEMATIC - PUMPS AT THE TANKS



NOTE: OPTIMUM LINE DIAMETER SAME FOR DUMP CASES 1 THROUGH 12

D03722
11m

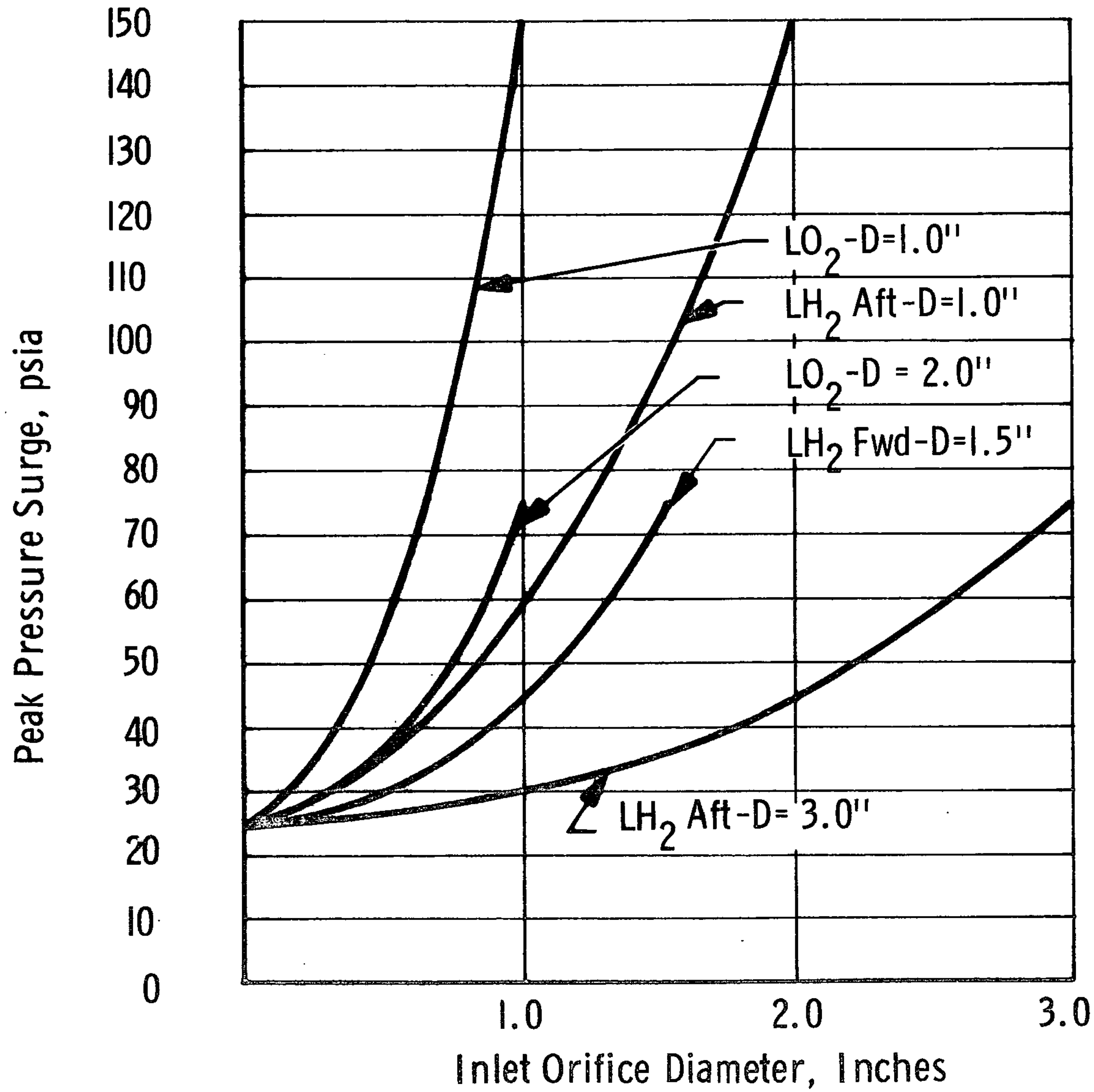
LOCKHEED

DETAILED ANALYSES

OMPS PRESSURIZATION ANALYSES SUMMARY

- VARIABLES:
  - HELIUM AND PROPELLANT GASES
  - INLET TEMPERATURES
  - EXPULSION PRESSURES
  - VENT PRESSURES
  - INSULATION THICKNESS
  - TANK GEOMETRY
  - DUTY CYCLES
- PREPRESSURIZATION:
  - MASS AND ENERGY BALANCES
- PRESSURIZATION:
  - MASS AND ENERGY BALANCE
  - HEAT TRANSFER BETWEEN ULLAGE AND TANK WALLS
  - HEAT ENTERING TANK EXAMINED FOR BOTH STORAGE AND BOILOFF

EFFECT OF INLET FLOW RESTRICTION ON SURGING



D03410
llm

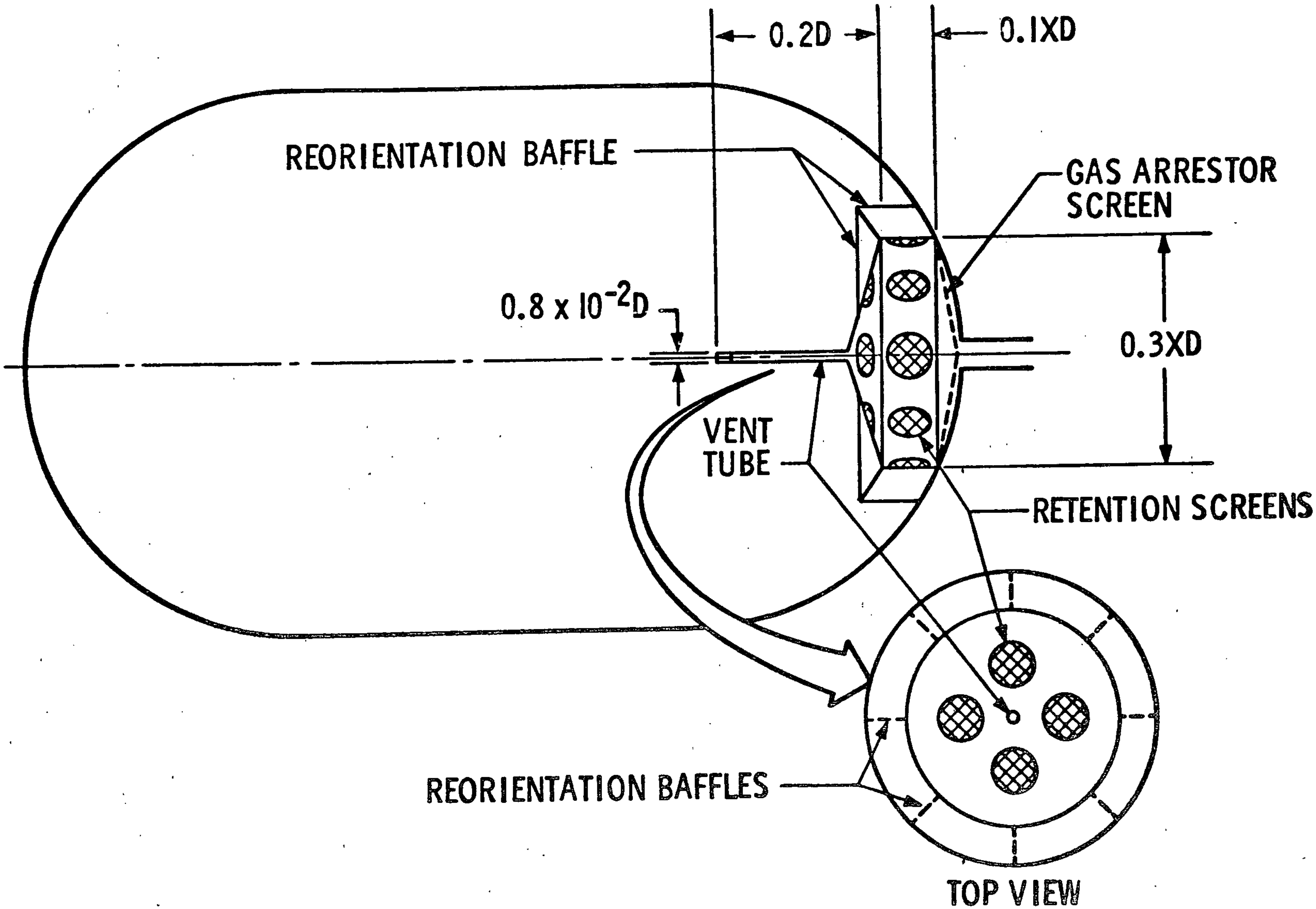
RESULTS OF FEEDLINE CHILLDOWN COMPUTATIONS

Feed System Configuration	Mean Line Diameter (in.)	Inlet/Outlet Orifice Diameters (in.)	Chilldown Time (sec)	Chilldown Propellant (lb)	Estimated Max Surge Pressure(1) (psia)
LH_2 Forward	1.50	None	5.1	15.1	75.0
LH_2 Forward	1.50	0.50/0.50	22.7	14.6	30.5
LH_2 Aft	3.00	None	2.8	26.2	75.0
LH_2 Aft	3.00	1.00/1.00	12.5	22.0	30.5
LH_2 Aft	1.00	None	4.2	3.9	75.0
LH_2 Aft	1.00	0.25/0.25	~70	3.8	28.5
LO_2	2.71(2)	None	5.0	32.0	150.0
LO_2	2.71(2)	0.25/0.25	31.3	28.0	29.0
LO_2	1.00	None	6.1	8.2	150.0
LO_2	1.00	0.125/0.125	~300	7.9	30.0

Notes:
(1) Inlet Pressure = 25 psia
(2) Upstream Line Diameter = 2.00 in.

D03433
llm

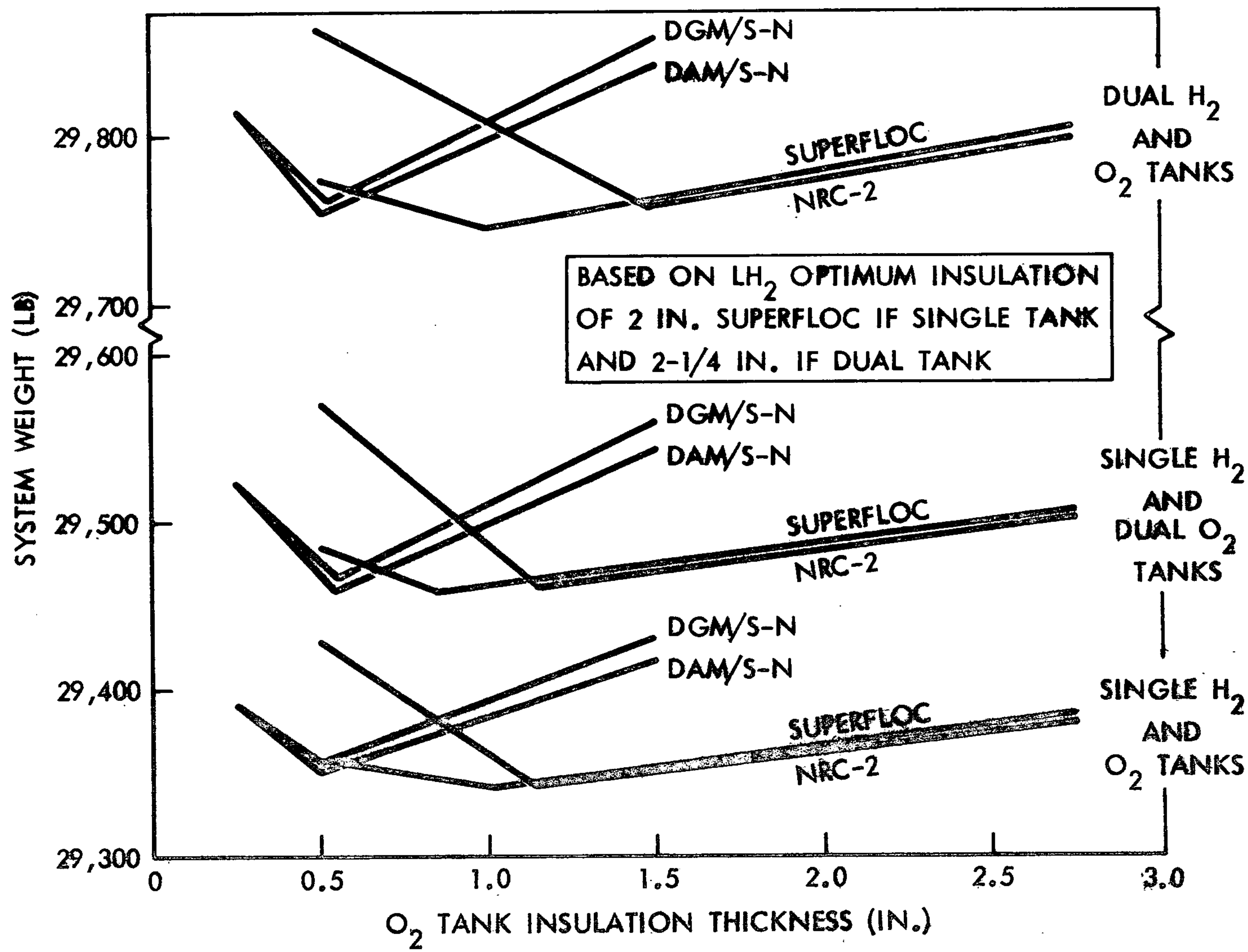
TYPICAL ACQUISITION DEVICE FOR ENGINE RESTART



D03765
llm

SENSITIVITY STUDIES

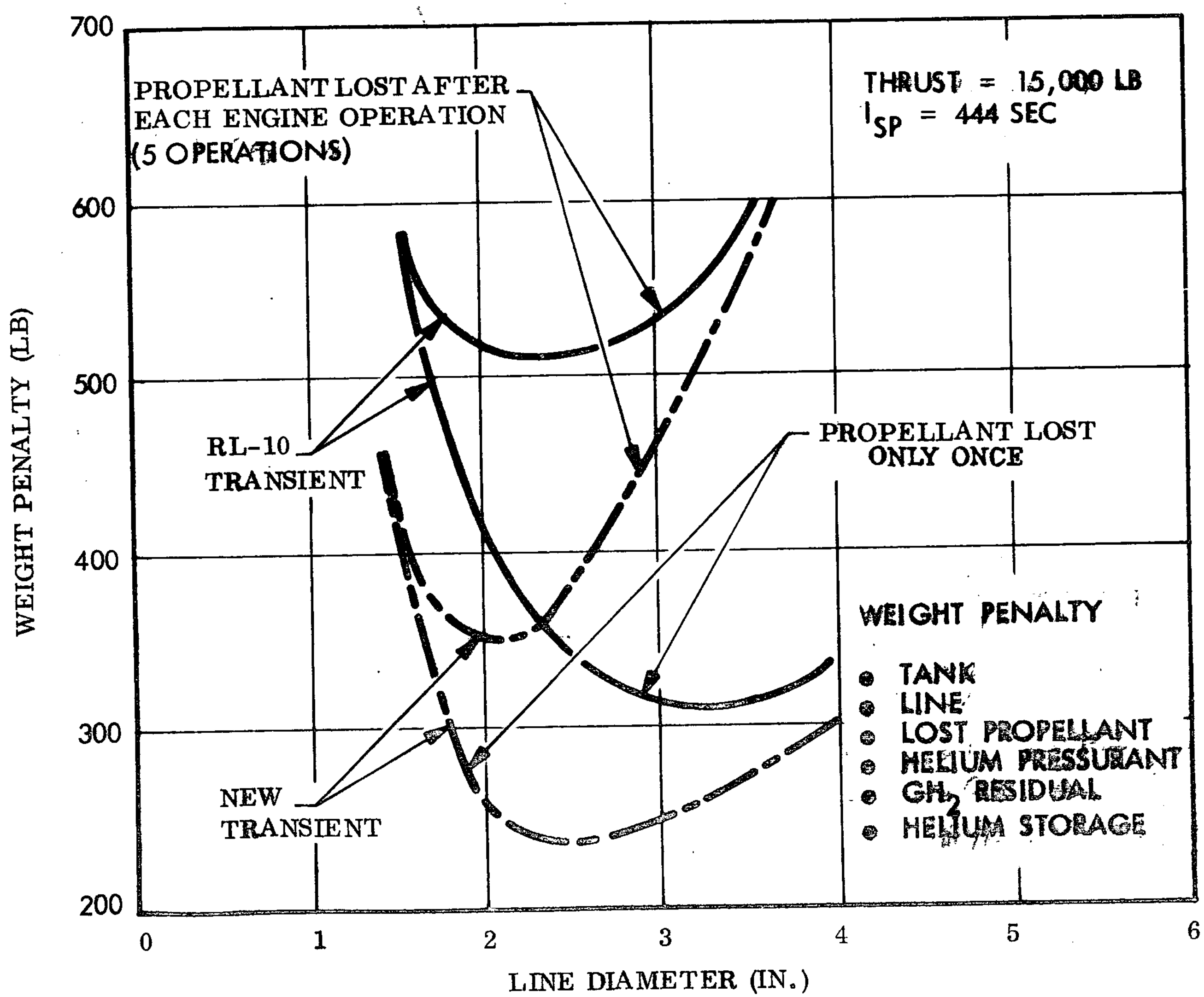
OMPS PROPELLANT STORAGE SYSTEM COMPARISON (168-HOUR MISSION)



D02979

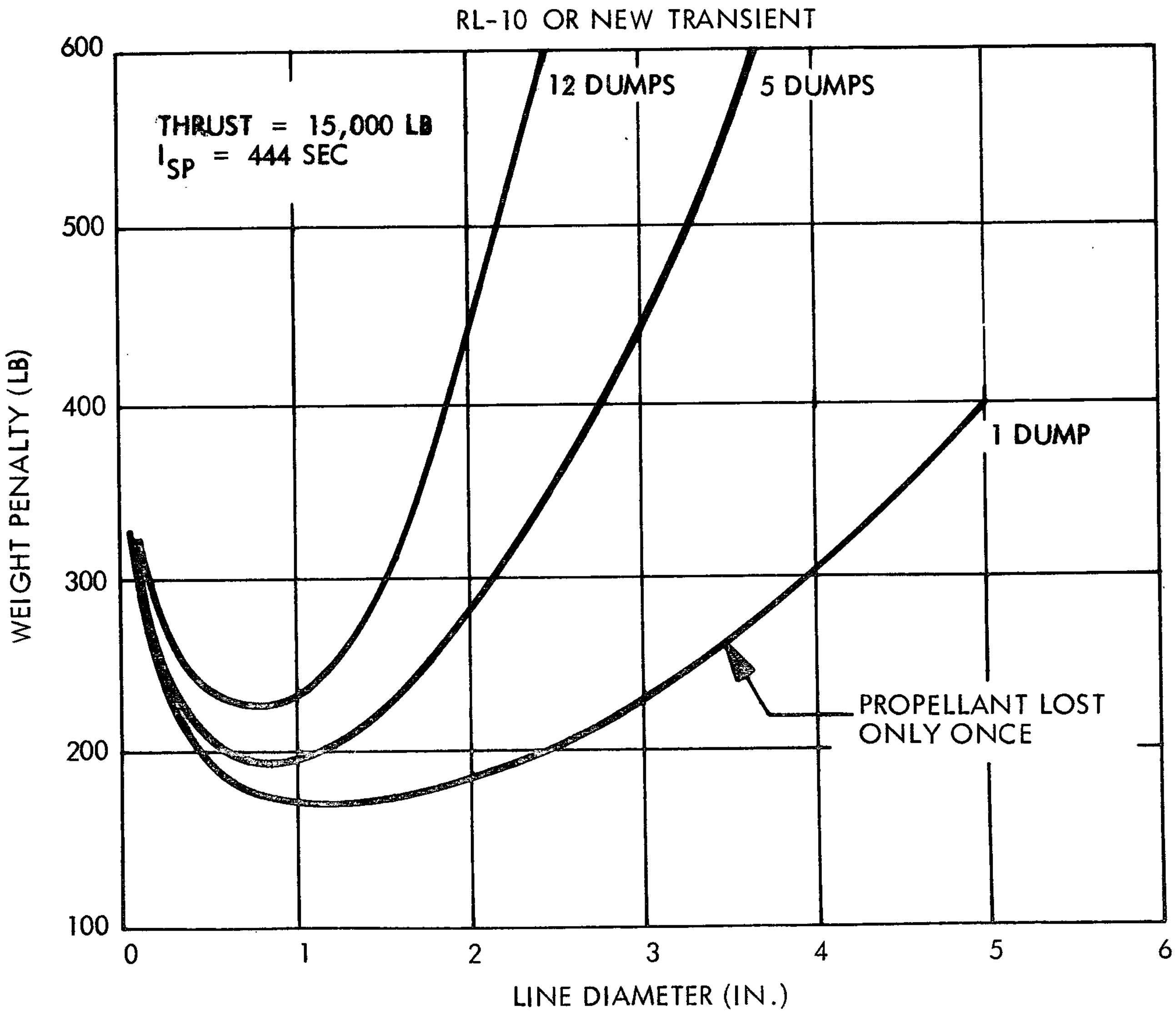
11m

SENSITIVITIES OF LINE SIZE, START TRANSIENT, AND LINE RECOVERY – LO_2 IN AFT TANKS (PUMP-AT-ENGINE)



D02655 (1)

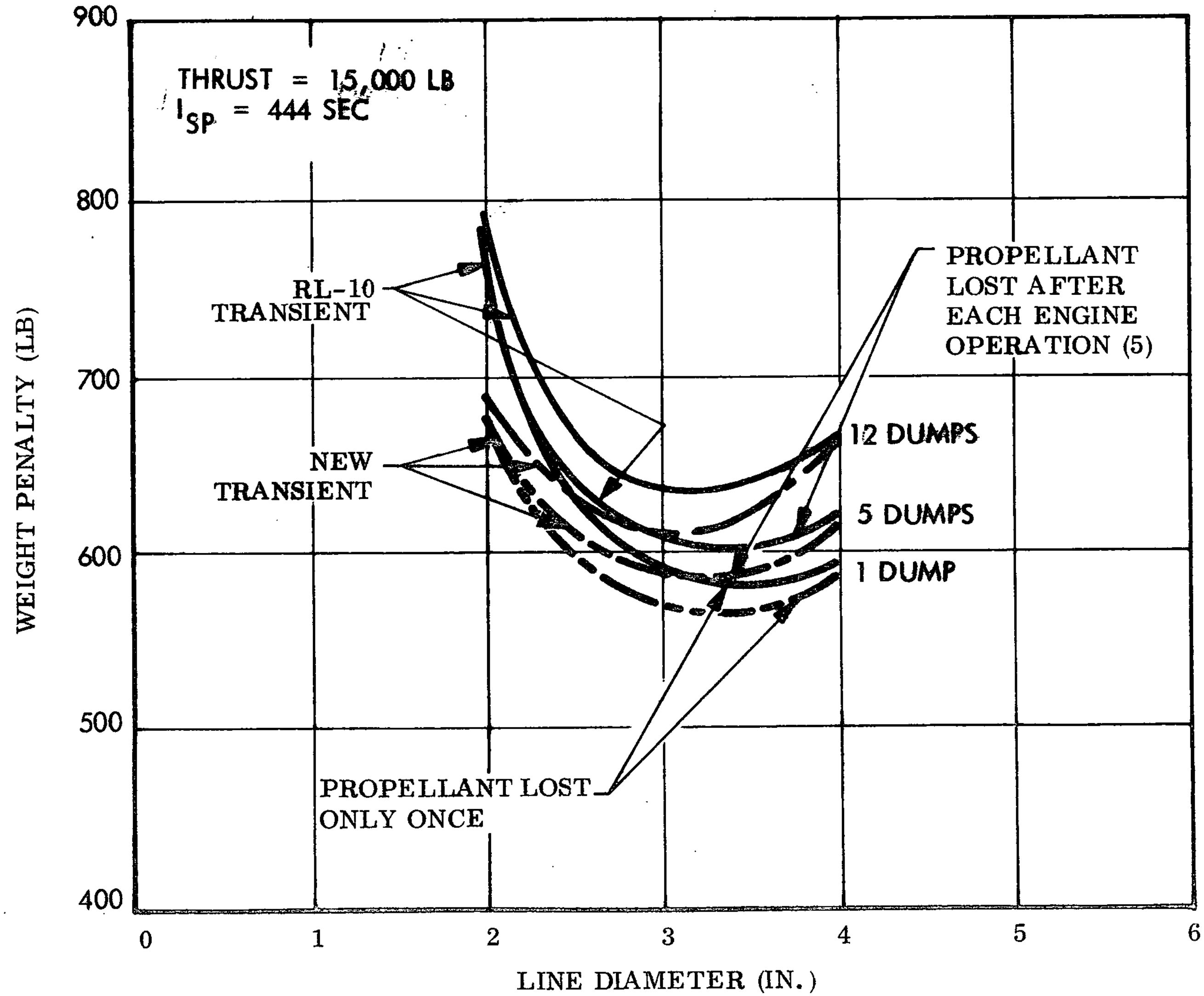
SENSITIVITIES OF LINE SIZE AND PROPELLANT RECOVERY – LO_2 IN AFT TANKS (PUMP-AT-TANK)



D02960(1)
llm

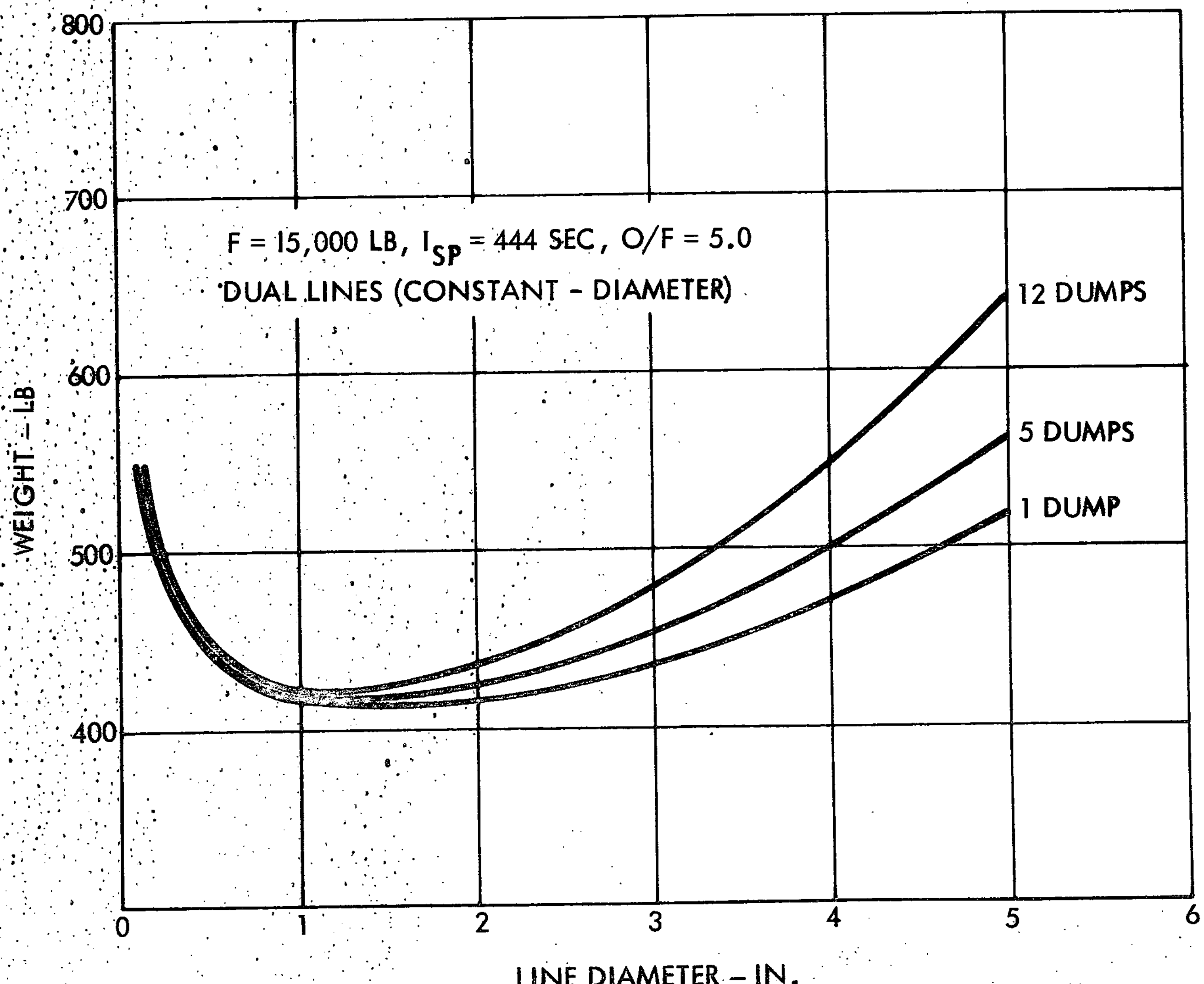
SENSITIVITIES OF LINE SIZE, START TRANSIENT, AND LINE RECOVERY – LH_2 IN AFT TANKS (PUMP-AT-ENGINE)

SINGLE LINE (CONSTANT DIAMETER)



D02649(1)
IIm

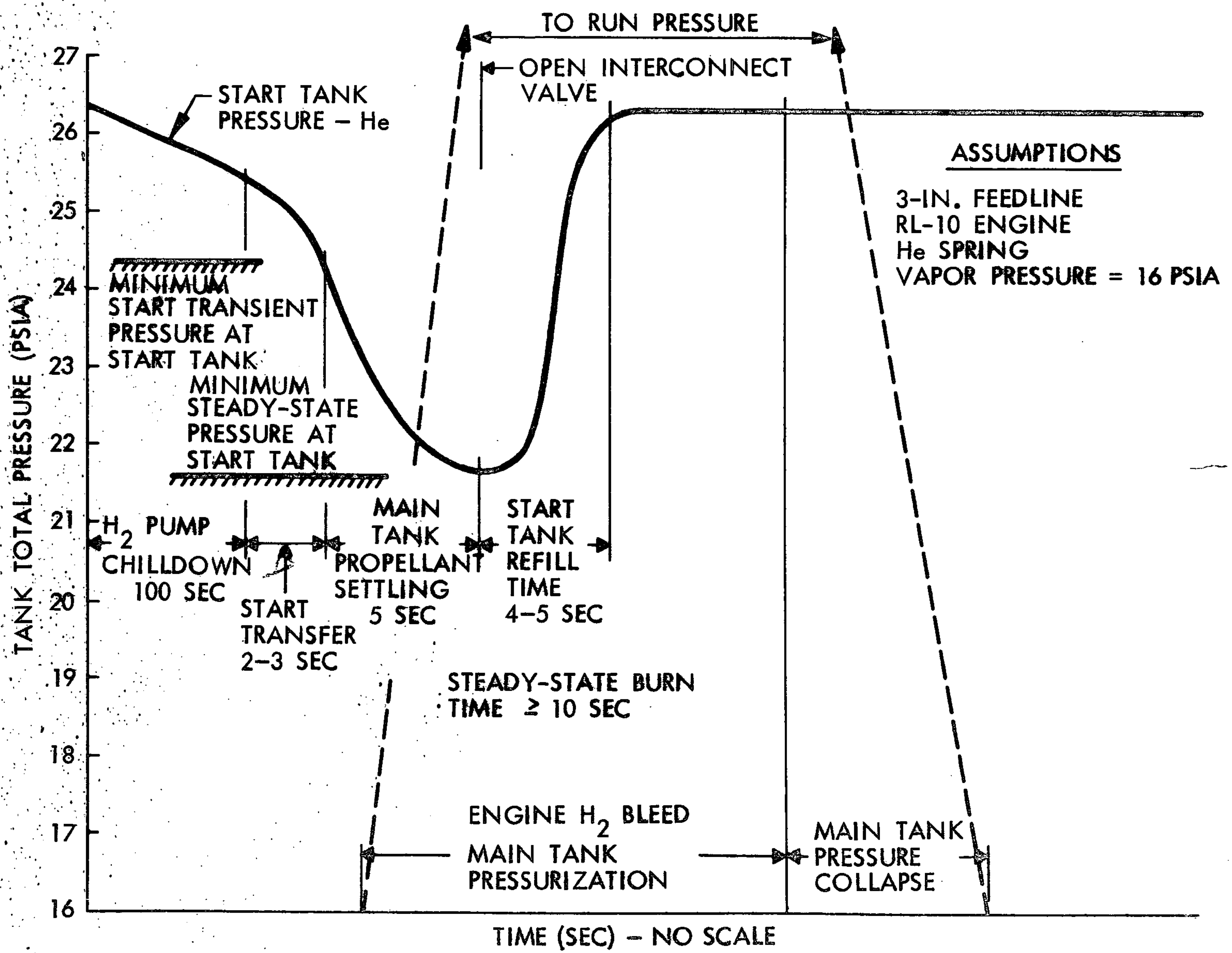
SENSITIVITIES COMPARISONS – H_2 IN AFT TANK
(PUMP-AT-TANK)



D04680
11m

START TANK CONFIGURATION

ASSUMED OPERATIONAL SEQUENCE – LH_2 TANK



D02954
11m

OMPS SYSTEM CHARACTERISTICS

CASE NO.	TANK CONFIGURATION	PUMP LOCATION	PRESSURANT	NUMBER OF DUMPS	OPTIMUM FEEDLINE DIAMETER (IN.)		ULLAGE PRESSURE (PSIA)	
					O_2	H_2	O_2	H_2
1	SINGLE	ENGINE	GO_2 AND GH_2	1	3	3 1/2	36.8	23.4
				5	2 1/2	3 1/4	45.2	23.8
				12	2	3	57.6	24.2
2	SINGLE	TANK	GO_2 AND GH_2	1	1	1	20.0	18.0
				5	1	1	20.0	18.0
				12	1	1	20.0	18.0
3	SINGLE	ENGINE	GHe	1	3	3 1/2	36.8	23.4
				5	2 1/2	3 1/4	47.2	23.8
				12	2	3	57.6	24.2
4	SINGLE	TANK	GHe	1	1	1	20.0	18.0
				5	1	1	20.0	18.0
				12	1	1	20.0	18.0
5	DUAL	ENGINE	GHe	1	2/3	3/3	34.4	23.5
				5	2/3	3/3	34.4	23.5
				12	2/3	3/3	34.4	23.5

NOTE: FOR THE DUAL TANK CASE, FEEDLINE DIAMETERS SIGNIFY: TANK OUTLET TO COMMON POINT/ COMMON POINT TO ENGINE INLET.

D03713
llm

OMPS WEIGHT COMPARISON

(ALL COMPARISONS BASED ON I_{SP} = 444, O/F = 5.0)

		NUMBER OF PROPELLANT FEEDLINE DUMPS					
		1		5		12	
	SYSTEM WEIGHT (LB)	VACUUM JACKETED	NON-VACUUM JACKETED	VACUUM JACKETED	NON-VACUUM JACKETED	VACUUM JACKETED	NON-VACUUM JACKETED
GO_2/GH_2 – SINGLE TANK PUMP AT ENGINE	DRY	3,249	2,517	3,423	2,689	3,676	2,915
	WET	32,357	31,716	32,825	32,152	33,542	32,871
GO_2/GH_2 – SINGLE TANK PUMP AT ENGINE IDLE MODE START	DRY	2,655	1,923	2,679	1,945	2,856	2,095
	WET	31,763	31,122	31,936	31,408	32,722	32,051
GO_2/GH_2 – SINGLE TANK PUMP AT TANK	DRY	2,828	2,146	2,831	2,138	2,834	2,145
	WET	31,550	30,910	31,545	30,894	31,684	31,035
GHe – SINGLE TANK PUMP AT ENGINE	DRY	2,657	1,961	2,715	2,021	2,812	2,112
	WET	31,500	30,947	31,707	31,150	32,079	31,507
GHe – SINGLE TANK PUMP AT TANK	DRY	2,407	1,665	2,403	1,663	2,408	1,665
	WET	31,082	30,410	31,070	30,401	31,211	30,538
GHe – DUAL TANKS PUMP AT ENGINE	DRY	3,097	2,267	3,280	2,332	3,307	2,357
	WET	31,989	31,269	32,355	31,516	32,955	32,112
CASCADE TANK	DRY	–	–	3,273	2,604	–	2,679
	WET	–	–	32,532	31,922	–	32,292

D03714(1)
llm

CONCLUSIONS REGARDING ORBIT MANEUVERING PROPELLANT SUPPLY (NONINTEGRATED)

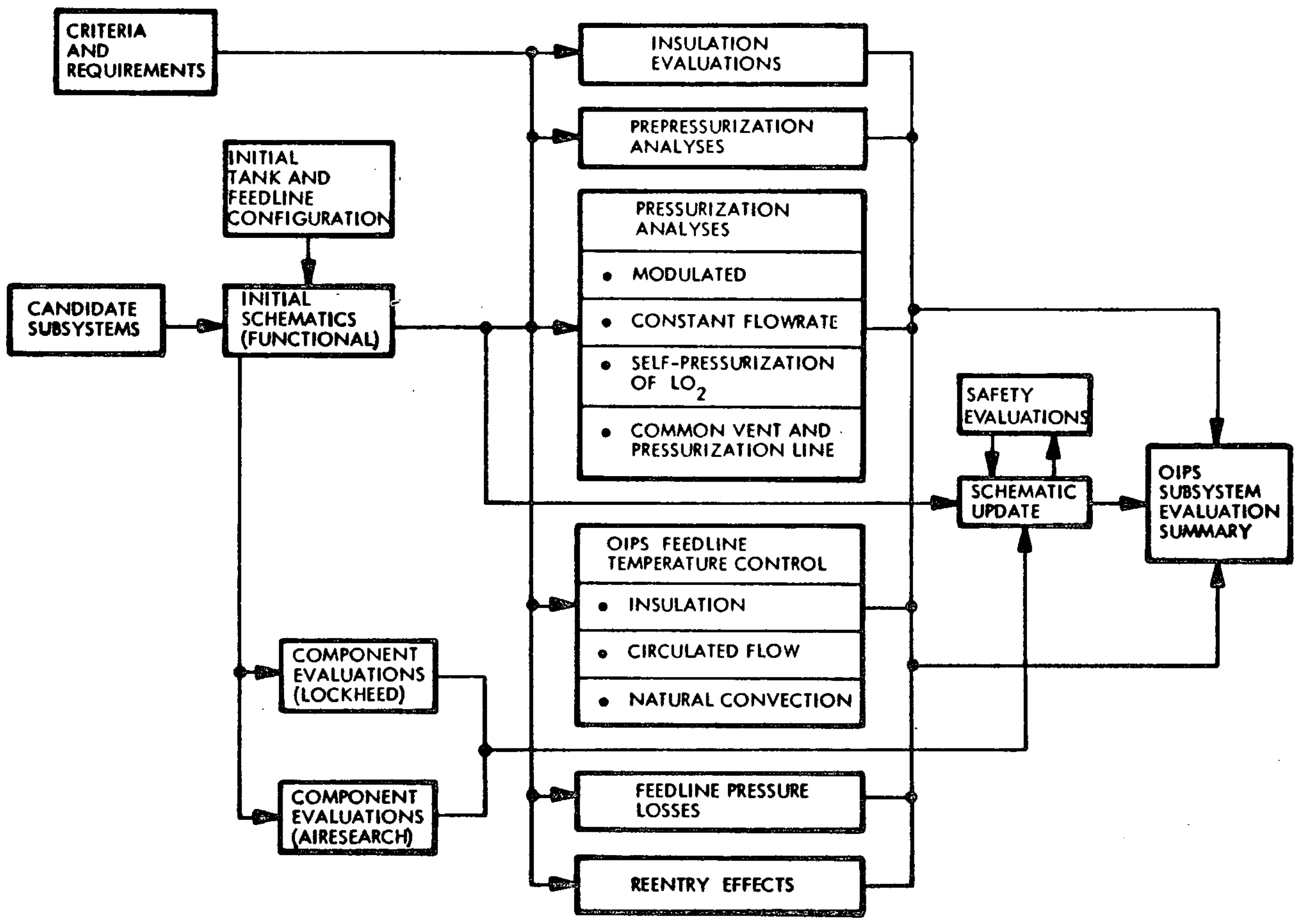
- PUMP-AT-TANK LOWER WEIGHT SYSTEM
- HELIUM PRESSURIZATION RESULTS IN LOWER PRESSURIZATION WEIGHTS
- GO_2 / GH_2 PRESSURIZATION:
  - SENSITIVITY TO DUTY CYCLE
  - USED ONLY WITH ORIENTED PROPELLANT
  - PROPELLANT ACQUISITION THERMAL PROBLEMS MORE SERIOUS
- VACUUM-JACKETED TANKS AND LINES HEAVIER, BUT PROTECT REUSABLE INSULATION SYSTEMS
- FEEDLINE SIZING AND PROPELLANT CONSERVATION IMPORTANT SENSITIVITIES
- USE OF CASCADE TANKS RESULTS IN WEIGHT PENALTY AS COMPARED TO DUAL TANKS
- START TANK NOT APPLICABLE TO NONINTEGRATED OMPS

llm

ORBIT INJECTION PROPULSION SUPPLY

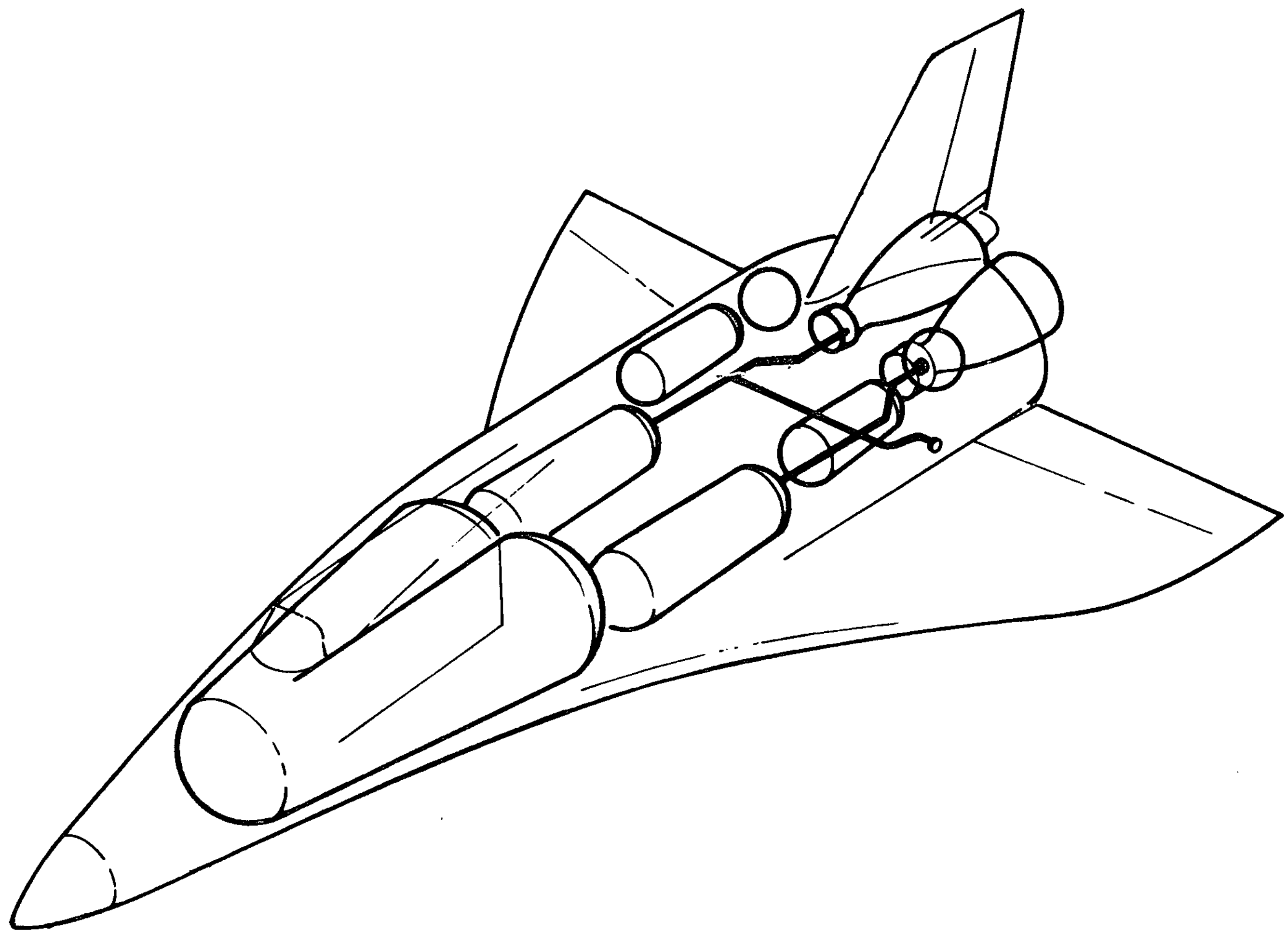
D03752
llm

APPROACH TO ORBIT INJECTION PROPELLANT SUPPLY EVALUATIONS (NONINTEGRATED)

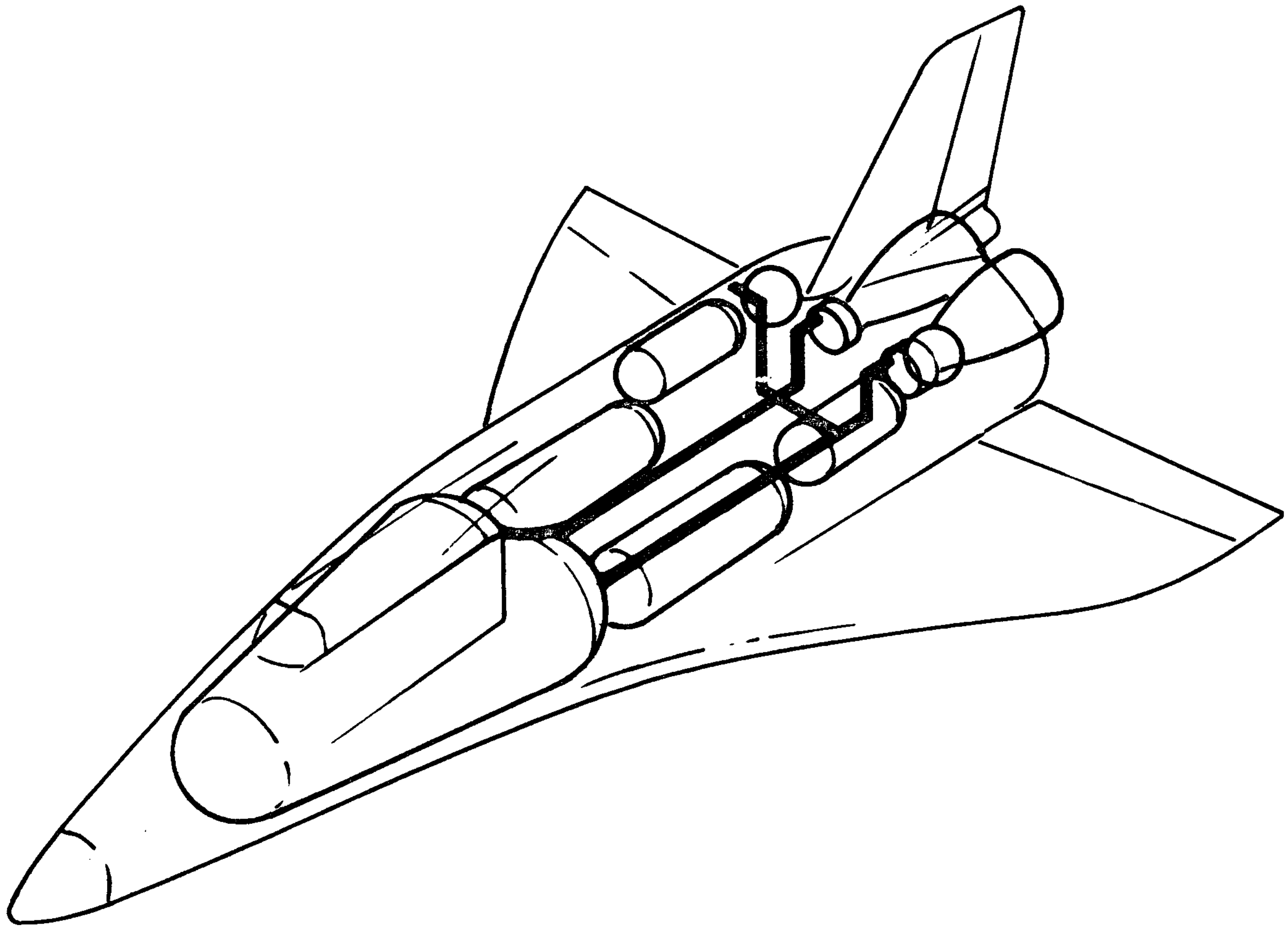


D04904

LO_2 TANKAGE AND FEEDLINE ARRANGEMENT (NA-R HCR ORBITER)

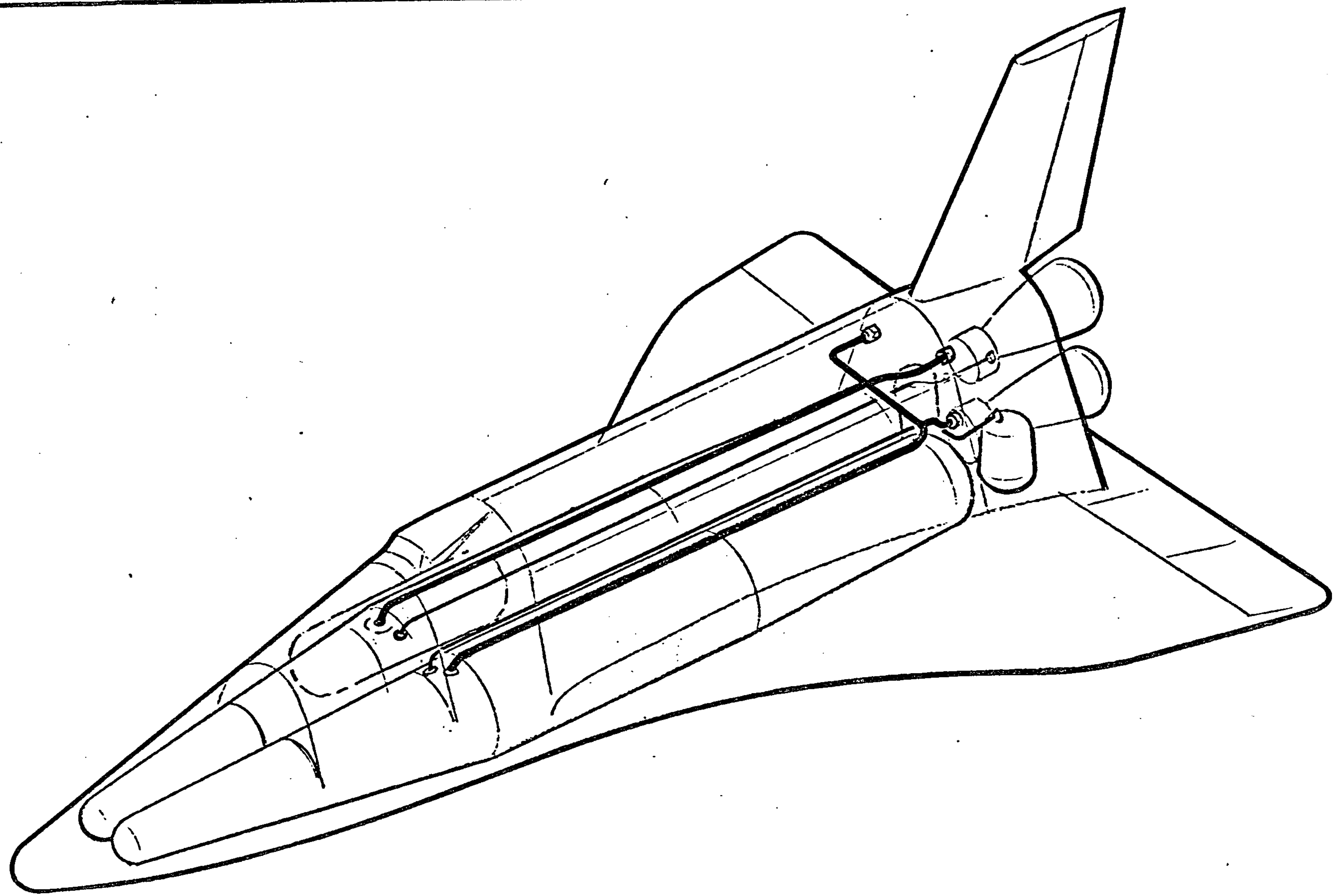


LH_2 TANKAGE AND FEEDLINE ARRANGEMENT (NA-R HCR ORBITER)



LOCKHEED

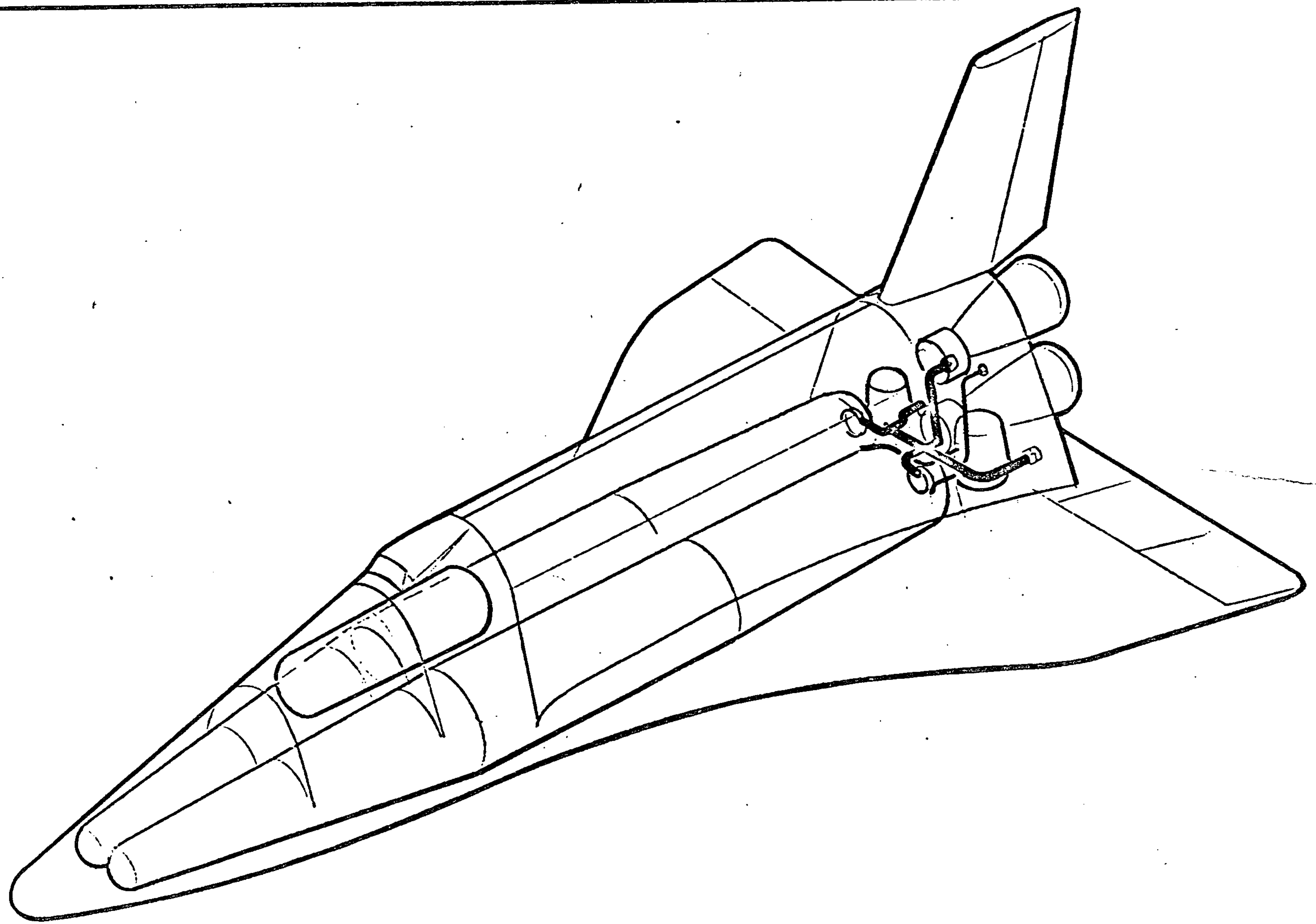
LO_2 TANKAGE AND FEEDLINE ARRANGEMENT
(MACDONNELL-DOUGLAS HCR ORBITER)



D02968
llm

LH_2 TANKAGE AND FEEDLINE ARRANGEMENT
(MACDONNELL-DOUGLAS HCR ORBITER)

LOCKHEED

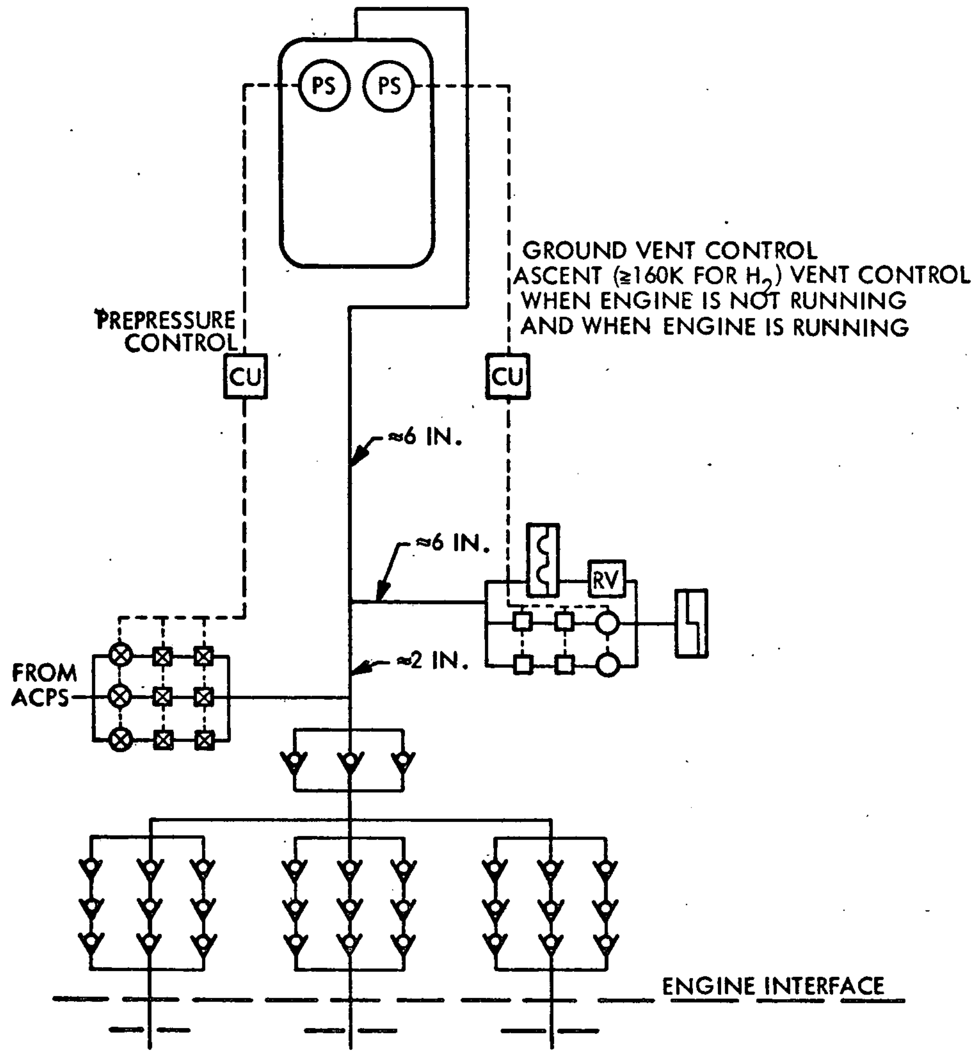


D02969
llm

COMMON VENT AND PRESSURIZATION LINES

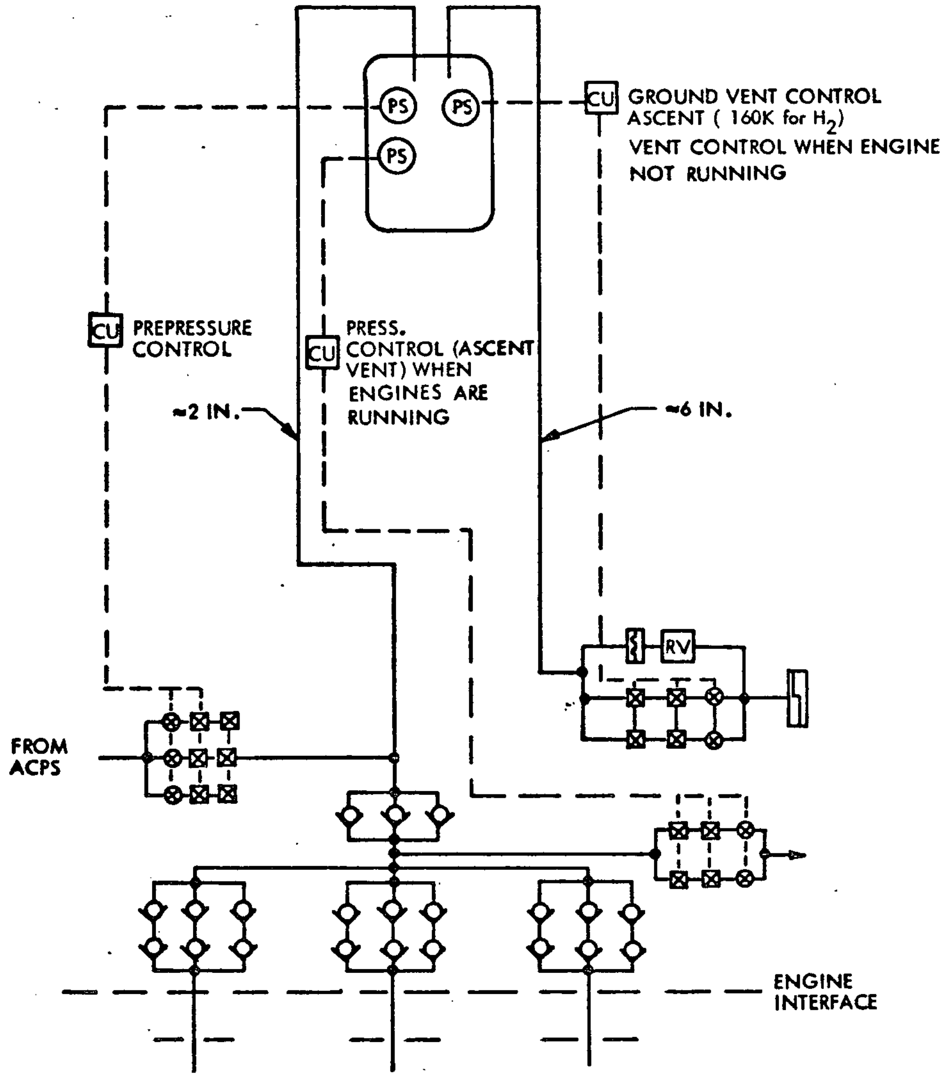
LOCKHEED

COMMON PRESSURIZATION AND VENT LINES

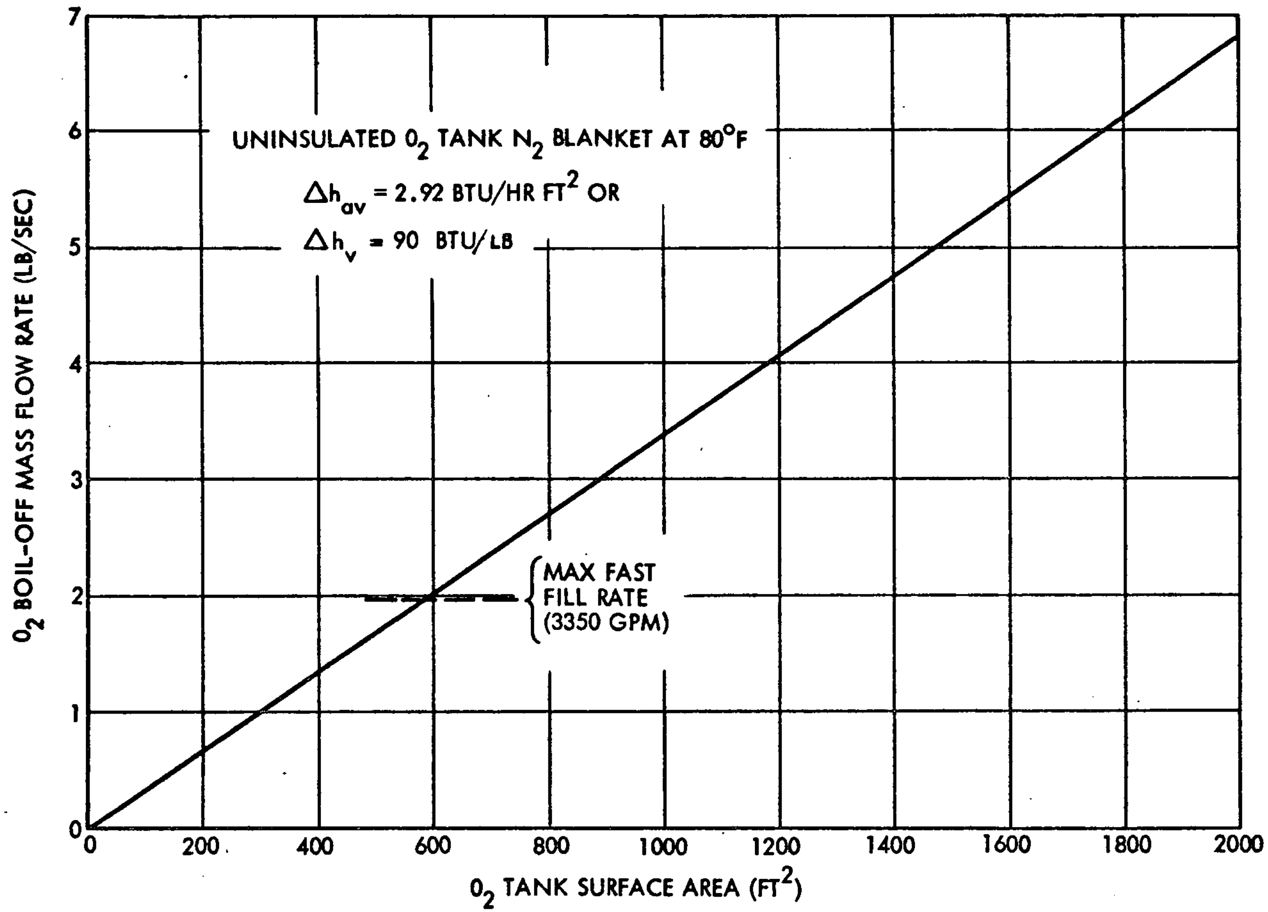


D04455(1)
llm

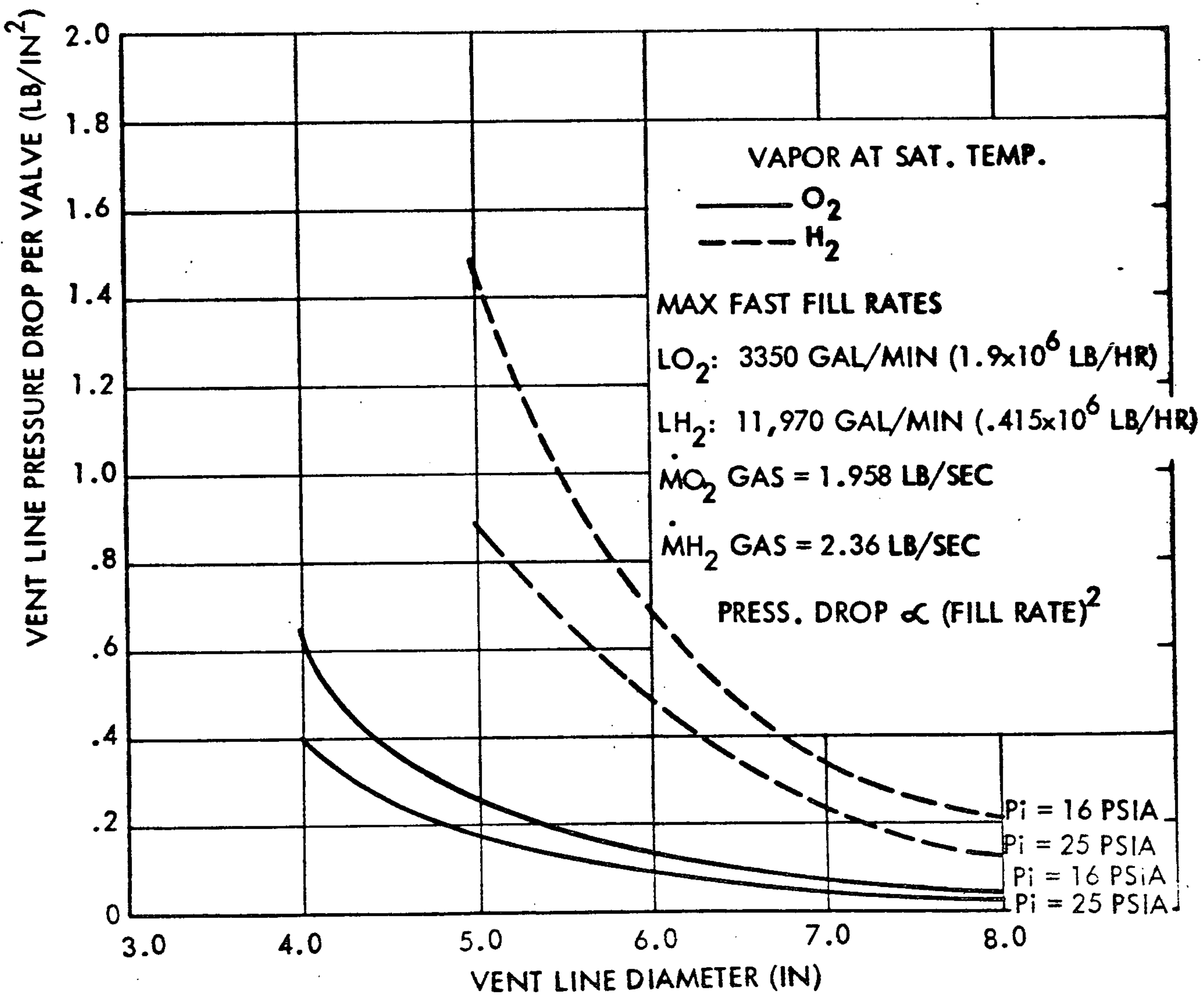
SEPARATE PRESSURIZATION AND VENT LINES



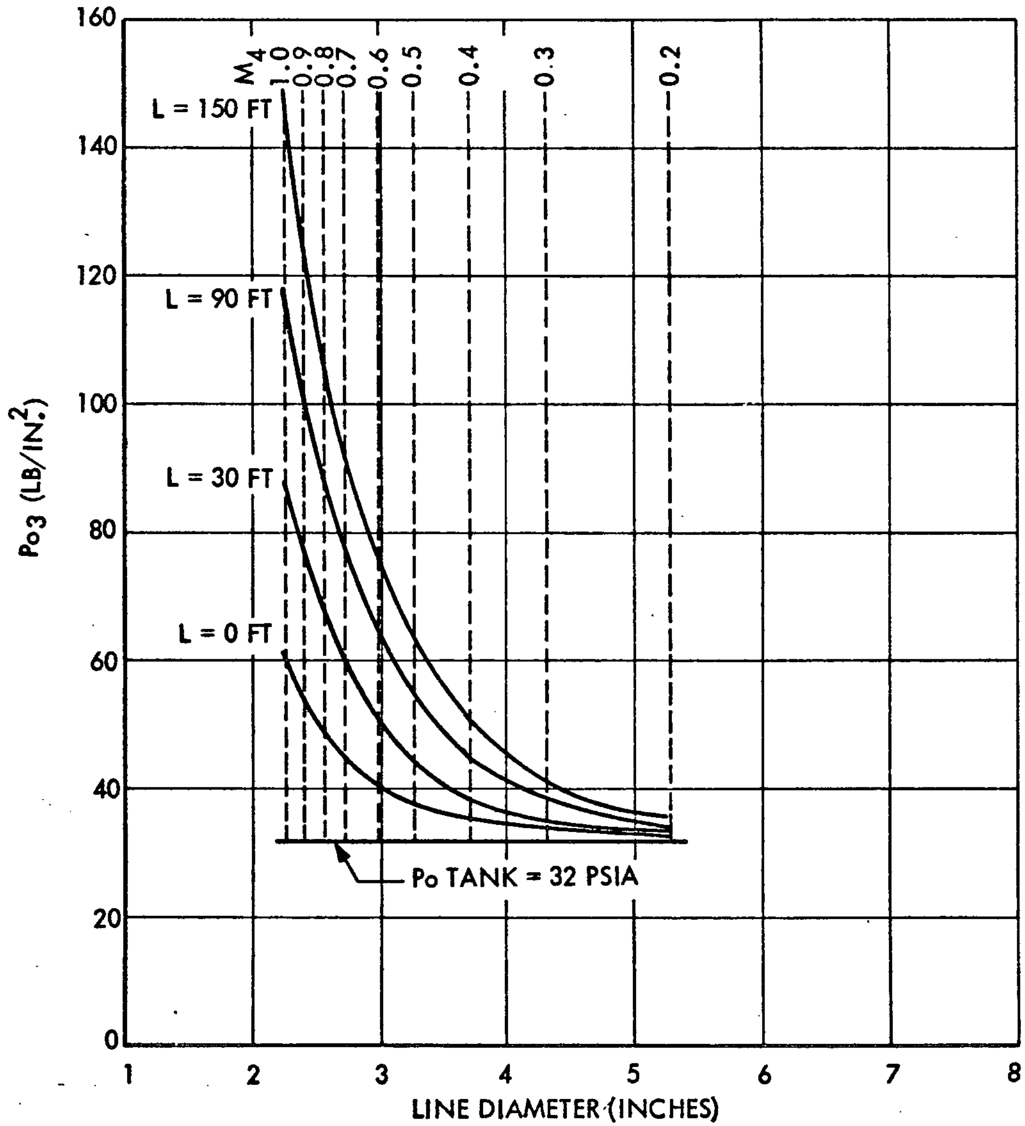
STEADY-STATE BOILOFF RATES



VENT LINE PRESSURE LOSSES

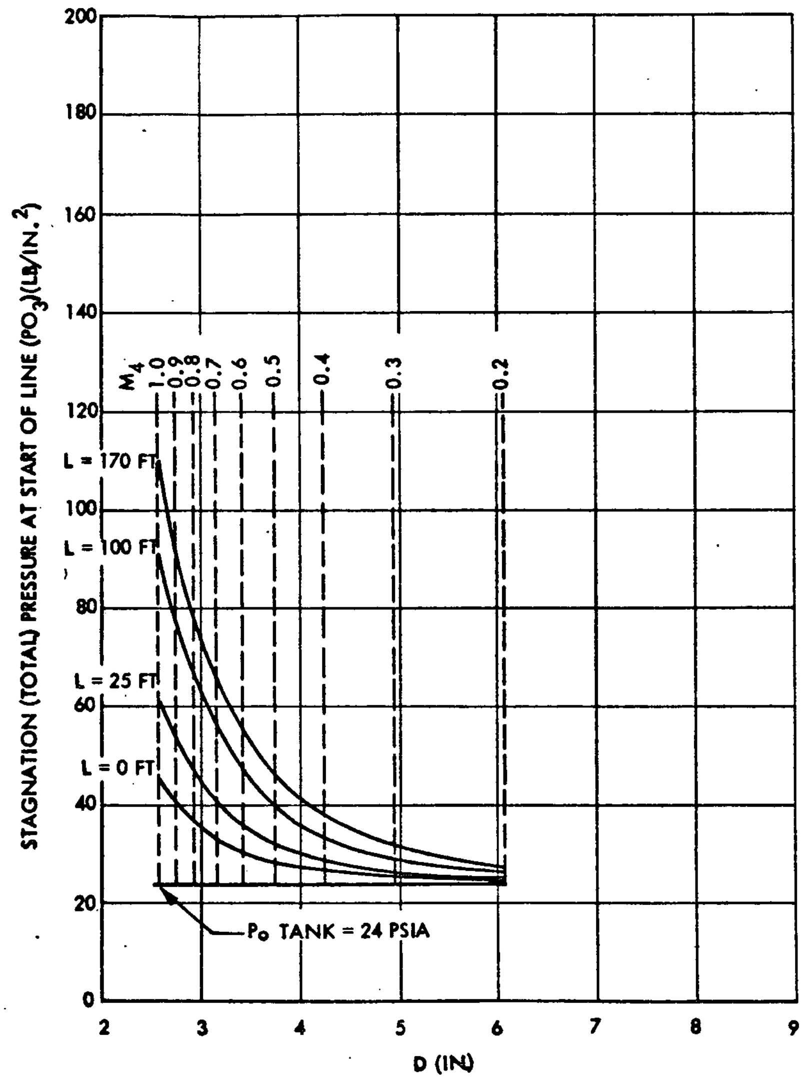


GEOMETRIC EFFECTS ON LINE INLET PRESSURE – OXYGEN



D04450
11m

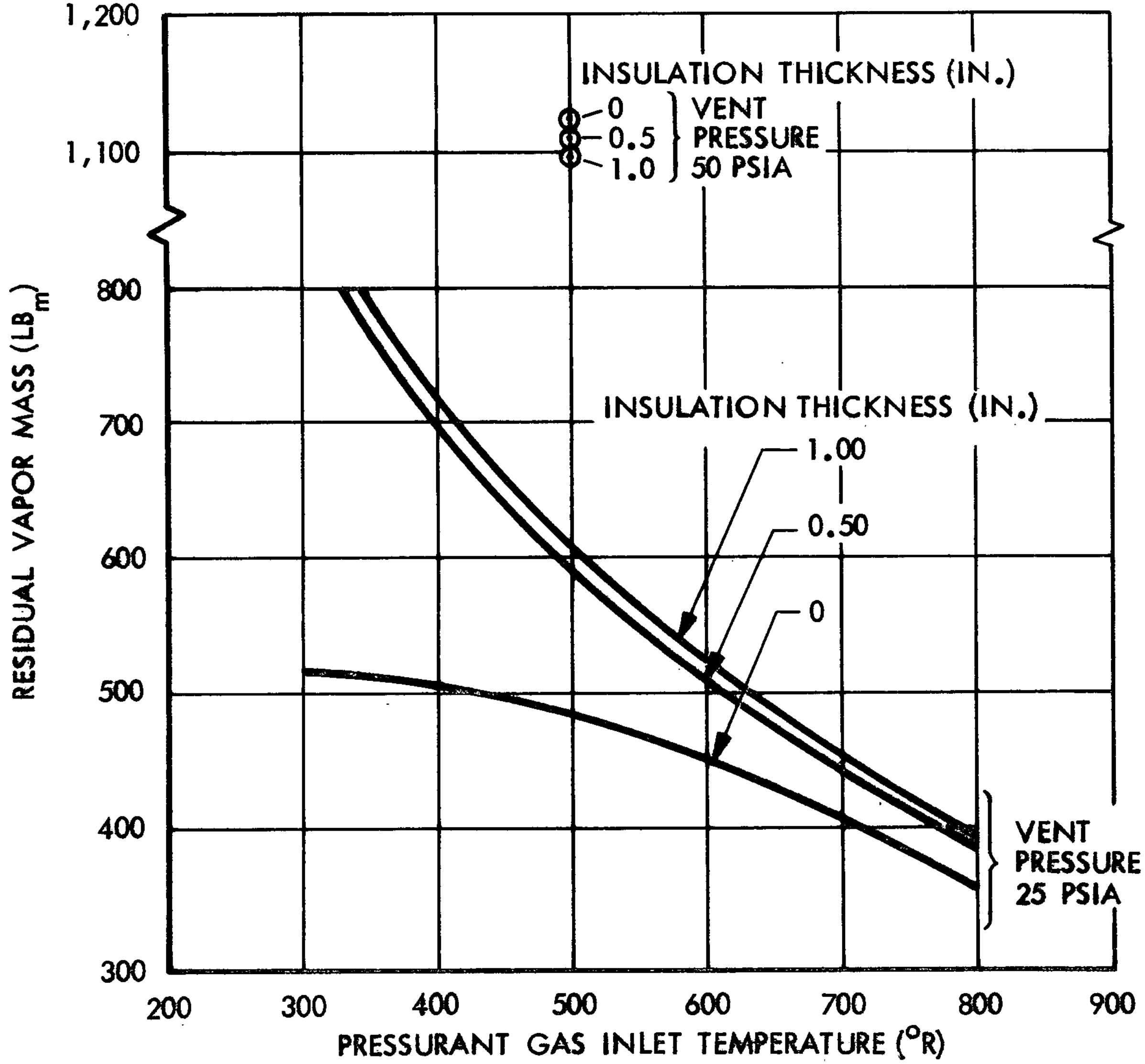
GEOMETRIC EFFECTS ON LINE INLET PRESSURE – HYDROGEN



D04451
11m

PRESSURIZATION APPROACHES

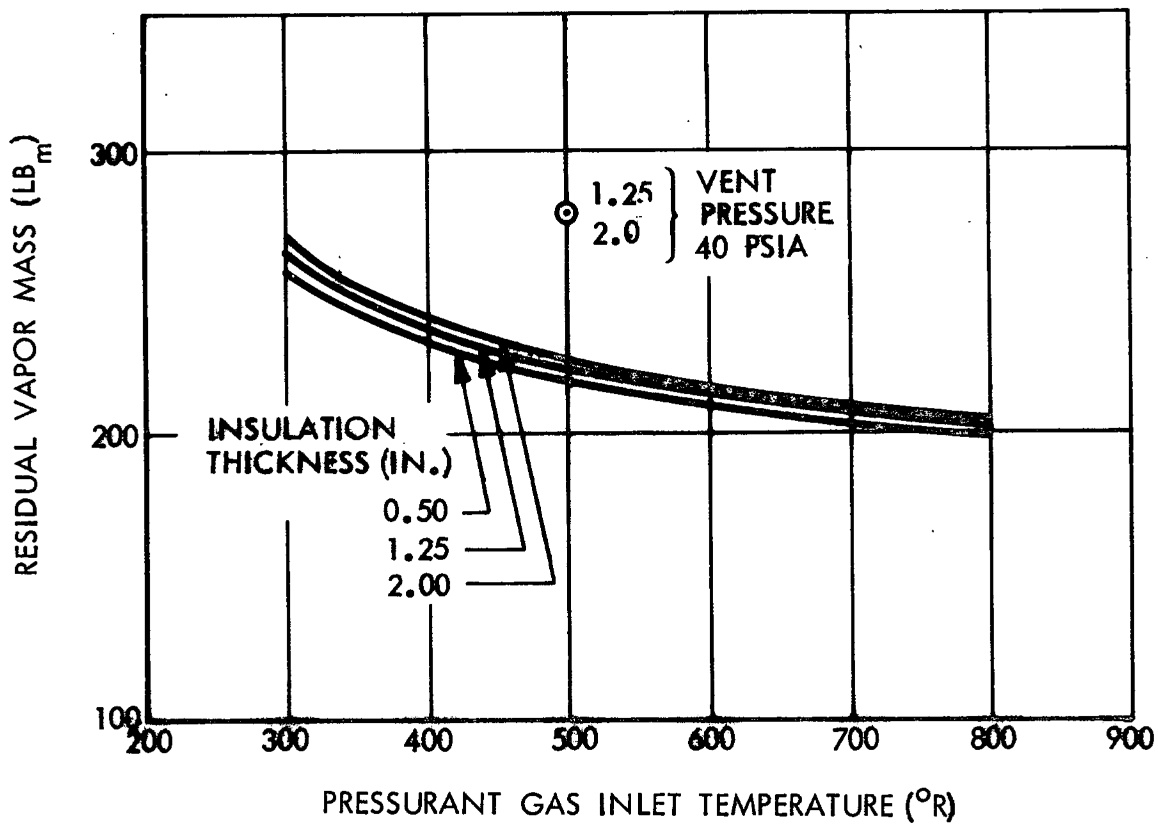
SENSITIVITY OF ORBIT INJECTION SUPPLY GO_2 RESIDUALS TO PRESSURANT INLET AND TEMPERATURE AND INSULATION CONDUCTIVITY



D02971
IIm

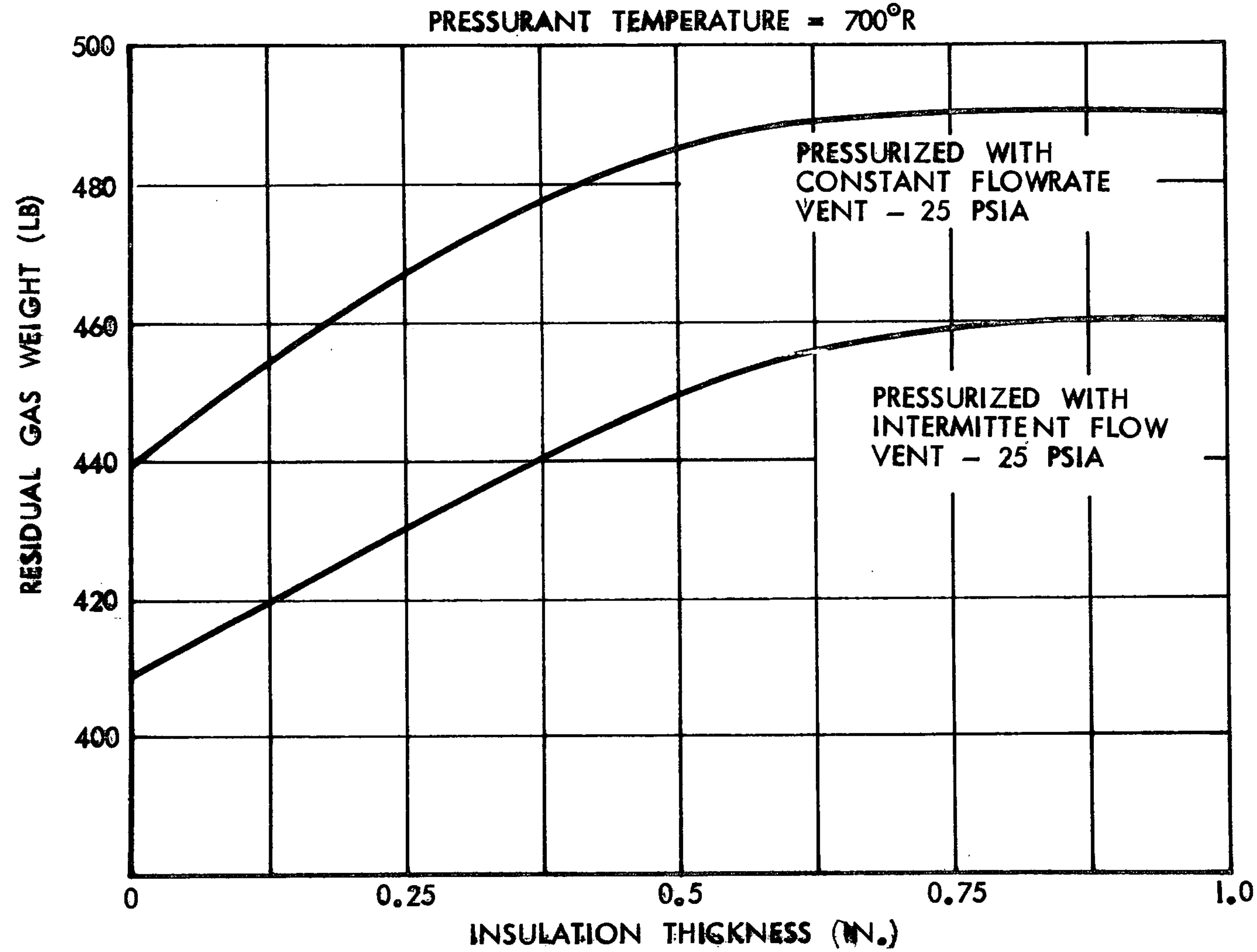
LOCKHEED

SENSITIVITY OF ORBIT INJECTION SUPPLY GH_2 RESIDUALS TO PRESSURANT INLET AND TEMPERATURE AND INSULATION CONDUCTIVITY



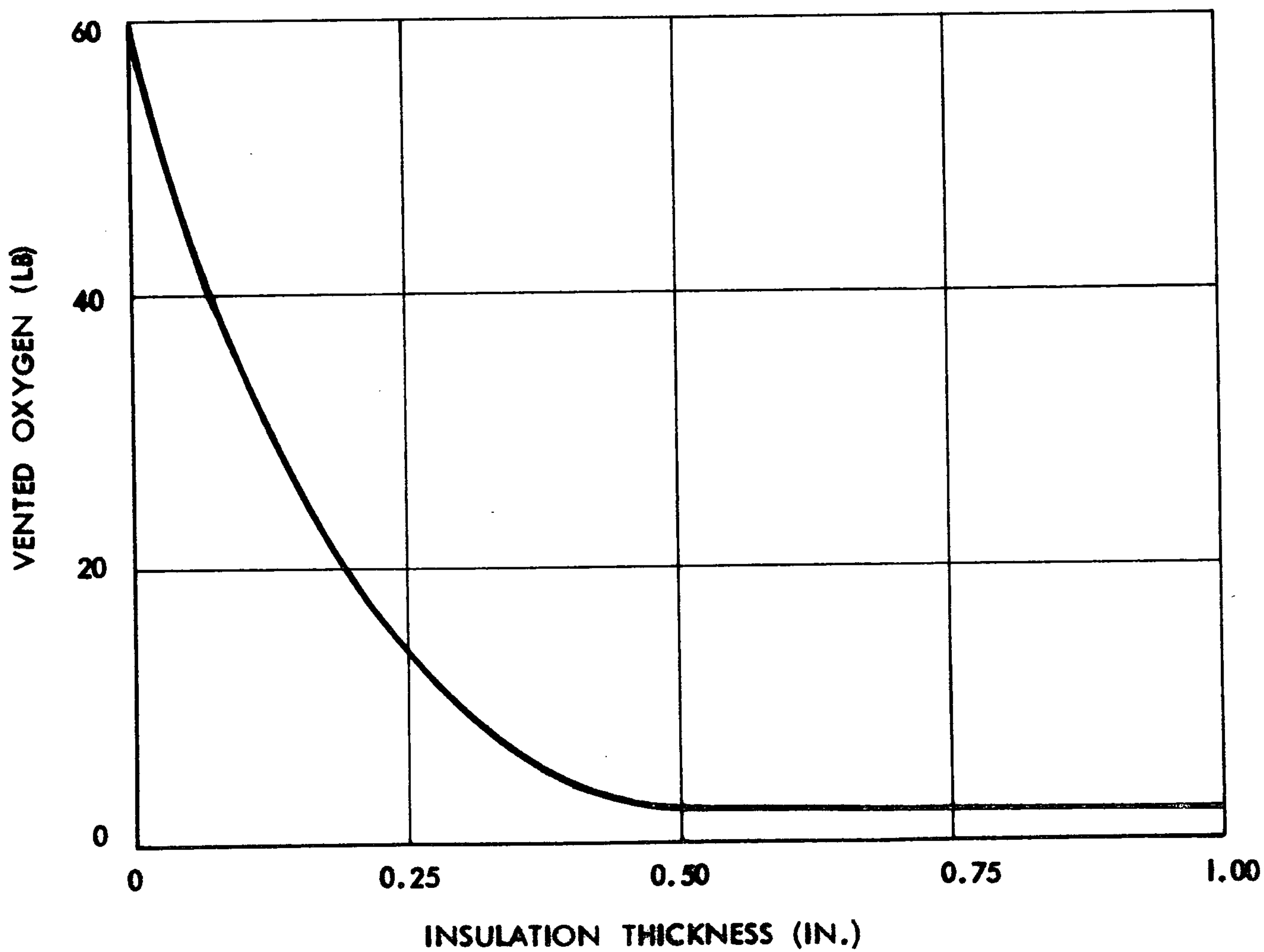
D02972
11m

COMPARISON OF OIPS PRESSURIZATION METHODS
(OXYGEN TANK RESIDUALS PER TANK)



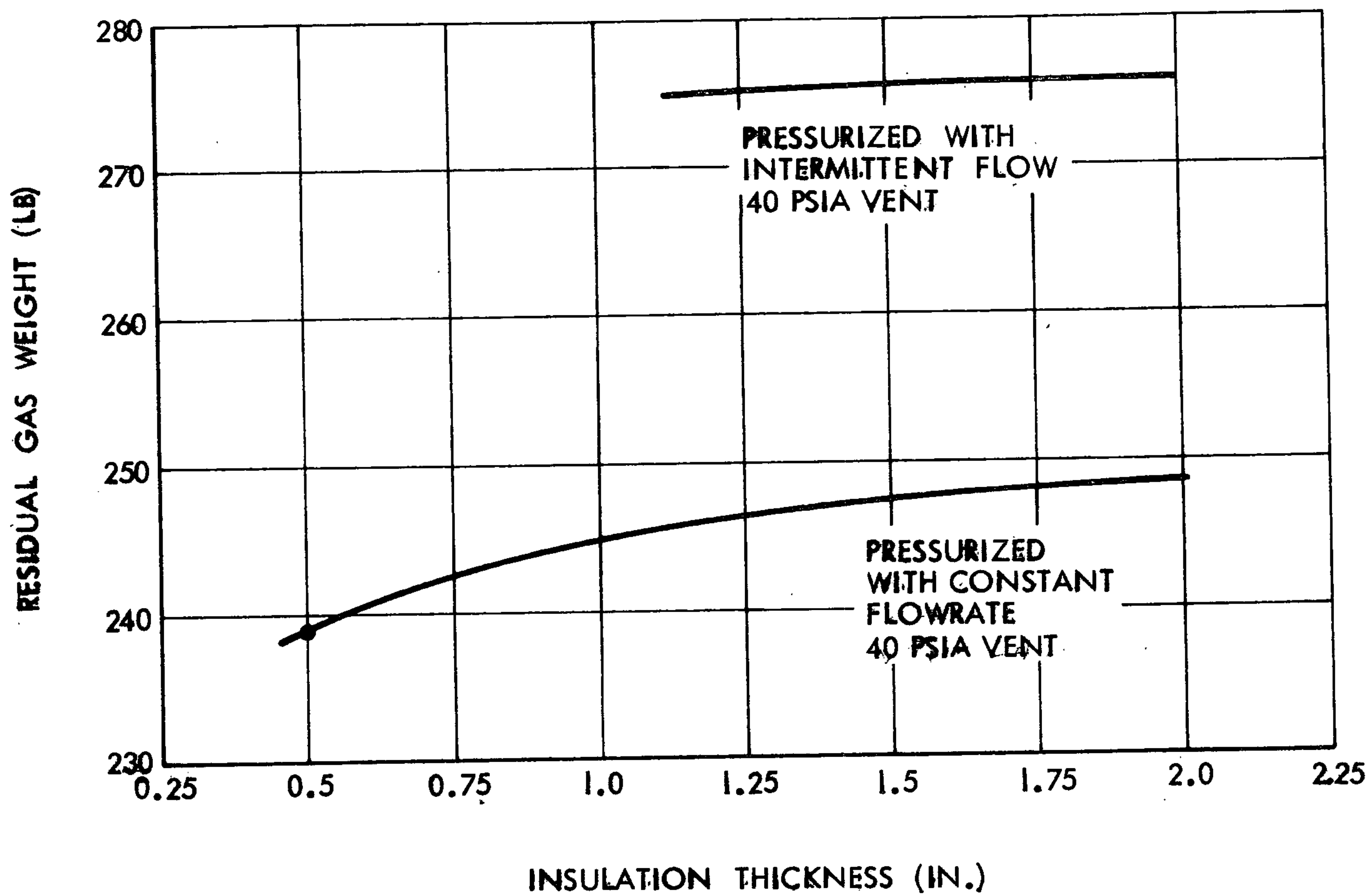
D03812(1)
Hm

OIPS OXYGEN TANK VENTED WEIGHT PER TANK WITH CONSTANT FLOWRATE PRESSURIZATION



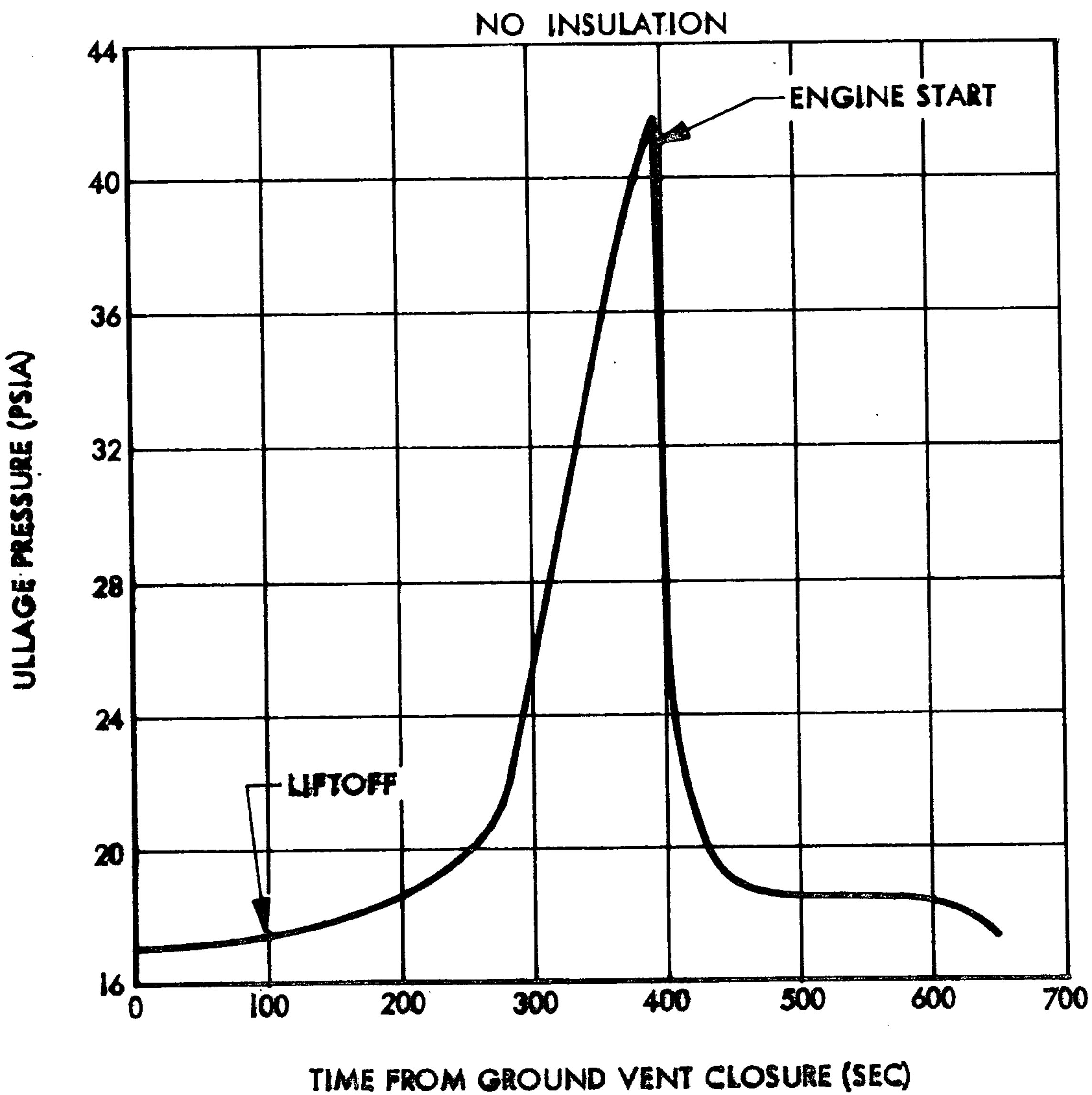
D03807
llm

COMPARISON OF OIPS PRESSURIZATION METHODS
(HYDROGEN TANK RESIDUALS PER TANK)

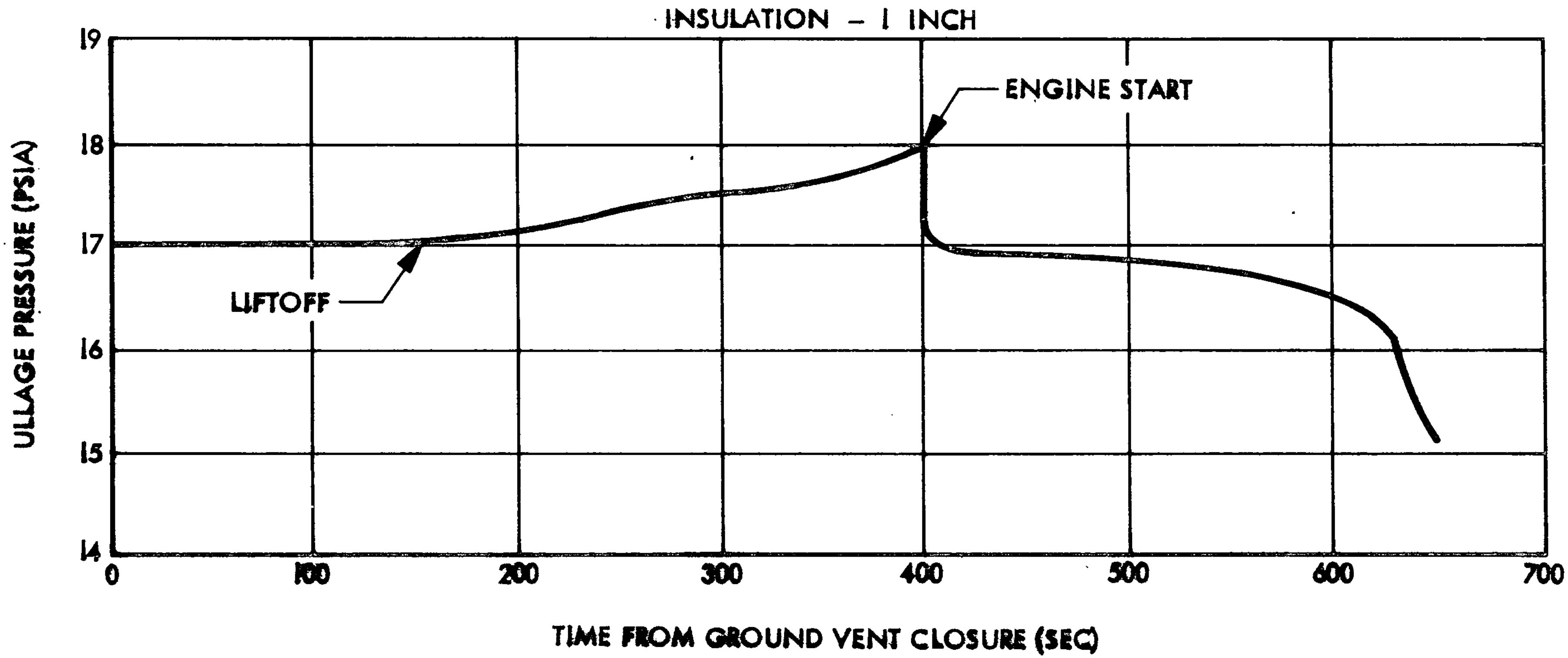


D03788
IIm

SELF-PRESSURIZED LIQUID-OXYGEN ORBIT INJECTION TANK



D03711
llm

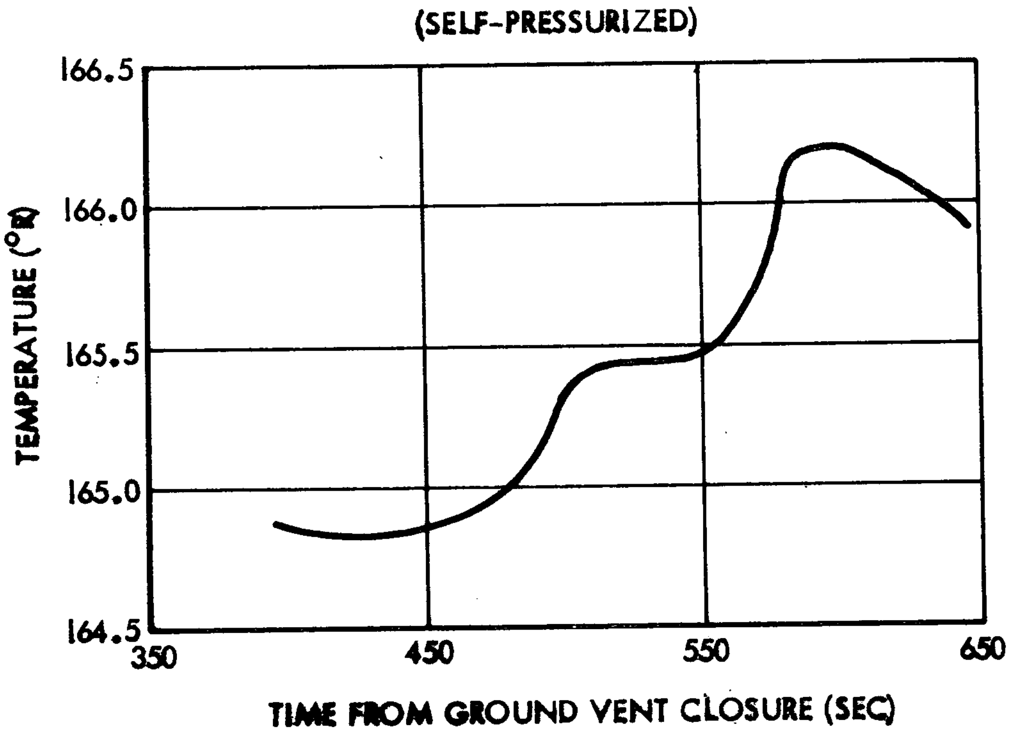

INSULATION – 1 INCH
ENGINE START
LIFTOFF
ULLAGE PRESSURE (PSIA)
19
18
17
16
15
14
0
100
200
300
400
500
600
700
TIME FROM GROUND VENT CLOSURE (SEC)

D03710
11m

2

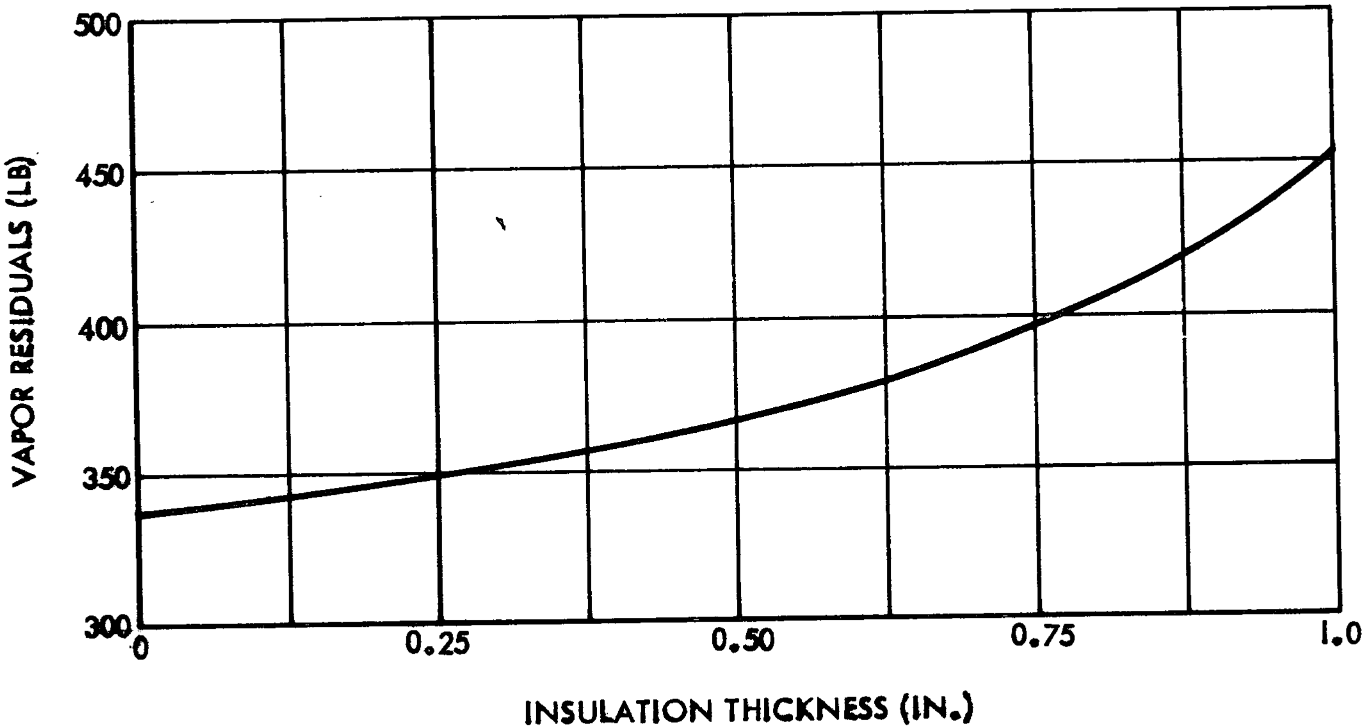
LOCKHEED

LOX ASCENT TANK DRAINED LIQUID TEMPERATURE



D03704
llm

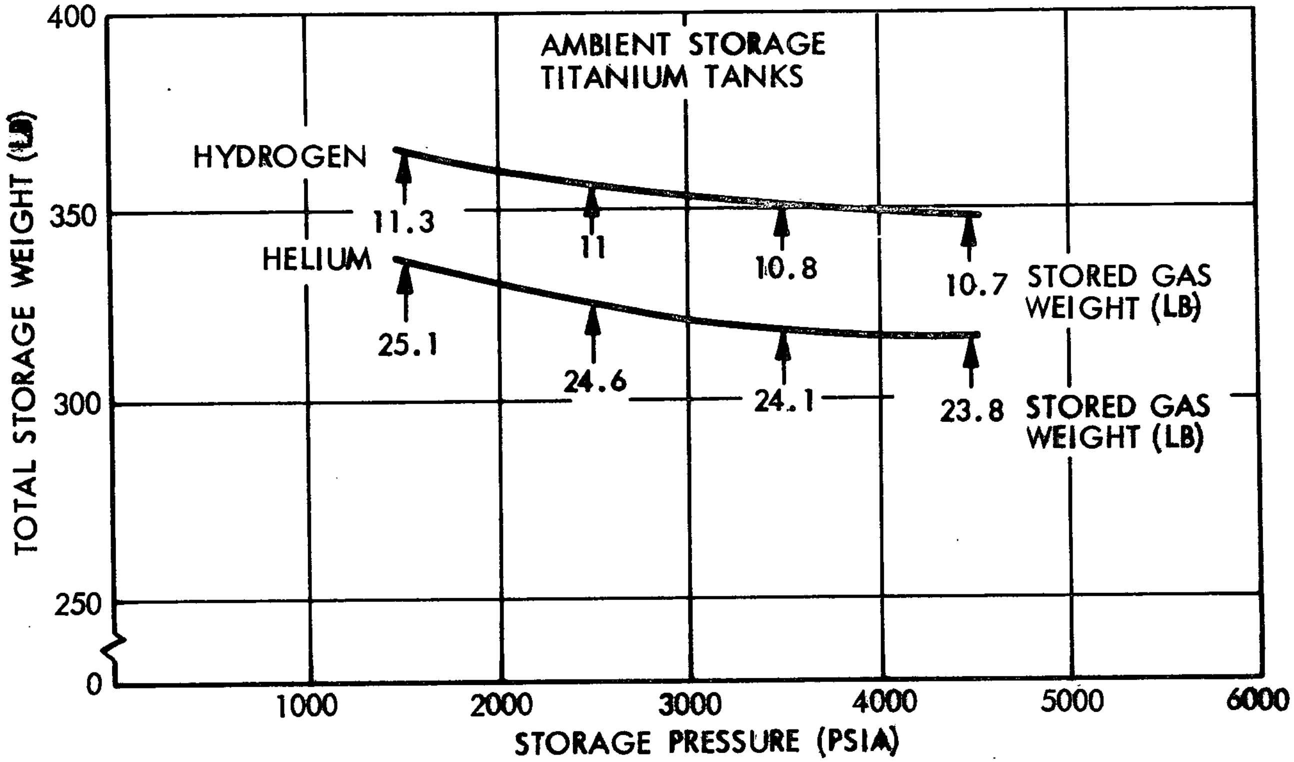
SELF-PRESSURIZED LIQUID-OXYGEN ORBIT INJECTION TANK
VAPOR RESIDUALS VS INSULATION THICKNESS



D03709
llm

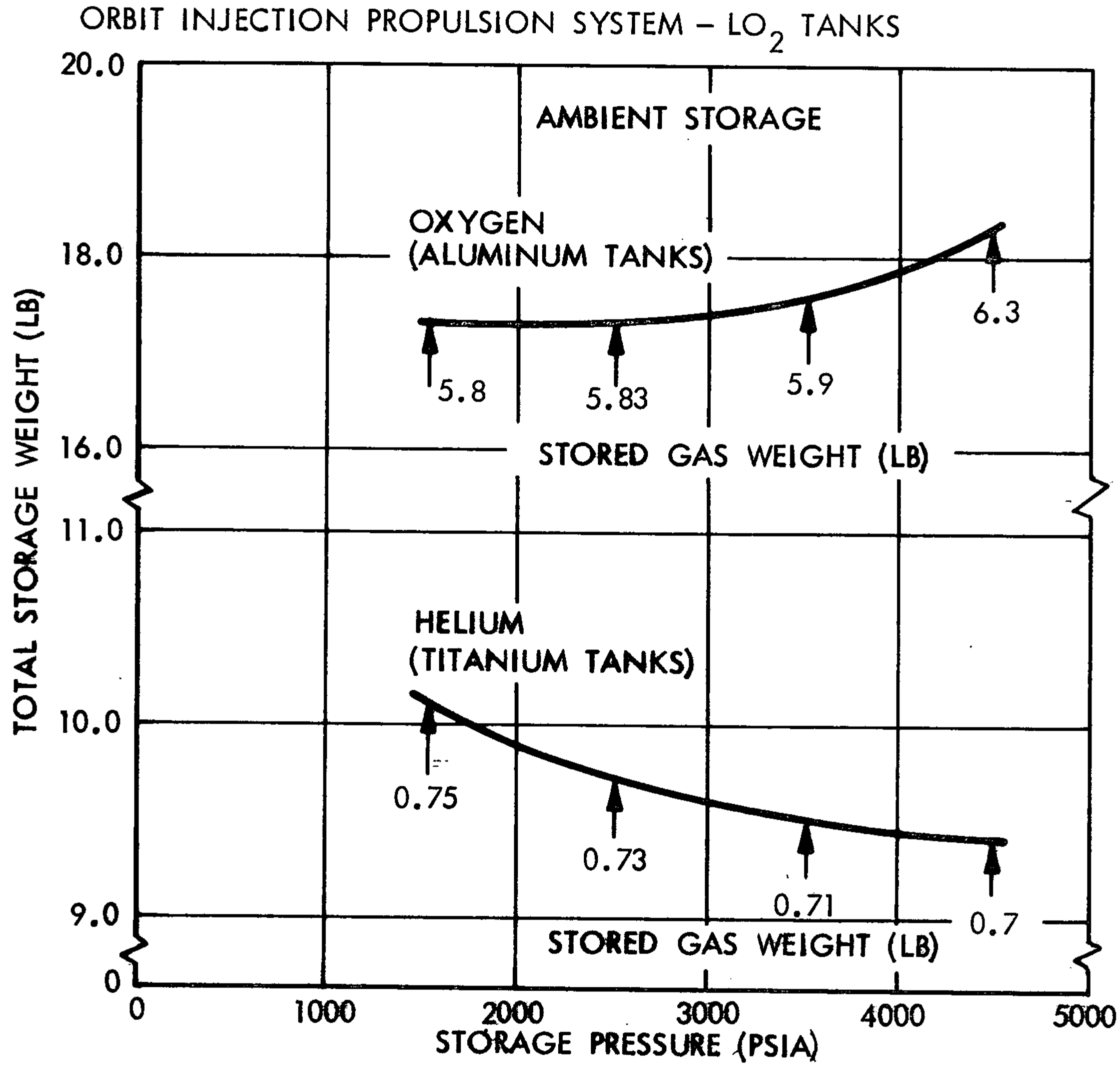
ONBOARD PREPRESSURIZATION

ORBIT INJECTION PROPULSION SYSTEM – LH_2 TANKS



D02981(1)
11m

ONBOARD PREPRESSURIZATION

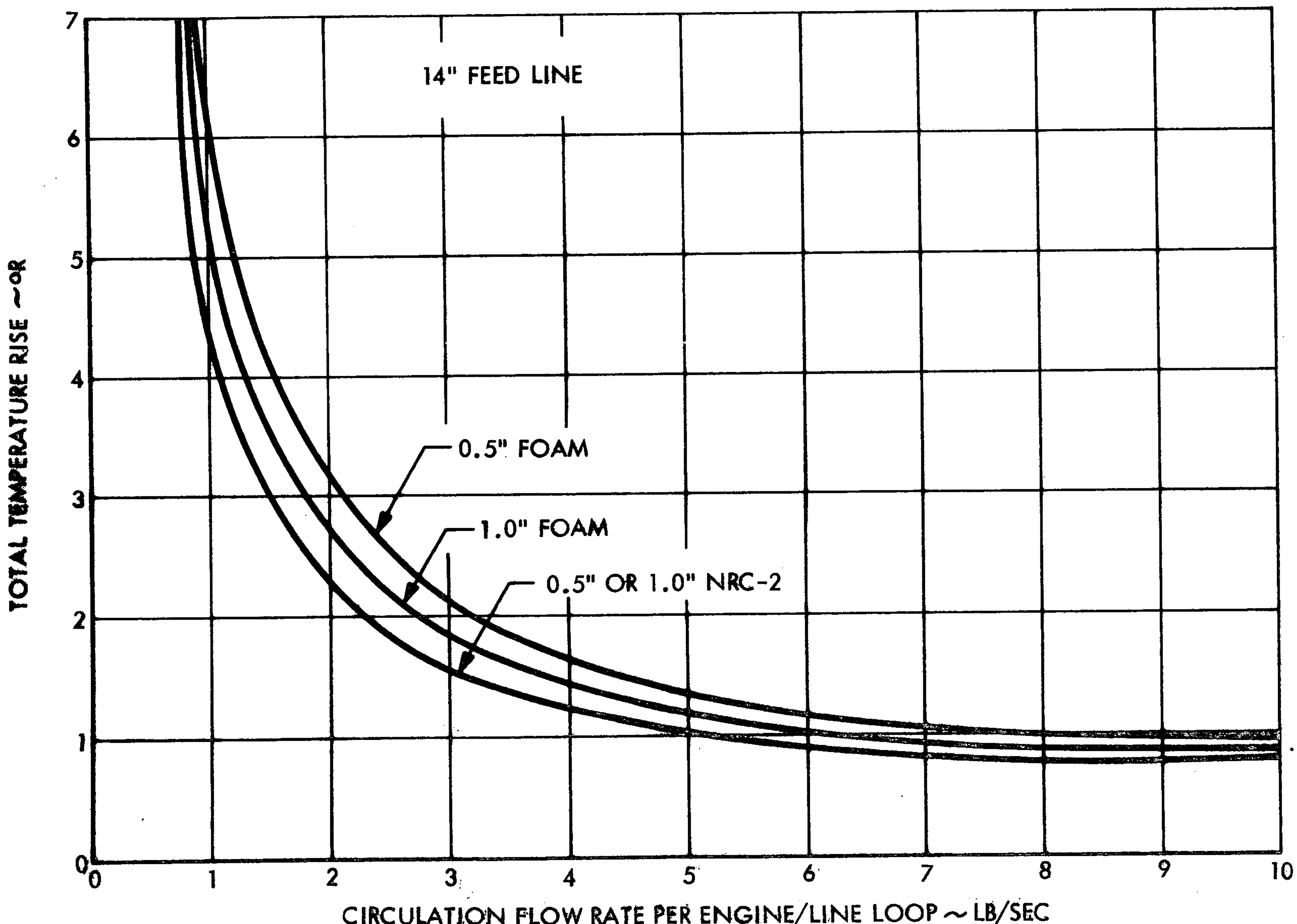


D02957

IIm

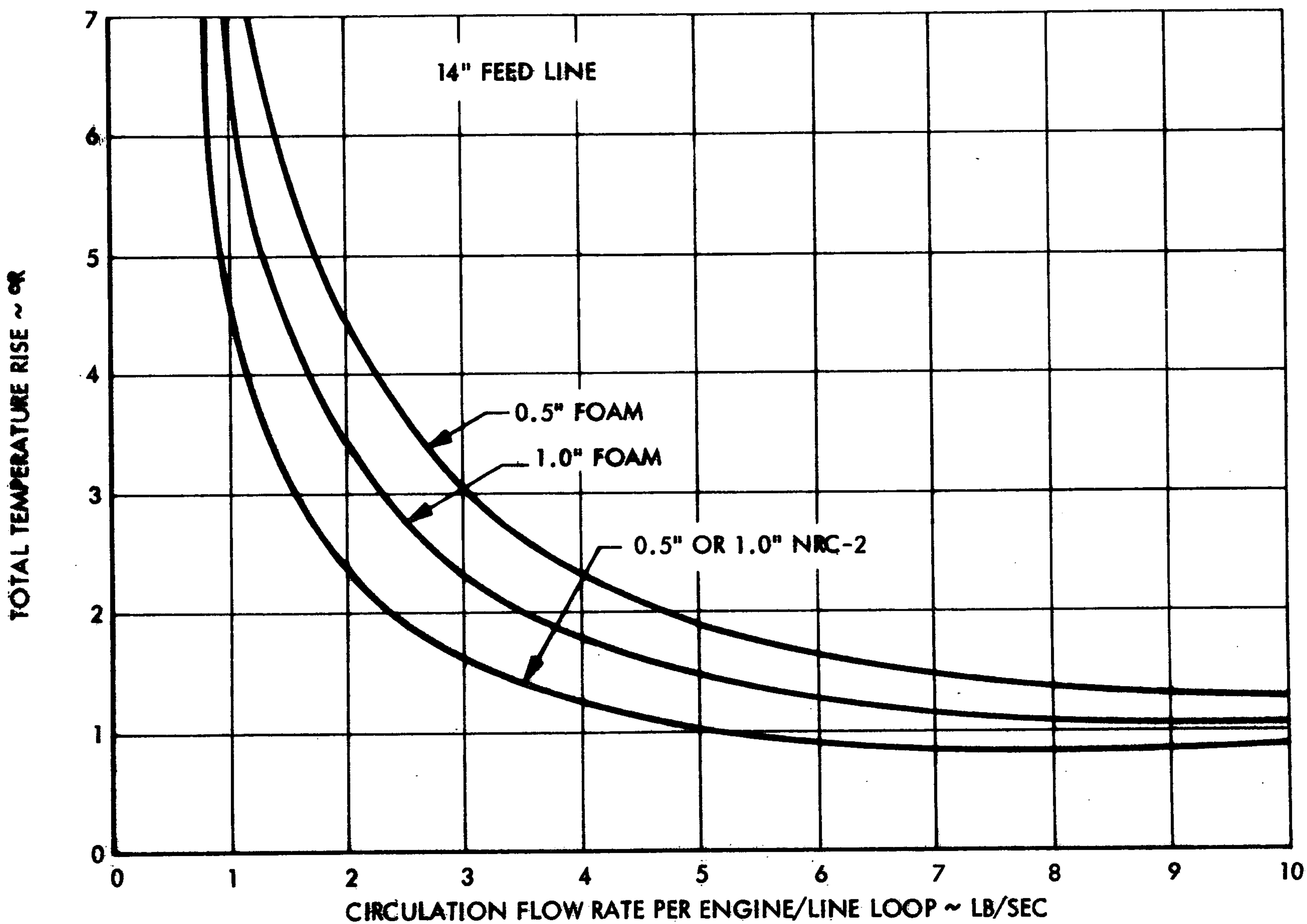
FEEDLINE TEMPERATURE CONTROL

OIPS FEEDLINE CIRCULATION EFFECTS MDAC - LH_2 SYSTEM (L = 76 FT)



D03756
llm

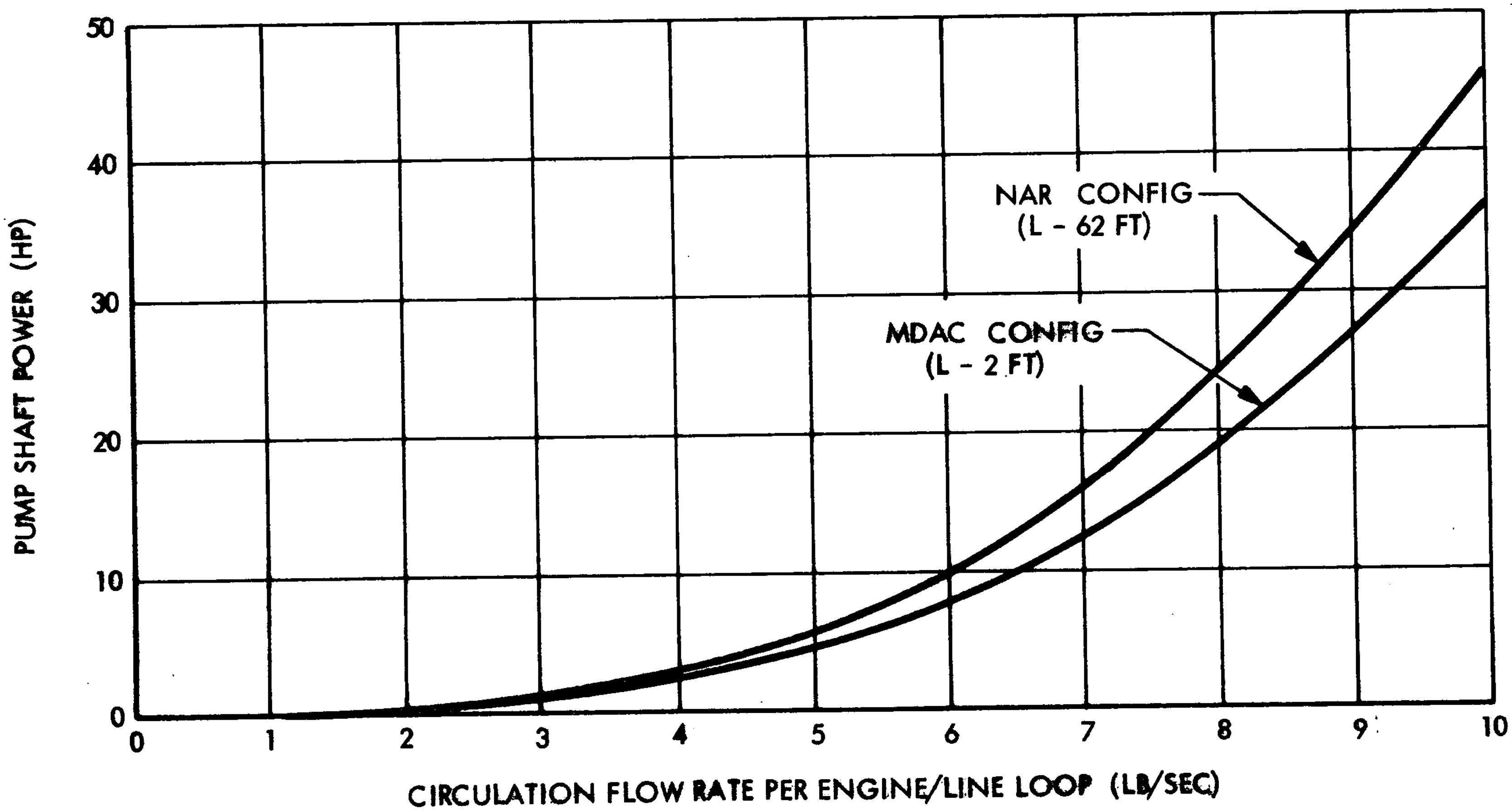
OIPS FEEDLINE CIRCULATION EFFECTS NAR - LH_2 SYSTEM (L = 31 FT)



D03760
II

REQUIRED PUMP SHAFT HORSEPOWER FOR CIRCULATION LH_2 TANKS

CIRCULATION LINE SIZE: 2 IN. DIA
PUMP EFFICIENCY: 72%
ENGINE RECIRCULATION VALVE AREA: 1.5 IN.^{2}

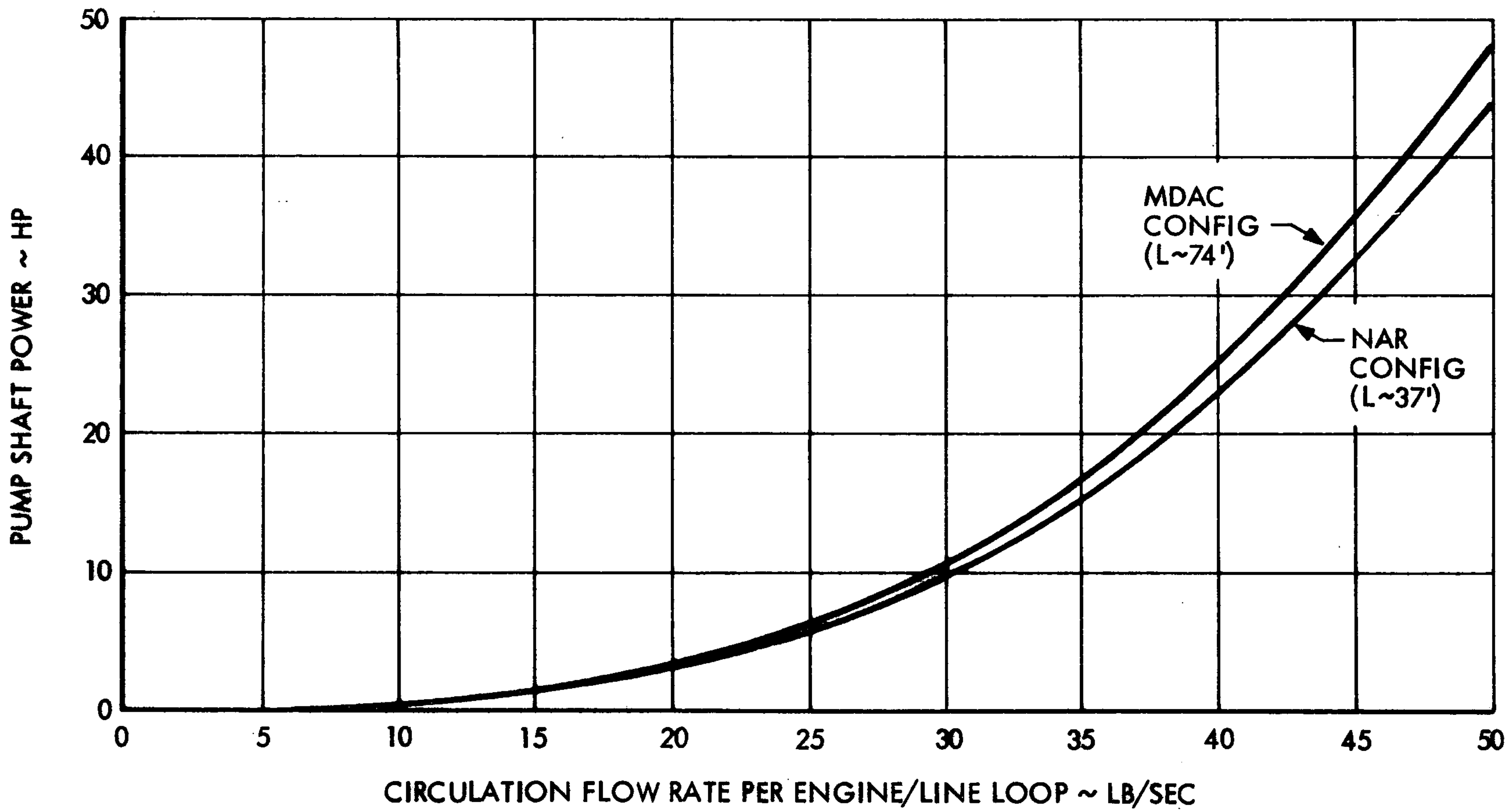


D03758
llm

no "B" in orig.
60c

REQUIRED PUMP SHAFT HORSEPOWER FOR CIRCULATION LO_2 TANKS

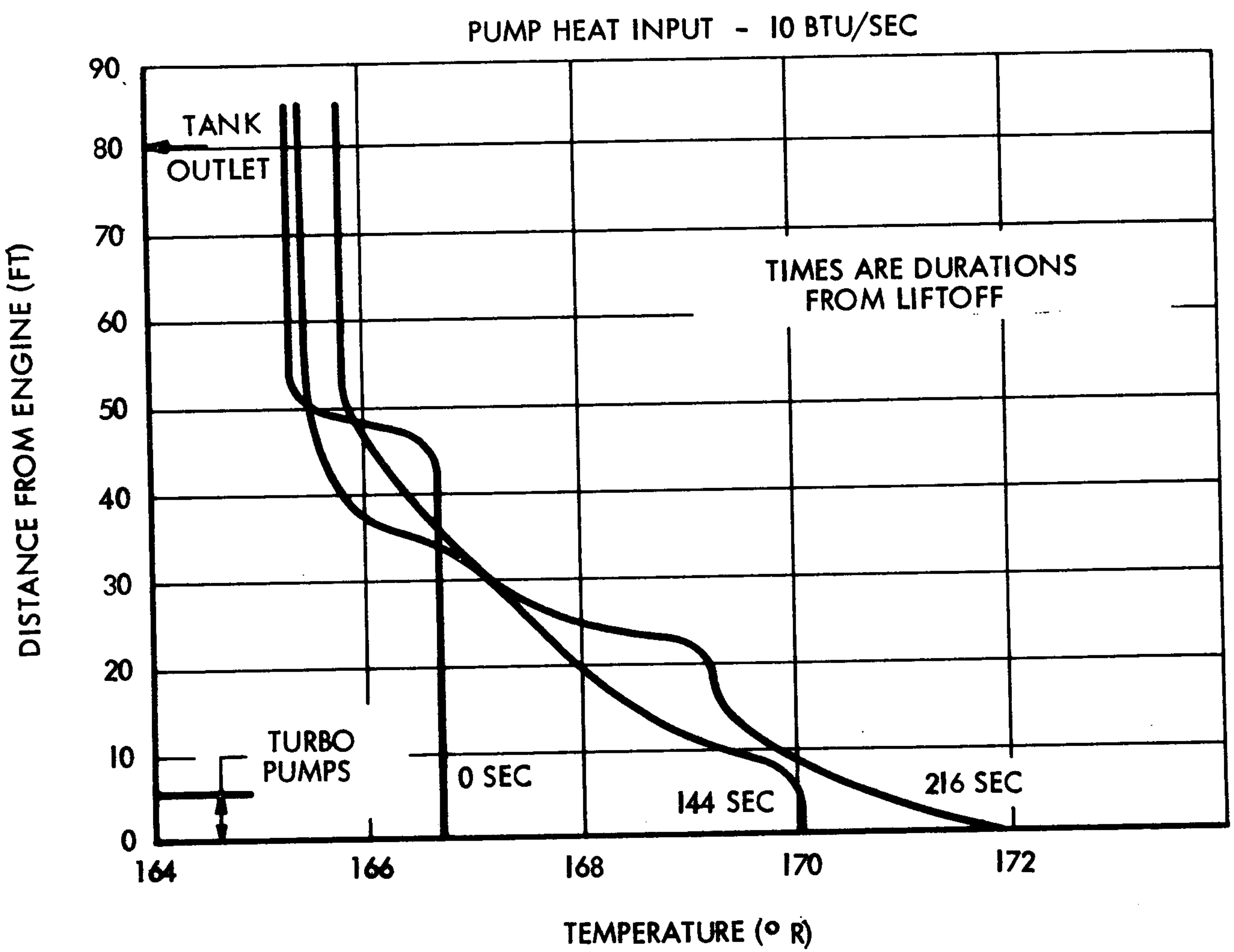
CIRCULATION LINE SIZE: 2" DIA.
PUMP EFFICIENCY: 72%
ENGINE RECIRCULATION VALVE AREA: 0.75 IN^2



D03757
llm

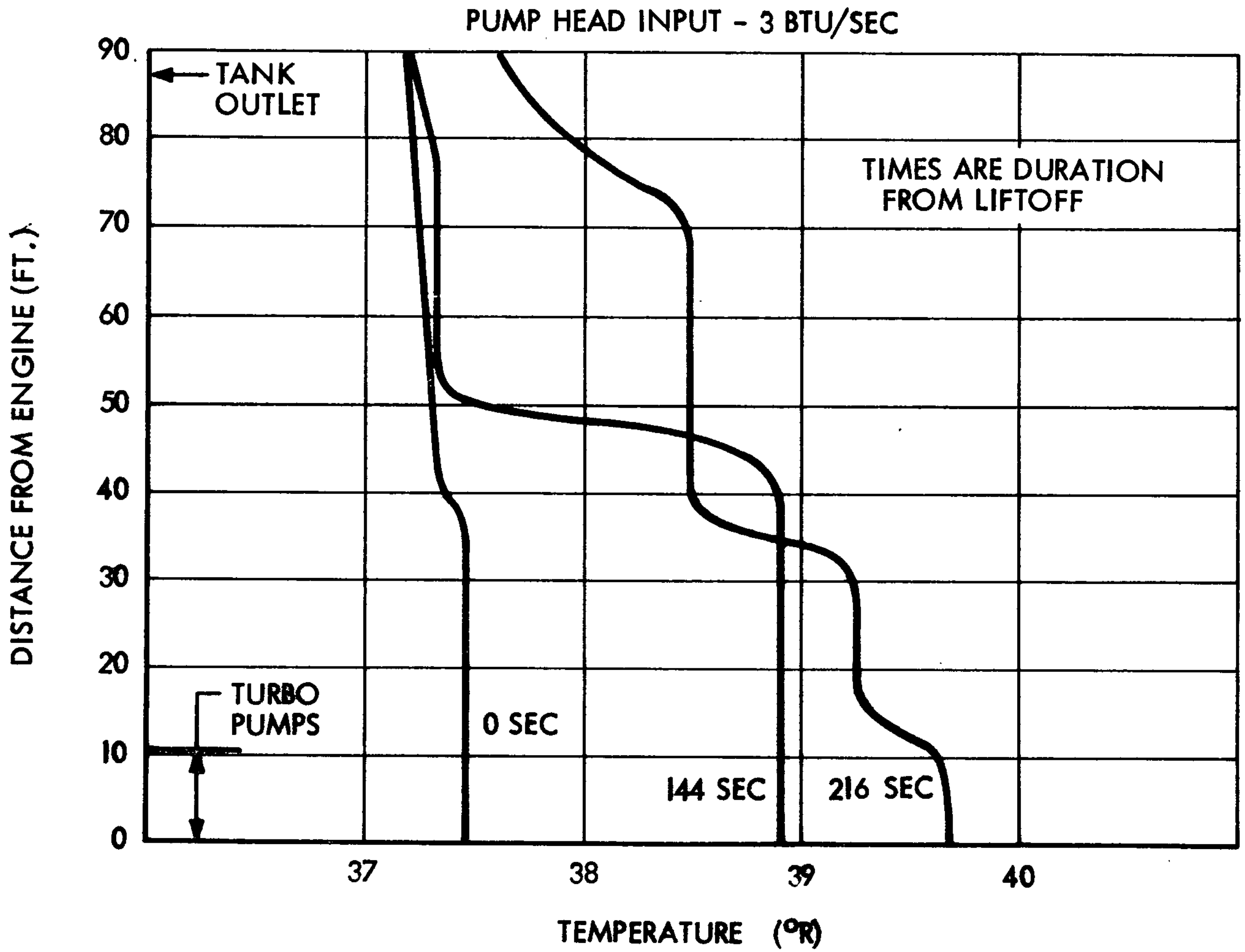
60d

LIQUID TEMPERATURE PROFILES LO_2 FEEDLINE – 0.5 IN. FOAM INSULATION



D04478
11m

LIQUID TEMPERATURE PROFILES LH_2 FEEDLINES – 1-IN. FOAM INSULATION



D04475
11m

CONCLUSIONS REGARDING ORBIT INJECTION PROPELLANT SUPPLY

- CONTINUOUS BLEED PRESSURIZATION COMPARABLE TO INTERMITTENT PRESSURIZATION
- COMMON VENT AND PRESSURIZATION LINES SATISFACTORY
- ON-BOARD PREPRESSURIZATION IS LOW PENALTY (HELIUM OR HYDROGEN)
- PRESSURIZATION NOT SENSITIVE TO INSULATION THICKNESS
- FEEDLINE TEMPERATURE CONTROL BY CIRCULATION MORE EFFECTIVE THAN BY INSULATION

llm

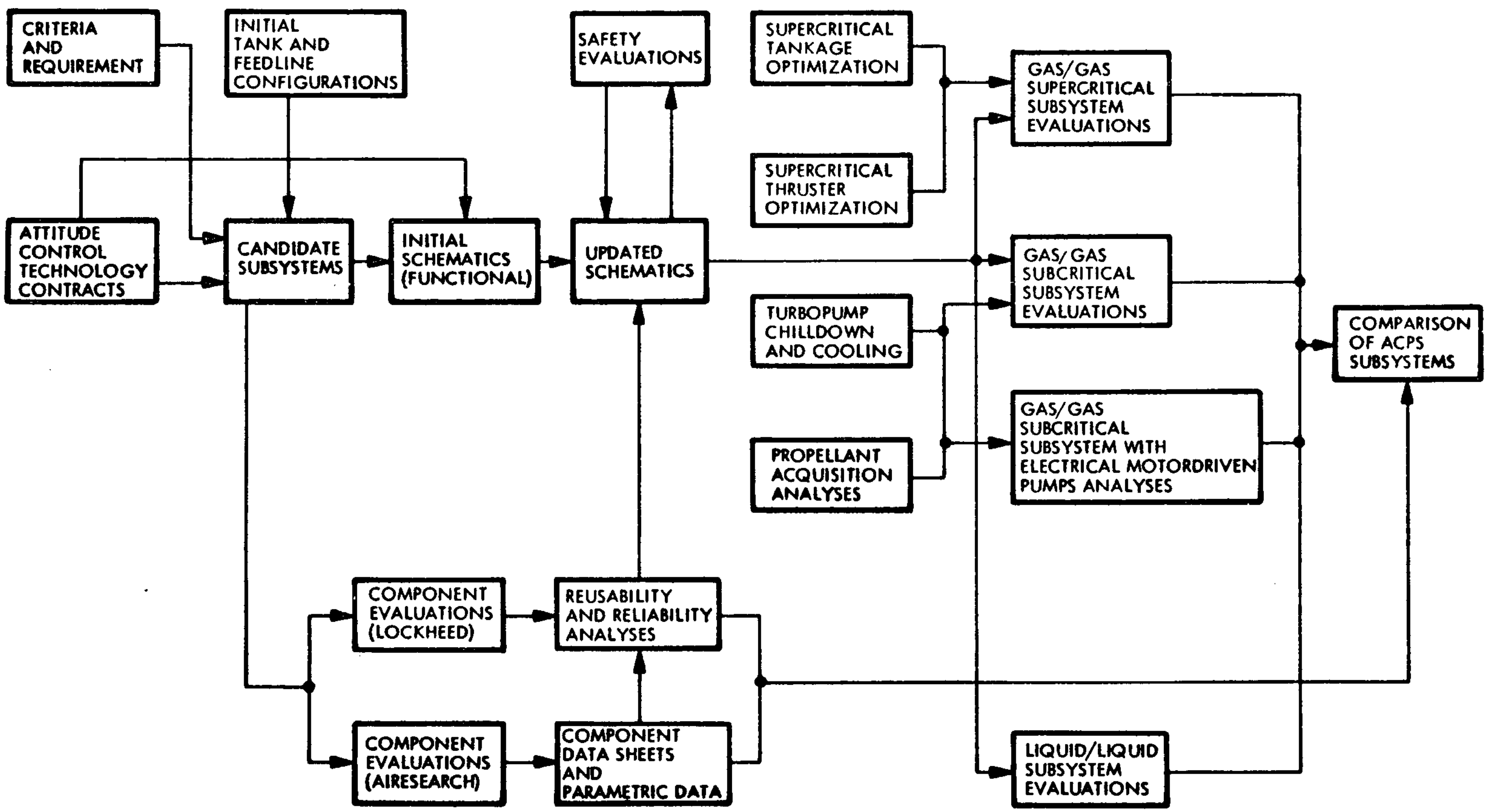
D04803

ATTITUDE CONTROL

PROPELLANT SUPPLY

APPROACH TO ATTITUDE CONTROL PROPELLANT SUPPLY EVALUATIONS (NONINTEGRATED)

LOCKHEED

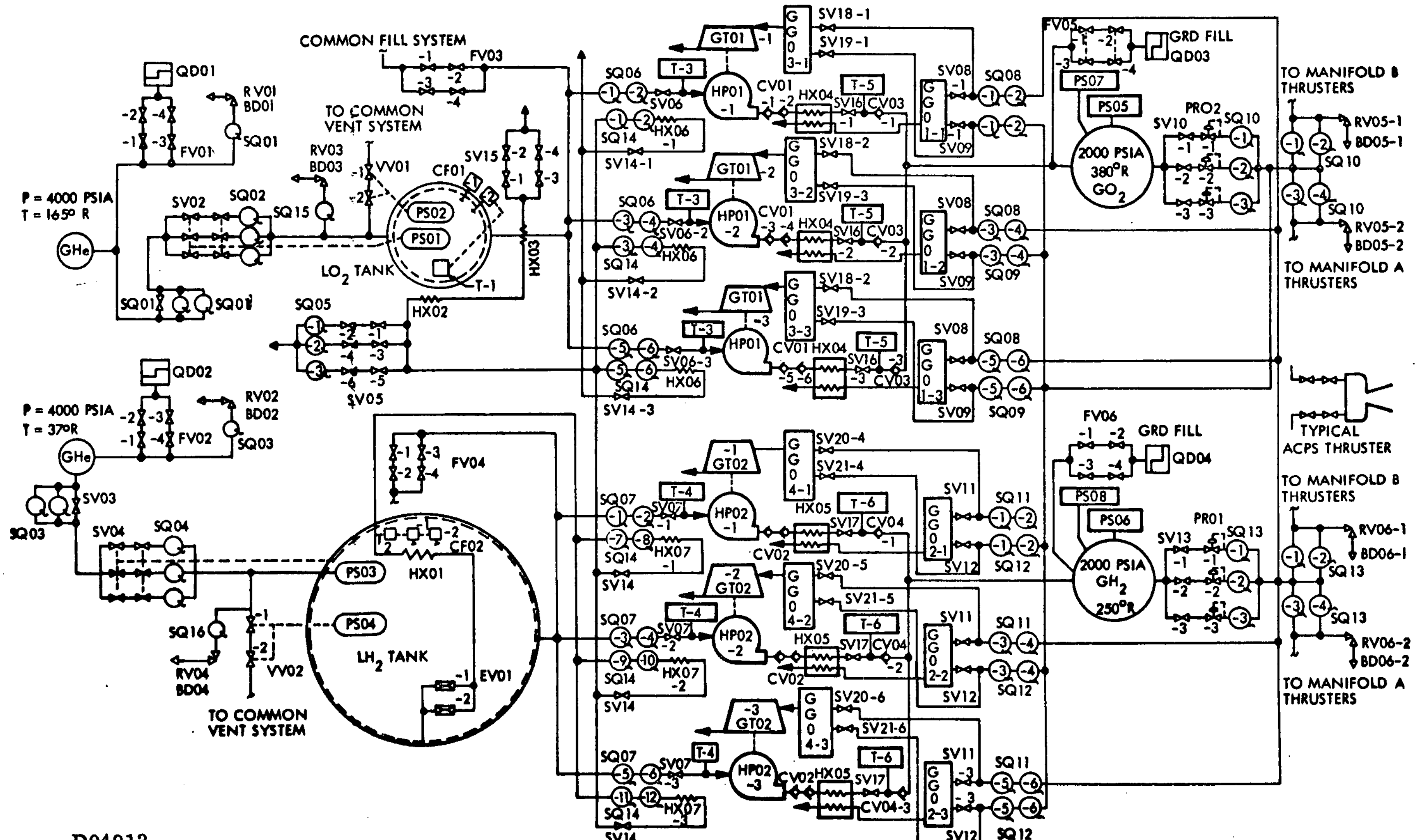


D04905

llm

LOCKHEED

ATTITUDE CONTROL PROPELLANT SUPPLY SYSTEM - SUBCRITICAL

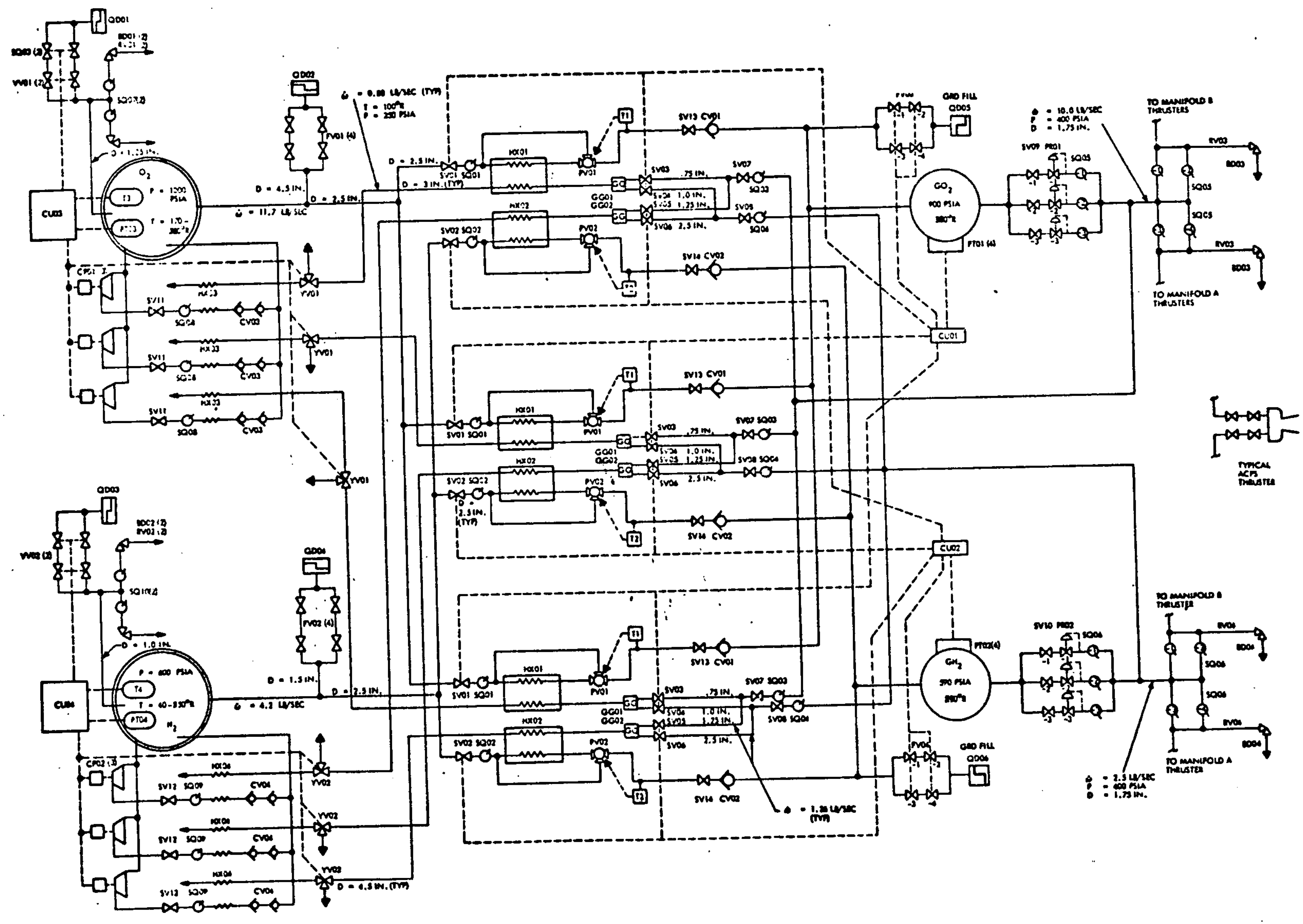


D04913

llm

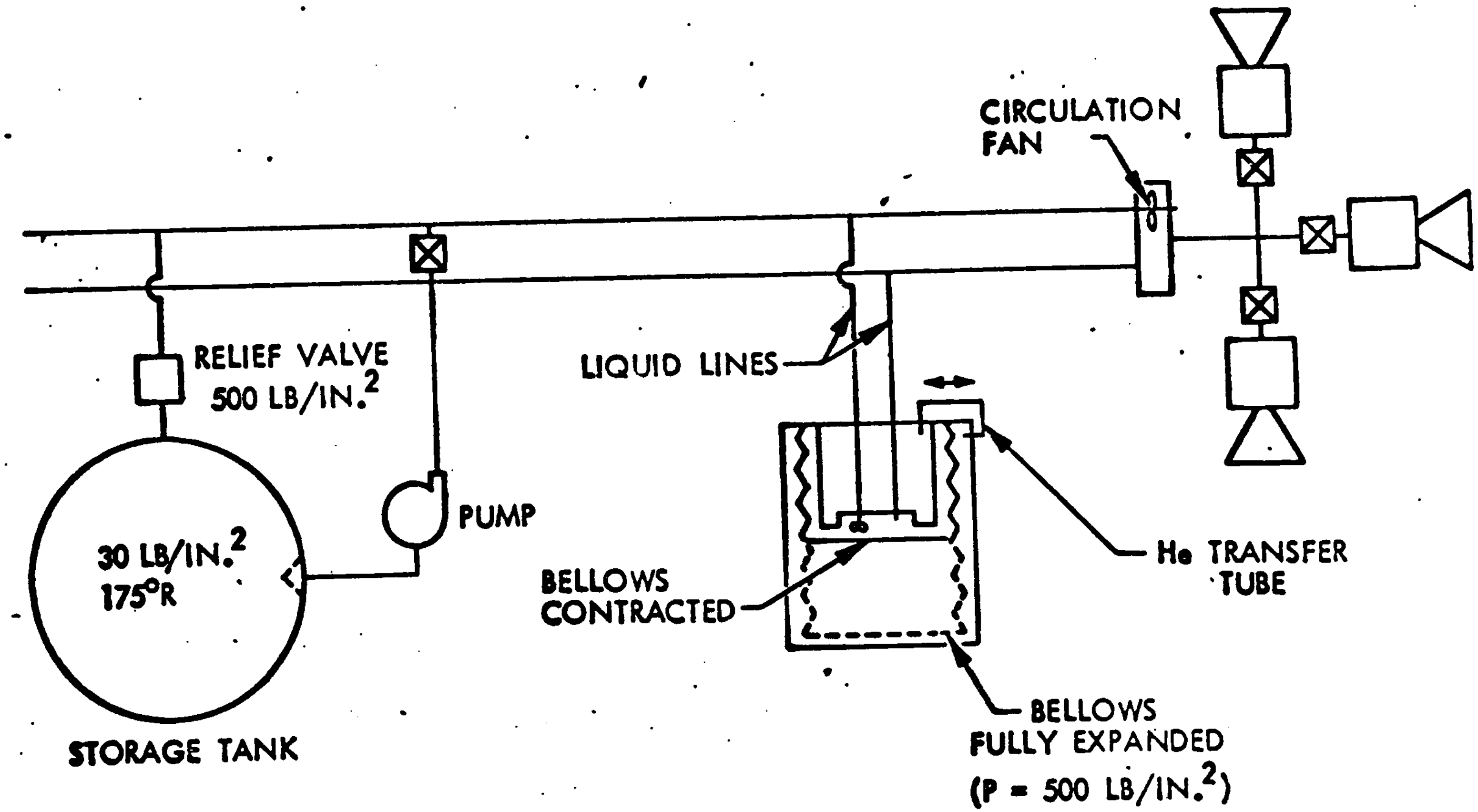
LOCKHEED

ATTITUDE CONTROL PROPULSION SUPPLY
SUPERCRITICAL STORAGE



D04783
LLM

LIQUID FEED ACPS SCHEMATIC

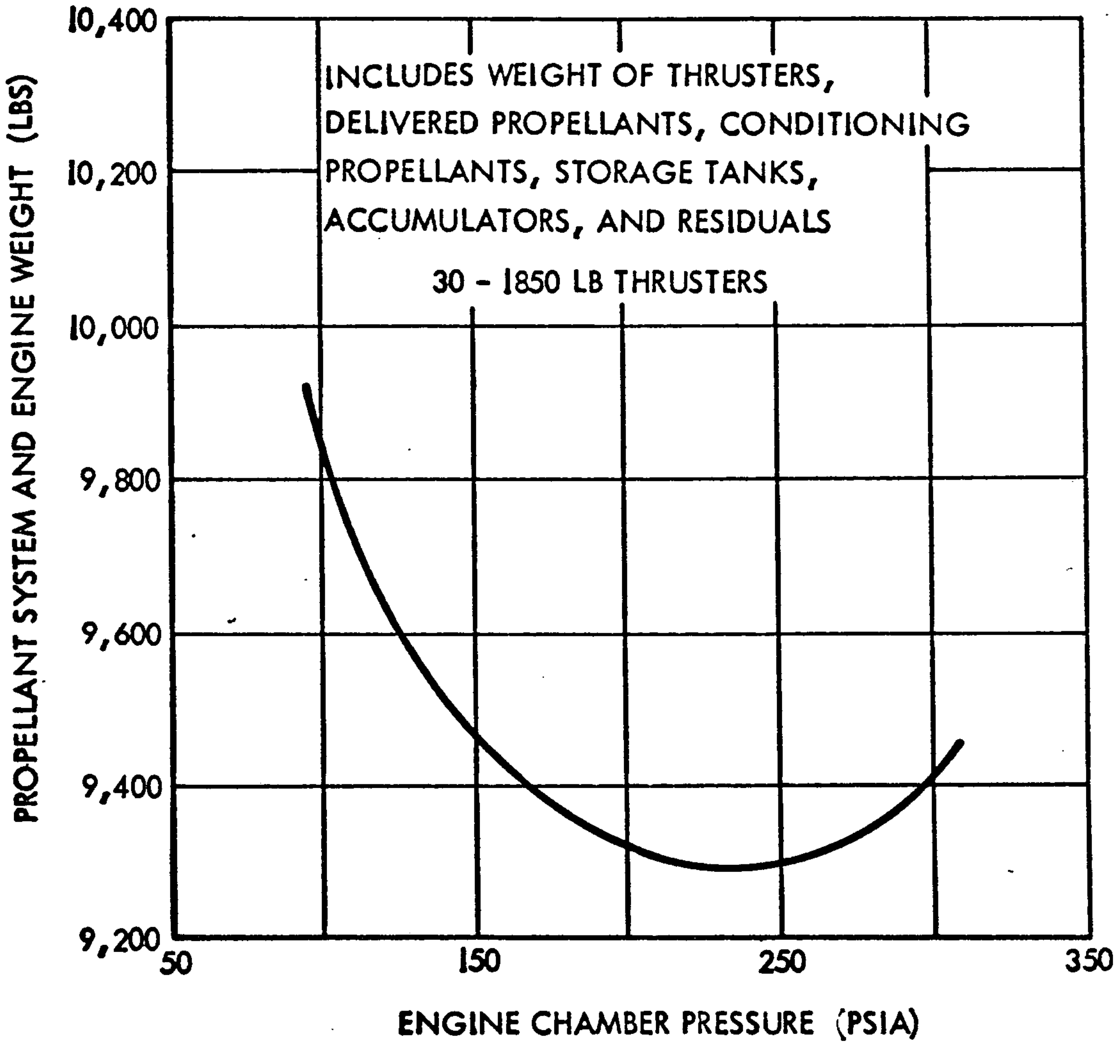


ONE PROPELLANT SYSTEM SHOWN
OTHER PROPELLANT SYSTEM SIMILAR

D03431

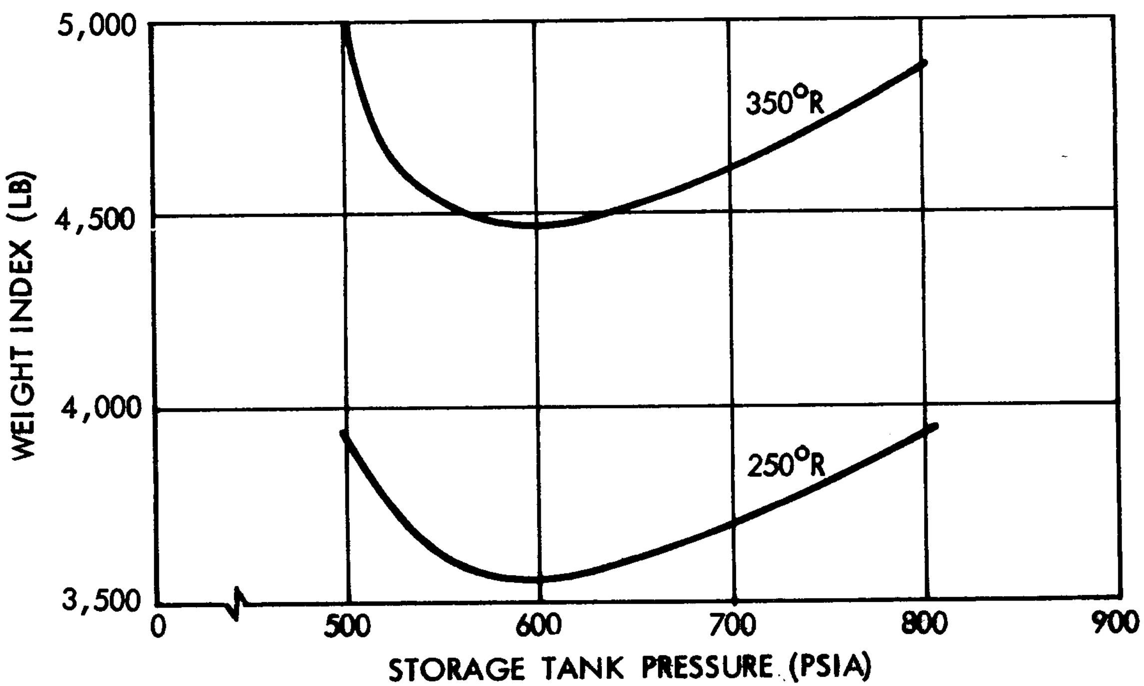
LOCKHEED

EFFECT OF CHAMBER PRESSURE ON SUPERCRITICAL ACPS WEIGHT



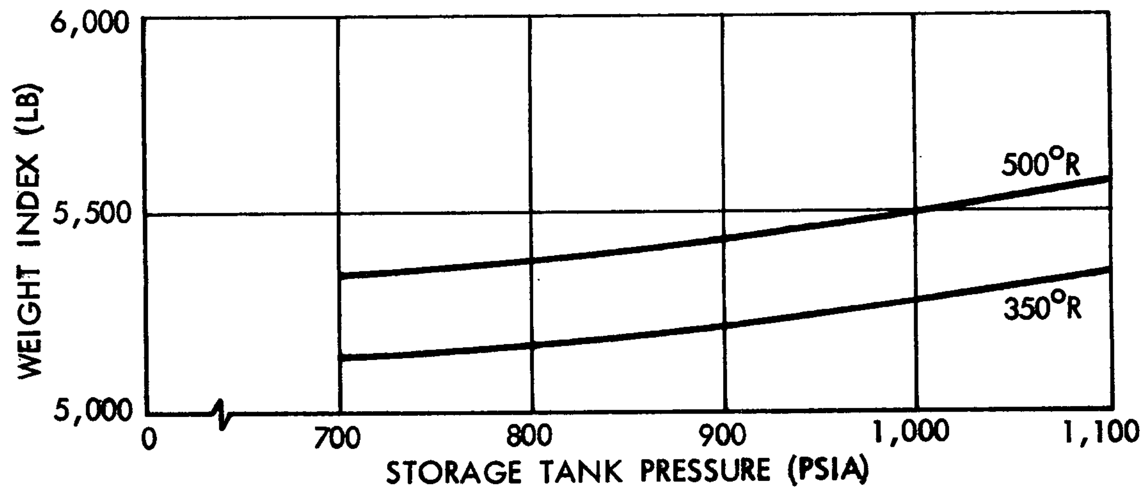
D03740
11m

ACPS LH_2 PROPELLANT - OPTIMIZATION OF SUPERCRITICAL STORAGE PRESSURE



D02989
llm

ACPS LO_2 PROPELLANTS – OPTIMIZATION OF SUPERCRITICAL STORAGE PRESSURE



D02990
11m

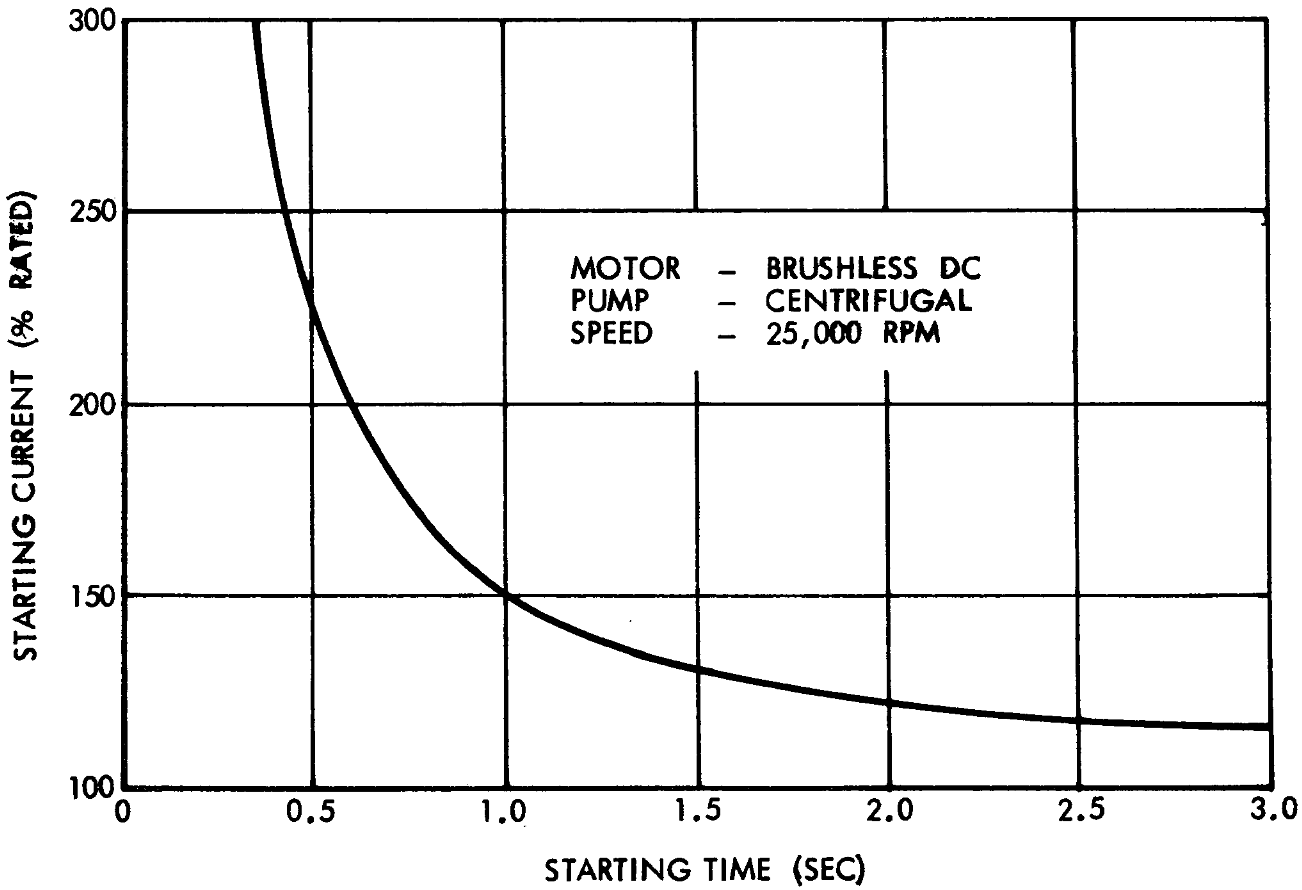
COMPARISON OF TURBOPUMPS AND PUMPS WITH ELECTRIC MOTORS

		THREE INSTALLED SETS*		FOUR INSTALLED SETS**	
TURBOPUMP CONCEPT(S)		USING ONBOARD APUs	USING SEPARATE APU TURBINE/GENERATOR	USING ONBOARD APUs	USING SEPARATE APU TURBINE/GENERATOR
COMPONENT — WT	COMPONENT	WT	WT	WT	WT
H_2 TURBOPUMP (3) ($\dot{\omega}$ = 3.80-LB/SEC AT 1043-PSIA ΔP EACH) — 75	H_2 PUMPS (3.80 LB/SEC AT 1043-PSI ΔP EACH)	69.0	69.0	64.0	64.0
O_2 TURBOPUMP (3) ($\dot{\omega}$ = 14.81 LB/SEC AT 940-PSIA ΔP EACH) — 124	O_2 PUMPS (14.81 LB/SEC AT 940-PSI ΔP EACH)	10.0	10.0	9.0	9.0
H_2 AND O_2 FOR COOLING AND HEATING — 125/595	H_2 PUMP MOTORS O_2 PUMP MOTORS	546.0 119.0	546.0 119.0	364.0 75.0	364.0 75.0
H_2 AND O_2 FOR DRIVING TURBINES (500-SEC DURATION) — 85	GENERATOR WEIGHT (3 AT 360 Kw) DELETE GENERATOR ON APU	774.0 -60.0	774.0 0	516.0 -60	516.0 0
	SEPARATE TURBINES/ COMBUSTORS/CONTROLS	0	168.0	0	214.0
	H_2 AND O_2 TO DRIVE APU TURBINES (500 SEC)	119.0	119.0	119.0	119.0
TOTAL — 409/880		1577.0	1805.0	1087.0	1361.0

*1 OUT OF 3 MUST OPERATE (EACH SET SIZED FOR FULL FLOW)
**2 OUT OF 4 MUST OPERATE (EACH SET SIZED FOR HALF FLOW)

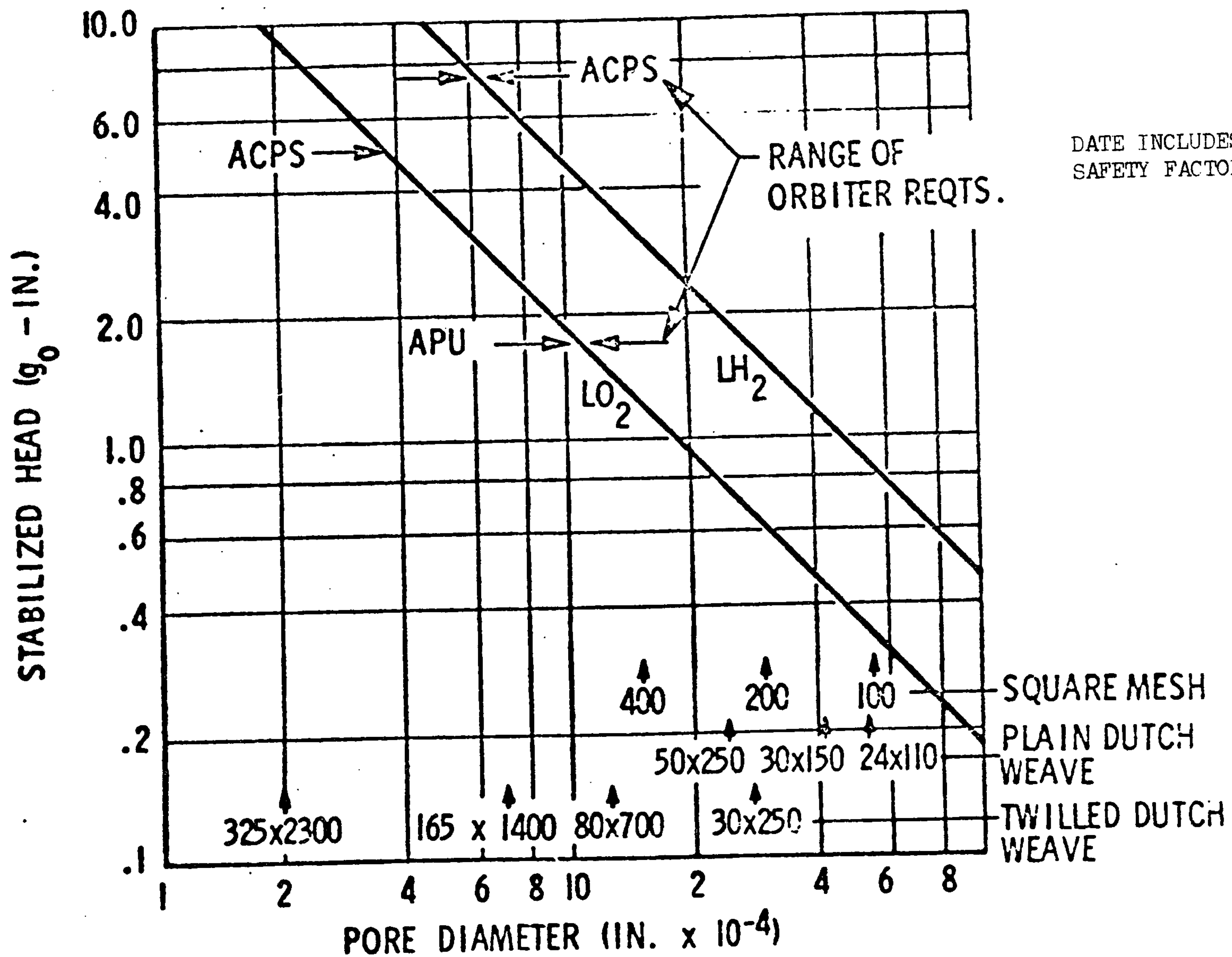
D03003
llm

STARTING CURRENT REQUIREMENTS



D04693
llm

CAPILLARY STABILITY MAP
(FOR SHUTTLE CRYOGENIC SUBSYSTEM REQUIREMENTS)

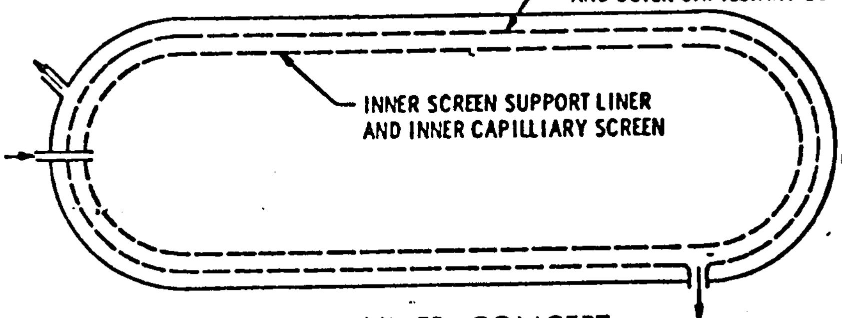


DATE INCLUDES A SAFETY FACTOR OF 2

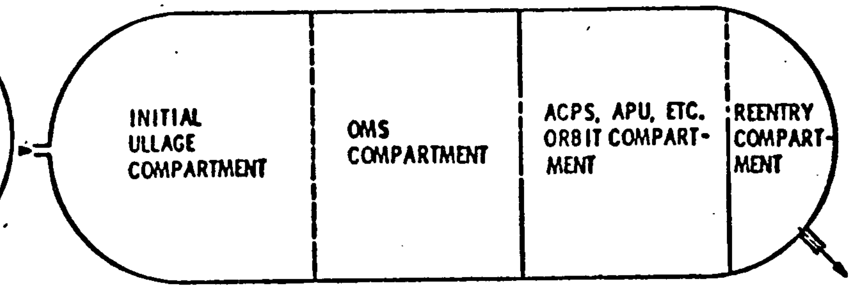
D03749

LOCKHEED

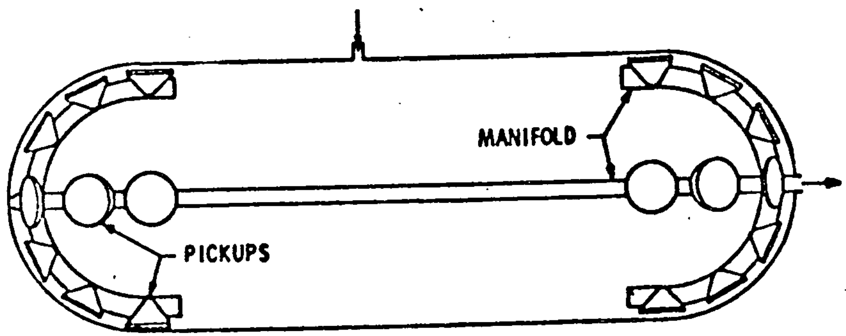
CANDIDATE DESIGN CONCEPTS



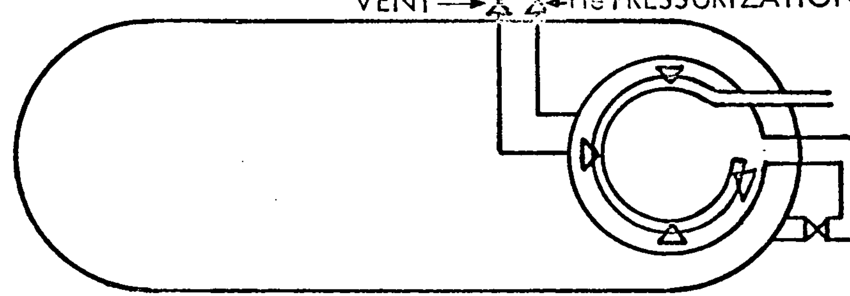
SCREEN LINER CONCEPT



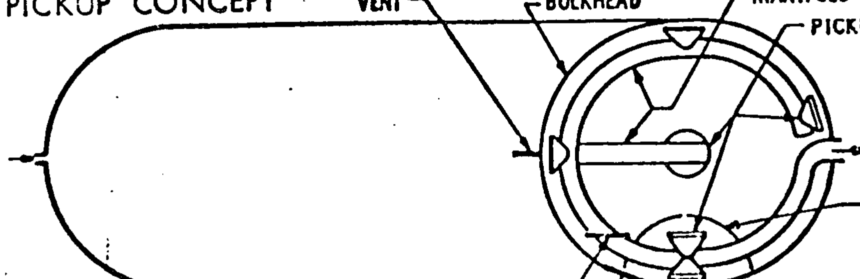
COMPARTMENTED CONCEPT



MANIFOLD PICKUP CONCEPT



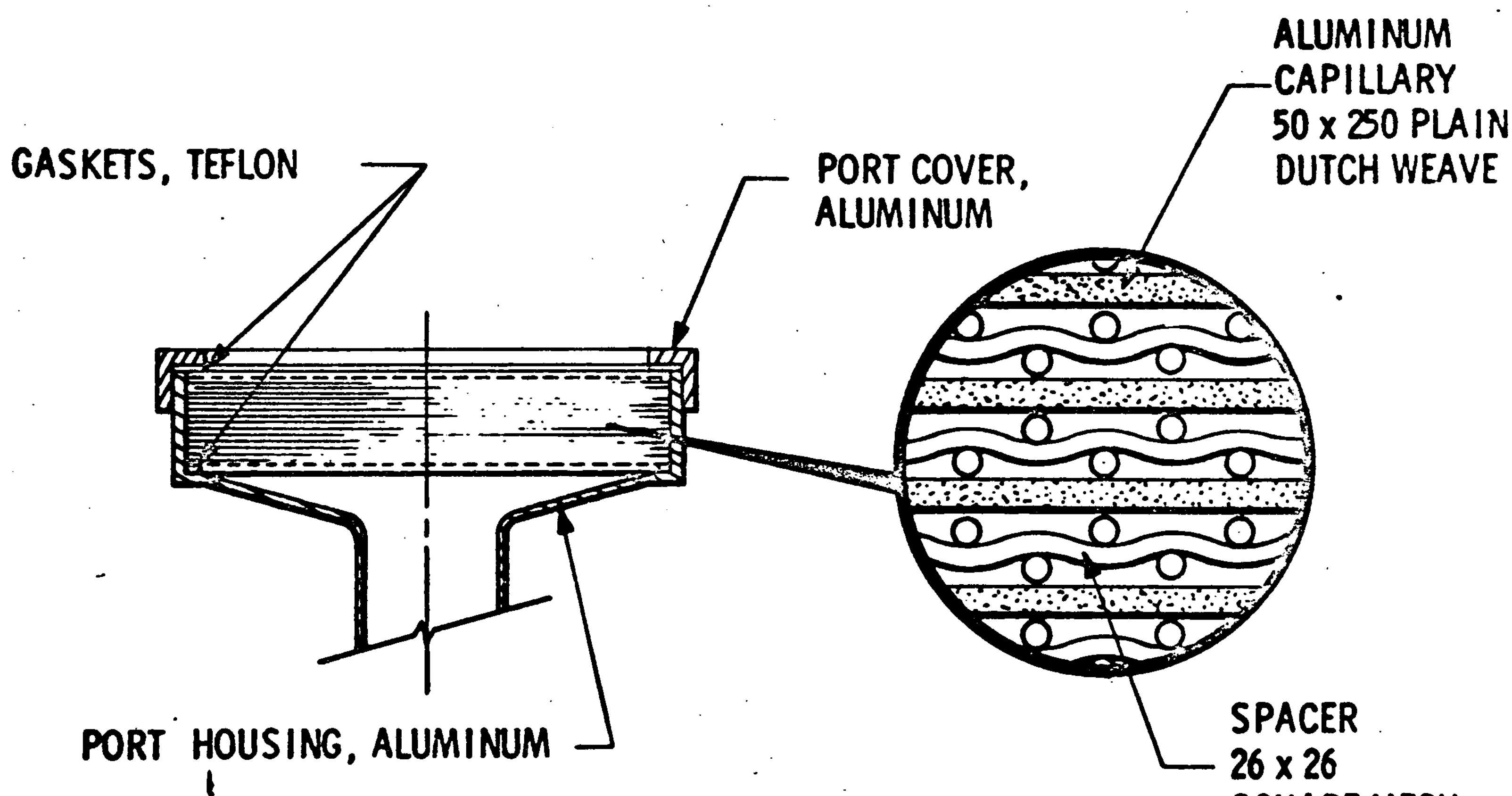
START TANK CONCEPT



COMPOSITE CONCEPT

DO3218(I)
llm

TYPICAL INLET PORT DETAIL

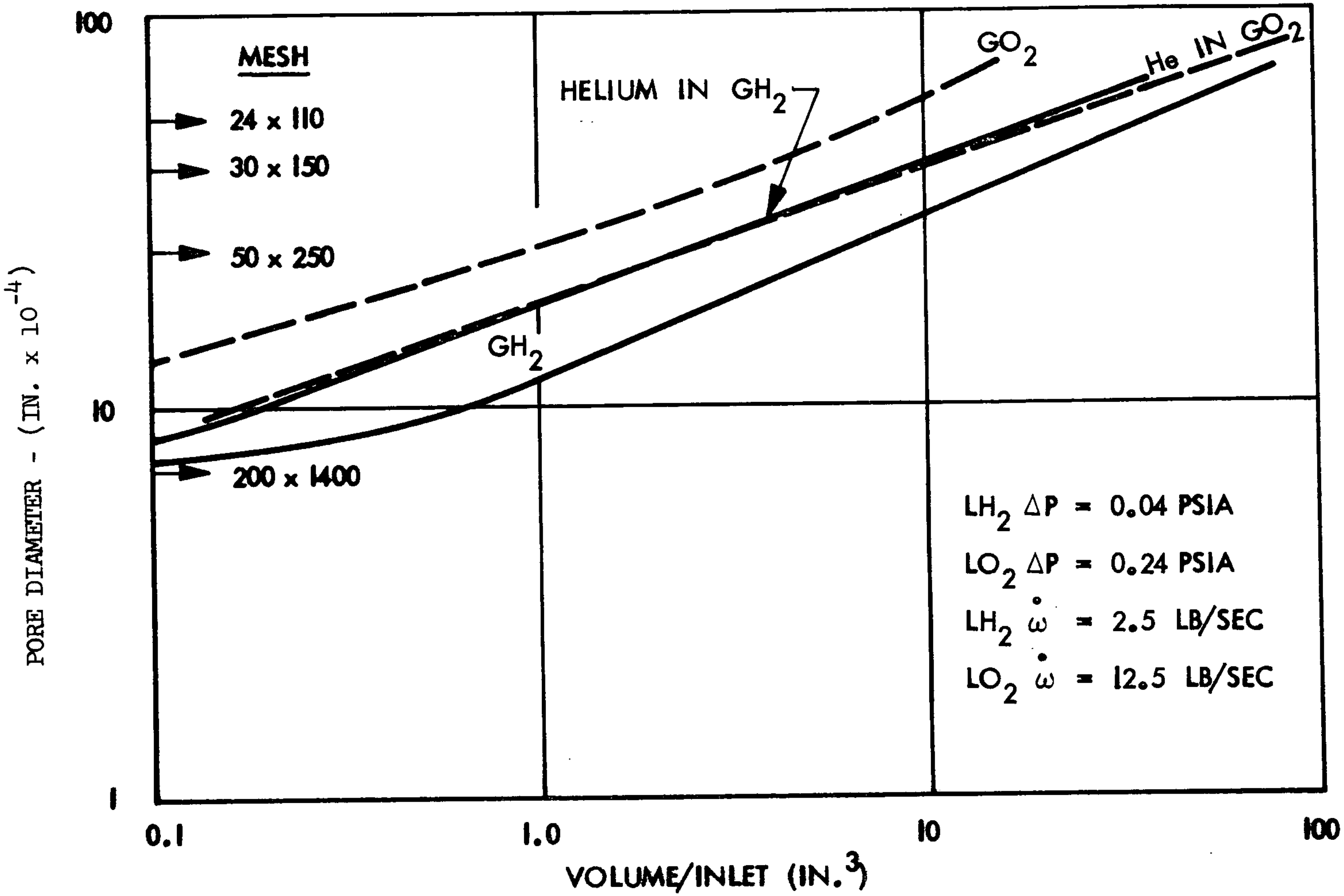


D03766
llm

LOCKHEED

MAXIMUM GAS IN MULTIPLE SCREEN DEVICES

TYPICAL CONDITIONS

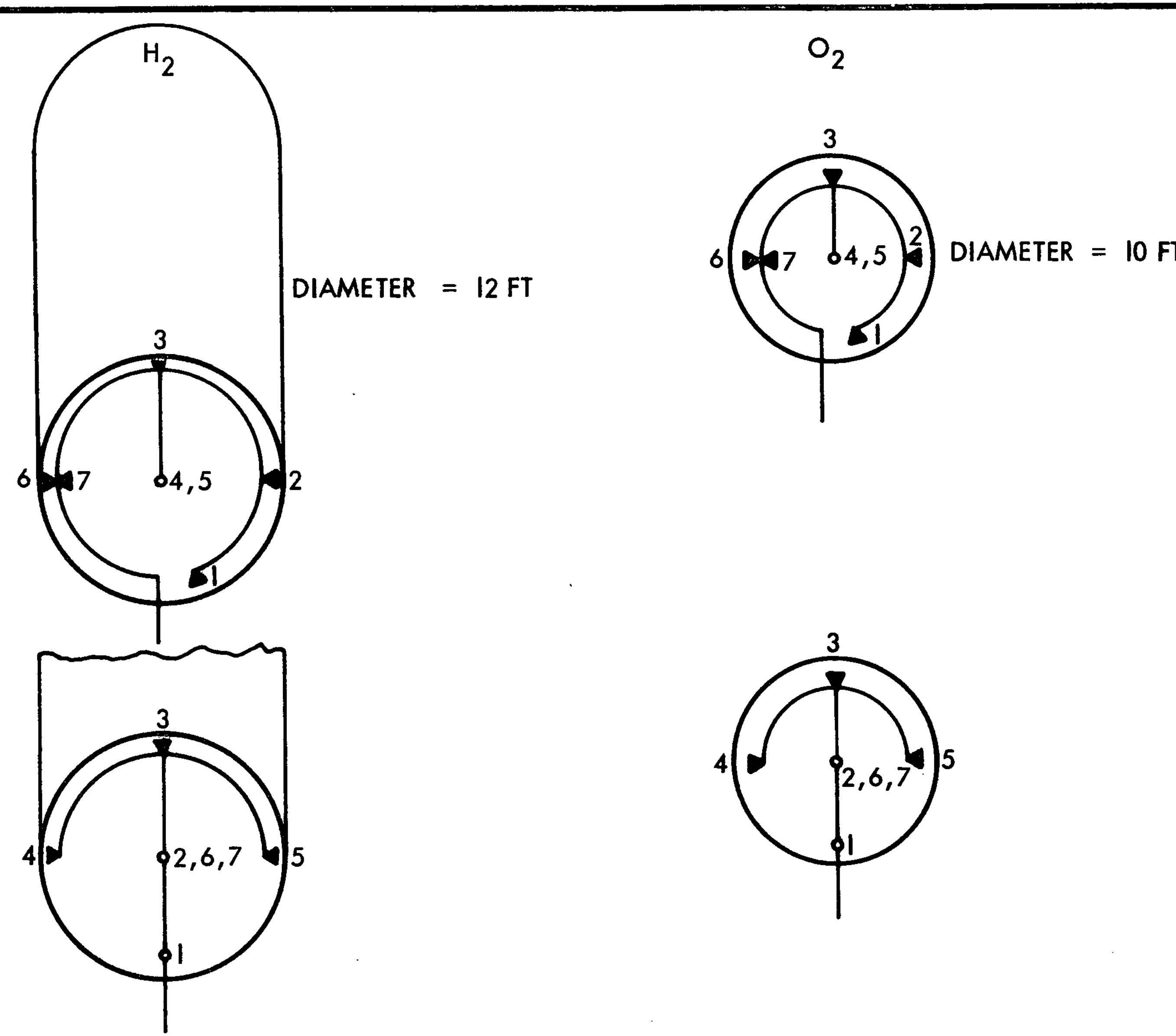


D03801

llm

LOCKHEED

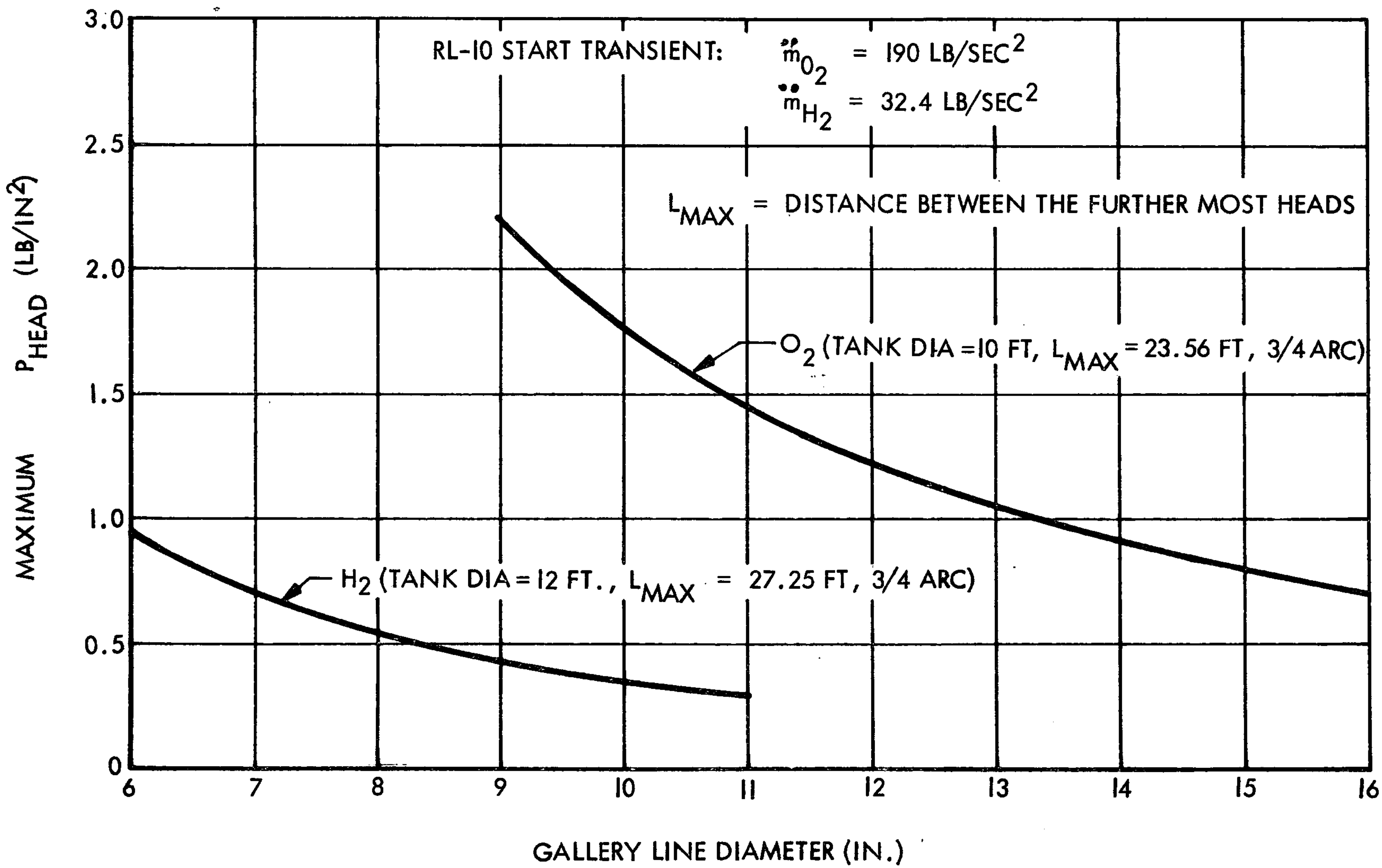
PROPELLANT ACQUISITION DEVICE CONFIGURATION



D04716

llm

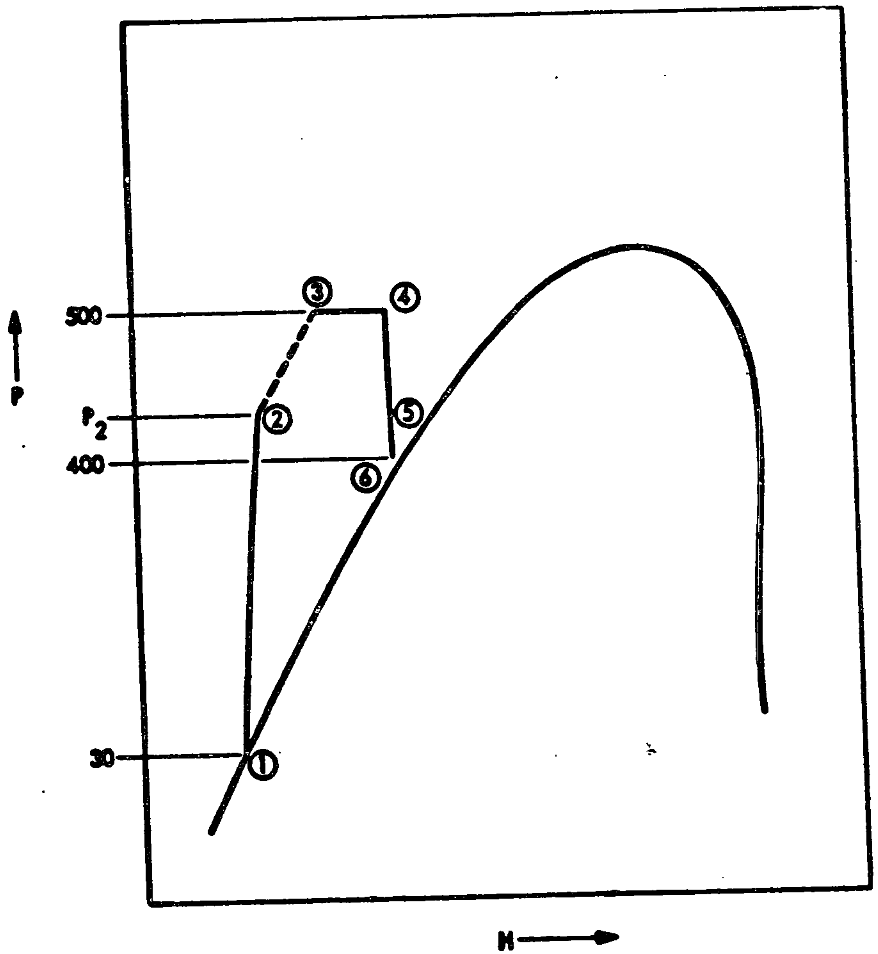
REQUIRED HEAD DIFFERENTIAL CAPABILITY VS. GALLERY LINE DIAMETER



D04715

llm

LIQUID/LIQUID ACPS THERMODYNAMIC CYCLE



D03432

LOCKHEED

COMPARISON OF LIQUID/LIQUID AND GAS/GAS ATTITUDE CONTROL PROPELLANT SUPPLY

TYPE OF STORAGE	TYPE OF FEED	TYPE OF PUMP DRIVE	NO. OF GENS.	ACCUAT. BELLOWS CONTRACT. RATIO (%)	MAX H_2 TEMP (°R)	DRY WEIGHT (LB)	TOTAL SYSTEM WEIGHT (LB)
SUBCRIT	GAS	TURBINE	–	–	–	3,009	11,198
SUPERCRIT	GAS	–	–	–	–	5,713	14,053
SUBCRIT	LIQUID	TURBINE	–	20	54	3,580	11,718
SUBCRIT	LIQUID	TURBINE	–	20	72	5,199	12,991
SUBCRIT	LIQUID	TURBINE	–	100	54	2,847	10,985
SUBCRIT	LIQUID	TURBINE	–	100	72	3,121	10,913
SUBCRIT	LIQUID	MOTOR	3	20	54	4,245	11,776
SUBCRIT	LIQUID	MOTOR	3	20	72	5,864	13,049
SUBCRIT	LIQUID	MOTOR	3	100	54	3,512	11,043
SUBCRIT	LIQUID	MOTOR	3	100	72	3,786	10,971
SUBCRIT	LIQUID	MOTOR	4	20	54	4,077	11,608
SUBCRIT	LIQUID	MOTOR	4	20	72	5,696	12,881
SUBCRIT	LIQUID	MOTOR	4	100	54	3,344	10,875
SUBCRIT	LIQUID	MOTOR	4	100	72	3,618	10,803

D04878

CONCLUSIONS REGARDING ATTITUDE CONTROL PROPULSION SUPPLY

- SUBCRITICAL STORAGE RESULTS IN SUBSTANTIALLY LOWER DRY WEIGHTS THAN SUPERCRITICAL STORAGE

- LIQUID/LIQUID ACPS CAN HAVE COMPARABLE WEIGHTS TO GAS/GAS ACPS, DEPENDING UPON BELLOWS CONTRACTION RATIOS

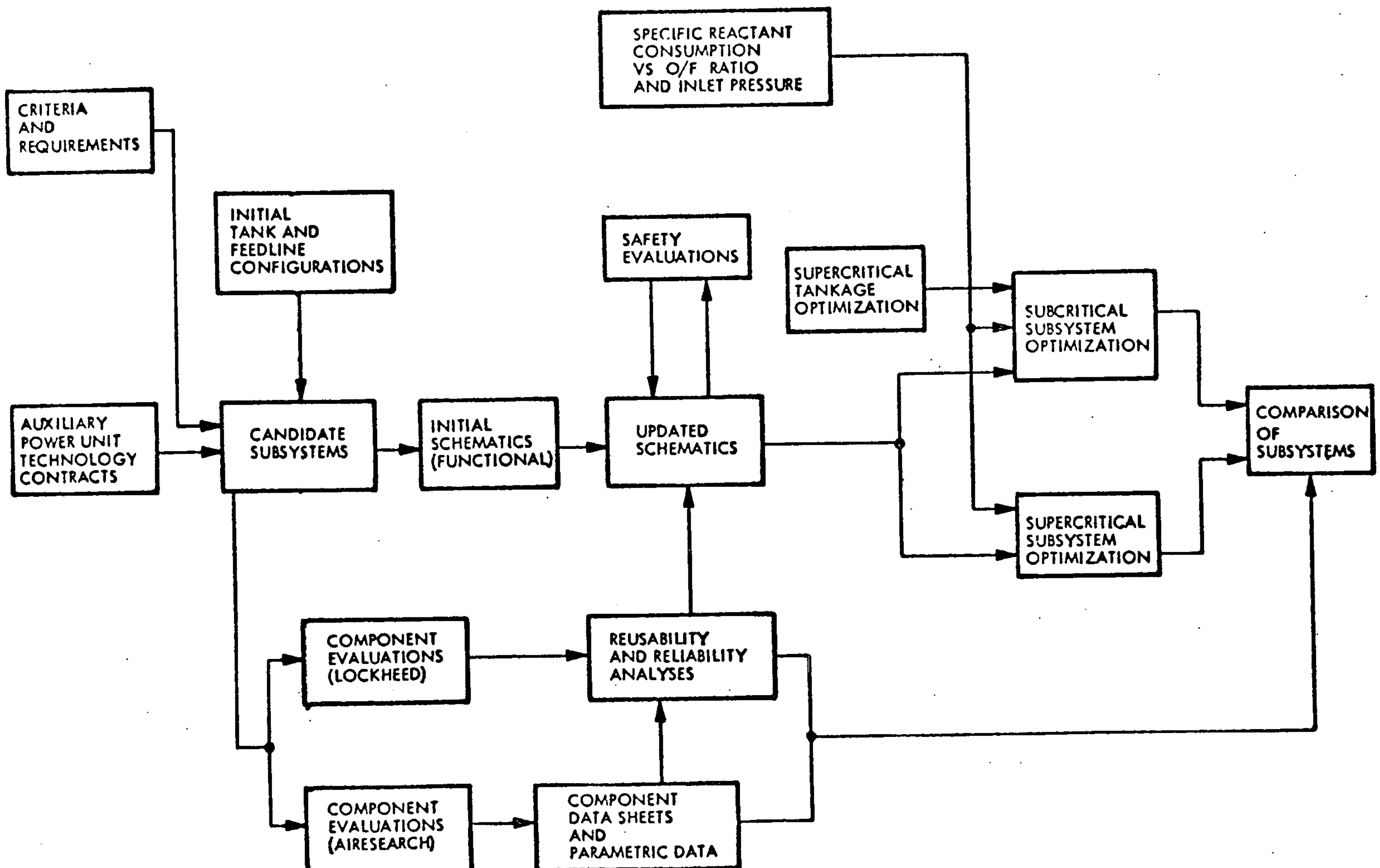
- ELECTRICAL MOTOR-DRIVEN PUMPS ARE APPLICABLE TO THE ACPS SUBSYSTEM

- PROPELLANT ACQUISITION FOR THE ACPS IS A MAJOR TECHNOLOGICAL PROBLEM

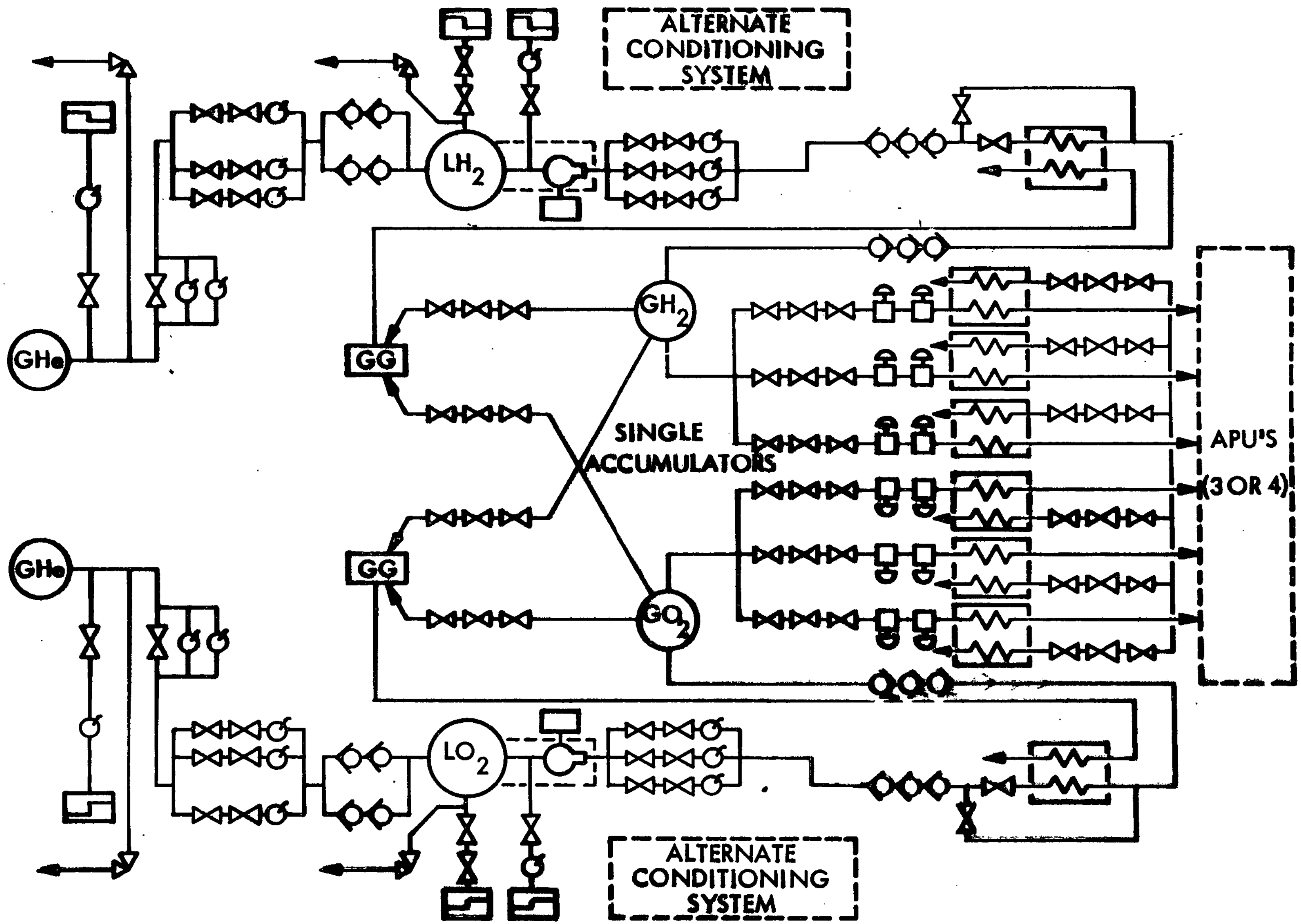
D04886

AUXILIARY POWER UNIT SUPPLY SYSTEMS

APPROACH TO AUXILIARY POWER UNIT SUPPLY EVALUATIONS (NONINTEGRATED)

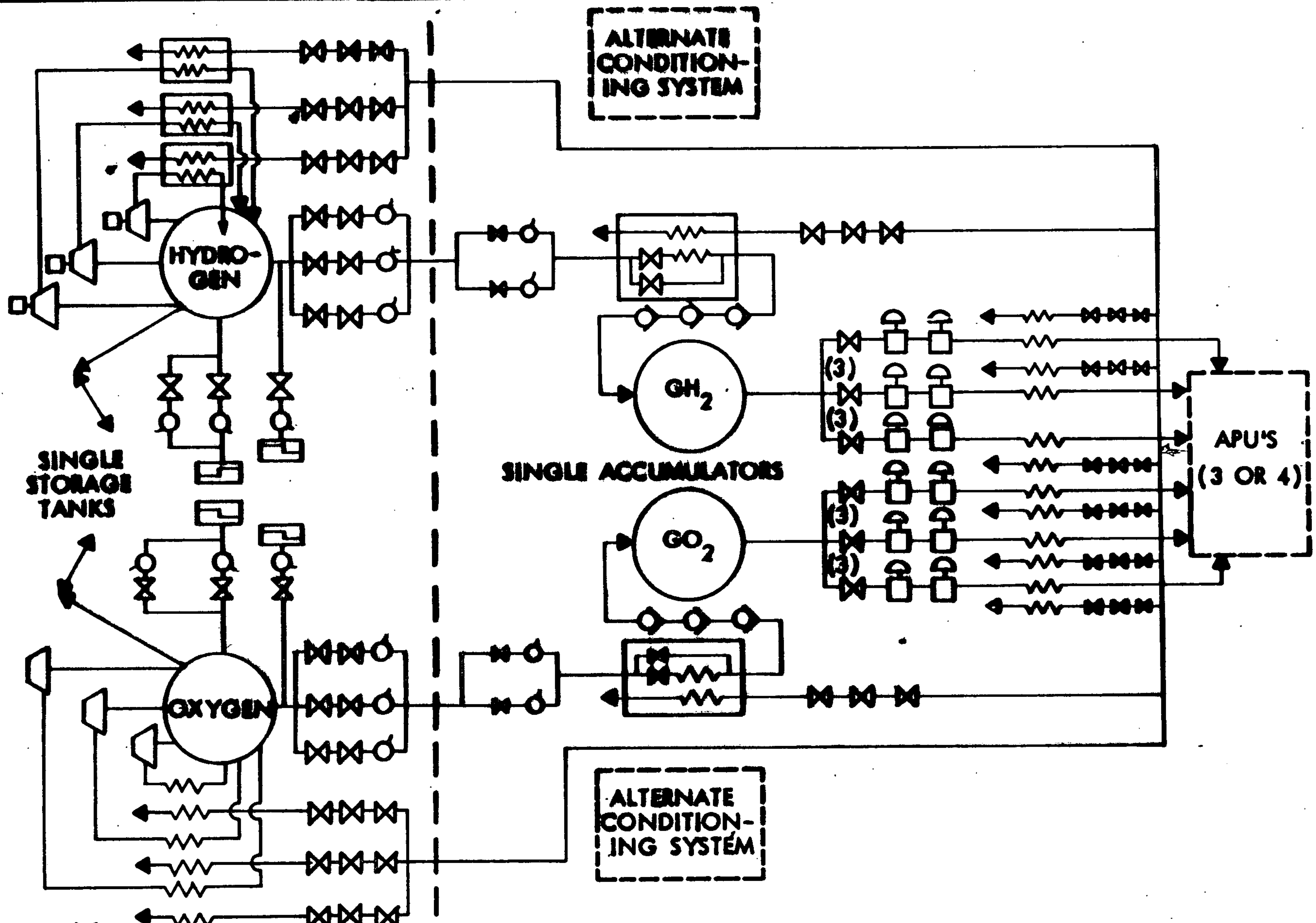


SUBCRITICAL APU SUPPLY



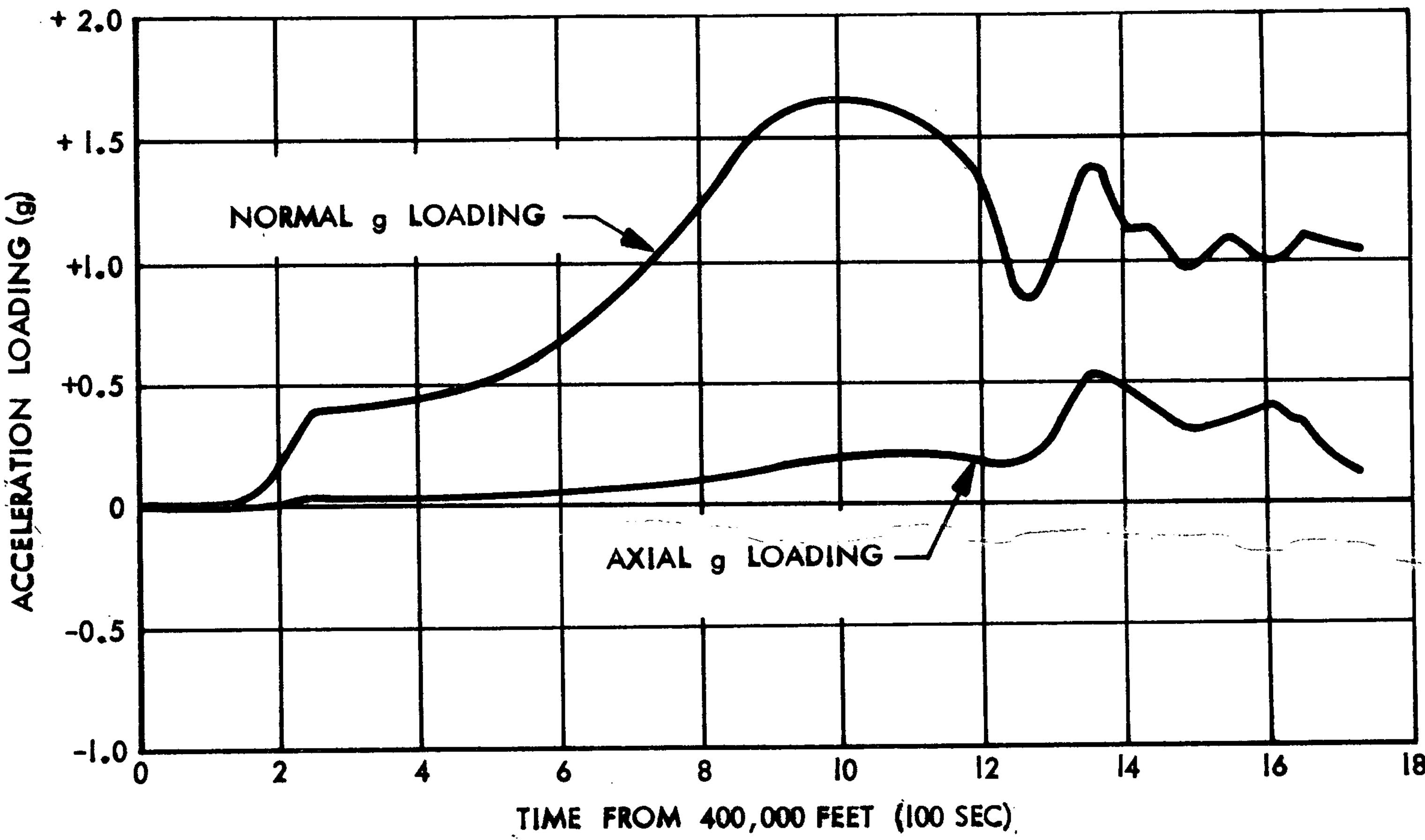
D03468

SUPERCRITICAL APU SUPPLY



D03467

TYPICAL REENTRY ACCELERATION (g) (HIGH CROSSRANGE)



D03705
llm

LOCKHEED

SUMMARY OF AUXILIARY POWER UNIT SUBCRITICAL SUPPLY SYSTEM

	MIXTURE RATIO 0.5		MIXTURE RATIO 0.9	
	3-450 HP	2-850 HP	3-450 HP	2-850 HP
TANKAGE: H_2	110	123	106	123
O_2	12	12	16	16
H_2 TO APU	332	342	314	332
H_2 TO CONDITIONING AND PUMPING	51	53	53	56
H_2 RESIDUALS AND VENTED	41	43	41	44
O_2 TO APU	166	171	282	298
O_2 TO CONDITIONING AND PUMPING	51	53	53	56
O_2 RESIDUALS AND VENTED	3	4	3	5
COMPONENTS	669	669	650	650
ACCUMULATORS	23	23	42	42
He TANKS	4	4	4	4
TOTAL (LBS.)	1,462	1,497	1,565	1,626

D03443

SUMMARY OF AUXILIARY POWER UNIT SUPERCRITICAL SUPPLY SYSTEM

	MIXTURE RATIO 0.5		MIXTURE RATIO 0.9	
	3–450 HP	2–850 HP	3–450 HP	2–850 HP
Tankage: H_2	471	508	700	738
O_2	31	33	54	57
H_2 TO APU	434	472	327	348
H_2 TO CONDITIONING	27	29	58	61
H_2 RESIDUALS AND VENTED	98	105	75	77
O_2 TO APU	217	236	294	313
O_2 TO CONDITIONING	27	29	58	61
O_2 RESIDUALS AND VENTED	11	12	19	20
COMPONENTS	784	784	765	765
ACCUMULATORS	45	45	44	44
TOTAL (LBS.)	2,145	2,253	2,394	2,484

D03444

COMPARISON OF AUXILIARY POWER UNIT SUPPLY SUBSYSTEMS

	SUBCRITICAL SUPPLY SYSTEM				SUPERCRITICAL SUPPLY SYSTEM			
	MIXTURE RATIO (0.5)		MIXTURE RATIO (0.9)		MIXTURE RATIO (0.5)		MIXTURE RATIO (0.9)	
	3-450 HP	2-850 HP	3-450 HP	2-850 HP	3-450 HP	2-850 HP	3-450 HP	2-850 HP
SYSTEM DRY WEIGHT (LB)	818	831	818	825	1,331	1,370	1,562	1,605
SYSTEM WET WEIGHT (LB)	1,462	1,497	1,565	1,626	2,145	2,253	2,390	2,484

D04876

LOCKHEED

CONCLUSIONS REGARDING AUXILIARY POWER UNIT SUPPLY

- SUBCRITICAL STORAGE RESULTS IN THE LOWEST WEIGHT SUBSYSTEMS
- EFFECTS OF O/F RATIO ARE SMALL
- OPTIMUM TURBINE INLET PRESSURES:
  - SUBCRITICAL AT HIGHER PRESSURES (900 PSIA)
  - SUPERCRITICAL DEPENDENT UPON MIXTURE RATIO:

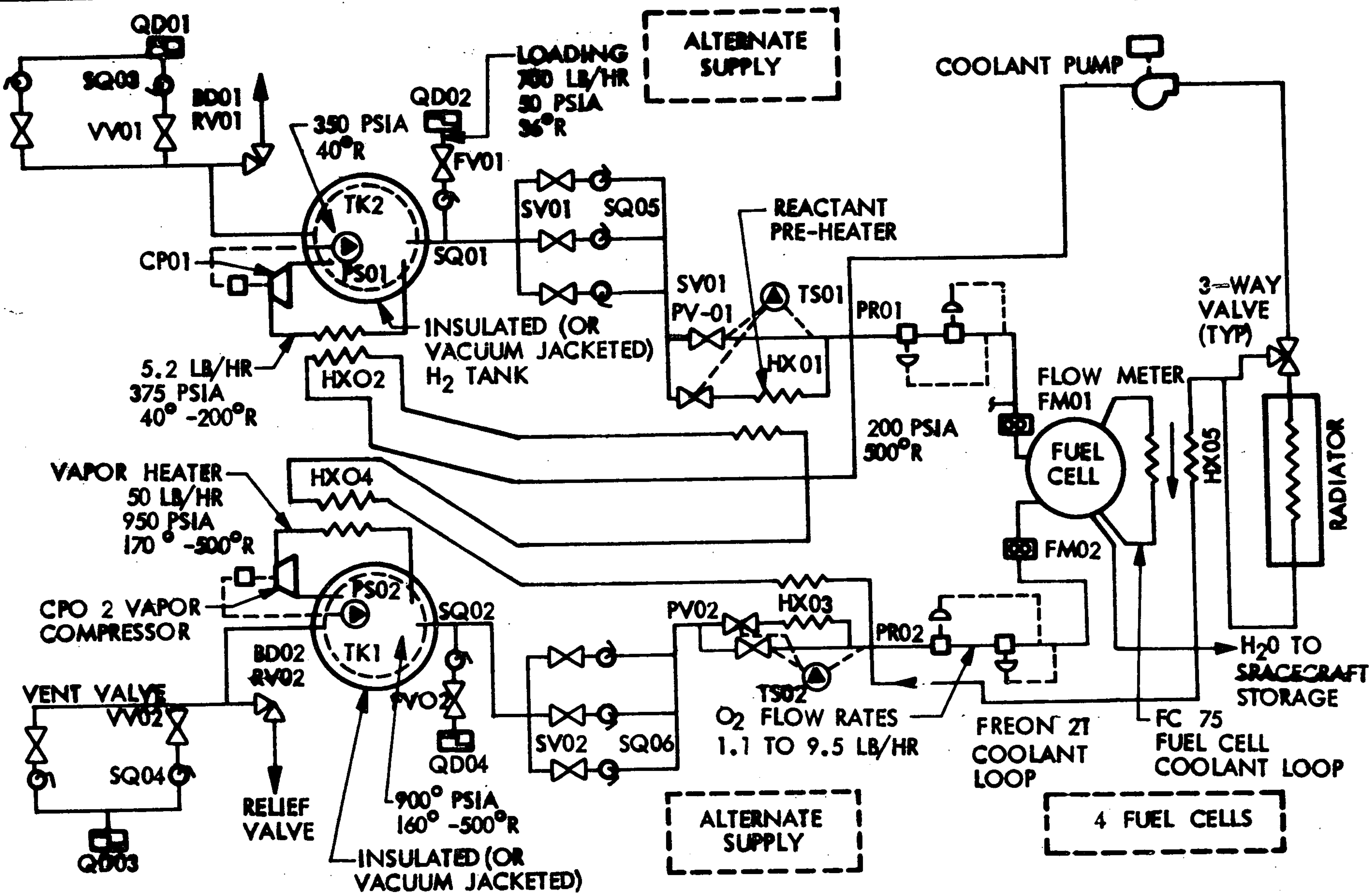
    O/F 0.5 NEAR 300 PSIA
    O/F 0.9 NEAR 600 PSIA
- APU REACTANT ACQUISITION IMPOSES MAJOR PROBLEM ON ACQUISITION DEVICES
- APU SUPPLY PUMP SHOULD OPERATE CONTINUOUSLY WHEN APU IS OPERATING

D04887

LOCKHEED

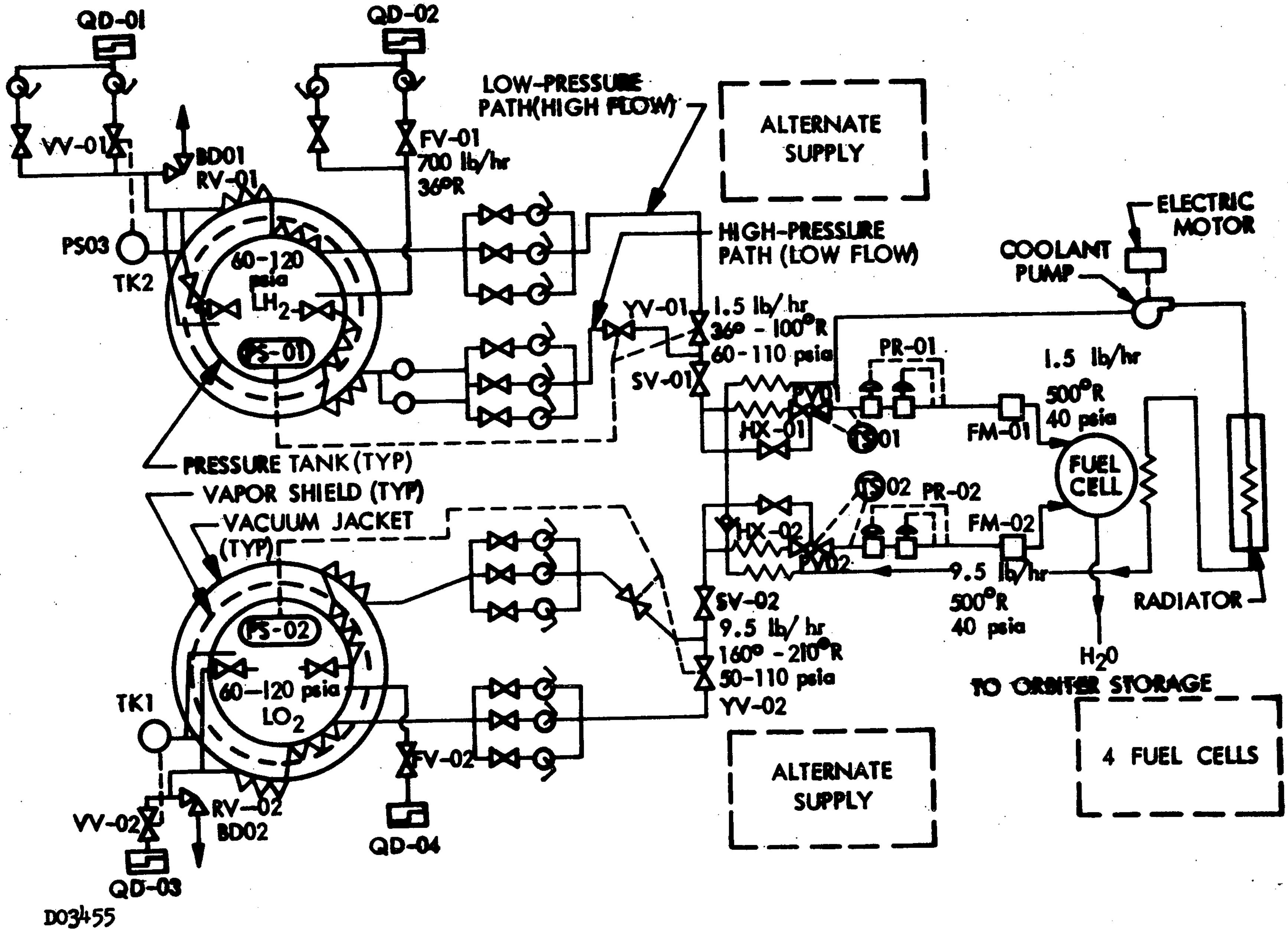
FUEL CELL SUPPLY SYSTEMS

SUPERCRITICAL FUEL CELL SUPPLY SYSTEM



D03434

SUBCRITICAL FUEL CELL SUPPLY SYSTEM



COMPARISON OF FUEL CELL SUPPLY - SYSTEM APPROACHES

ITEM	MIN. SUPPLY PRESSURE (psia)	SUPERCRITICAL 20	SUPERCRITICAL 100	SUPERCRITICAL 200	SUBCRITICAL 20	SUBCRITICAL >60
TANKAGE:	O_2	180	169	171	50	60
	H_2	115	113	114	79	90
COMPONENTS		199	199	199	311	311
REACTANTS:	O_2	1520	1450	1450	1520	1450
	H_2	184	175	175	184	175
RESIDUALS:	O_2	3.52	18.85	39.1	19	36
	H_2	0.43	2.2	4.4	2	4
TOTAL		2202	2127	2153	2165	2126

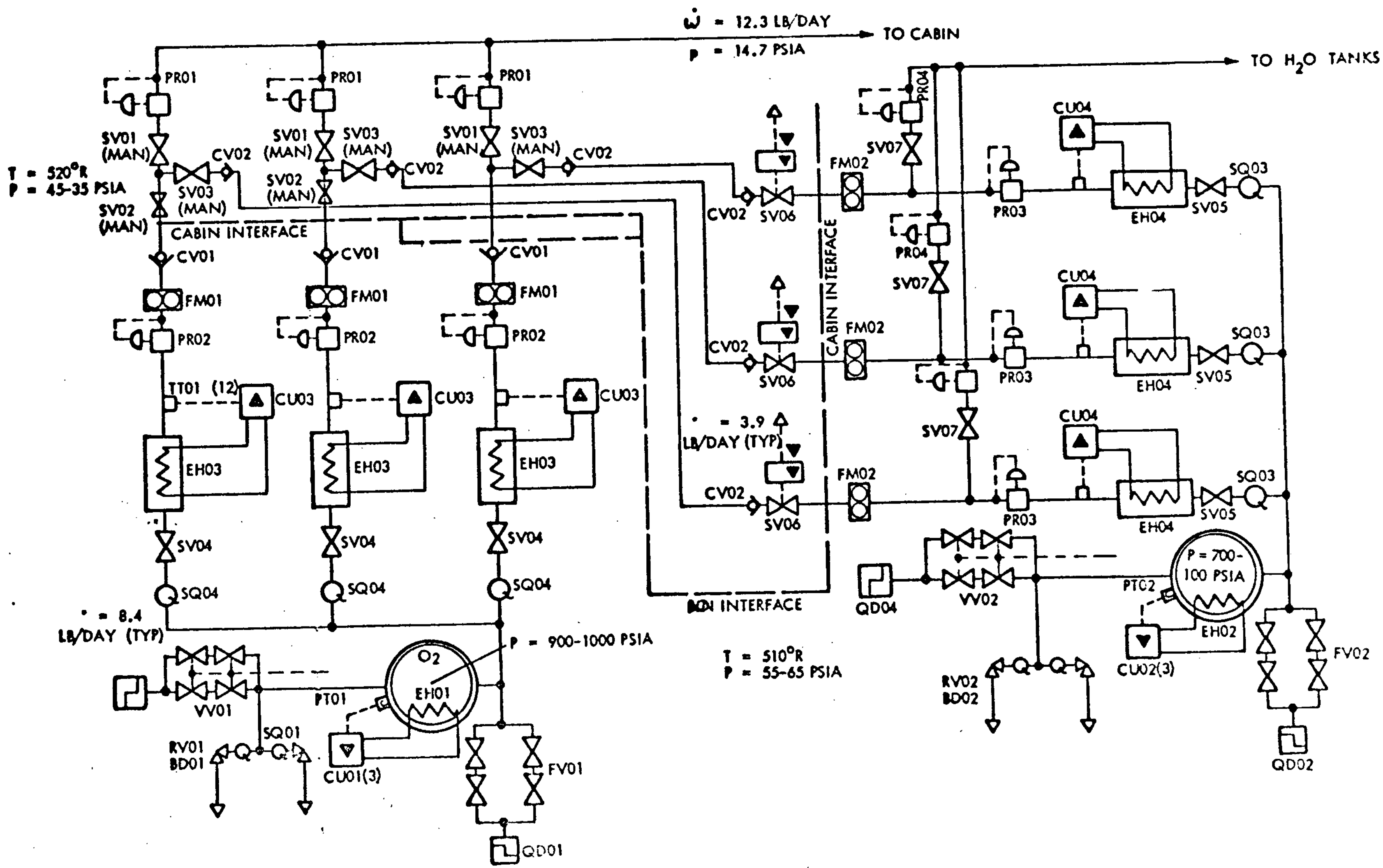
D03424

CONCLUSIONS REGARDING FUEL CELL SUPPLY SUBSYSTEMS

- SUPERCRITICAL AND SUBCRITICAL SUPPLY SYSTEMS ARE APPROXIMATELY THE SAME WEIGHT.
- THERE ARE NO ADVANTAGES TO A LOW-PRESSURE CELL SUPPLY.
- FUEL CELL SUPPLY SYSTEMS HAVE RELATIVELY HIGH COMPONENT REPLACEMENTS BECAUSE OF THE EXTENDED DUTY CYCLES.
- FUEL CELL PURGING TO REMOVE HELIUM (WHICH HAS ENTERED THROUGH BEING DISSOLVED IN LO_2 OR LH_2) IS NOT A SIGNIFICANT PENALTY.

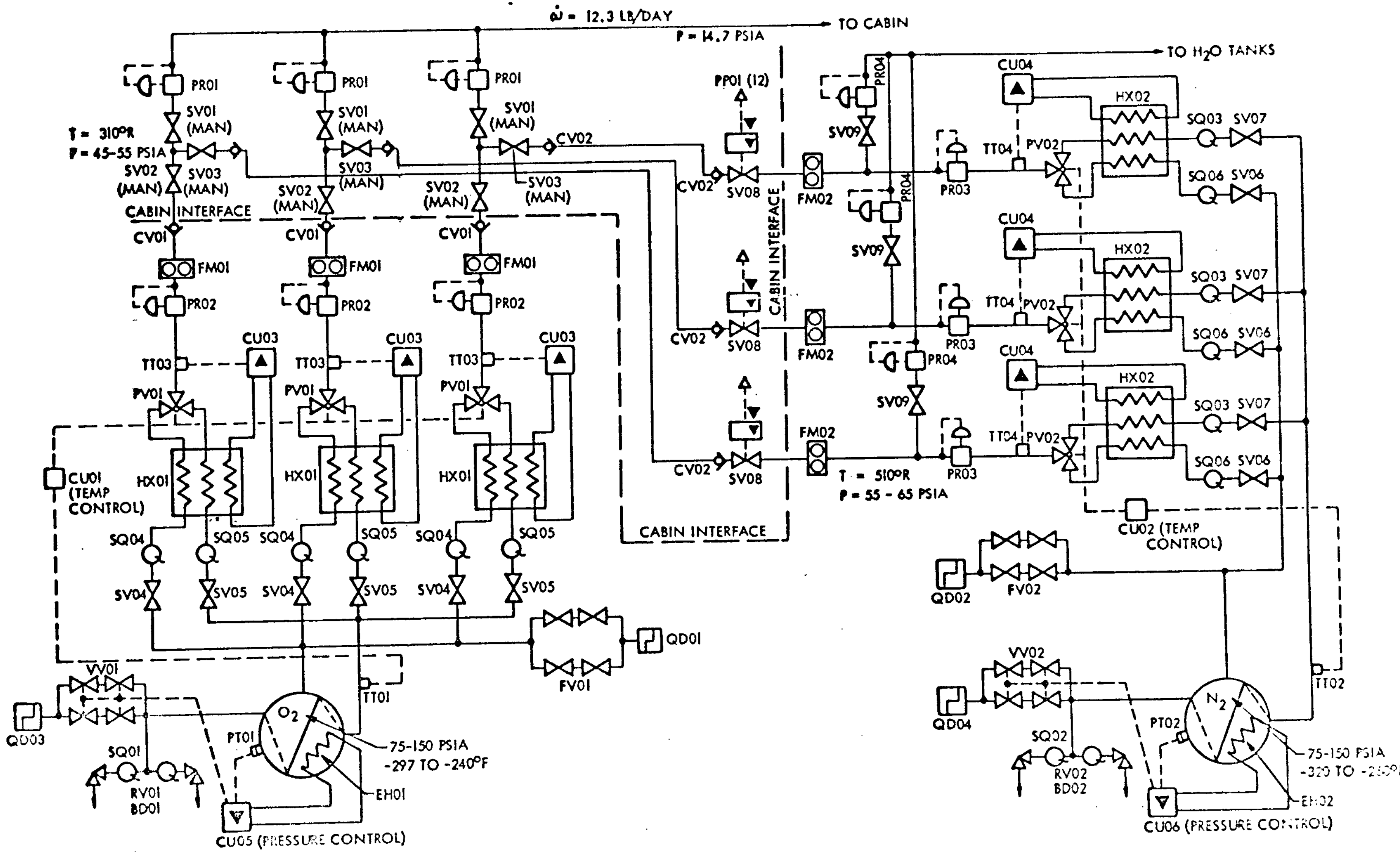
LIFE SUPPORT SUPPLY

LIFE SUPPORT CRYOGENIC SUPPLY SYSTEM - SUPERCRITICAL



LOCKHEED

LIFE SUPPORT CRYOGENIC SUPPLY SYSTEM - SUBCRITICAL



LIFE SUPPORT SUBSYSTEM COMPARISON

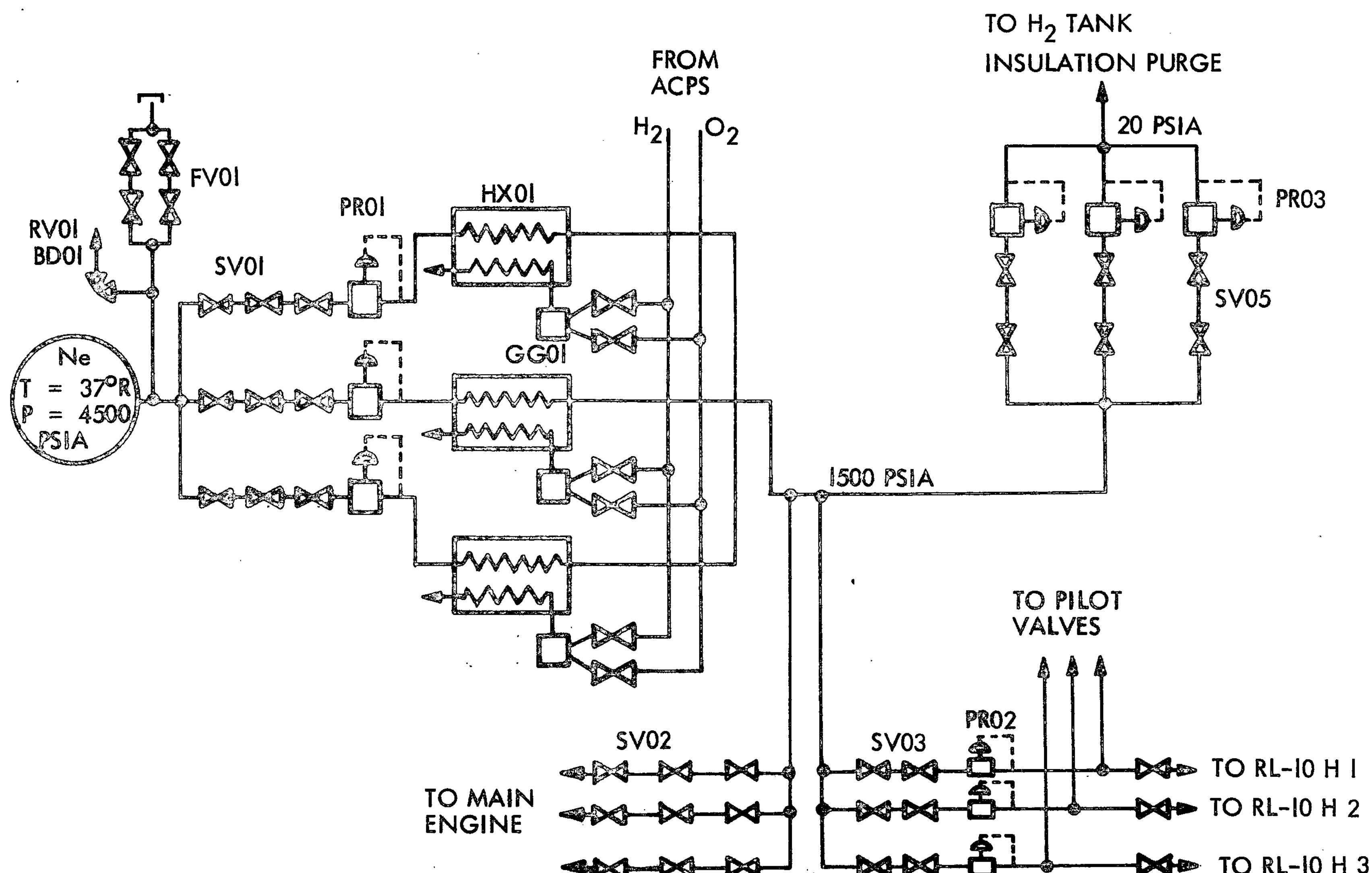
ITEM	SUPERCRITICAL SUBSYSTEM (LB)	SUBCRITICAL SUBSYSTEM (LB)
O_2 SUPPLY		
• COMPONENTS	61.6	81.2
• LINES	7.3	7.3
• STORAGE TANK	8.4	3.4
– VACUUM SHELL PLUS INSULATION	3.6	3.6
N_2 SUPPLY		
• COMPONENTS	85.5	110.4
• LINES	7.3	7.3
• STORAGE TANK	10.8	4.8
– VACUUM SHELL PLUS INSULATION	4.3	5.2
CONDITIONING		
• TANK WEIGHT PENALTY (FUEL CELL SYSTEM)	1.8	1.8
TOTAL DRY WEIGHT	190.6 LB	225.0 LB
FLUIDS		
• USABLE O_2	50.0	50.0
• USABLE N_2	65.0	65.0
• CONDITIONING CRYOGENS	6.0	6.0
• RESIDUALS	1.2	1.2
TOTAL FLUIDS	122.2 LB	122.2 LB
TOTAL SUBSYSTEM WEIGHT	312.8 LB	347.2 LB

D04879

llm

PURGING, INERTING, AND PNEUMATIC SUPPLY

HELIUM-STORED AT LH_2 TEMPERATURE

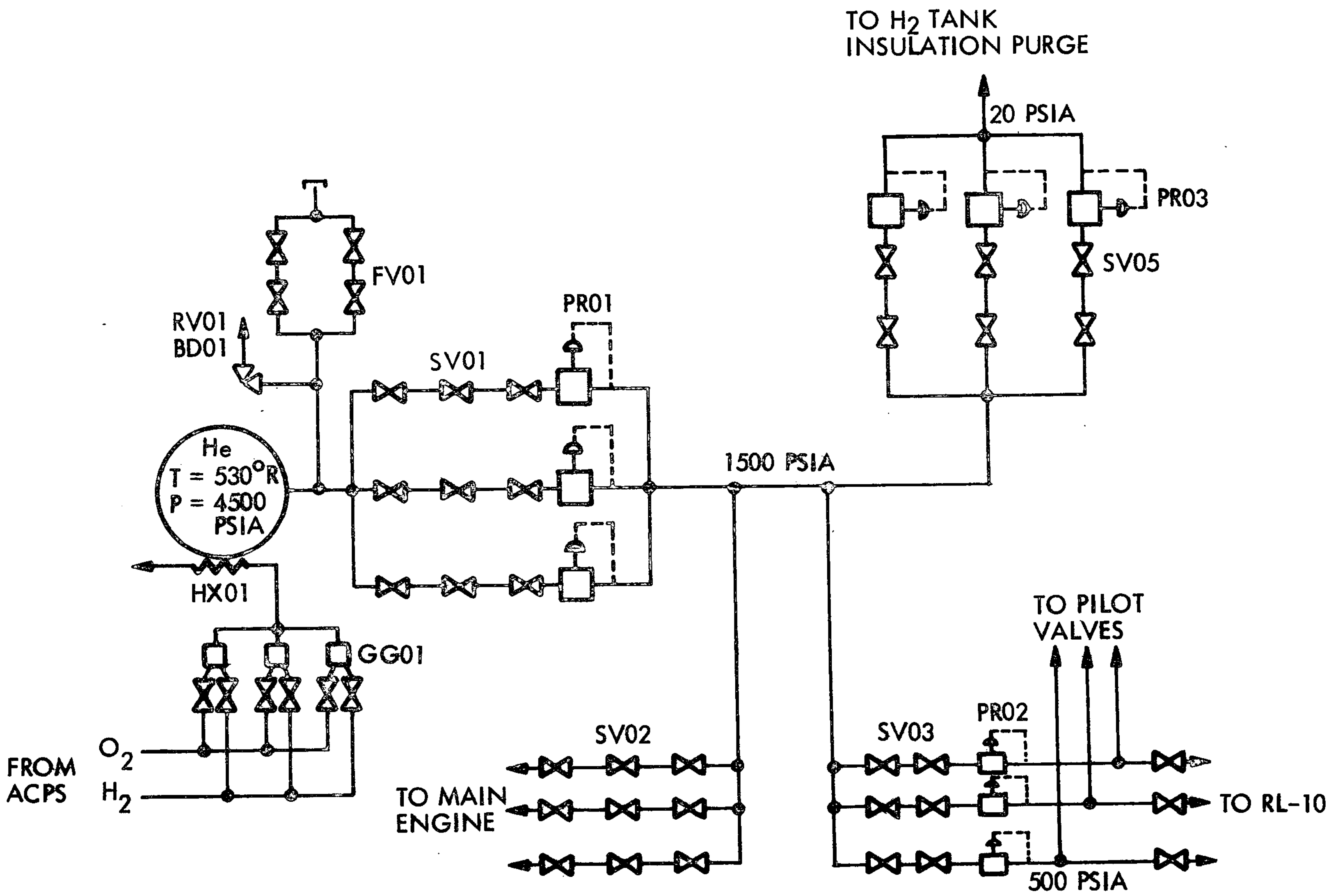


LMSC-A991396

D04923

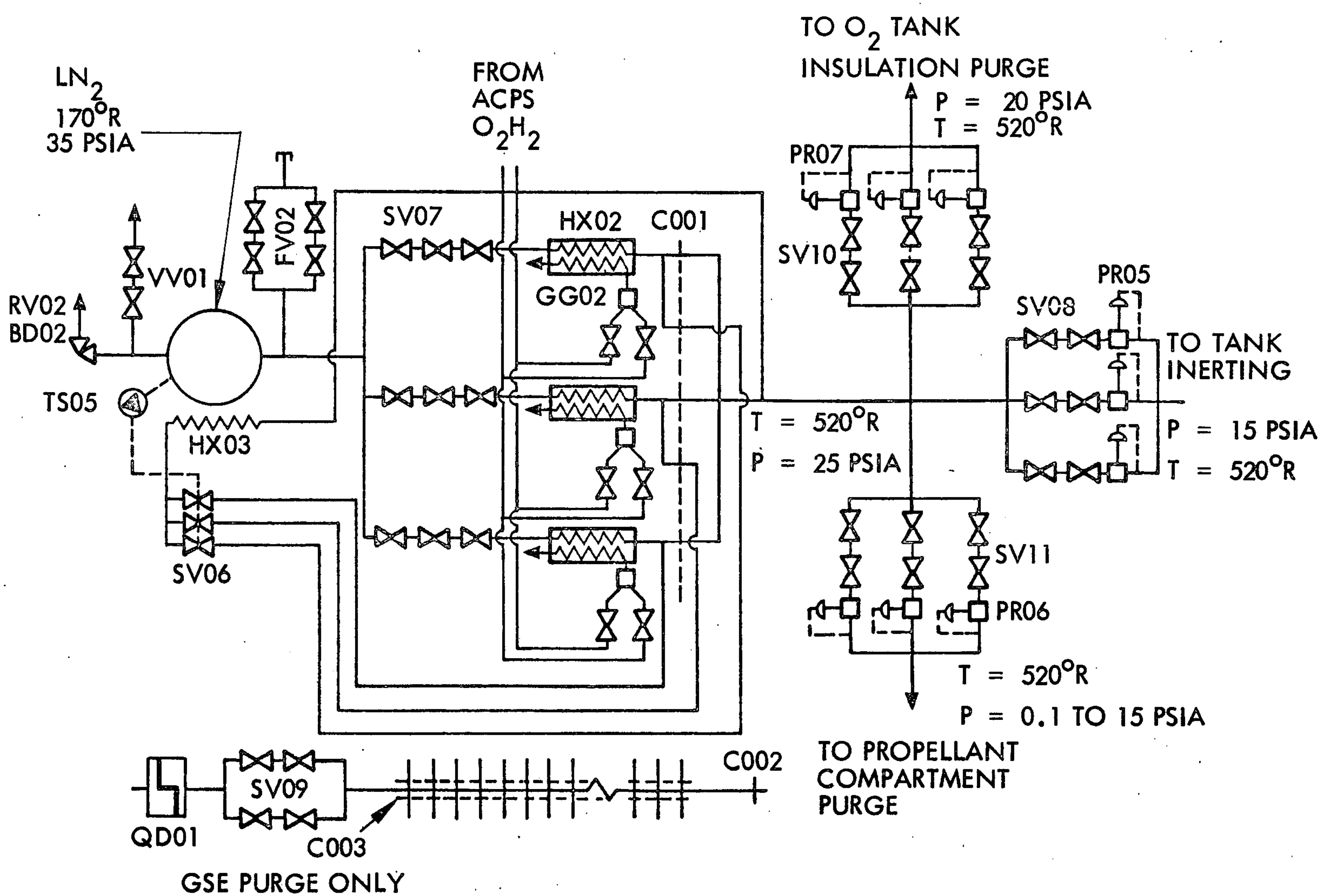
LOCKHEED

HELIUM STORED AT AMBIENT TEMPERATURE



D04681
LLm

SUBCRITICAL STORAGE OF NITROGEN



D04683
11m

LOCKHEED

PRELAUNCH PURGING

- FLOW RATES ARE VEHICLE-DESIGNED DEPENDENT

  PHASE B CONTRACTORS SELECTIONS RANGED FROM 25,000 TO 65,000 LB/HR (7 TO 18 LB/SEC).

- POSSIBLE APPROACHES INCLUDE:

  - INTRODUCTION THROUGH LOW-PRESSURE DUCTS
  - INTRODUCTION THROUGH MODERATE TO HIGH-PRESSURE LINES WITH DIFFUSERS

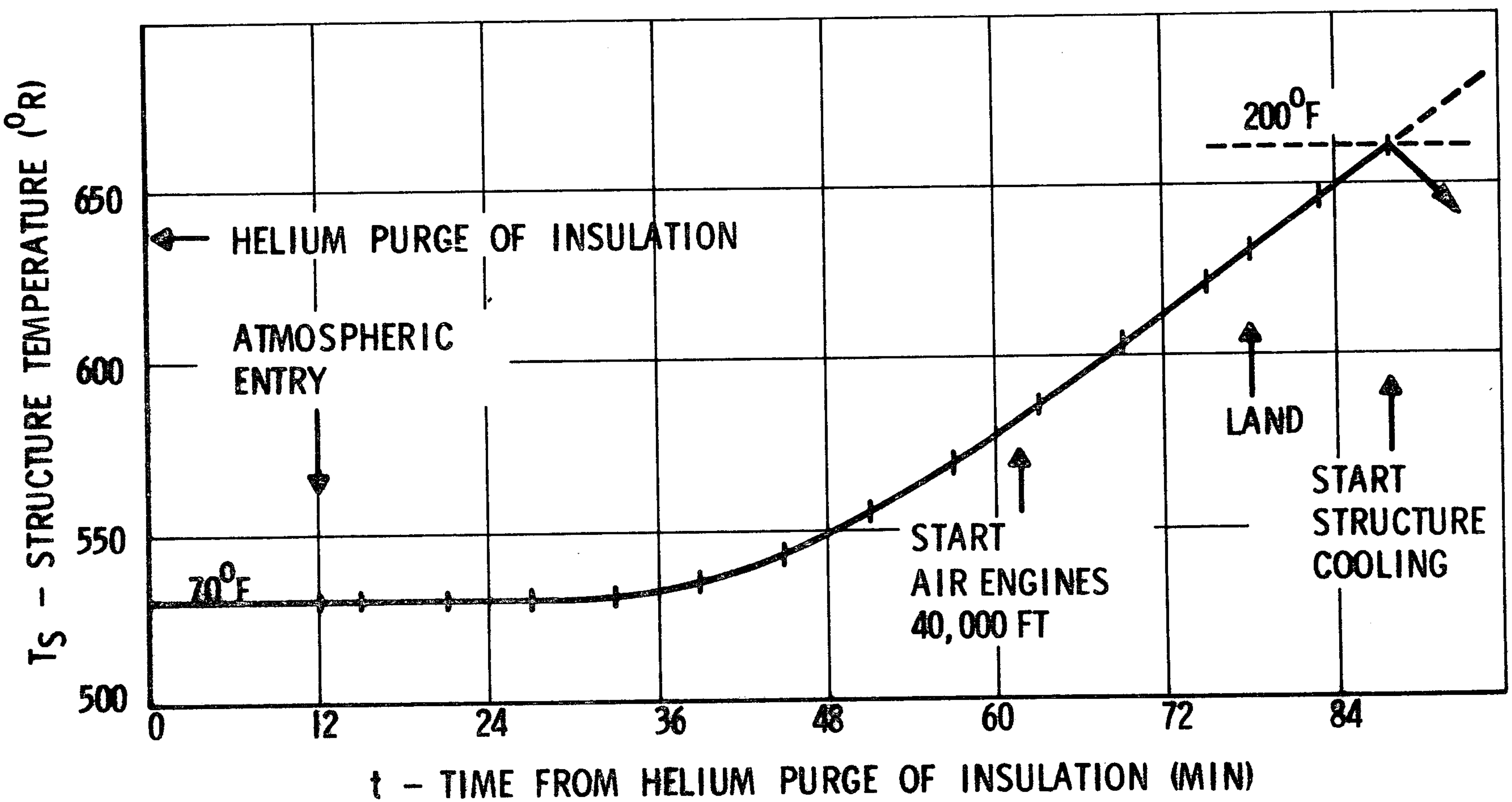
- EVALUATION RESULTS

  - LINE SIZES

    10 LB/SEC – 3.5 IN.
    20 LB/SEC – 4.5 IN.

  - PRESSURE – 100 PSIA

ASSUMPTIONS FOR STRUCTURE TEMPERATURE VS TIME FOR REENTRY

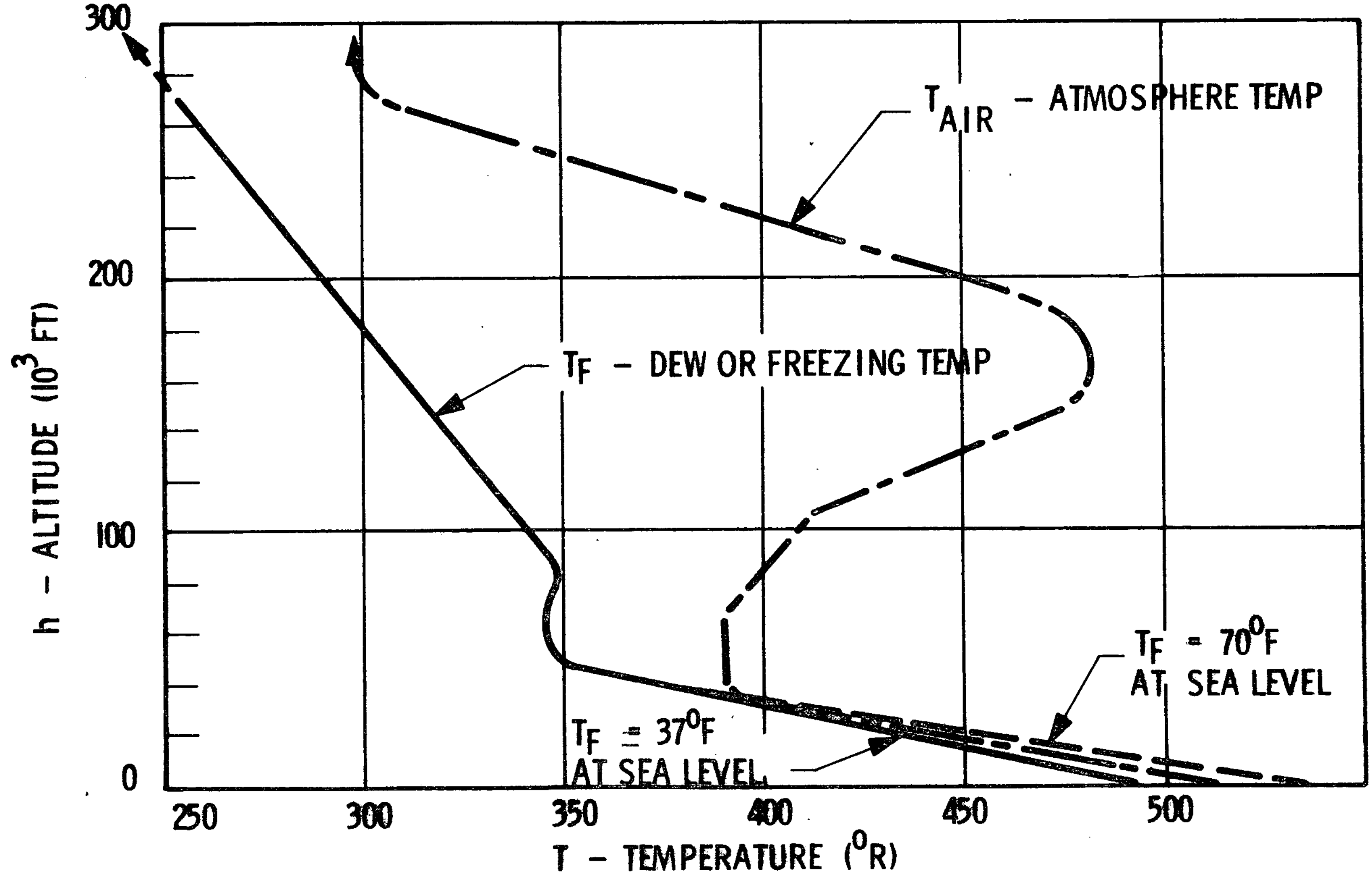


D04708
11m

LOCKHEED

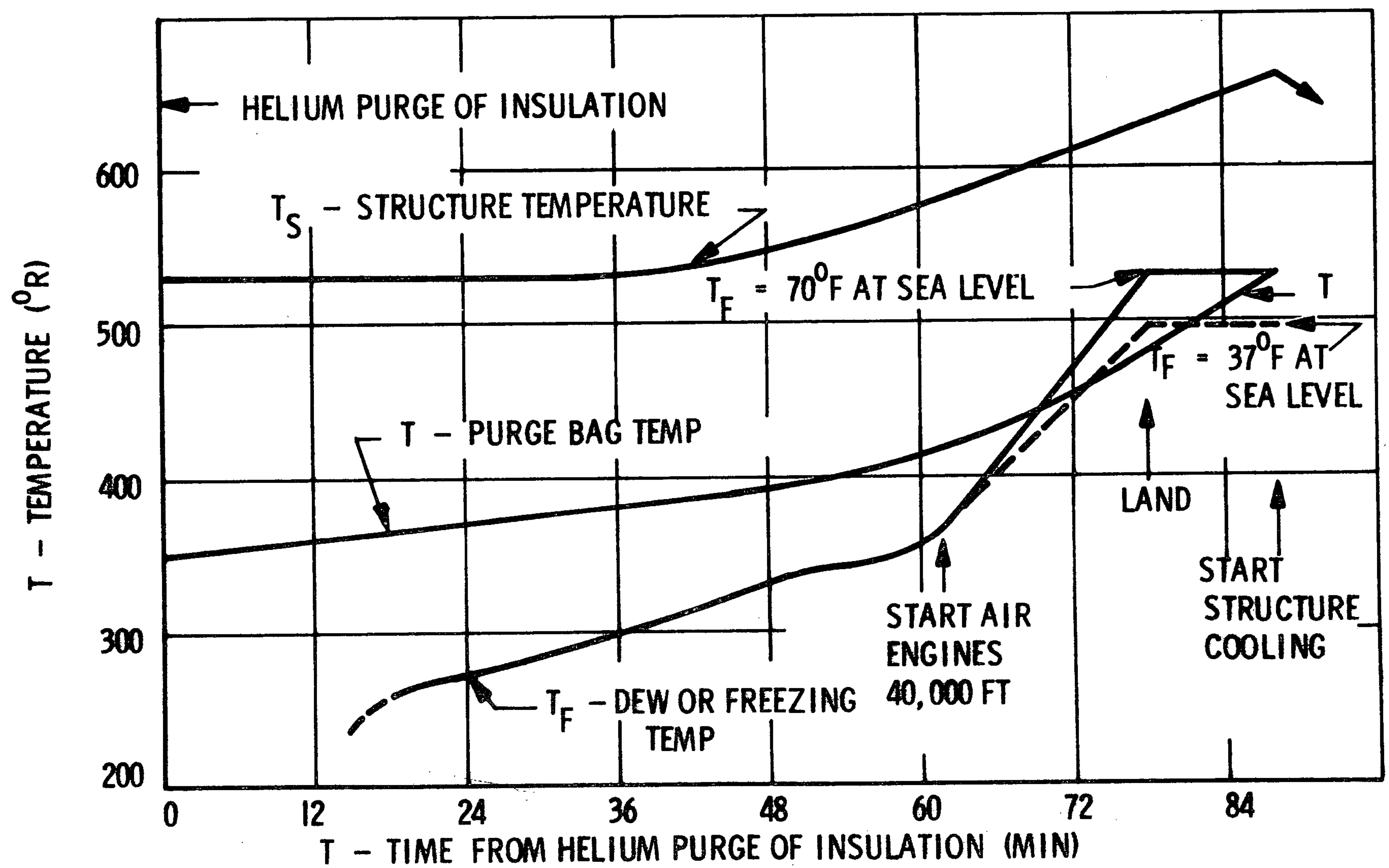
ATMOSPHERIC AND DEW OR FREEZING TEMPERATURES FOR AIR

(MID-LATITUDES)



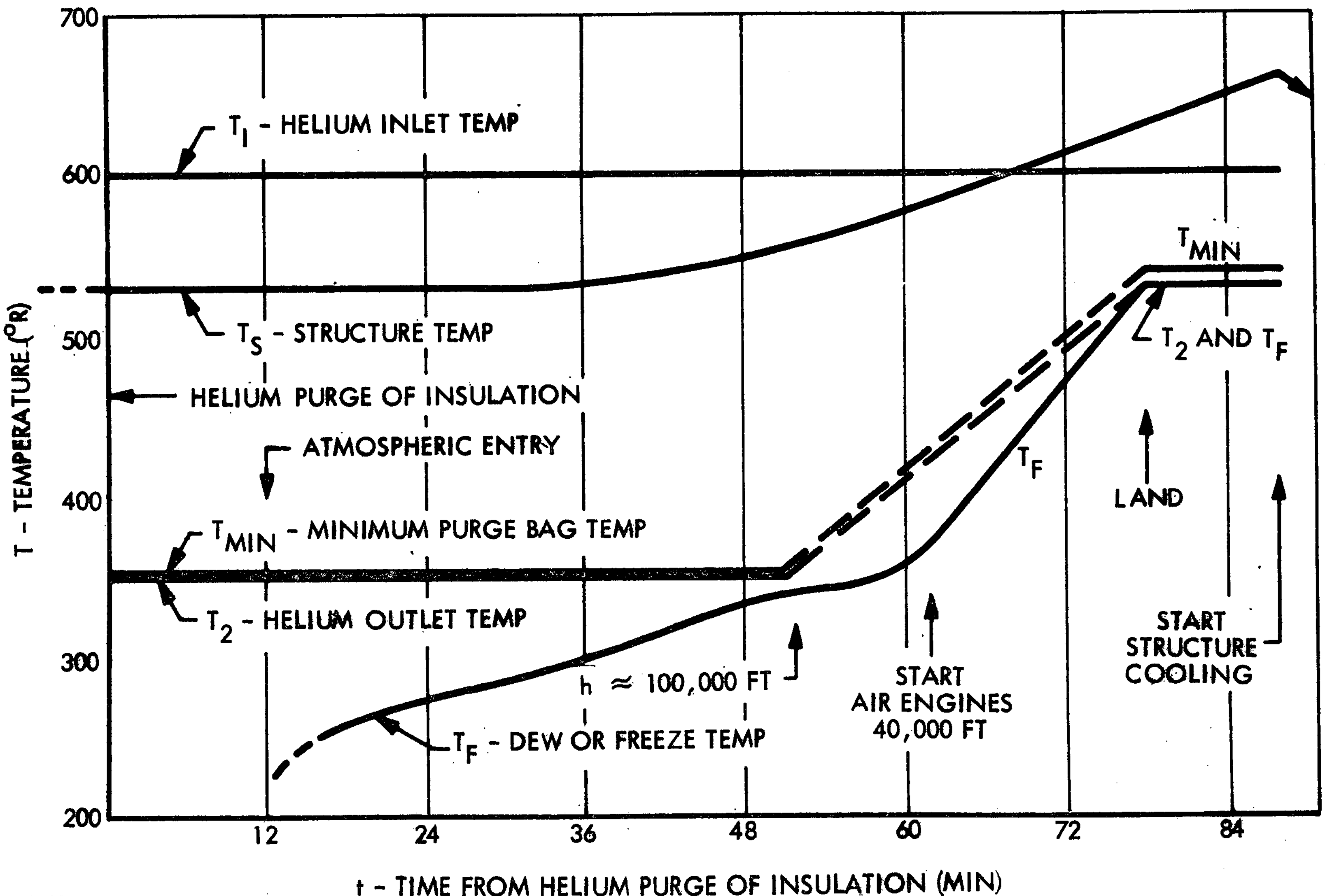
D04707
11m

TEMPERATURES ASSOCIATED WITH REENTRY OF LH_2
OMS TANK EMPTIED AFTER RETRO



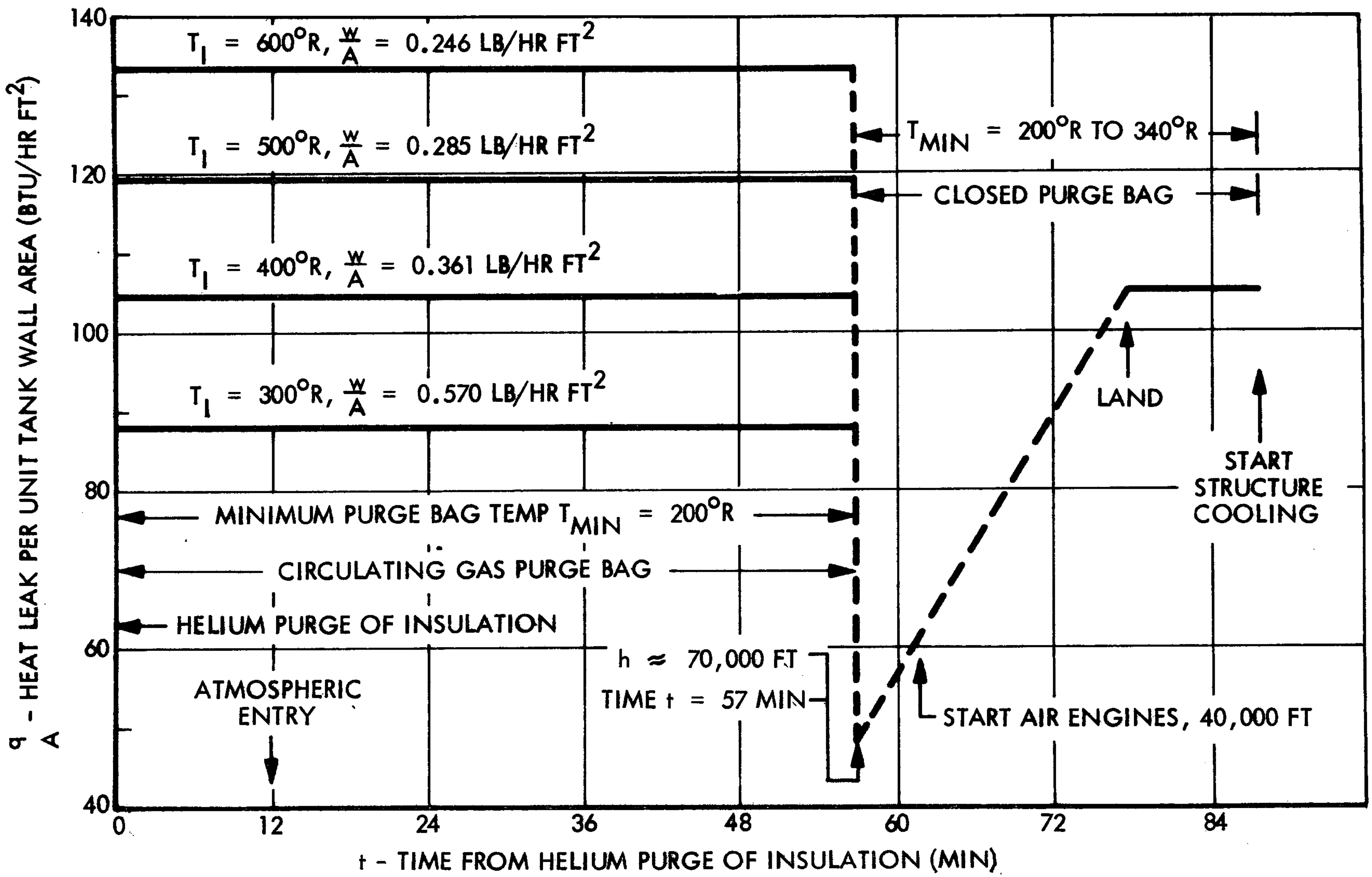
D04709
11m

VARIOUS TEMPERATURES VS TIME FROM HELIUM PURGE OF INSULATION



D04685
11m

HEAT LEAK PER UNIT AREA VS REENTRY TIME FOR LH_2 TANKS WITH 1.0-IN. INSULATION



D04688
11m

W

LOCKHEED

PURGING, INERTING, AND PNEUMATIC SUPPLY HELIUM REQUIREMENTS

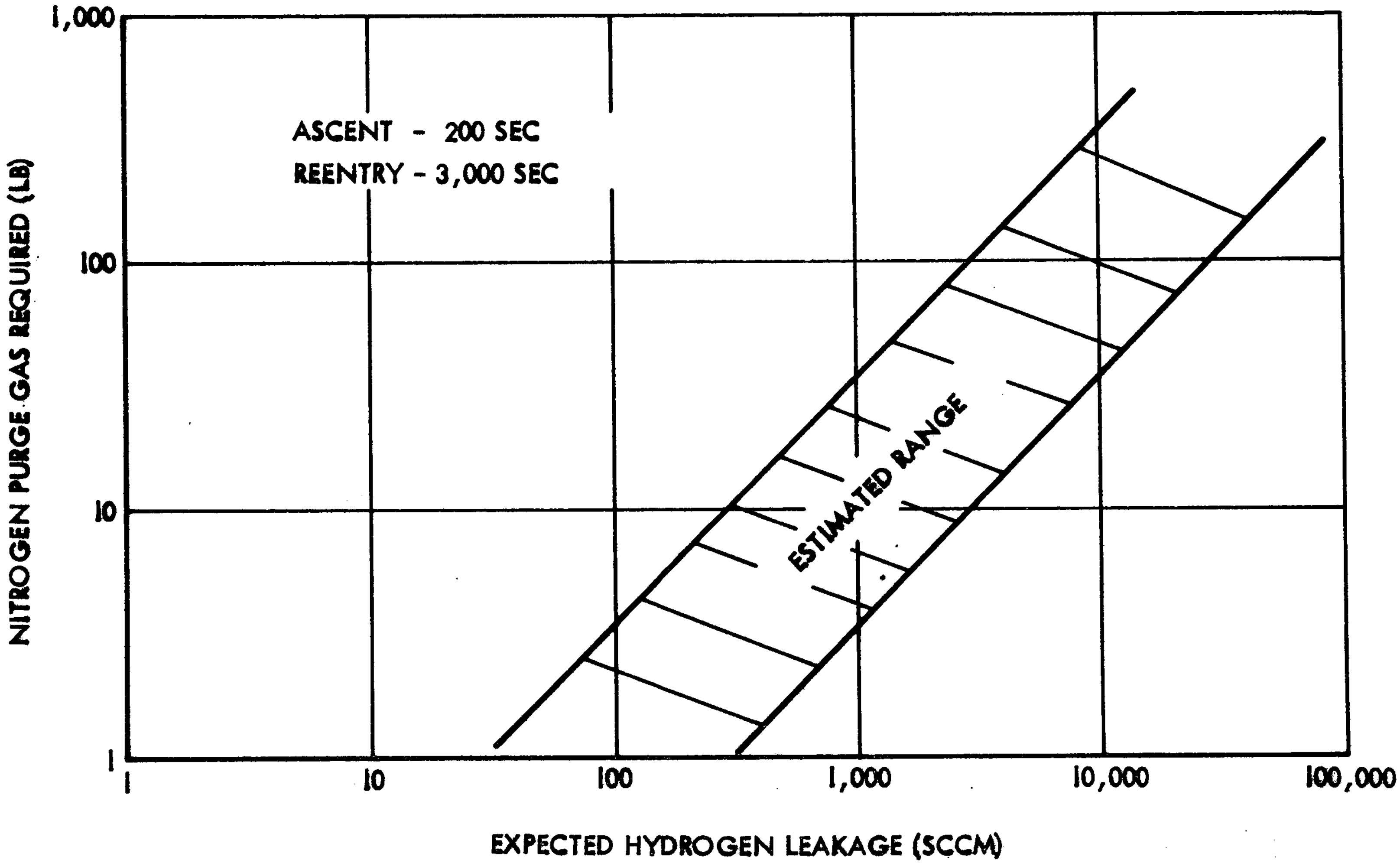
SUBSYSTEM	FUNCTION	REENTRY WITHOUT LH_2 IN TANKS (LB)	REENTRY WITH LH_2 IN TANKS (LB)	PRESSURE (PSIA)	TEMPERATURE (°R)	FLOWRATE (LB/SEC.)
OIPS	ENGINE PNEUMATIC AND PURGE	60	60	1,500	490-600	6 (MAX)
	PNEUMATIC VALVES	5	5	1,500	490-600	0.6 (MAX)
OMPS/ACPS	RL-10 PURGE & PNEUMATIC WITHOUT CONTINUOUS BLEED	1.7	1.7	470 ± 30	140-620	< 0.01
	WITH CONTINUOUS BLEED	27	27			
	H_2 TANK INSULATION PURGE	1.5-3		15	520 (INLET)	< 0.01
			10 (INVENTORY)	15	520 (INLET)	0.02
	PNEUMATIC VALVES	0.95	0.95	700	460-600	< 0.01
APU	PNEUMATIC VALVES	0.04	0.04	700	460-600	< 0.01
FUEL CELL/ EC/LSS	PNEUMATIC VALVES	0.35	0.35	700	460-600	< 0.01

D04472(1)
llm

LOCKHEED

NITROGEN PURGING REQUIREMENTS FOR COMPONENT HYDROGEN LEAKAGE

(MAINTAIN BELOW FLAMMABILITY LIMITS)



D03712
llm

LOCKHEED

PURGING, INERTING, AND PNEUMATIC SUPPLY NITROGEN REQUIREMENTS

SUBSYSTEM	FUNCTION	WITHOUT TANK INERTING (LB)	WITH TANK INERTING (LB)
ORBIT INJECTION PROPULSION SUPPLY	TANK INERTING		1,820
	LEAKAGE PURGING	1,230	340 (ASCENT)
OMPS/ACPS	TANK INERTING		150
	LEAKAGE PURGING	66	35
	OXYGEN INSULATION PURGING	4	4
APU	LEAKAGE PURGING	13	–
FUEL CELL/ECLSS	LEAKAGE PURGING	10	–
AIRBREATHING ENGINE	O_2 REMOVAL	–	0.5
	TANK INERTING		10

D04446
11m

PURGING, INERTING, AND PNEUMATIC SUPPLY

	(1) WITH LH_2 IN OMPS TANK DURING REENTRY (2) WITH RECIRCULATION OF PURGE BAG He		(1) WITH LH_2 IN OMPS TANK DURING REENTRY (2) NO RECIRCULATION OF PURGE BAG He		W/O LH_2 IN OMPS TANK DURING REENTRY OR VACUUM-JACKATED	
ITEM	STORAGE AT LH_2 TEMPERATURE	AMBIENT STORAGE	STORAGE AT LH_2 TEMPERATURE	AMBIENT STORAGE	STORAGE AT LH_2 TEMPERATURE	AMBIENT STORAGE
HELIUM REQUIREMENTS	80	80	72	72	70	70
CONDITIONING REACTANTS:						
O_2	127	127	12	14	12	14
H_2	127	127	12	14	12	14
TANKAGE	310 (433)	1,060	280 (390)	1,060	270 (379)	1,040
COMPONENTS	402	408	327	333	327	333
RESIDUAL HELIUM	133	33	125	25	122	24
TOTAL DRY	712 (835)	1,468	607 (717)	1,393	596 (706)	1,373
TOTAL FLUID	467	367	221	125	216	122
TOTAL	1,179 (1,302)	1,835	828 (938)	1,518	812 (922)	1,495

D04504 (1)
11m

LOCKHEED

PURGING, INERTING, AND PNEUMATIC SUPPLY NITROGEN SUBSYSTEM ALTERNATIVES

	(1) VACUUM-JACKETED OMPS TANKS (2) W/O H_2 LEAKAGE PURGING			(1) W/O H_2 TANK INERTING (2) W/O H_2 LEAKAGE PURGING			(1) W/O H_2 TANK INERTING (2) WITH H_2 LEAKAGE PURGING			(1) WITH H_2 TANK INERTING (2) WITH H_2 LEAKAGE PURGING			(1) W/O H_2 TANK INERTING (2) W/O OIPS LEAKAGE PURGING		
ITEM	SUB-CRITICAL	SUPER-CRITICAL	AMBIENT STORAGE	SUB-CRITICAL	SUPER-CRITICAL	AMBIENT STORAGE	SUB-CRITICAL	SUPER-CRITICAL	AMBIENT STORAGE	SUB-CRITICAL	SUPER CRITICAL	AMBIENT STORAGE	SUB-CRITICAL	SUPER CRITICAL	AMBIENT STORAGE
N_2 REQUIREMENTS:															
INERTING	11	11	11	11	11	11	10	10	10	1,980	1,980	1,980	10	10	10
PURGING	-	-	-	4	4	4	1,320	1,320	1,320	400	400	400	84	84	84
TOTAL N_2	11	11	11	15	15	15	1,330	1,330	1,330	2,380	2,380	2,380	94	94	94
CONDITIONING REACTANTS:															
O_2				0.8	0.77	0.77	66	65	65	118	116	116	4.6	4.5	4.5
H_2				0.8	0.77	6.77	66	65	65	118	116	116	4.6	4.5	4.5
TANKAGE	2	3	20	2.25	4.25	27	25	250	2,300	45	444	4,120	5	18	140
OTHER COMPONENTS	90	138	113	170	183	158	213	203	179	269	238	214	213	203	179
TRAPPED N_2	-	-	-	-	-	-	26	119	18	47	211	30	2	8	1.5
TOTAL DRY WEIGHT	92	141	133	172.25	187.25	185	238	453	2,479	314	682	4,334	218	221	319
TOTAL FLUID WEIGHT	11	11	11	16.6	16.5	16.5	1,488	1,581	1,480	2,663	2,827	2,646	105	111	104
TOTAL	103	152	144	189	204	202	1,726	2,033	3,958	2,977	3,507	6,978	323	332	423

INTEGRATED SYSTEMS

SYSTEMS INTEGRATION APPROACH

DEVELOPED GENERAL CONCEPTS

- SUBSYSTEM STORAGE COMBINATIONS (30 CASES)
- LINES
- TANK PRESSURE CONTROL
- THERMAL CONTROL
- FLUID CONTROL
- FLUID CONDITIONING

566 ELEMENTS

DEVELOPED CONCEPT BLOCK FLOW CHARTS

COMMON STORAGE MAINTAINED AS PRIMARY INTEGRATION MODE

LOCKHEED

INTEGRATION MODES

COMMON CRYOGENS STORAGE IS PRIMARY MODE OF INTEGRATION - 8 SYSTEMS

- SUBCRITICAL TANKS
- SUPERCRITICAL TANKS

SECONDARY INTEGRATION MODES - 16 SYSTEMS

- PUMPS - COMMON OR SEPARATE
  - AT TANK
  - AT ENGINE
- PRESSURIZATION - HELIUM - CRYOGENS GAS
- VACUUM JACKET
- ACQUISITION SYSTEMS

D04784
llm

SUBSYSTEM CRYOGENIC FLUID REQUIREMENTS

		O_2 QUANTITY (LB)	O_2 FLOW RATE (LB/SEC)	H_2 QUANTITY (LB)	H_2 FLOW RATE (LB/SEC)	WHEN USED
OIPS	MAX MIN	532,000 360,000	2,374 593	86,000 60,000	396 99	EARLY
OMPS	MAX MIN	27,000 18,300	38 13	5,400 3,700	8 4	EARLY LATE
ACPS	MAX MIN	6,900 2,000	26 2	2,150 500	7.0 0.5	MOST EARLY SOME CONT. SOME LATE
ABE	MAX MIN			2,800 1,500	5.0 1.0	LATE
FUEL CELL	MAX MIN	1,450 730	.0053 .0008	175 90	.0006 .0001	CONTINU- OUSLY
APU		500 100	.25 .02	525 100	.29 .02	EARLY LATE
LIFE SUPPORT		83 8	.0001 .00004			CONTINU- OUSLY

D02687(1)
llm

CRYOGEN WEIGHTS USED FOR COMPARISON

	O_2	H_2	I_{sp}
OIPS	450,000	75,000	
OMPS	23,128	4,626	444 (1)
ACPS (2) (3)	5,793 (4)	1,645	379 SS., 341 PULSING MR = 3.52
APU (5)	408	454	P = 300 PSIA, MR = 0.9
FC (6)	1,475	175	
EC/LSS	50		

(1) BASED ON RL-10 I_{sp} FOR COMPARISON - HIGHER VALUES CAN BE READILY ACHIEVED

(2) BASED ON A Δ V SPLIT WHICH DEVOTES 185 FT/SEC TO THE ACPS

(3) TOTAL IMPULSE = 1,687,000 LB/SEC S. S., 1,018,000 LB/SEC PULSING

(4) THESE VALUES RESOLVE TO O_2 = 5,230 AND H_2 = 1,310 DELIVERED AT THE THRUSTER FOR I_{sp} = 430 S.S. AND 388 PULSING

(5) OTHER VALUES USED DEPENDING ON INTEGRATION MODES AT MR = 0.9

(6) NEAR THE MAXIMUM WAS USED. CURRENT NOMINAL VALUES ARE APPROXIMATELY 750 LB TOTAL

INTEGRATED SYSTEMS

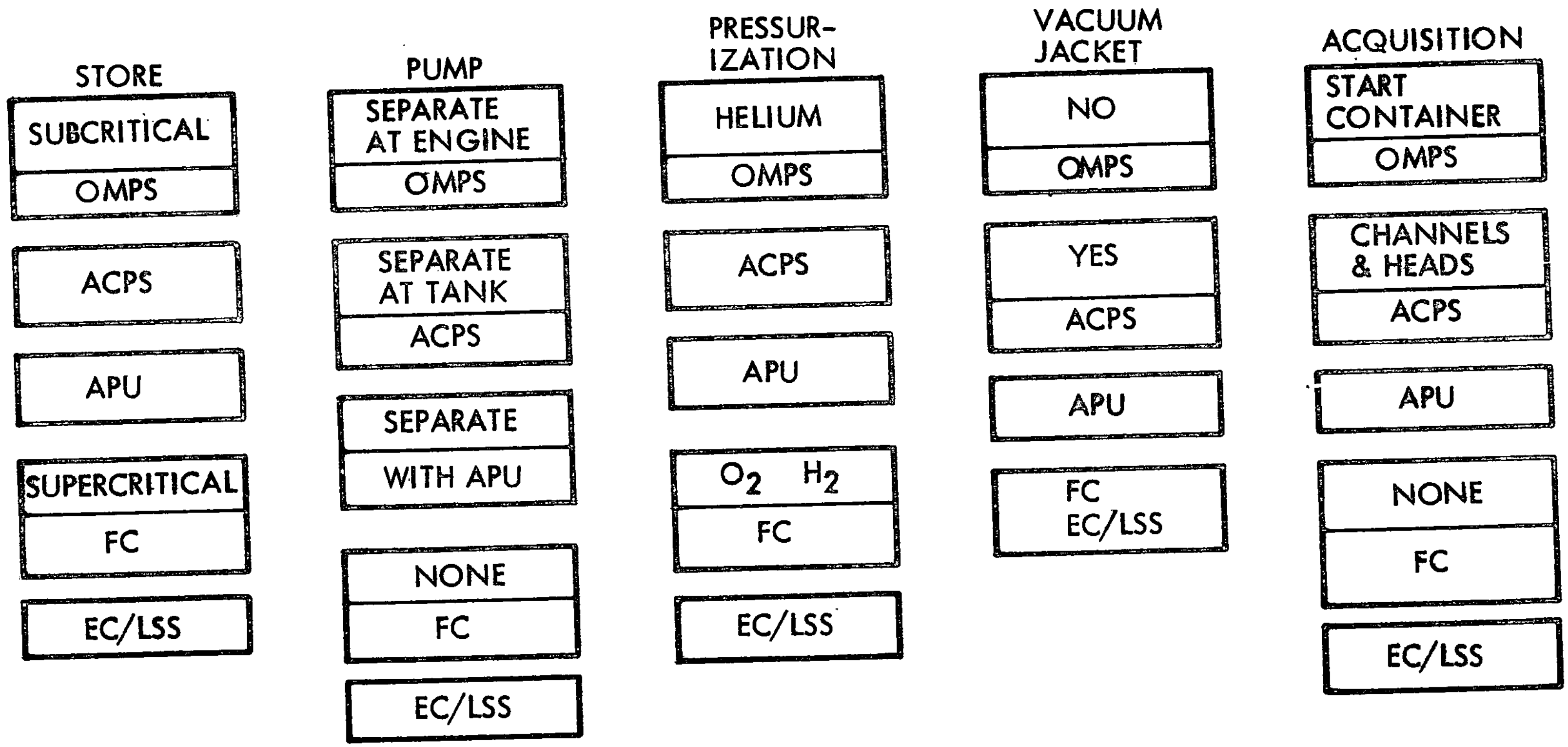
LOCKHEED

	I	II	III	IV	V	VI	VII	VIII	REF
SUBCRITICAL	OMPS ACPS APU FC EC/LSS	OMPS ACPS APU	OMPS ACPS APU	OMPS ACPS	OMPS ACPS APU FC EC/LSS	OMPS	OMPS ACPS APU	OMPS	OMPS ACPS APU
SUPERCRITICAL		FC EC/LSS	FC EC/LSS	APU FC EC/LSS		ACPS APU FC EC/LSS	FC EC/LSS	ACPS APU FC EC/LSS	FC EC/LSS
SYSTEM WEIGHT									
DRY (INERT) WT	8,678	9,155	8,695	9,373	8,854	12,705	9,410	12,424	9,936
CRYOGENS	40,020	39,803	39,415	39,780	40,549	41,035	39,691	40,365	39,754
TOTAL	48,698	48,958	48,110	49,153	49,403	53,740	49,101	52,789	49,690
NO. OF COMPONENTS	375	451	679	608	433	431	519	488	774

ALL CASES INCLUDE OIPS FEED AND FILL COMPONENT WEIGHTS BUT NOT INCLUDED IN COMPONENT

D03817(1)
llm

REFERENCE SYSTEM



INTEGRATED SYSTEM I

STORE	PUMP	PRESSURIZATION	VACUUM JACKET	ACQUISITION
SUBCRITICAL OMPS ACPS APU FC EC/LSS	**COMMON AT TANK** OMPS ACPS APU FC EC/LSS	**HELIUM** OMPS ACPS APU FC EC/LSS	**YES** OMPS ACPS APU FC EC/LSS	**COMPARTMENT WITH HEADS** OMPS ACPS APU FC EC/LSS
SUBCRITICAL OMPS ACPS APU FC EC/LSS	**SEPARATE AT ENGINE** OMPS **COMMON AT TANK** ACPS APU FC EC/LSS	**HELIUM** OMPS ACPS APU FC EC/LSS	**YES** OMPS ACPS APU FC EC/LSS	**COMPARTMENT WITH HEADS** OMPS ACPS APU FC EC/LSS
SUBCRITICAL OMPS ACPS APU FC EC/LSS	**SEPARATE AT ENGINE** OMPS **COMMON AT TANK** ACPS APU FC EC/LSS	**HELIUM** OMPS ACPS APU FC EC/LSS	**NO** OMPS ACPS APU FC EC/LSS	**START TANK WITH HEAD** OMPS ACPS APU FC EC/LSS

INTEGRATED SYSTEM II

a)

STORE	PUMP	PRESSUR- IZATION	VACUUM JACKET	ACQUISITION
SUBCRITICAL	COMMON AT TANK	HELIUM	YES	COMPARTMENT WITH HEADS
OMPS ACPS APU	OMPS ACPS APU	OMPS ACPS APU	OMPS ACPS APU	OMPS ACPS APU
SUPERCRITICAL	NONE	O_2 H_2	YES	NONE
FC EC/LSS	FC EC/LSS	FC EC/LSS	FC EC/LSS	FC EC/LSS

b)

STORE	PUMP	PRESSUR- IZATION	VACUUM JACKET	ACQUISITION
SUBCRITICAL	COMMON AT TANK	HELIUM	NO	START TANK WITH HEADS
OMPS ACPS APU	OMPS ACPS APU	OMPS ACPS APU	OMPS ACPS APU	OMPS ACPS APU
SUPERCRITICAL	NONE	O_2 H_2	YES	NONE
FC EC/LSS	FC EC/LSS	FC EC/LSS	FC EC/LSS	FC EC/LSS

INTEGRATED SYSTEM III

a)

STORE	PUMP	PRESSUR-IZATION	VACUUM JACKET	ACQUISITION
SUBCRITICAL OMPS ACPS	COMMON AT TANK OMPS ACPS	HELIUM OMPS ACPS APU	NO OMPS ACPS	COMPARTMENT WITH HEADS OMPS ACPS
SUBCRITICAL APU	SEPARATE AT APU APU	O_2 H_2 FC EC/LSS	YES APU FC EC/LSS	WITH HEADS APU
SUPERCRITICAL FC EC/LSS	NONE FC EC/LSS			NONE FC EC/LSS

b)

STORE	PUMP	PRESSUR-IZATION	VACUUM JACKET	ACQUISITION
SUBCRITICAL OMPS ACPS	COMMON AT TANK OMPS ACPS	HELIUM OMPS ACPS	NO OMPS ACPS	COMPARTMENT WITH HEADS OMPS ACPS
SUPERCRITICAL APU FC EC/LSS	NONE APU FC EC/LSS	O_2 H_2 APU FC EC/LSS	YES APU FC EC/LSS	NONE APU FC EC/LSS

D04440
11m

INTEGRATED SYSTEMS IV

	STORE	PUMP	PRESSUR-IZATION	VACUUM JACKET	ACQUISITION
a)	SUBCRITICAL	COMMON AT TANK	HELIUM	NO	COMPARTMENT WITH HEADS
	OMPS ACPS	OMSP ACPS	OMPS ACPS	OMPS ACPS	OMPS ACPS
	SUPERCRITICAL	NONE	O_2 H_2	YES	NONE
	APU FC EC/LSS	APU FC EC/LSS	APU FC EC/LSS	APU FC EC/LSS	APU FC EC/LSS
b)	SUBCRITICAL	COMMON AT TANK	HELIUM	NO	START TANK WITH HEADS
	OMPS ACPS	OMPS ACPS	OMPS ACPS	OMPS ACPS	OMPS ACPS
	SUPERCRITICAL	NONE	O_2 H_2	YES	NONE
	APU FC EC/LSS	APU FC EC/LSS	APU FC EC/LSS	APU FC EC/LSS	APU FC EC/LSS
c)	SUBCRITICAL	COMMON AT TANK	HELIUM	YES	COMPARTMENT WITH HEADS
	OMPS ACPS	OMPS ACPS	OMPS ACPS	OMPS ACPS	OMPS ACPS
	SUPERCRITICAL	NONE	O_2 H_2	YES	NONE
	APU FC EC/LSS	APU FC EC/LSS	APU FC EC/LSS	APU FC EC/LSS	APU FC EC/LSS

D04441
11m

INTEGRATED SYSTEM V

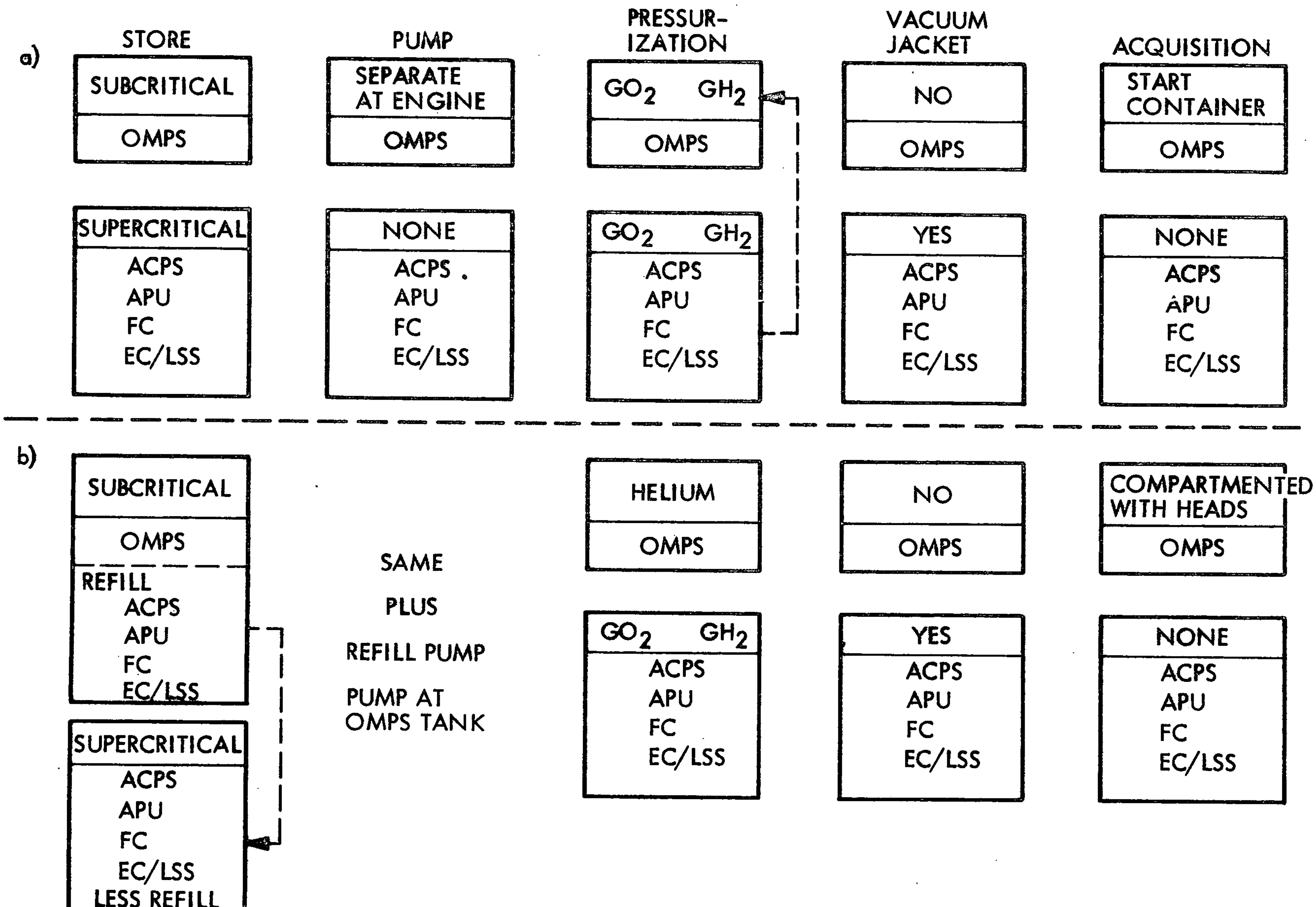
a)

	STORE	PUMP	PRESSUR-IZATION	VACUUM JACKET	ACQUISITION
OMPS	SUBCRITICAL	SEPARATE AT ENGINE	GO_2 GH_2	NO	START CONTAINER
ACPS, APU, FC, EC/LSS	SUBCRITICAL	COMMON AT TANK	HELIUM	YES	CHANNELS & HEADS

b)

	STORE	PUMP	PRESSUR-IZATION	VACUUM JACKET	ACQUISITION
OMPS	SUBCRITICAL	SEPARATE AT ENGINE	HELIUM	NO	START CONTAINER
ACPS, APU, FC, EC/LSS	SUBCRITICAL	COMMON AT TANK	HELIUM	YES	CHANNELS & HEADS

INTEGRATED SYSTEM VI



D04443
llm

INTEGRATED SYSTEM VII

STORE	PUMP	PRESSUR-IZATION	VACUUM JACKET	ACQUISITION
SUBCRITICAL	SEPARATE AT ENGINE	HELIUM	NO	START CONTAINER
OMPS	OMPS	OMPS	OMPS	OMPS
SUBCRITICAL	COMMON AT TANK	HELIUM	YES	CHANNELS & HEADS
ACPS APU	ACPS APU	ACPS APU	ACPS APU	ACPS APU
SUPERCRITICAL	NONE	O_2 & H_2	YES	NONE
FC EC/LSS	FC EC/LSS	FC EC/LSS	FC EC/LSS	FC EC/LSS

INTEGRATED SYSTEM VIII

STORE	PUMP	PRESSUR-IZATION	VACUUM JACKET	ACQUISITION
SUBCRITICAL	SEPARATE AT ENGINE	GO_2 GH_2	NO	START CONTAINER
OMPS	OMPS	OMPS	OMPS	OMPS
SUPERCRITICAL	NONE	O_2 H_2	YES	NONE
ACPS APU	ACPS APU	ACPS APU	ACPS APU	ACPS APU
FC EC/LSS	FC EC/LSS	FC EC/LSS	FC EC/LSS	FC EC/LSS

D04445
11m

SUMMARY OF WEIGHTS AND COMPONENTS

Integrated Systems	Ia	Ib	Ic	IIa	IIb	IIIa	IIIb	IVa	IVb	IVc	Va	Vb	VIa	VIb	VII	VIII	Ref
Subsystem	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens	Inert/ Cryogens
OIPS	3,298	3,298	3,298	3,298	3,298	3,298	3,298	3,298	3,298	3,298	3,298	3,298	3,298	3,298	3,298	3,298	3,731
OMPS																	
ACPS						3,946/ 37,003	3,946/ 37,003	3,946/ 37,003	4,763/ 36,673	4,733/ 37,003	2,084/ 29,143	2,126/ 29,022	2,084/ 29,143	2,084/ 29,143	2,128/ 29,022	2,084/ 29,143	2,021/ 29,129
APU	5,380/ 40,020	5,983/ 39,858	6,123/ 40,172	5,283/ 38,128	5,497/ 38,781	877/ 737	1,601/ 828										2,763/ 8,191
FC								2,129/ 2,777	2,129/ 2,777						3,410/ 8,994	6,468/ 9,547	877/ 737
EC/LSS				574/ 1,675	574/ 1,675	574/ 1,675	574/ 1,675			2,129/ 2,777	3,472/ 11,406	3,450/ 10,950	7,323/ 11,892	5,287/ 11,892			481/ 1,646
															574/ 1,675	574/ 1,675	63/51
Total	8,678/ 40,020	9,281/ 39,858	9,421 40,172	9,155/ 39,803	9,369/ 40,456	8,695/ 39,415	9,419/ 39,506	9,373/ 39,780	10,190/ 39,450	10,160/ 39,780	8,854/ 40,549	8,878/ 39,972	12,705/ 41,035	10,669/ 41,035	9,410/ 39,691	12,424/ 40,365	9,936/ 39,754
Number of Components (1)	375	396	422	451	477	679	622	608	634	608	433	443	431	484	519	488	774

(1) Does not include OIPS components

LOCKHEED

OIPS PREPRESSURANT CHANGES

REMOVED FROM OMPS (433 LB TOTAL)

PREPRESSURANT (520°R ISOTHERM)

GO_2	5
GH_2	15

TANKS (4,000 PSIA)

O_2	17
H_2	350

COMPONENTS	NO.	WEIGHT
FV01	1	5.7
RV01	2	13.5
BD03	2	3.0
SV02	1	5.2
RV02	2	15.3
BD04	2	3.0
	10	45.7 LB

ADDED TO ACPS (109 LB TOTAL)

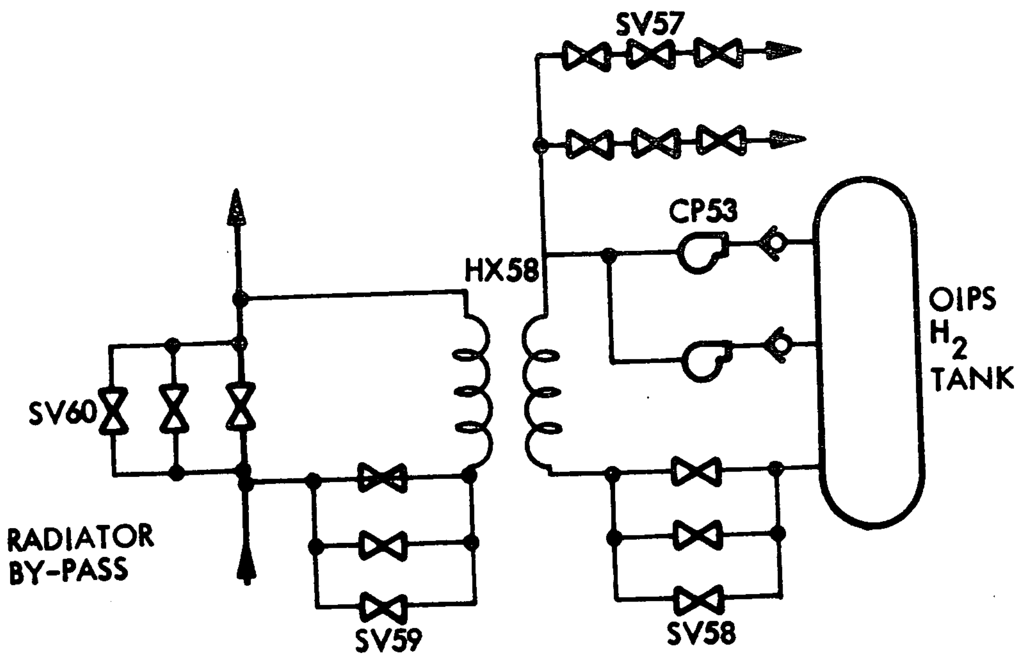
PREPRESSURANT	CONDITIONING	STORAGE TANK ΔWEIGHT	LINE WEIGHT
GO_2 (350°R) 6.0	–	2.0	15.0
GH_2 (250°R) 23.0	8.0	40.0	15.0

D03453

HEAT GENERATION AND REJECTION – FIRST TWO ORBITS

PHASE	DURATION (HR)	CABIN AND CREW MIN. (BTU/HR)	CABIN AND CREW MAX. (BTU/HR)	ELECTRONIC MIN. (BTU/HR)	ELECTRONIC MAX. (BTU/HR)	TOTAL MIN. (BTU)	TOTAL MAX. (BTU)
PRELAUNCH	0.083	860	2,600	24,200	34,130	2,100	3,010
ASCENT	0.11	1,860	4,600	24,270	36,860	2,970	4,670
PHASING	3.0	0	3,600	19,440	43,680	58,100	142,000

7,680 BTU THROUGH ASCENT – NO VENTING $\Delta P = 0.15$



COMPONENT	NO.	WEIGHT
CP53	2	6
SV57	6	15
SV58	3	8
SV59	3	4
SV60	3	4
HX58	2	2
		39

D03488

OMPS PREPRESSURANT SYSTEM CHANGES

REMOVED FROM OMPS (965 LB TOTAL)

PREPRESSURANT (520°R ISOTHERM)

GO_2	359 LB
GH_2	3 LB

TANKS (4,000 TO 200 PSI)

O_2	435 LB
H_2	155 LB

COMPONENTS	NO.	WEIGHT
FV01	1	1.5
SQ01	1	0.75
QD01	1	1.75
RV01	1	1.92
BD01	1	0.2
QD02	1	2.0
SQ02	1	0.9
FV02	1	1.77
RV02	1	1.77
BD02	1	0.2
	10	12.8 LB

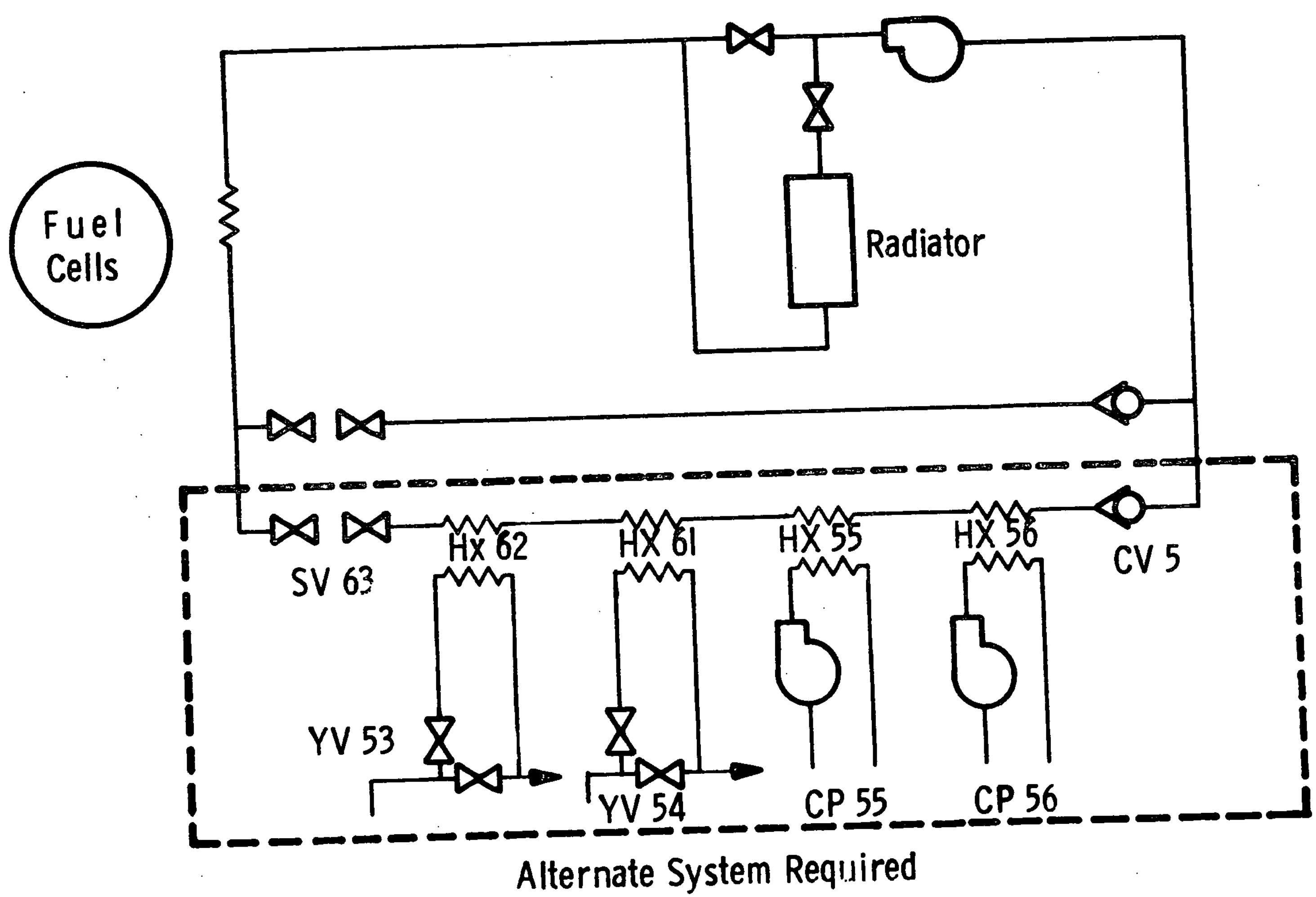
ADDED TO ACPS (541 LB TOTAL)

PREPRESSURANT		CONDITIONING	STORAGE TANK ΔWEIGHT
GO_2 (350°R)	420	23	~61
GH_2 (250°R)	6	2	~29

D03457

LOCKHEED

FUEL CELL TO CRYOGENS HEAT TRANSFER SYSTEM



HEAT TRANSFER SYSTEM WEIGHTS

Components	Number	Weight
HX 61	2	0.8
HX 62	2	0.4
HX 55	2	1.0
HX 56	2	0.4
CP 56	2	4.0
CP 55	2	8.0
YV 53	4	12.0
YV 54	4	12.0
SV 63	6	18.0
CV 51	3	4.5
Total		61.0
Lines (Estimate)		10.0
		71.1

Conditioning required if fuel cell heat is not used to condition fuel cell reactant.

Condition 175 lb H_2 = 64 lb
Condition 1,450 lb O_2 = 80 lb
144 lb

D03441

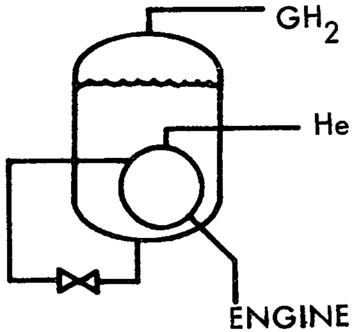
LOCKHEED

REFILL COMPARISON FOR ACPS + FC + APU + EC/LSS

	NO REFILL	REFILL	WEIGHT
O_2 TANK	1,020	280	-740
INSULATION	8	3	-5
VACUUM JACKET	59	16	-43
H_2 TANK	3,600	2,240	-1,360
INSULATION	61	39	-22
VACUUM JACKET	217	138	-79
O_2 RESIDUAL	515	113	-402
H_2 RESIDUAL	203	72	-131
ADDED COMPONENTS	-	370	+370
ADDED CONDITIONING	-	53	+53
ADDED STORAGE, OMPS TANKS	-	123	+123
ACQUISITION	-	200	+200
TOTAL WEIGHT SAVINGS			2,036

D03780
llm

START TANK CONCEPT



ADVANTAGES:

- LIMITS HELIUM USE
- PROVIDES FINITE ACQUISITION METHOD
- PERMITS ELIMINATION OF VACUUM JACKETING

DISADVANTAGES:

- HEAVY
- DUTY CYCLE RESTRICTED
- HEATED HELIUM PURGE REQUIRED

LOCKHEED

CASE Ia INTEGRATED PURGING, INERTING, PNEUMATIC, AND PRESSURIZATION SUPPLY HELIUM REQUIREMENTS

SUBSYSTEM	FUNCTION	HELIUM WEIGHT (LB)	PRESSURE (PSIA)	TEMPERATURE (°R)	FLOW RATE (LB/SEC)
OIPS	ENGINE PNEUMATIC AND PURGE	60	1500	490-600	6 (MAX)
	PNEUMATIC VALVES	5	500-700	490-600	0.6 (MAX)
OMPS/ACPS/APU/FC/EC/LSS VACUUM-JACKET TANKS	H_2 TANK INSULATION PURGE	-	-	-	-
	ACPS VALVES	0.95	500-700	460-600	< 0.01
	APU VALVE	0.04	500-700	460-600	< 0.01
	FC/EC/LSS VALVES	0.35	500-700	460-600	< 0.01
	H_2 TANK PRESSURIZATION	45	18 (MIN)	37	0.4 (MAX)(1)
	O_2 TANK PRESSURIZATION	6	20 (MIN)	165	0.046 (MAX)(1)

(1) BASED ON THREE TURBOPUMPS OPERATING AT 2.9 LB/SEC FOR H_2 AND 14.5 LB/SEC EACH FOR O_2.

D04934

llm

CASE IIIa INTEGRATED PURGING, PNEUMATIC, AND PRESSURIZATION SUPPLY HELIUM REQUIREMENTS

LOCKHEED

SUBSYSTEM	FUNCTION	HELIUM WEIGHT (LB)	PRESSURE (PSIA)	TEMPERATURE (°R)	FLOW RATE (LB/SEC)
OIPS	ENGINE PNEUMATIC AND PURGE	60	1500	490-600	6 (MAX)
	PNEUMATIC VALVES	5	500-700	490-600	0.6 (MAX)
OMPS/ACPS (PUMPS-AT-TANKS)	H_2 TANK INSULATION PURGE WITH LH_2 IN TANK	10	15	520 (INLET)	0.02
	PNEUMATIC VALVES	0.95	500-700	460-600	< 0.01
	H_2 TANK PRESSURE	43	22 (MIN)	37	0.4 (MAX)
	O_2 TANK PRESSURE	5	2 (MIN)	165	0.046 (MAX)
APU	PNEUMATIC	0.04	500-700	460-600	< 0.01
	H_2 TANK PRESSURE	15	31	37	< 0.09
	O_2 TANK PRESSURE	1	31	165	< 0.01
FC/EC/LSS	PNEUMATIC	0.35	500-700	460-600	< 0.01

D04933

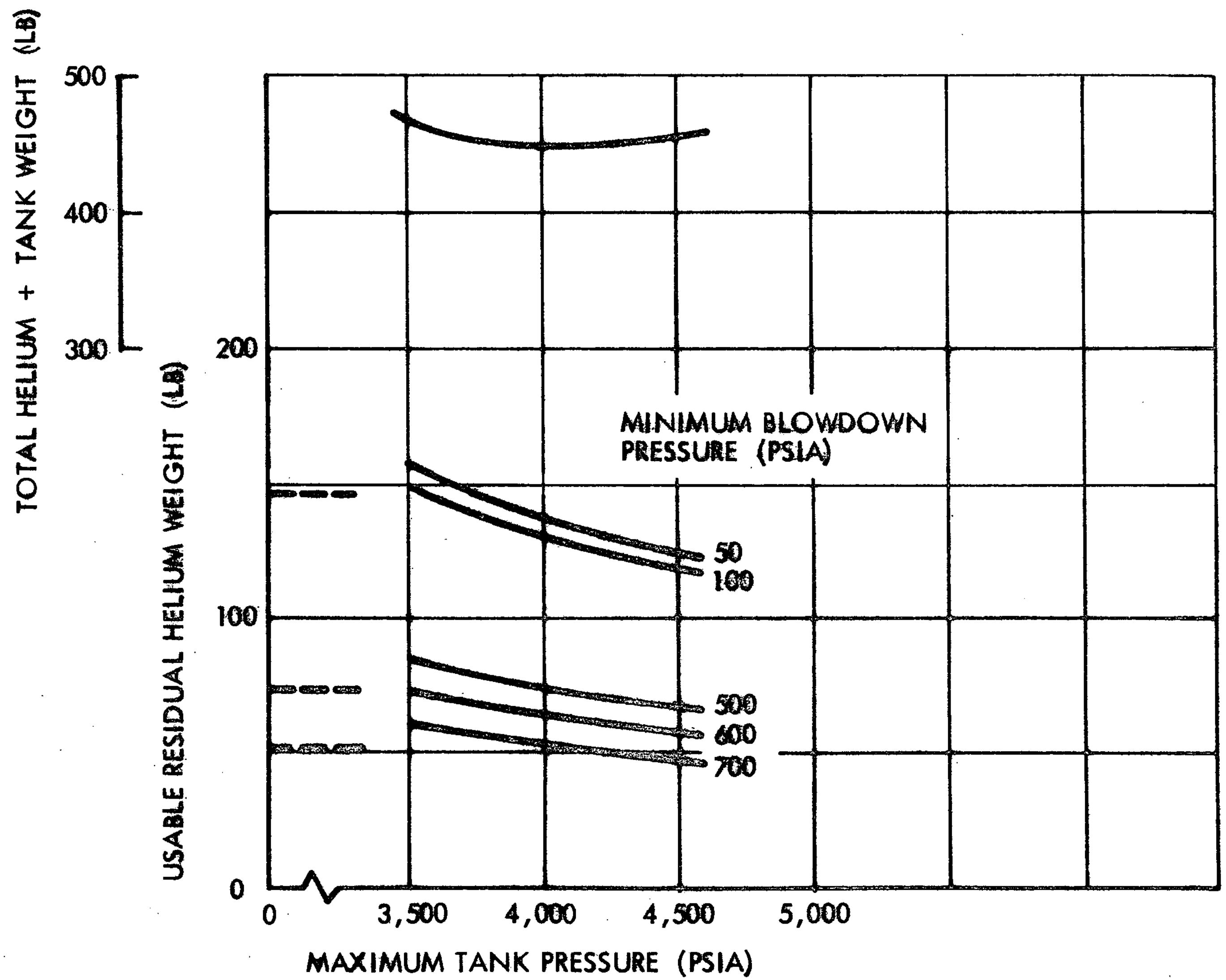
LOCKHEED

CASE IIIa[1] INTEGRATED PURGING, PNEUMATIC, AND PRESSURIZATION SUPPLY HELIUM REQUIREMENTS

SUBSYSTEM	FUNCTION	HELIUM WEIGHT (LB)	PRESSURE (PSIA)	TEMPERATURE (^{o}R)	FLOW RATE (LB/SEC)
OIPS	ENGINE PNEUMATIC AND PURGE	60	1500	490-600	6 (MAX)
	PNEUMATIC VALVES	5	500-700	490-600	0.6 (MAX)
OMPS/ACPS PUMPS-AT-ENGINE	RL-10 PURGE PNEUMATIC WITHOUT CONTINUOUS BLEED	1.7	500-700	140-620	< 0.01
	H_2 TANK INSULATION PURGE WITH LH_2 IN TANK	10	15	520 (INLET)	0.02
	PNEUMATIC VALVES	0.95	500-700	460-600	< 0.01
	H_2 TANK PRESSURE	115	31	37	0.6[2]
	O_2 TANK PRESSURE	28	3	53	0.046[2]
APU	PNEUMATIC	0.04	500-700	460-600	< 0.01
	H_2 TANK PRESSURE	15	31	37	< 0.09
	O_2 TANK PRESSURE	1	31	165	< 0.11
FC/EC/LSS	PNEUMATIC	0.35	500-700	460-600	< 0.01

(1) MODIFIED FOR USE OF RL-10 ENGINES FOR THE OMPS.
(2) BASED ON H_2 AT 8.5 LB/SEC AND O_2 AT 45.5 LB/SEC

HELIUM SUPPLY TANK AND USABLE HELIUM WEIGHT



D04936

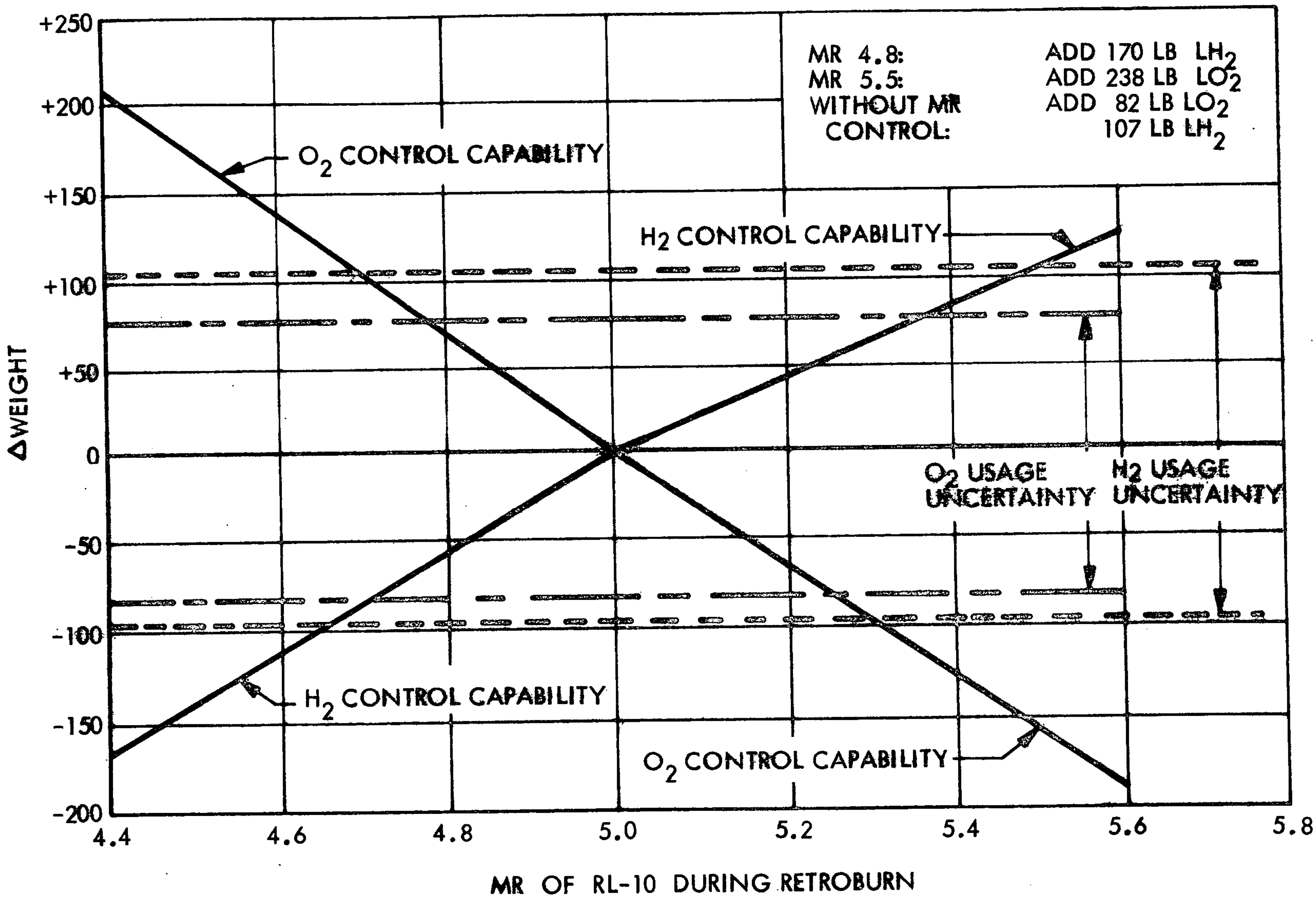
INTEGRATED PIP AND PRESSURIZATION HELIUM SUPPLY

ITEM	PIPS WT (LB)		PRESSURIZATION SYSTEM WEIGHT (LB)			INTEGRATED SYSTEM WEIGHT (LB)		
	Ia	IIIa	Ia	IIIa	IIIa MOD	Ia	IIIa	IIIa MOD
HELIUM REQUIREMENTS	72	80	45	58	130	111	134	208
CONDITIONING REACTANTS:								
O_2	12	127	-	-	-	12	127	127
H_2	12	127	-	-	-	12	127	127
TANKAGE	280	310	50	72	152	265	265	315
COMPONENTS	327	402	64	64	64	375	375	468
RESIDUAL He	125	133	3	4	10	195	72	22
TOTAL DRY	607	712	114	136	216	630	640	783
TOTAL FLUID	221	467	48	62	140	230	460	484
TOTAL	828	1,197	162	198	356	860	1,100	1,267
WEIGHT SAVINGS						130	295	286

IIm

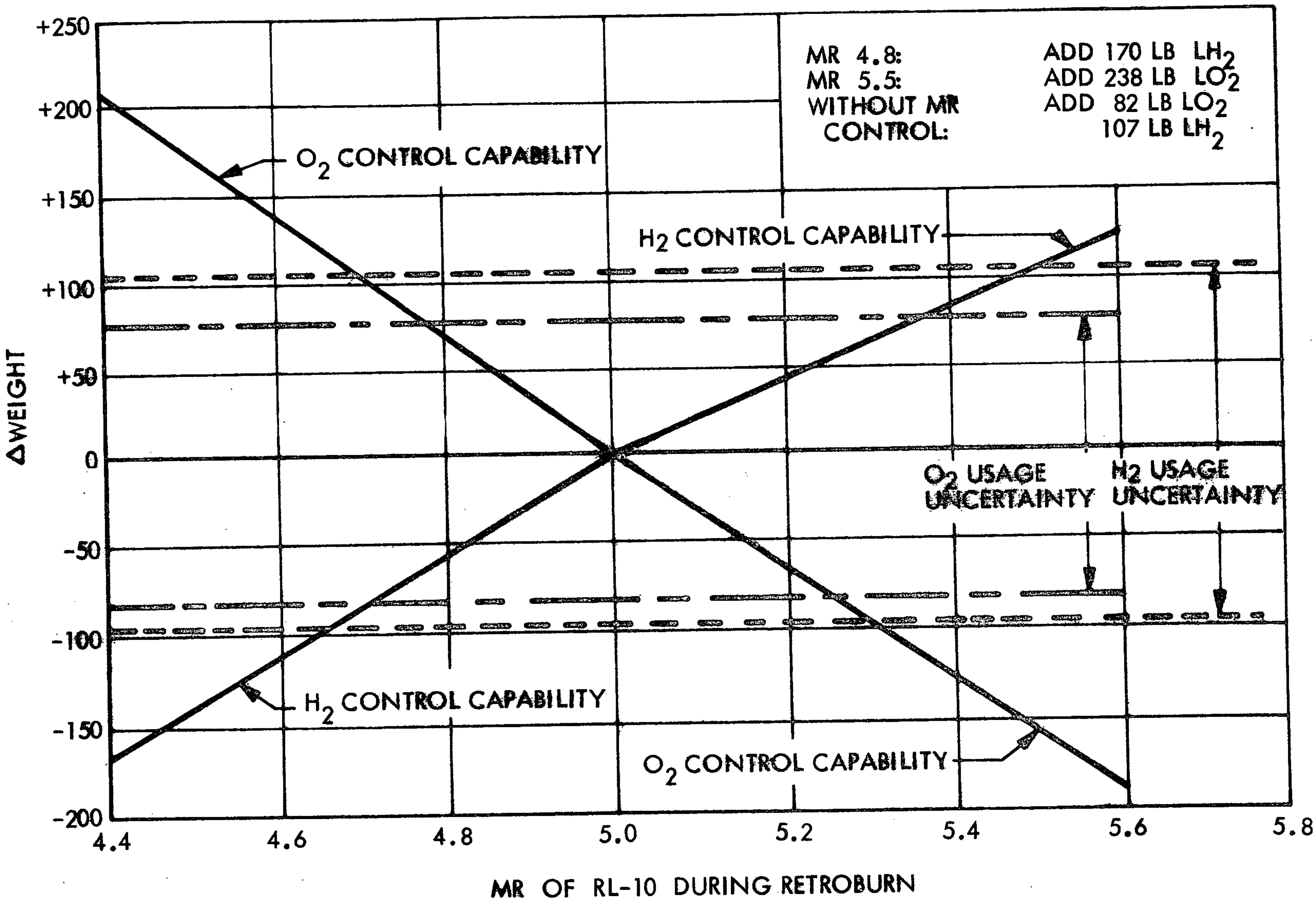
D04937

COMPATIBILITY BETWEEN PROPELLANT USAGE UNCERTAINTY AND PROPELLANT USAGE CONTROL



D04938

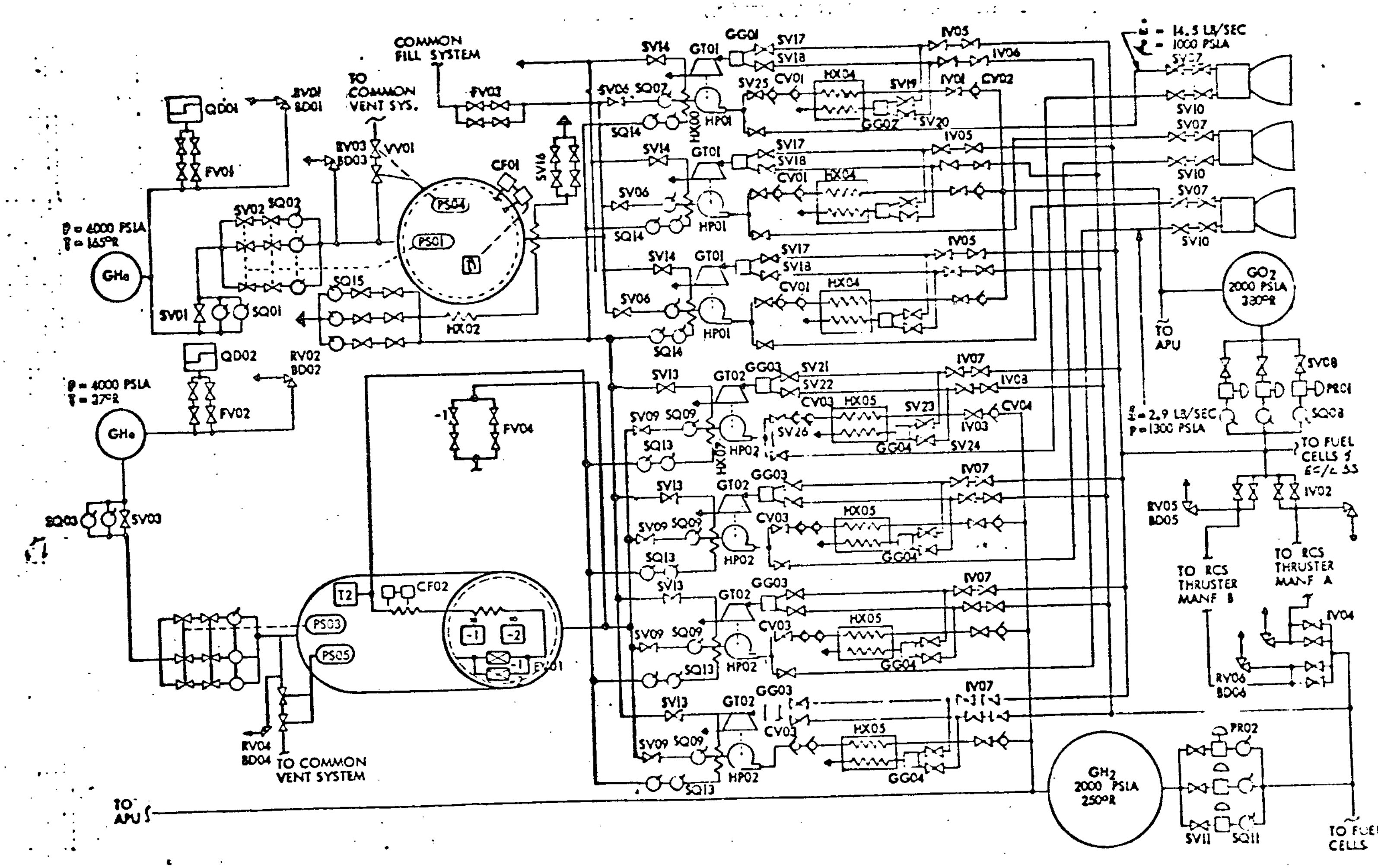
COMPATIBILITY BETWEEN PROPELLANT USAGE UNCERTAINTY AND PROPELLANT USAGE CONTROL



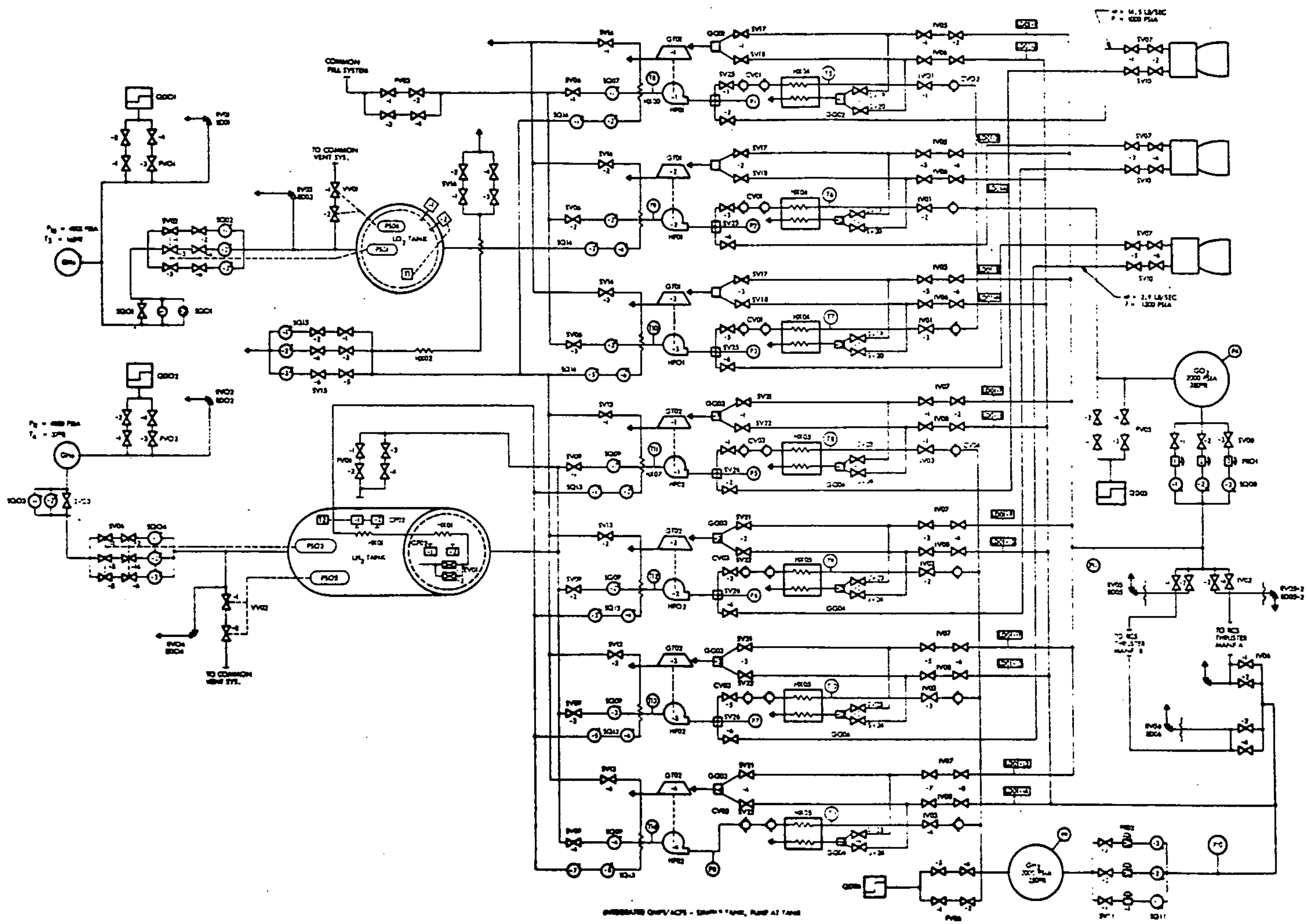
D04938

LOCKHEED

INTEGRATED OMPS/ACPS/APU/FC/EC/LSS WITH COMMON PUMPS



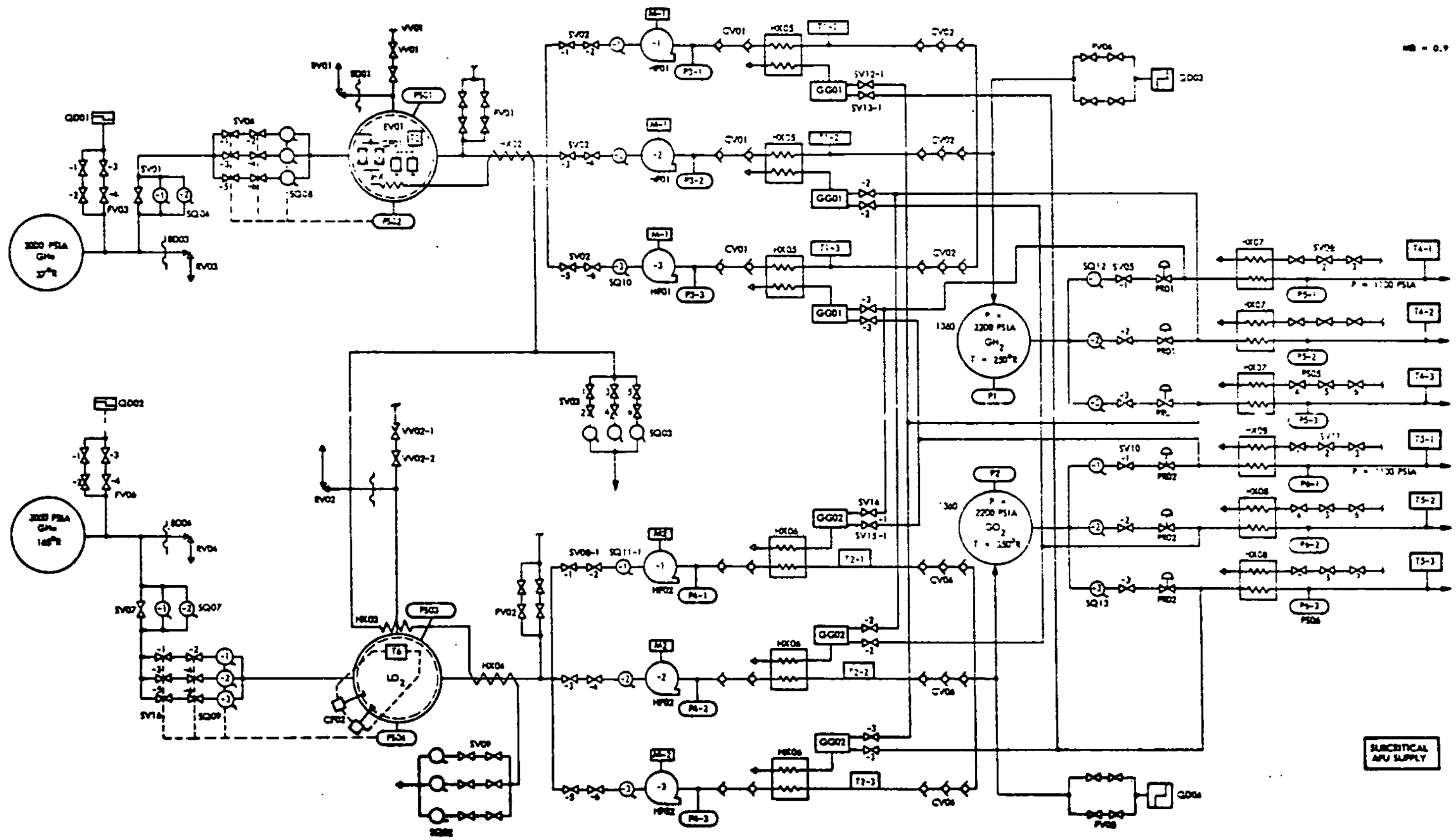
OMPS/ACPS WITH PUMP-AT-TANK



D04448

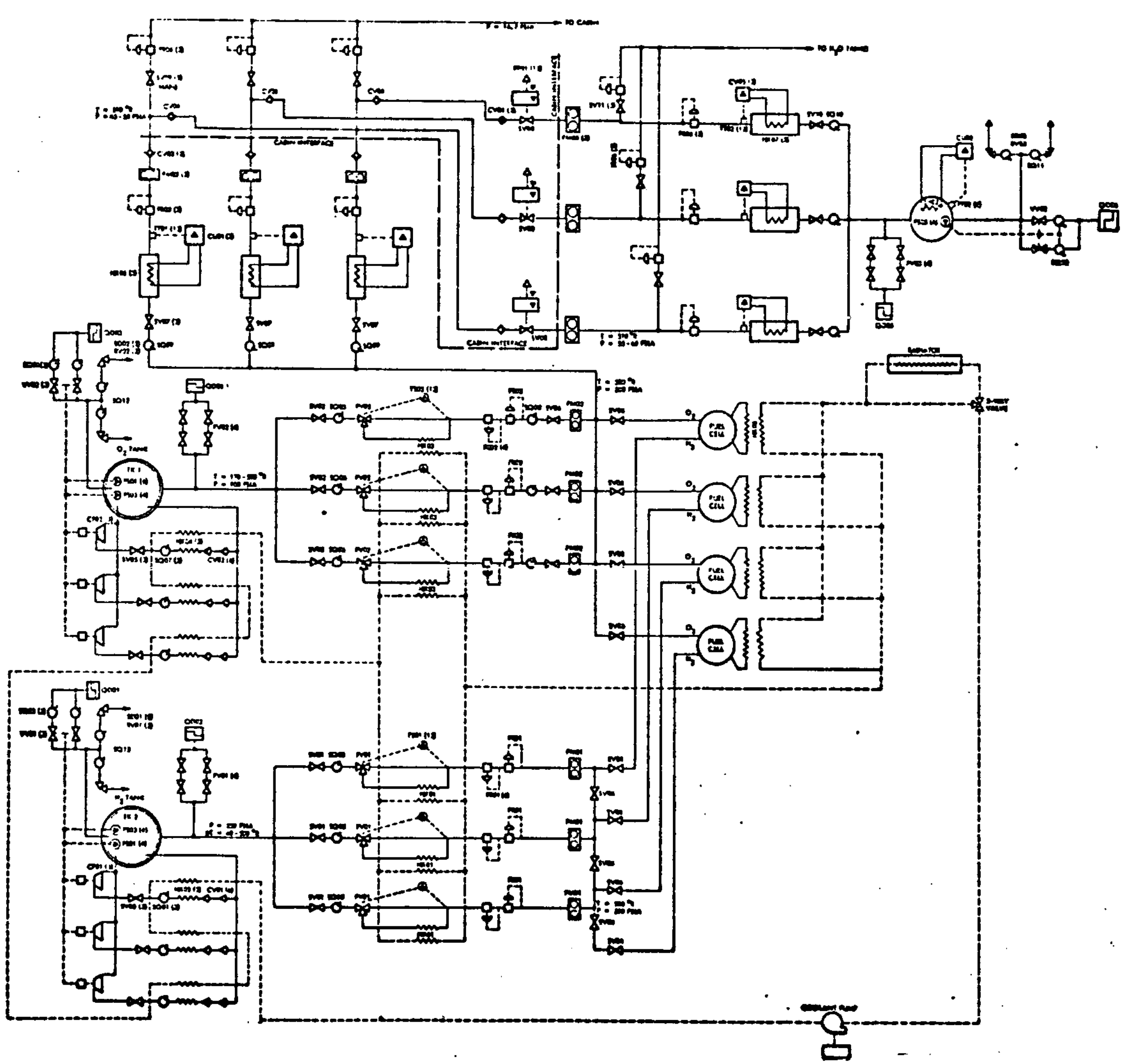
LOCKHEED

SUBCRITICAL APU CRYOGENIC SUPPLY SUBSYSTEM



D04483

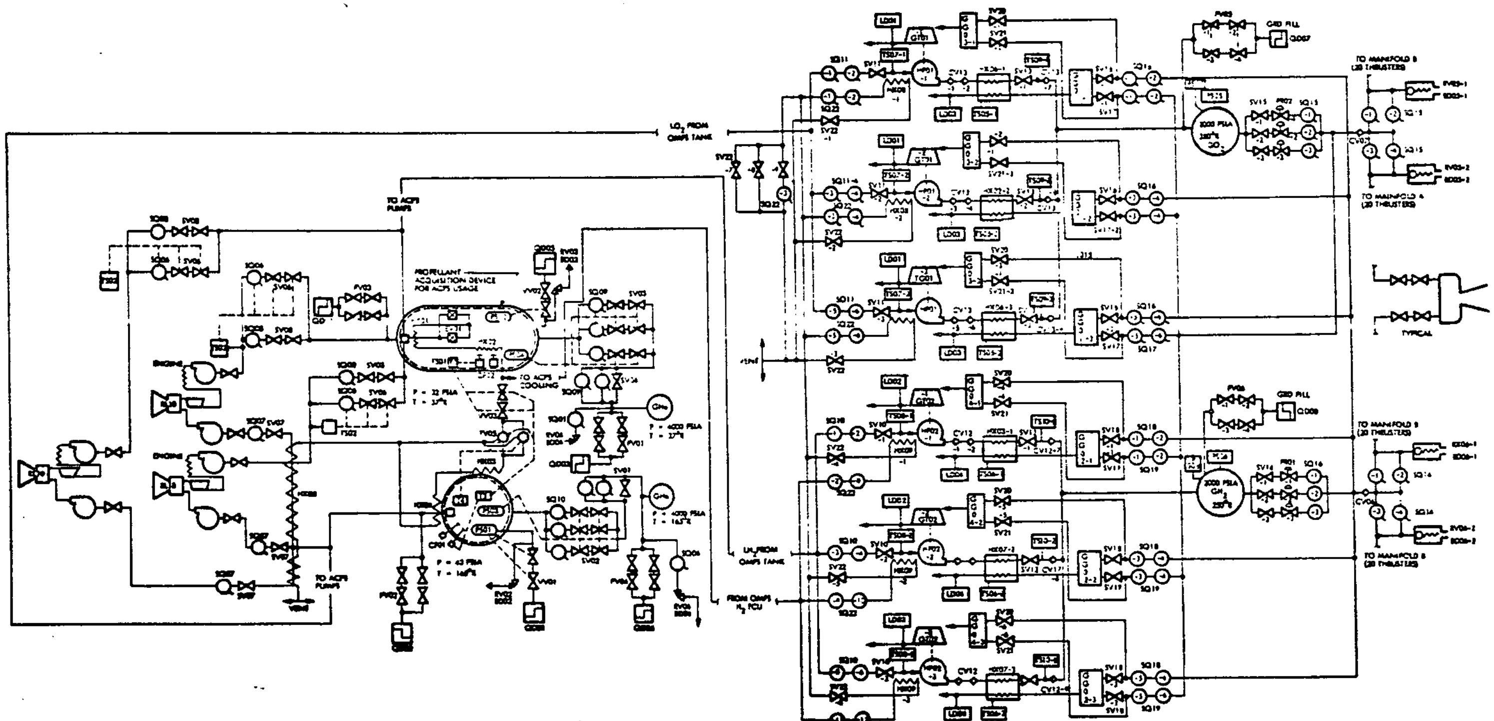
INTEGRATED SUPERCRITICAL FUEL CELL/LIFE SUPPORT SUBSYSTEM



D04480

LOCKHEED

INTEGRATED OMPS/ACPS WITH PUMP-AT-ENGINE



D04481
llm

LOCKHEED

SUMMARY OF EFFECTS

OF

DEGREE OF INTEGRATION

AND

OPERATIONAL MODE

LOCKHEED

INTEGRATED SYSTEMS RESULTS

- WEIGHT PENALTY OF 600 LB FOR USING TWO RL-10 ENGINES INSTEAD OF LIQUID-FED OMPS THRUSTERS
- WEIGHT PENALTY OF 180 LB FOR A START TANK SYSTEM
- FULLY INTEGRATED SYSTEM IS LIGHTEST AND HAS FEWER COMPONENTS (Ia)
- SYSTEM WITH SEPARATE SUBCRITICAL APU IS NEXT LIGHTEST - LARGE COMPONENT COUNT (IIIa)
- VACUUM JACKET ON OMPS TANKS RESULTS IN WEIGHT PENALTY OF 550-TO-750 LB
- INTEGRATED SYSTEMS CAUSE DIFFICULT ACQUISITION PROBLEMS
- HELIUM REQUIRED IN ALMOST ALL ATTRACTIVE SYSTEMS

llm

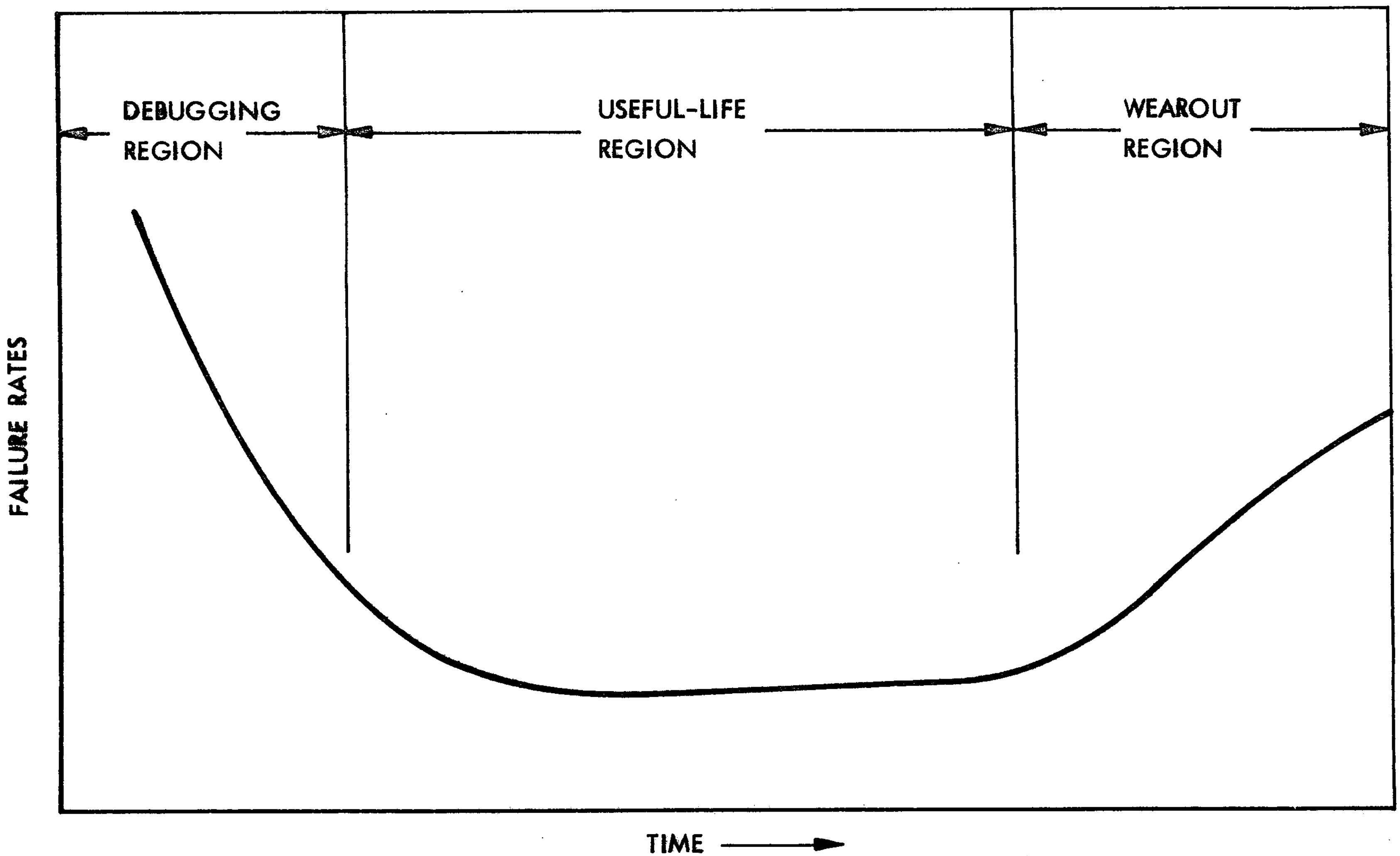
D04802

INTEGRATED SYSTEM RESULTS (Cont'd)

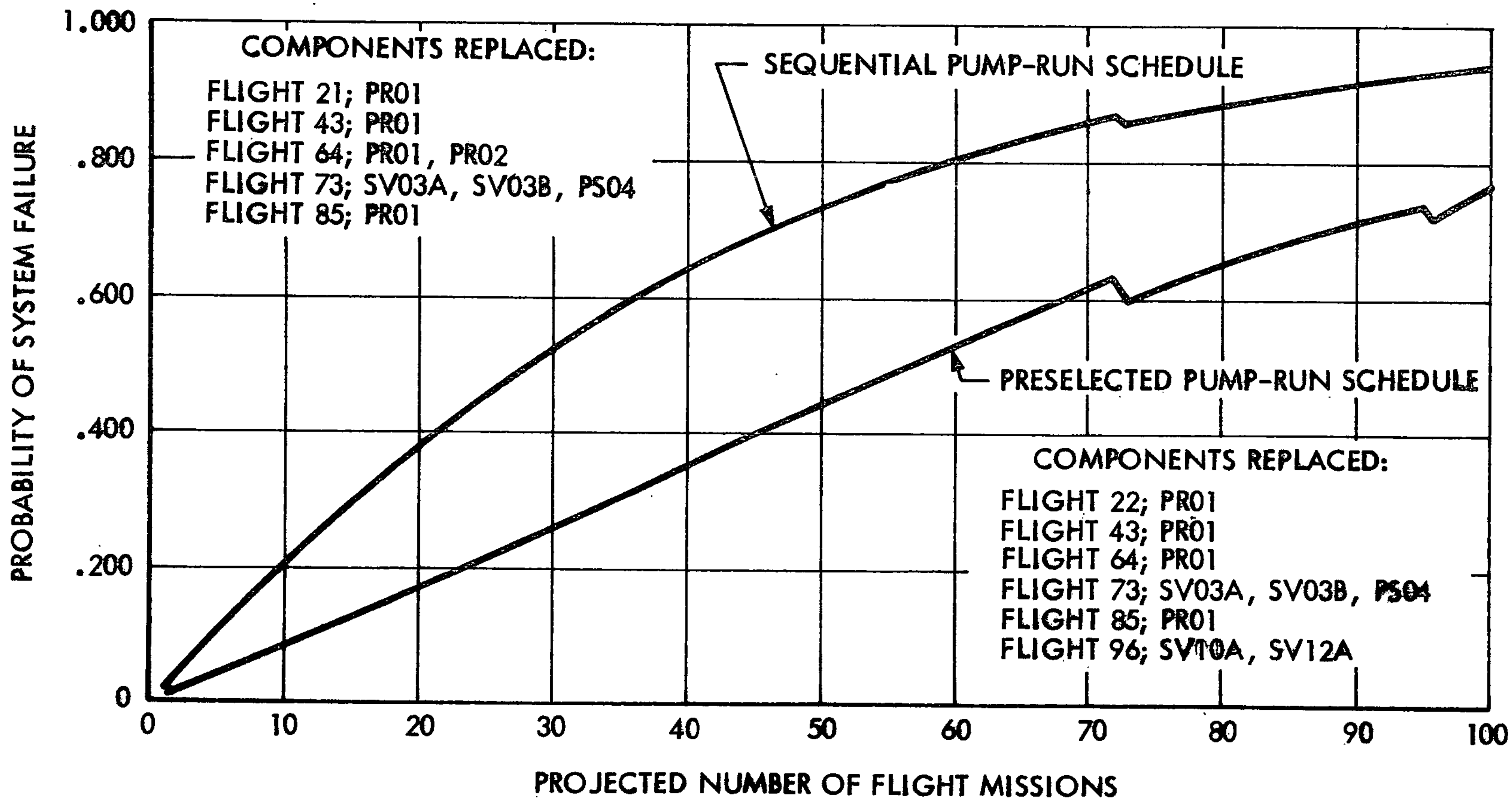
- REFILL OF SUPERCRITICAL TANKS SAVES 2000 LB, BUT INTRODUCES DISADVANTAGES ORIGINALLY ELIMINATED BY USE OF SUPERCRITICAL STORAGE
- ASCENT TANKS USABLE FOR HEAT SINK PRIOR TO DEPLOYMENT OF RADIATORS
- ACCENT TANKS CAPABLE OF PREPRESSURIZATION FROM ACPS ACCUMULATORS
- EC/LSS HEAT USABLE FOR FUEL CELL REACTANT CONDITIONING
- COMMON PUMPS CAPABLE OF SUPPLYING LIQUID TO OMPS AND TO ACPS CONDITIONERS
- APU REACTANTS USABLE AS HEAT SINK FOR EC/LSS DURING REENTRY

REUSABILITY/RELIABILITY EVALUATIONS

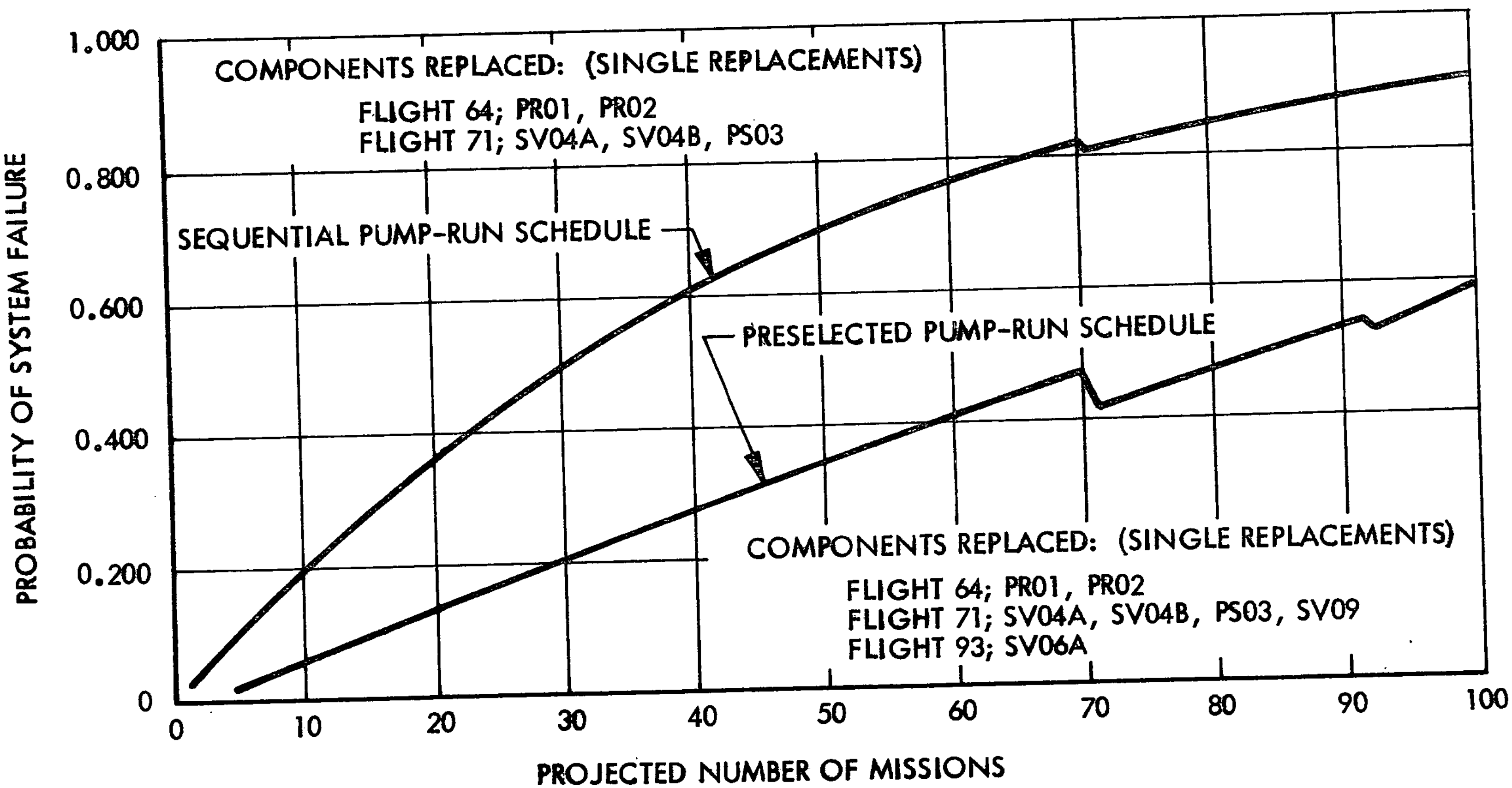
TYPICAL FAILURE RATES AS FUNCTION OF TIME



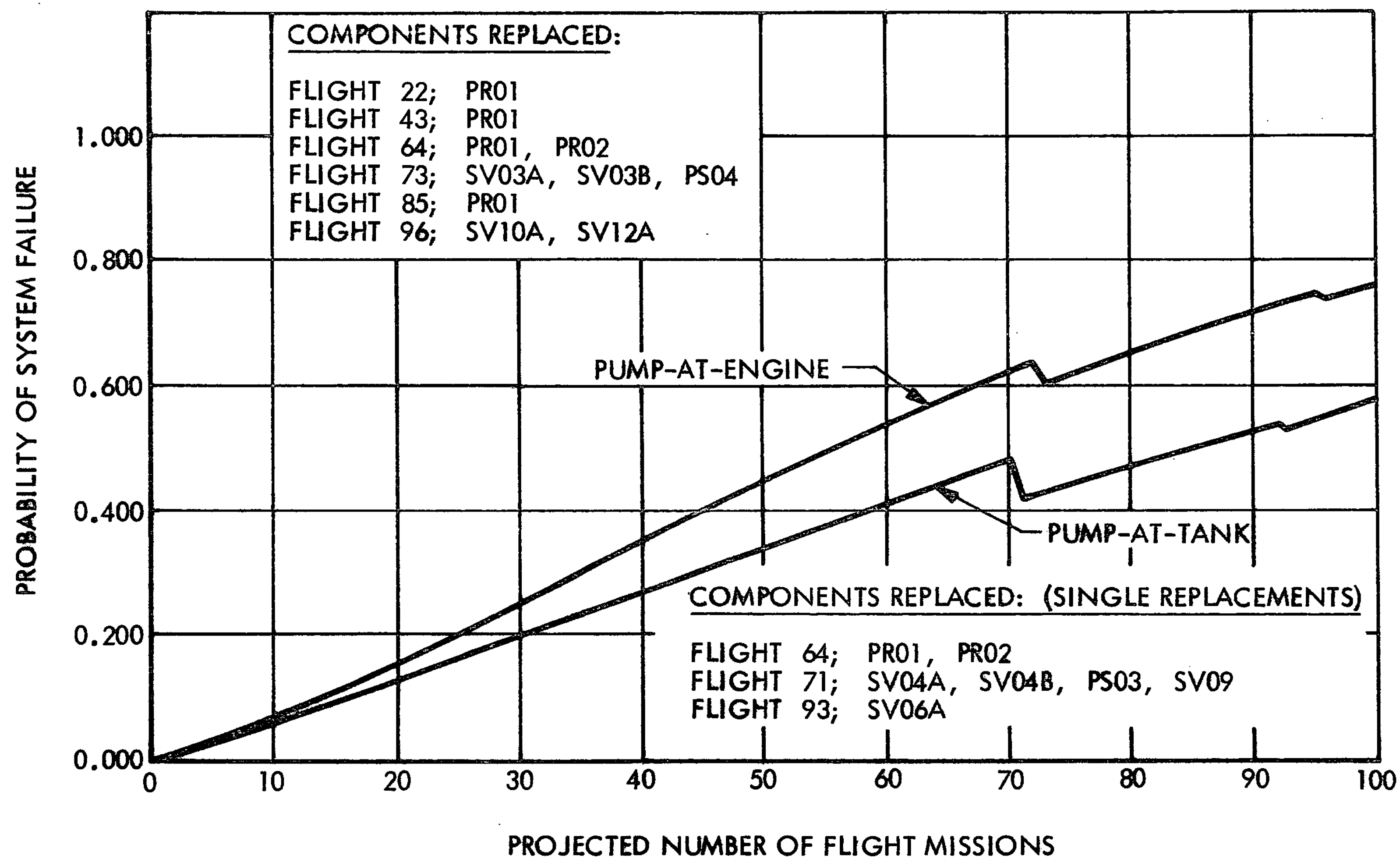
D02956
11m


COMPONENTS REPLACED:
FLIGHT 21; PR01
FLIGHT 43; PR01
FLIGHT 64; PR01, PR02
FLIGHT 73; SV03A, SV03B, PS04
FLIGHT 85; PR01
SEQUENTIAL PUMP-RUN SCHEDULE
PRESELECTED PUMP-RUN SCHEDULE
COMPONENTS REPLACED:
FLIGHT 22; PR01
FLIGHT 43; PR01
FLIGHT 64; PR01
FLIGHT 73; SV03A, SV03B, PS04
FLIGHT 85; PR01
FLIGHT 96; SV10A, SV12A
PROBABILITY OF SYSTEM FAILURE
1.000
.800
.600
.400
.200
0
0
10
20
30
40
50
60
70
80
90
100
PROJECTED NUMBER OF FLIGHT MISSIONS

OMPS/ACPS SYSTEMS (PUMP-AT-TANK) – SYSTEM III

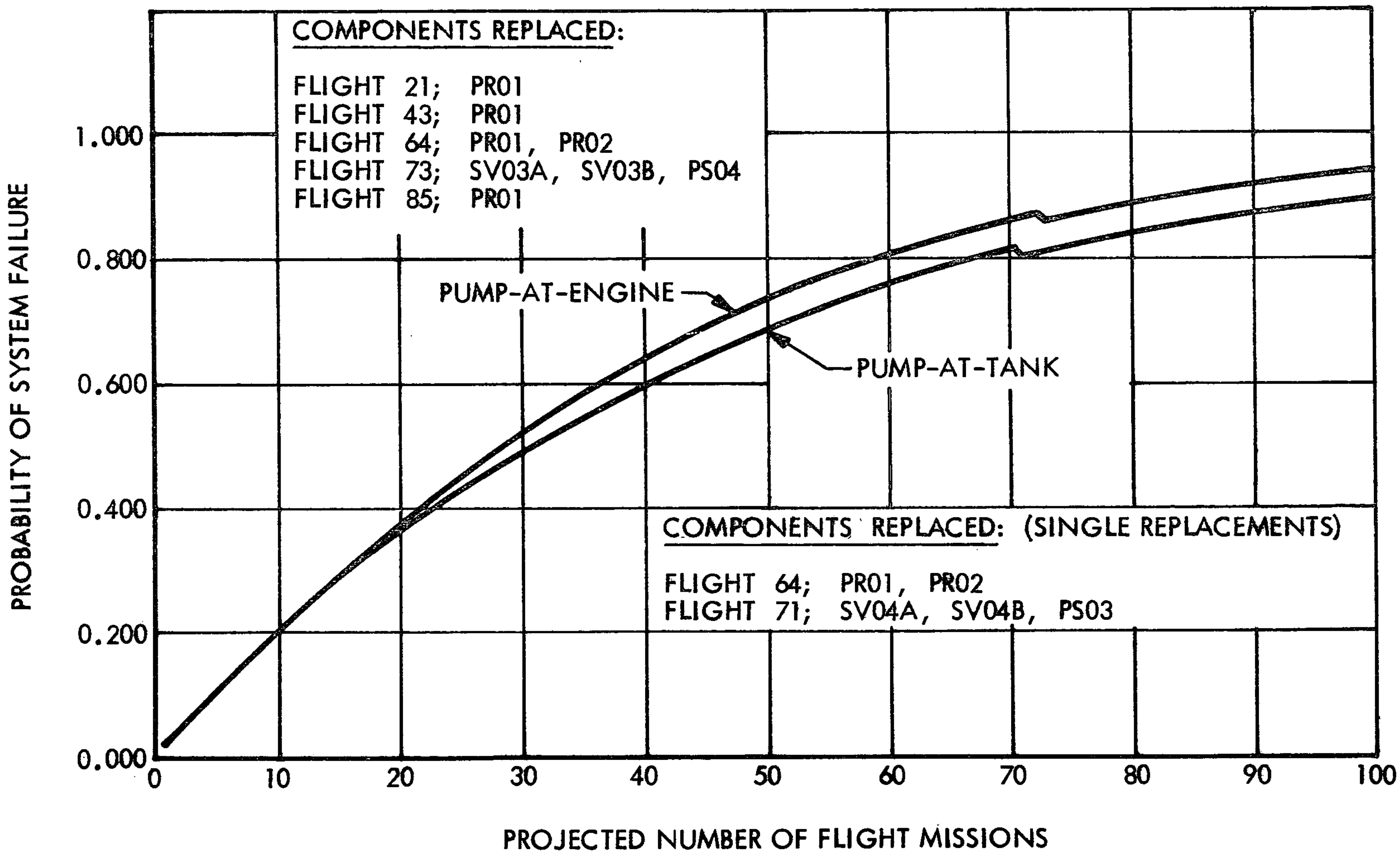


COMPARISON OF PUMP-AT-TANK AND PUMP-AT-ENGINE – PRESELECTED PUMP-RUN SCHEDULE – SYSTEM III

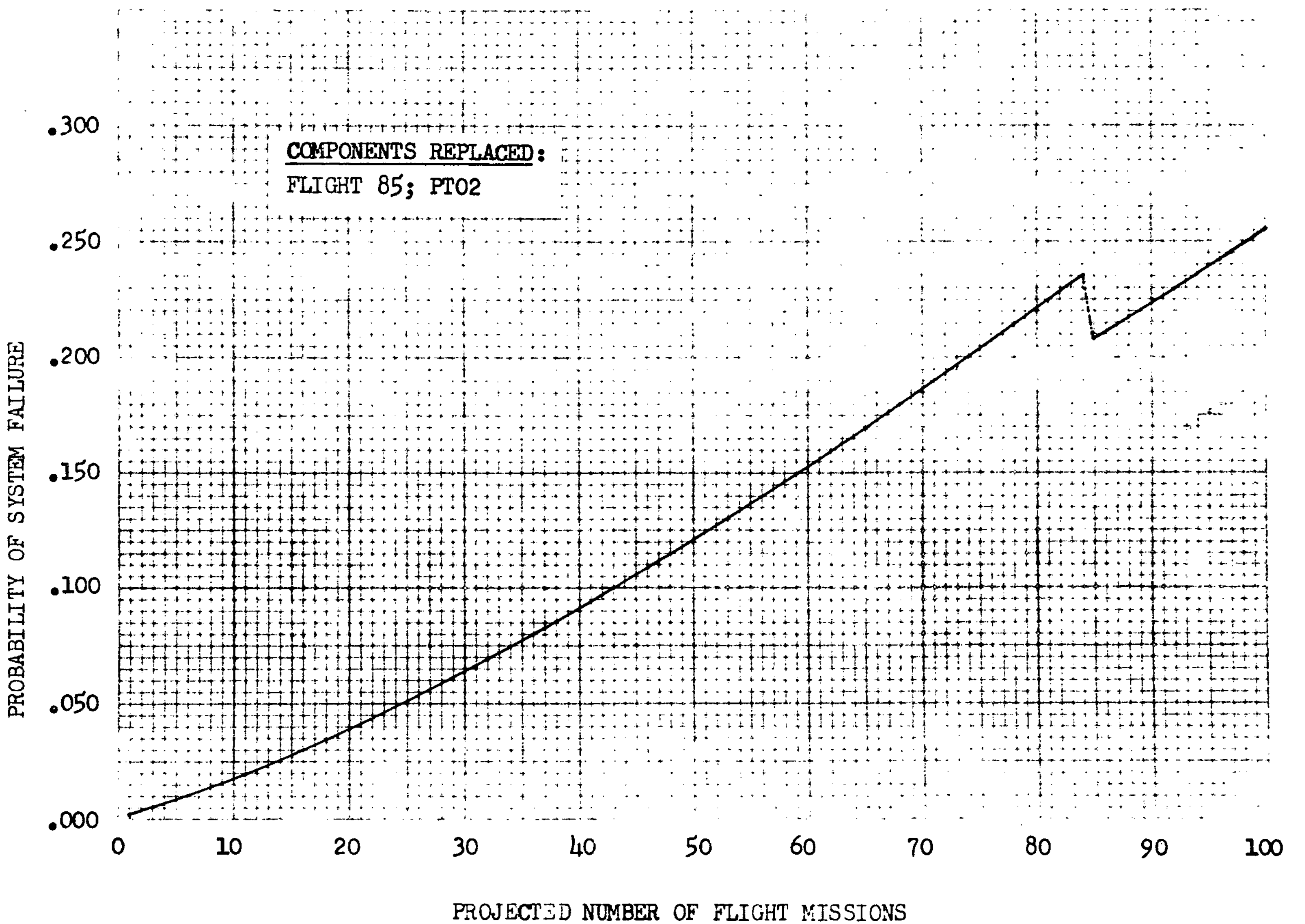


D04697
11m

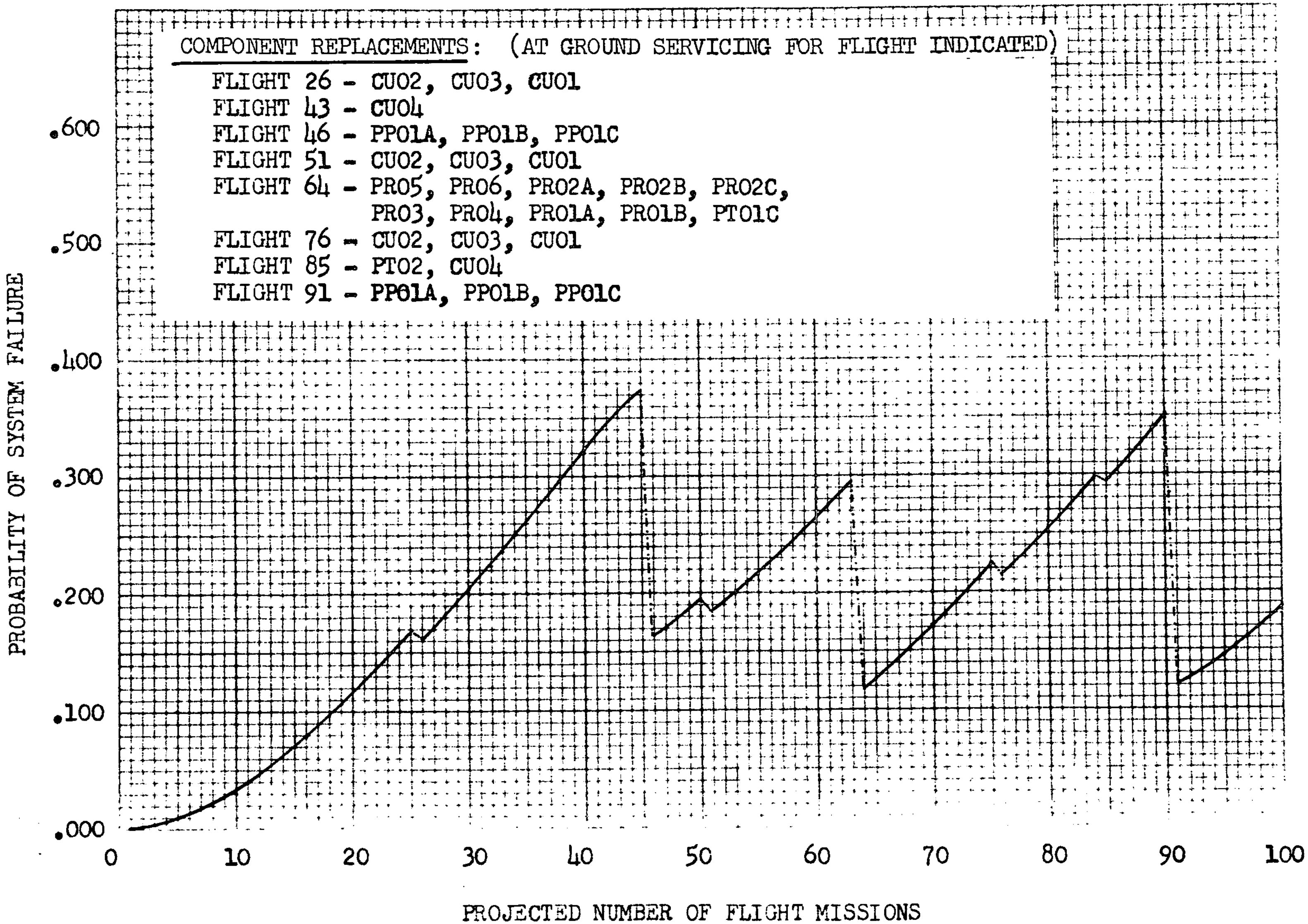
COMPARISON OF PUMP-AT-TANK AND PUMP-AT-ENGINE - SEQUENTIAL PUMP-RUN SCHEDULE - SYSTEM III



D04696
11m

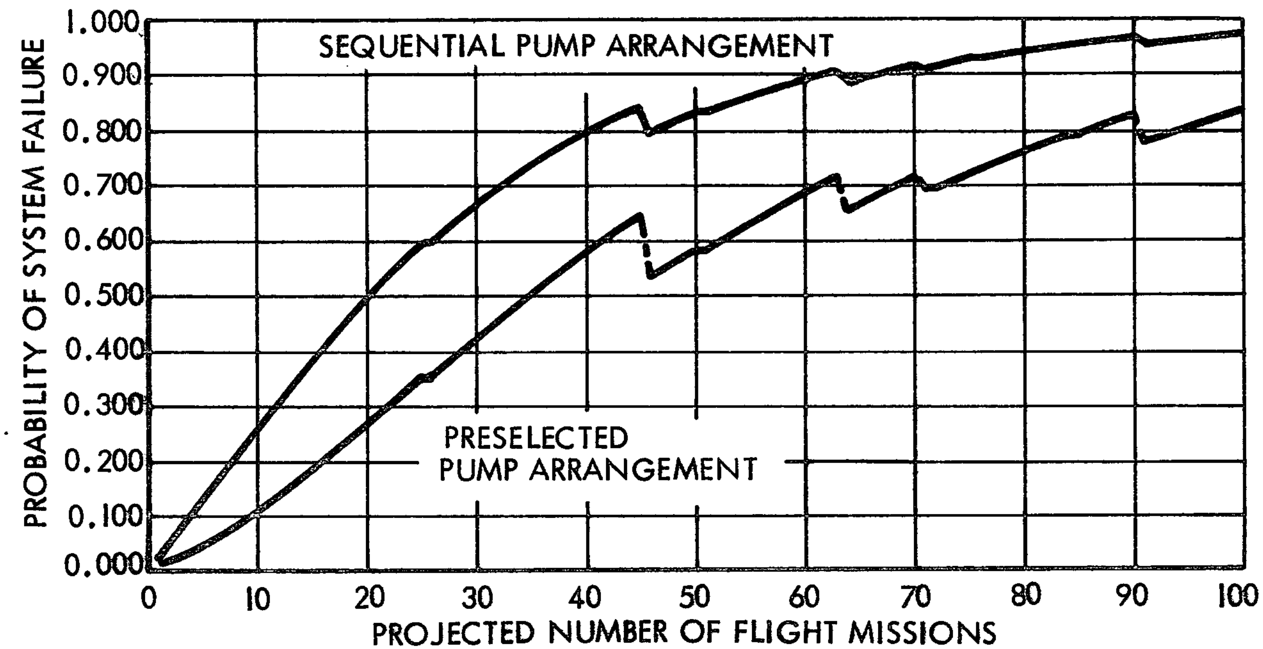

COMPONENTS REPLACED:
FLIGHT 85; PT02
.300
.250
.200
.150
.100
.050
.000
PROBABILITY OF SYSTEM FAILURE
0
10
20
30
40
50
60
70
80
90
100
PROJECTED NUMBER OF FLIGHT MISSIONS

D04467
11m


COMPONENT REPLACEMENTS: (AT GROUND SERVICING FOR FLIGHT INDICATED)
FLIGHT 26 - CU02, CU03, CU01
FLIGHT 43 - CU04
FLIGHT 46 - PP01A, PP01B, PP01C
FLIGHT 51 - CU02, CU03, CU01
FLIGHT 64 - PR05, PR06, PR02A, PR02B, PR02C,
PR03, PR04, PR01A, PR01B, PT01C
FLIGHT 76 - CU02, CU03, CU01
FLIGHT 85 - PT02, CU04
FLIGHT 91 - PP01A, PP01B, PP01C
PROBABILITY OF SYSTEM FAILURE
.600
.500
.400
.300
.200
.100
.000
0
10
20
30
40
50
60
70
80
90
100
PROJECTED NUMBER OF FLIGHT MISSIONS

D04482
11m

COMPARISON FOR PRESELECTED AND SEQUENTIAL PUMP ARRANGEMENT FOR PUMP-AT-ENGINE - SYSTEM I



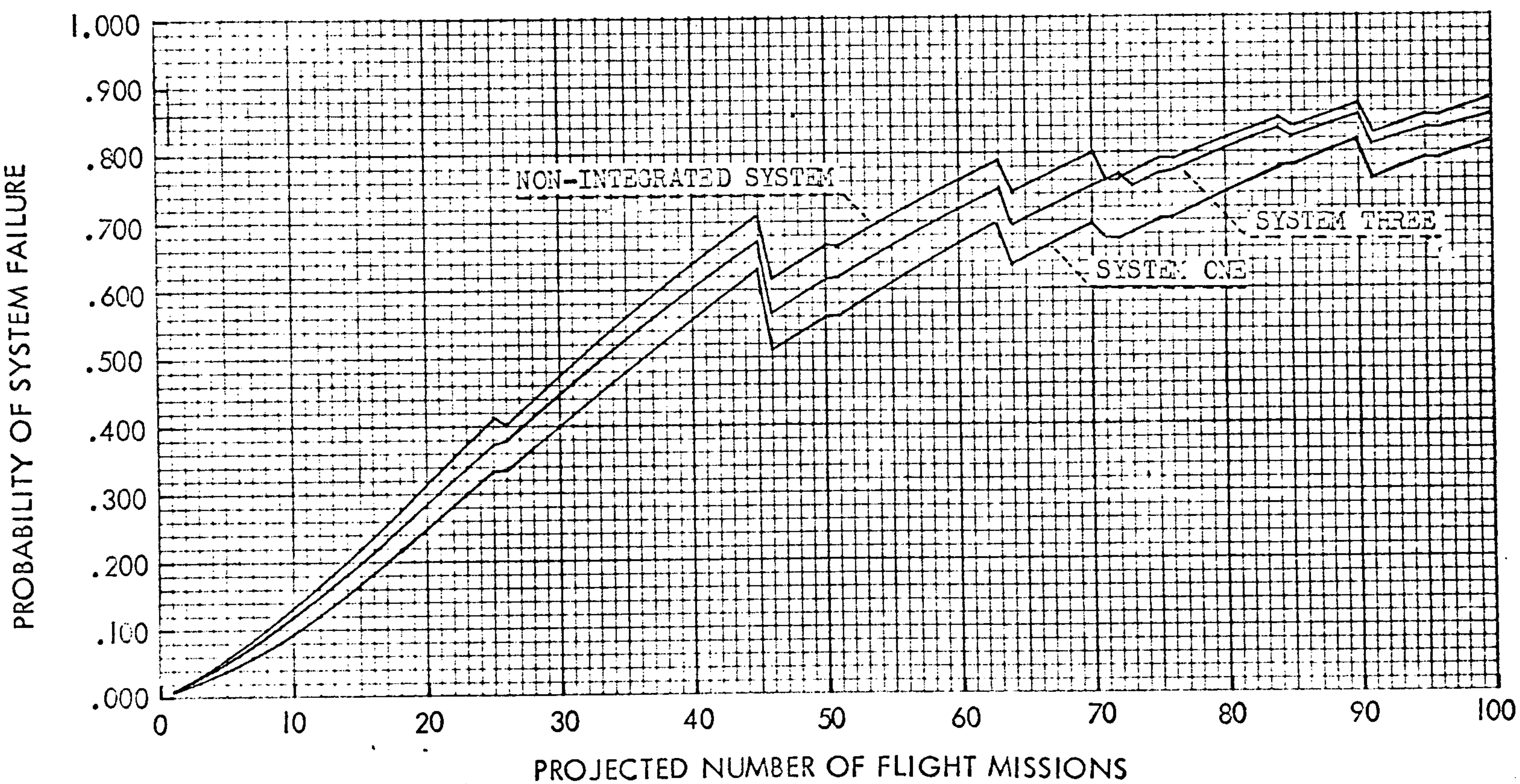
COMPONENT REPLACEMENTS: (AT GROUND SERVICING FOR FLIGHT INDICATED)

FLIGHT 22 - PR01
FLIGHT 26 - CU01, CU02, CU03
FLIGHT 43 - PR01, CU05
FLIGHT 46 - PP01A, PP01B, PP01C
FLIGHT 51 - CU01, CU02, CU03
FLIGHT 64 - PR01, PR02, PR05, PR06, PR07, PR08, PR09A, PR09B, PR09C, PR10A, PR10B, PR01C
FLIGHT 71 - SV04A, SV04B, PS03
FLIGHT 76 - CU01, CU02, CU03
FLIGHT 85 - PR01, CU05
FLIGHT 86 - PT01
FLIGHT 91 - PP01A, 01B, PP01C
FLIGHT 100 - CU01, CU02, CU03

D04713
llm

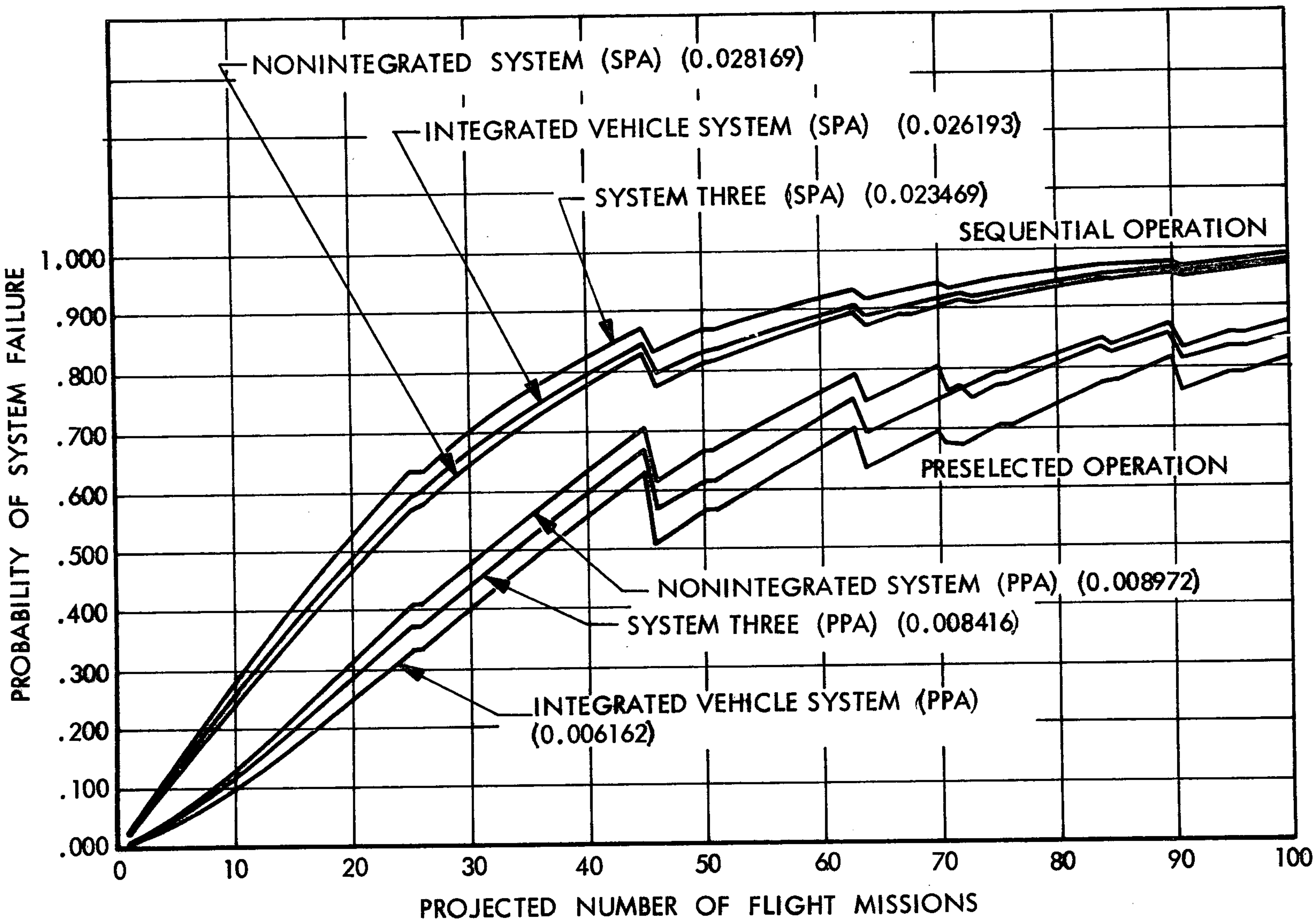
LOCKHEED

COMPARISON OF RELATIVE RELIABILITY OF SYSTEM I, SYSTEM III, AND NONINTEGRATED SYSTEMS (PUMP-AT-ENGINE)



D04819

EFFECT OF OPERATIONAL MODE
AS COMPARED TO INTEGRATION METHOD



D04911

LOCKHEED

CONCLUSIONS REGARDING EFFECTS OF INTEGRATION ON REUSABILITY AND RELIABILITY

- COMPONENT REPLACEMENT REQUIREMENTS AS A RESULT OF WEAROUT ARE RELATIVELY LOW

- INTEGRATION HAS A SIGNIFICANT EFFECT ON PER-FLIGHT RELIABILITY, BUT LITTLE ON RELIABILITY/REUSABILITY

- OPERATIONAL MODE (USE OF REDUNDANCY) HAS A SIGNIFICANT EFFECT ON RELATIVE RELIABILITY, AND MODERATE EFFECT ON REPLACEMENT

LOCKHEED

INSTRUMENTATION AND CONTROL

INSTRUMENTATION AND CONTROL APPROACH

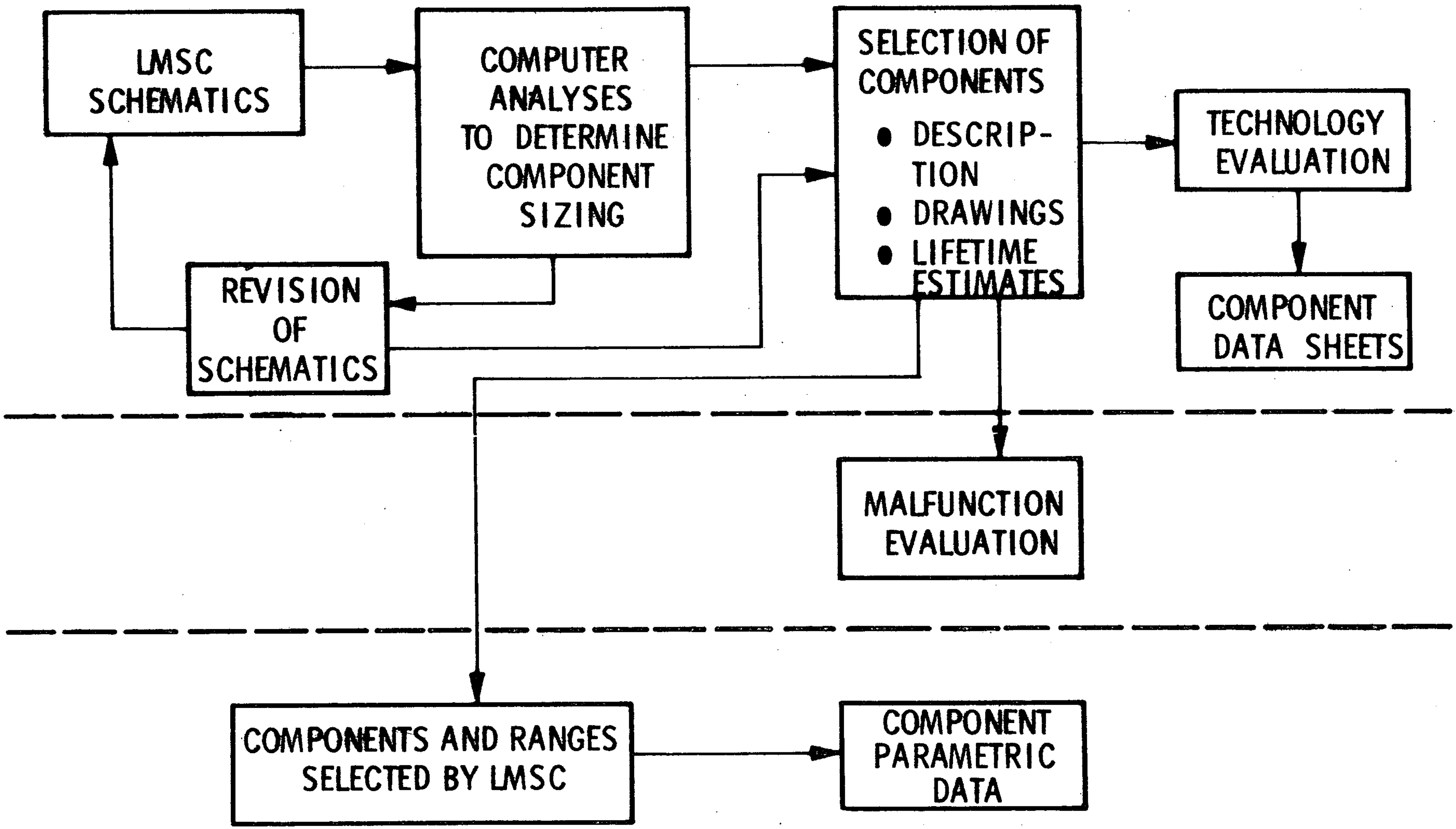
EACH SUBSYSTEM AND INTEGRATED SYSTEM EXAMINED FOR INSTRUMENTATION AND CONTROL AND MODIFIED ACCORDINGLY.

- DETAILED INFORMATION PROVIDED FOR
  - INTEGRATED OMPS/ACPS SUPPLY
  - SUBCRITICAL AUXILIARY POWER
  - INTEGRATED FUEL CELL/LIFE SUPPORT SUPPLY
- INFORMATION CONSISTS OF:
  - FUNCTIONAL FLOW
  - EVENT FLOW CHART
  - CONTROL SCHEMATICS FOR EACH MAJOR SUBSYSTEM FUNCTION (CONDITIONING, PRESSURIZATION, ETC.)

D04926

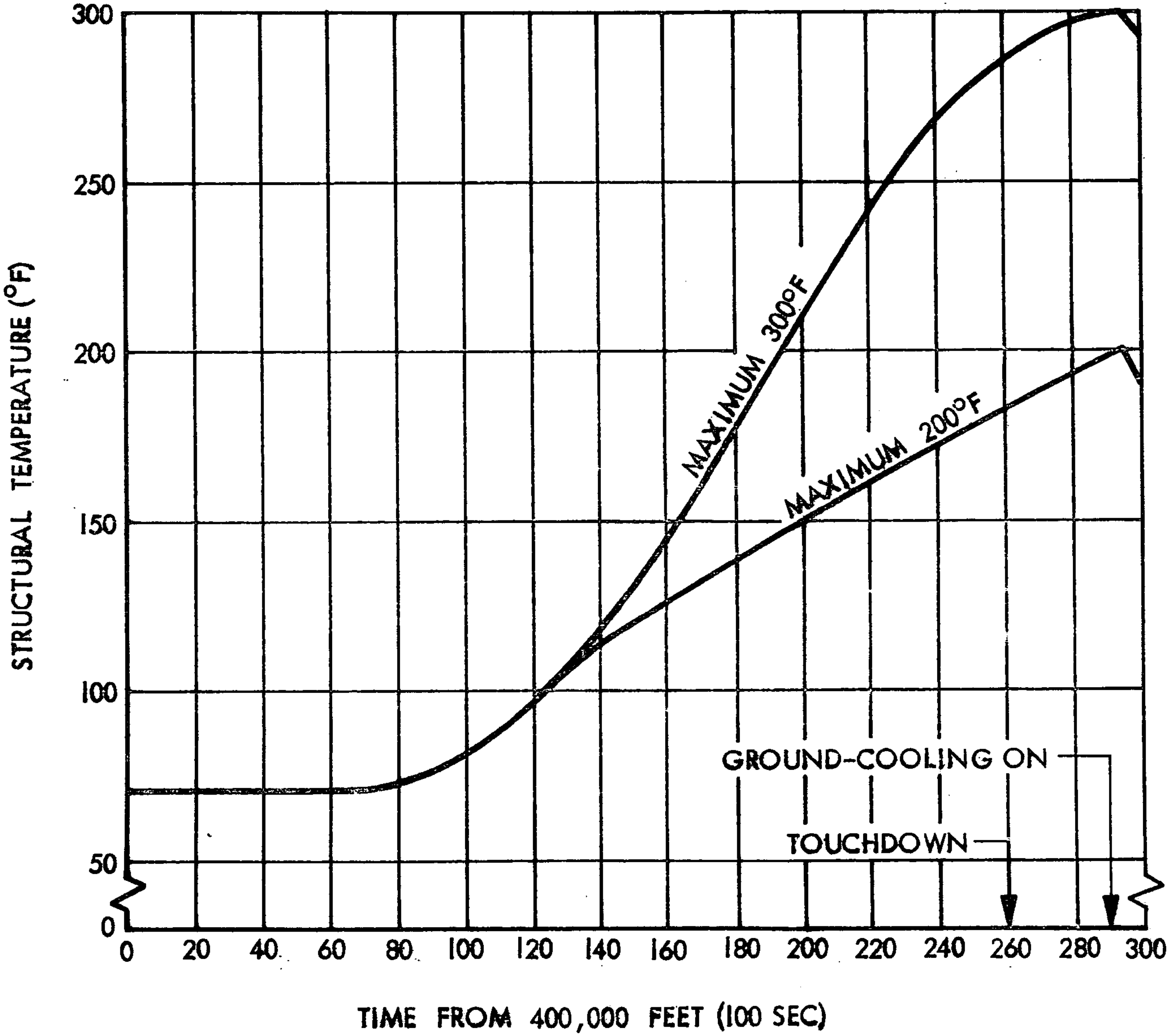
COMPONENT EVALUATIONS

COMPONENT EXAMINATION APPROACH



LOCKHEED

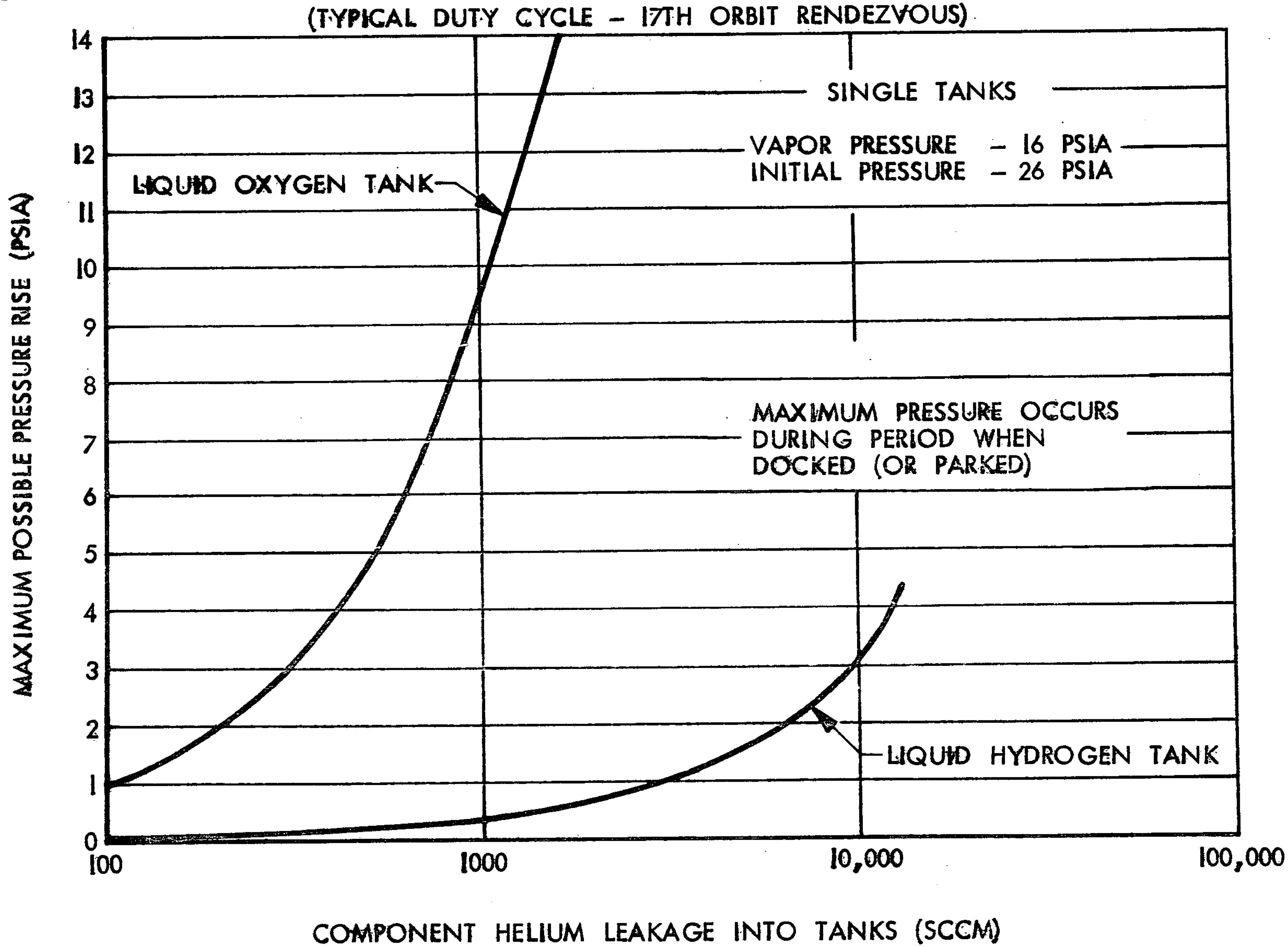
TYPICAL REENTRY STRUCTURAL TEMPERATURES (HIGH CROSSRANGE)



D03706
11m

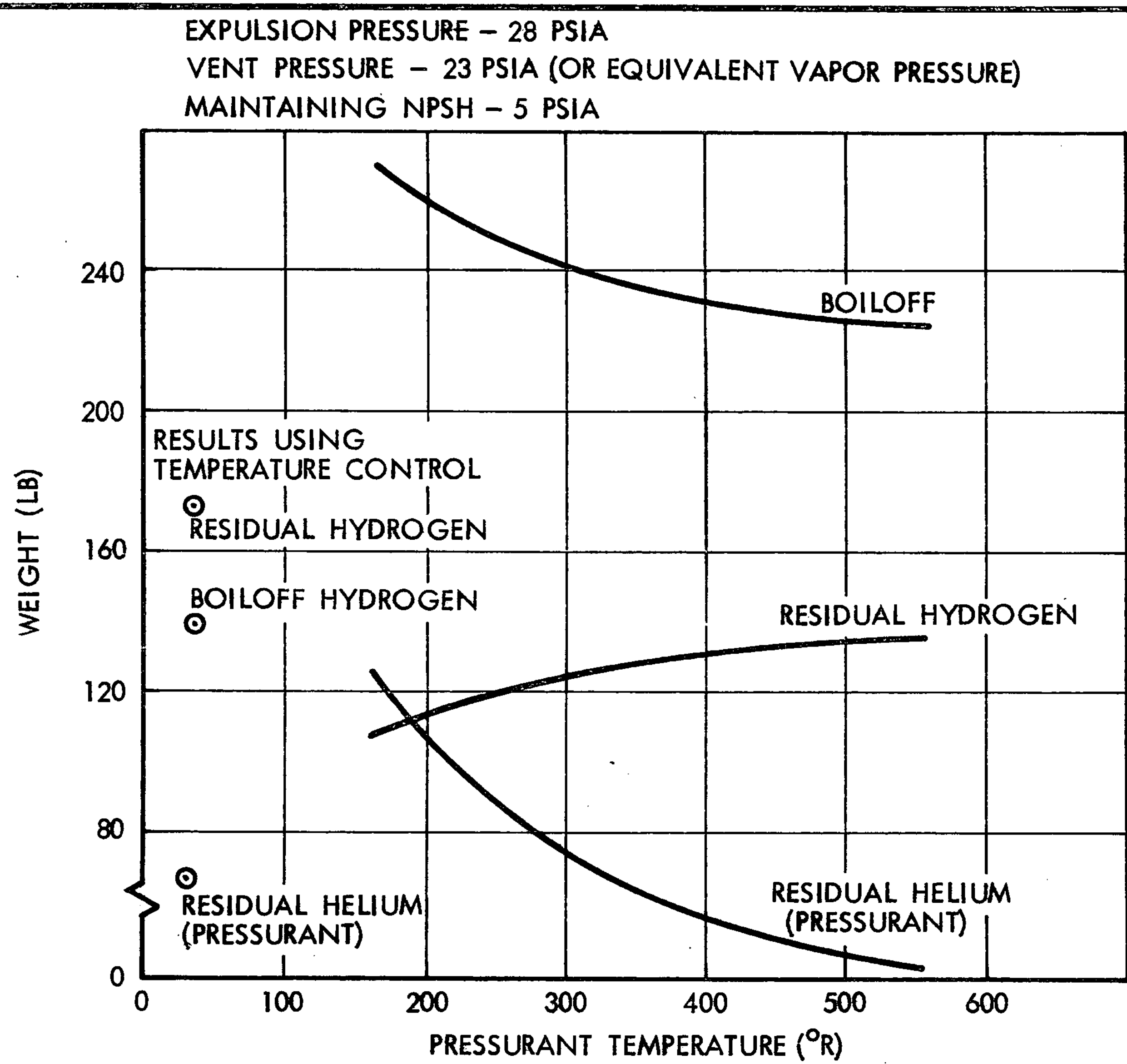
LOCKHEED

EFFECT OF HELIUM LEAKAGE INTO TANKS WITH INTEGRATED OMPS/ACPS PROPELLANTS



D03787
llm

EFFECTS OF PRESSURE CONTROL APPROACH ON OMPS LH_2 TANK

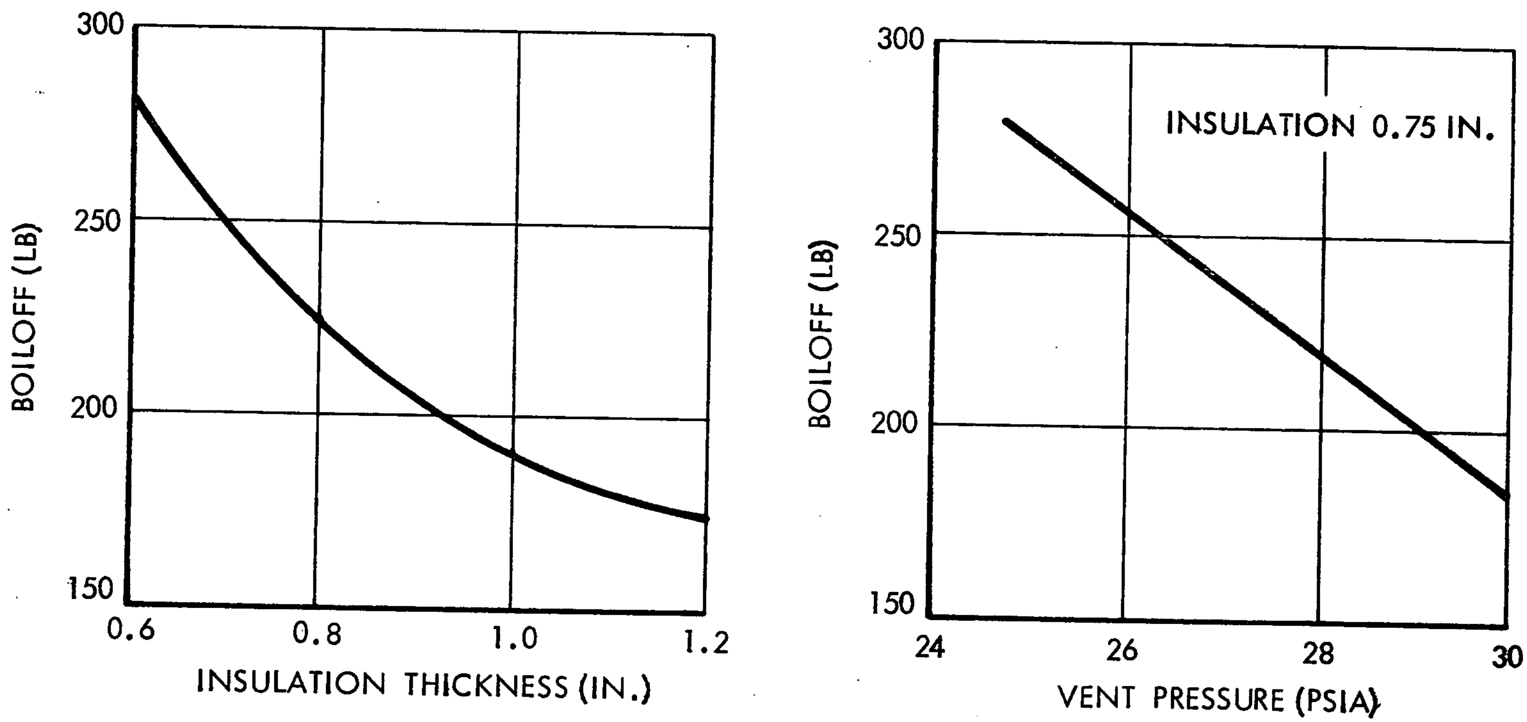


D02967
IIm

LOCKHEED

COMPARISON OF EFFECTS ON OMPS FROM PRESSURIZATION AND INSULATION VARIABLES

GH_2 PRESSURIZATION (350°R – 36 PSIA)



D02948
Um

CONCLUSIONS RELATED TO COMPONENTS MECHANICAL AND ELECTRICAL

- COMPONENTS ARE AVAILABLE AND PRESENT TECHNOLOGY SATISFACTORY FOR MOST APPLICATIONS.
- COMPONENT REPLACEMENT AS A RESULT OF WEAROUT WILL NOT BE SEVERE.
- LIFETIME FACTORS ASSOCIATED WITH ORGANIC MATERIALS IS MAJOR CAUSE FOR REPLACEMENT.
- COMPONENT FAILURES BY WEAROUT MOST LIKELY IN:

    SEATS

    BELLOWS AND DIAPHRAGMS.
- COMPONENT LEAKAGES CAN BE "MODERATE" TO "HIGH".
- DISCONNECTS SHOULD BE IMPROVED.

D04889
llm

CONCLUSIONS RELATED TO COMPONENTS INSTRUMENTATION AND CONTROL

- PRESSURE SWITCHES REQUIRE IMPROVEMENT.
- LIQUID-HYDROGEN PRESSURE TRANSDUCERS ARE NEEDED.
- CONTROL OF LH_2 TANK VENTING BY TEMPERATURE IS DESIRABLE.
- ZERO-g SENSING DEVICES ARE NOT NECESSARY.
- LEAKAGE DETECTION IMPROVEMENT IS NEEDED.

LOCKHEED

CONCLUSIONS RELATED TO COMPONENTS TANKAGE AND FEEDLINES

- TANKAGE REUSABILITY APPROACHES ARE SATISFACTORY, BUT FRACTURE MECHANICS DATA ARE SHORT.
- ACCUMULATOR WEIGHT REDUCTION IS DESIRABLE (COMPOSITE TANKS).
- FEEDLINE COMPONENTS ARE CAPABLE OF DESIRED CYCLE LIFE.
- FEEDLINE WEIGHTS CAN BE REDUCED BY ALUMINUM FEEDLINES WITH STAINLESS STEEL EXPANSION JOINTS.
- VACUUM SEALOFF VALVE LIFETIME IMPROVEMENT IS NEEDED.
- FIBERGLASS SUPPORTS FAIL IN TENSION LOADING AT WARM END.
- PROPELLANT ACQUISITION IS A MAJOR PROBLEM.

LOCKHEED

CONCLUSIONS RELATED TO COMPONENTS INSULATION

- SUBSYSTEMS ARE NOT SENSITIVE TO:

  MULTILAYER INSULATION TYPE

  THERMAL CONDUCTIVITY OF FOAM (WEIGHT TO PREVENT AIR LIQUIFICATION AND EXCESSIVE ICING IMPORTANT).

- MULTILAYER INSULATION REQUIRES LITTLE DEVELOPMENT. PROTECTION FROM ENVIRONMENT IS PRINCIPAL PROBLEM.

- REUSABLE GROUNDHOLD AND ASCENT (AND REENTRY) INSULATION NEEDED.

- FEEDLINE INSULATION DESIGNS NEED IMPROVEMENT.

TECHNOLOGY EVALUATION

MAJOR CRYOGENIC TECHNOLOGY REQUIRING ADVANCEMENT

CONSIDERATIONS

- ADVERSE ACCELERATION REQUIREMENTS ARE HIGH, PROBABLY REQUIRING MULTIPLE SCREENS
- SEVERE START TRANSIENTS
- GAS INGESTION MAY NOT BE EXCLUDABLE
- THERMAL PROBLEMS IN SUBCOOLED SYSTEMS MAY NOT BE AS SEVERE AS GAS INGESTION

LOCKHEED

TECHNOLOGY EVALUATION SUMMARY
MECHANICAL AND ELECTRICAL COMPONENTS

- VALVES AND REGULATORS REQUIRE LITTLE TECHNOLOGY ADVANCEMENTS OTHER THAN DESIGN IMPROVEMENTS. DISCONNECTS NEED ADVANCEMENT.
- CRYOGENIC-COOLED ELECTRICAL MOTORS TECHNOLOGY ADVANCEMENT (AND RELATED ALTERNATORS)
- ATTITUDE CONTROL PROPELLANT SUPPLY PUMP:

    LINEAR START TRANSIENT

    LOW HEAT SOAK BACK
- AUXILIARY POWER UNIT SUPPLY PUMP SHOULD OPERATE CONTINUOUSLY

D04898
IIm

TECHNOLOGY EVALUATION SUMMARY
INSTRUMENTATION AND CONTROL

- PRESSURE SWITCH LIFETIME IMPROVEMENT
- LIQUID-HYDROGEN PRESSURE TRANSDUCER DEVELOPMENT
- LEAKAGE-DETECTION DEVICES
- TEMPERATURE CONTROL OF HYDROGEN VENTING

LOCKHEED

TECHNOLOGY EVALUATION SUMMARY
TANKAGE AND FEEDLINES

- REUSABLE COMPOSITE TANKAGE FOR ACCUMULATOR WEIGHT REDUCTION
- IMPROVEMENTS IN VACUUM SHELLS FOR LARGE TANKS
- ALUMINUM FEEDLINE TECHNOLOGY
- VACUUM SEALOFF VALVE IMPROVEMENT

D04896
llm

TECHNOLOGY EVALUATION SUMMARY
INSULATION

- MULTILAYER INSULATION DOES NOT REQUIRE SIGNIFICANT TECHNOLOGY ADVANCEMENT. SOME DESIRABLE PROGRAMS ARE:

  "BREATHING" TYPE DEVICE TO REMOVE WATER AND MOISTURE IN AREAS WHERE REENTRY PURGING IS NOT REQUIRED.

  PURGING STUDIES TO IMPROVE ANALYTICAL TECHNIQUES.

- GROUNDHOLD, ASCENT, AND REENTRY INSULATION IMPROVEMENT (FOAMS, SURFACE TENSION, ETC.)

- REMOVABLE FEEDLINE INSULATION SYSTEM

TECHNOLOGY EVALUATION SUMMARY
ANALYTICAL TECHNIQUES

- PRESSURIZATION ANALYTICAL TECHNIQUES
- CRYOGENIC LIQUID-STRATIFICATION ANALYTICAL TECHNIQUES, COUPLED WITH PRESSURIZATION
- IMPROVEMENTS IN ANALYSIS OF INSULATION PURGING AND VENTING OF PURGE GAS

TECHNOLOGY EVALUATION SUMMARY
BASIC DATA

- HELIUM SOLUBILITY IN CRYOGENICS
- HYDROGEN FLAME DATA (LOW LEAKAGE)
- FRACTURE MECHANIC DATA FOR TANKAGE REUSABILITY
- GENERAL BELLOWS DATA
- ORGANIC MATERIALS LIFETIME DATA FOR SHUTTLE DUTY CYCLE
- CRYOGENIC FLUID CAPILLARY-RETENTION PROPERTIES

TECHNOLOGY EVALUATION SUMMARY
SUBSYSTEM TECHNOLOGY

- LIQUID/LIQUID ATTITUDE CONTROL EVALUATION
- ELECTRICAL INTEGRATION OF CRYOGENIC SUBSYSTEMS (AIRCRAFT APPROACH – MAXIMIZATION OF ELECTRICAL MOTORS)
- CRYOGENIC COOLING SUBSYSTEM FOR ENVIRONMENTAL CONTROL, HYDRAULICS, ETC.
- INSTRUMENTATION AND CONTROL INTEGRATION

D04895
IIm