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SPACE SHUTTLE ENGINEERING AND OPERATIONS SUPPORT

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EPS/ECLSS CONSUMABLES ANALYSES FOR THE SPACELAB 1 FLIGHT

MISSION PLANNING, MISSION ANALYSIS AND SOFTWARE FORMULATION

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SYMBOLS

APU	Auxiliary Power Unit
ARS	Atmospheric Revitalization System
ATCS	Active Thermal Control System
BTU	British Thermal Unit
CO2	Carbon Dioxide
CRT	Cathode Ray Tube
D&C	Displays and Controls
ECLSS	Environmental Control/Life Support System
EOM	End of Mission
EPDS	Electrical Power Distribution Subsystem
EPS	Electrical Power System
F	Fahrenheit
FEAR	Fortran Environmental Analysis Routines
FCP	Fuel Cell Powerplant
FCS	Flight Control Surface
FM	Frequency Modulation
F/C	Fuel Cell
GN2	Gaseous Nitrogen
GPC	General Purpose Computer
GSE	Ground Support Equipment
HX	Heat Exchanger
H2	Hydrogen
H2O	Water
IMU	Inertial Measurement Unit
JSC	Johnson Space Center
KSC	Kennedy Space Center

KW	Kilowatt
KWH	Kilowatt Hour
LB	Pounds
LiOH	Lithium Hydroxide
LV	Local Vertical
MDTSCO	McDonnell-Douglas Technical Services Company
MR	Metabolic Rate
MSFC	Marshall Space Flight Center
MSS	Mission Specialist Station
NH3	Ammonia
OFI	Operational Flight Instrumentation
OMS	Orbiter Maneuvering System
O2	Oxygen
PCM	Pulse Code Modulation
PLB	Payload Bay
PM	Phase Modulation
POP	Perpendicular to Orbital Plane
PSIA	Pounds per Square Inch Absolute
PSID	Pounds Per Square Inch Differential
RI	Rockwell International
SECRET	Shuttle Environmental Consumables Requirements Evaluation Tool
SEPS	Shuttle Electrical Power System Analysis Computer Program
SI	Solar Inertial
SOURCE	Shuttle Orbiter Unified Records for Consumables Evaluation
STS	Space Transportation System

S/L	Spacelab
TCS	Thermal Control System
TD	Touchdown
TV	Television
VV	Velocity Vector

1.0 INTRODUCTION

This document presents the results of electrical power system (EPS) and environmental control/life support system (ECLSS) consumables analyses of the Spacelab 1 mission (ref. 1). The analyses were performed to assess the capability of the orbiter systems to support the proposed mission and to establish the various non-propulsive consumables requirements.

The EPS analysis was performed using the Shuttle Electrical Power System (SEPS) analysis computer program (ref. 2). The ECLSS analysis was performed using the Shuttle Environmental Consumables Requirements Evaluation Tool (SECRET) program. No auxiliary power unit/hydraulic system analysis was performed at this time.

2.0 SYSTEM DEFINITION DATA

2.1 EPS Characteristics

The EPS system, as modeled by the SEPS program, consists of the orbiter electrical power generation and distribution subsystems. The system generates required orbiter electrical power and delivers it to end item loads in accordance with a predefined equipment time line. The sections which follow define the EPS system characteristics and the system loads used in this analysis.

2.1.1 Fuel Cell Characteristics.- The fuel cell performance characteristics, used in the analysis, are those illustrated in figure 2.1-1. These characteristics represent predicted initial powerplant performance. They were derived from the Shuttle Operational Data Book (ref. 3). For purposes of the analysis, the SEPS fuel cells were operated at a constant temperature of 180°F.

2.1.2 Circuit Description.- The SEPS circuit description, used in this analysis, is defined in reference 4. The description is in conformance with amendment 29 to the Shuttle Operational Data Book (ref. 3). The guidelines and assumptions used in formulating the circuit are discussed, in detail, in reference 5.

2.1.3 Inverter Characteristics.- The inverter performance characteristics used in the analysis are shown in figure 2.1-2.

2.1.4 Orbiter Electrical Loads.- The orbiter electrical equipment list, utilized in the performance of this analysis, is that defined in reference 6 for the operational configuration of Orbiter OV-102.

2.1.5 Payload Power Allocation.- The total orbiter payload was simulated by a series of steady state loads. The loads were applied in conformance with the requirements of paragraph 9.2 of the Payload Accommodations Handbook (ref. 7). The specific loads applied, and their associated times and points of application, are as delineated below.

a. Prelaunch (Internal Power Source), Ascent, Descent, and Post Landing (Internal Power Source);

(1). A 350 watt continuous load was applied at the Aft Flight Deck load input.

(2). A 1000 watt continuous load was applied at the orbiter/payload electrical interface.

b. On-Orbit (After Circuit Reconfiguration and Payload Activation;

(1). A 750 watt continuous load was applied at the AFT Flight Deck load input.

(2). A 7000 watt continuous load was applied at the orbiter/payload electrical interface.

The transitions between ascent/descent and on-orbit loads were scheduled to occur incrementally during intervals of thirty minutes each.

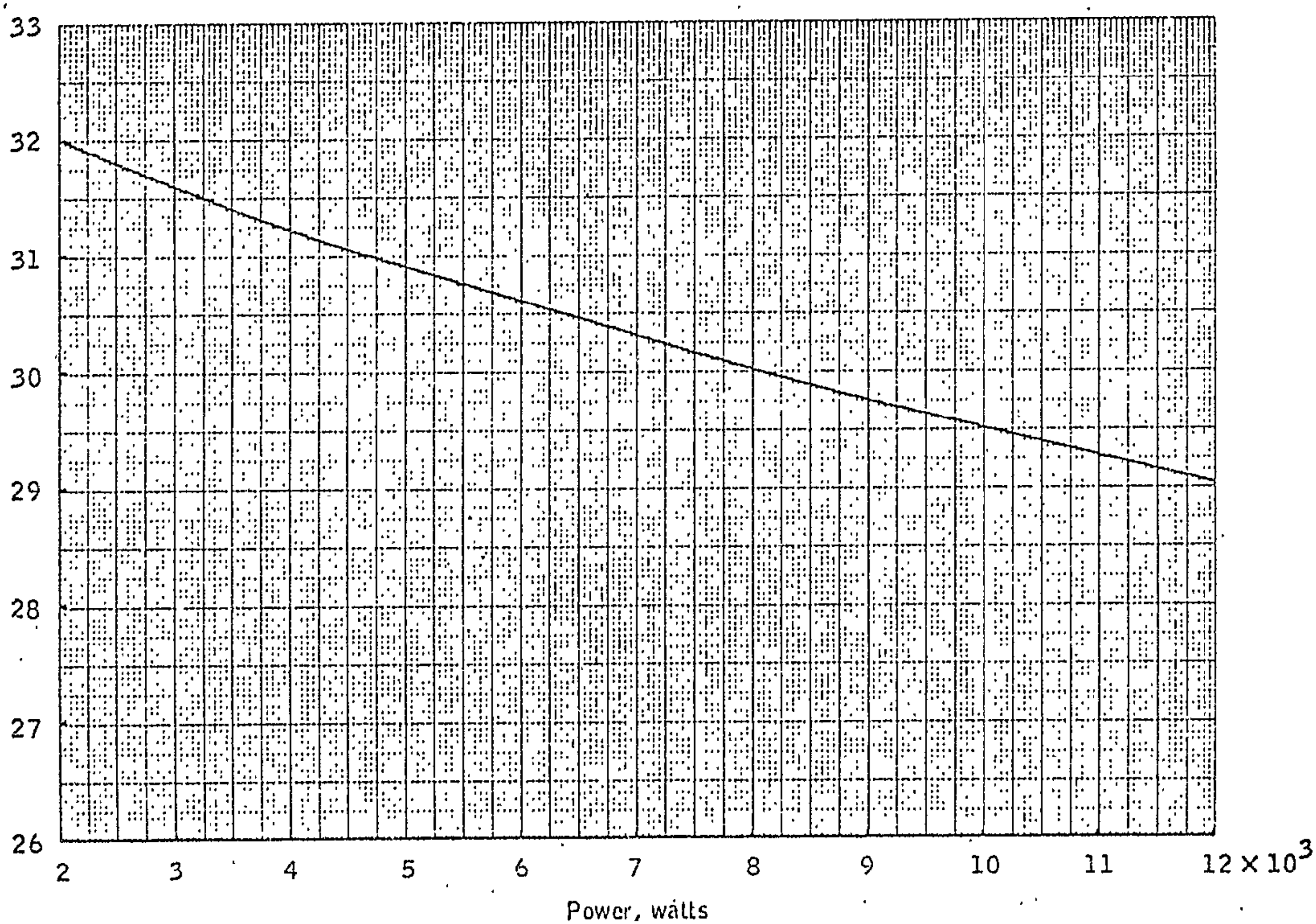

Figure 2.1-1 - Fuel cell performance characteristics.

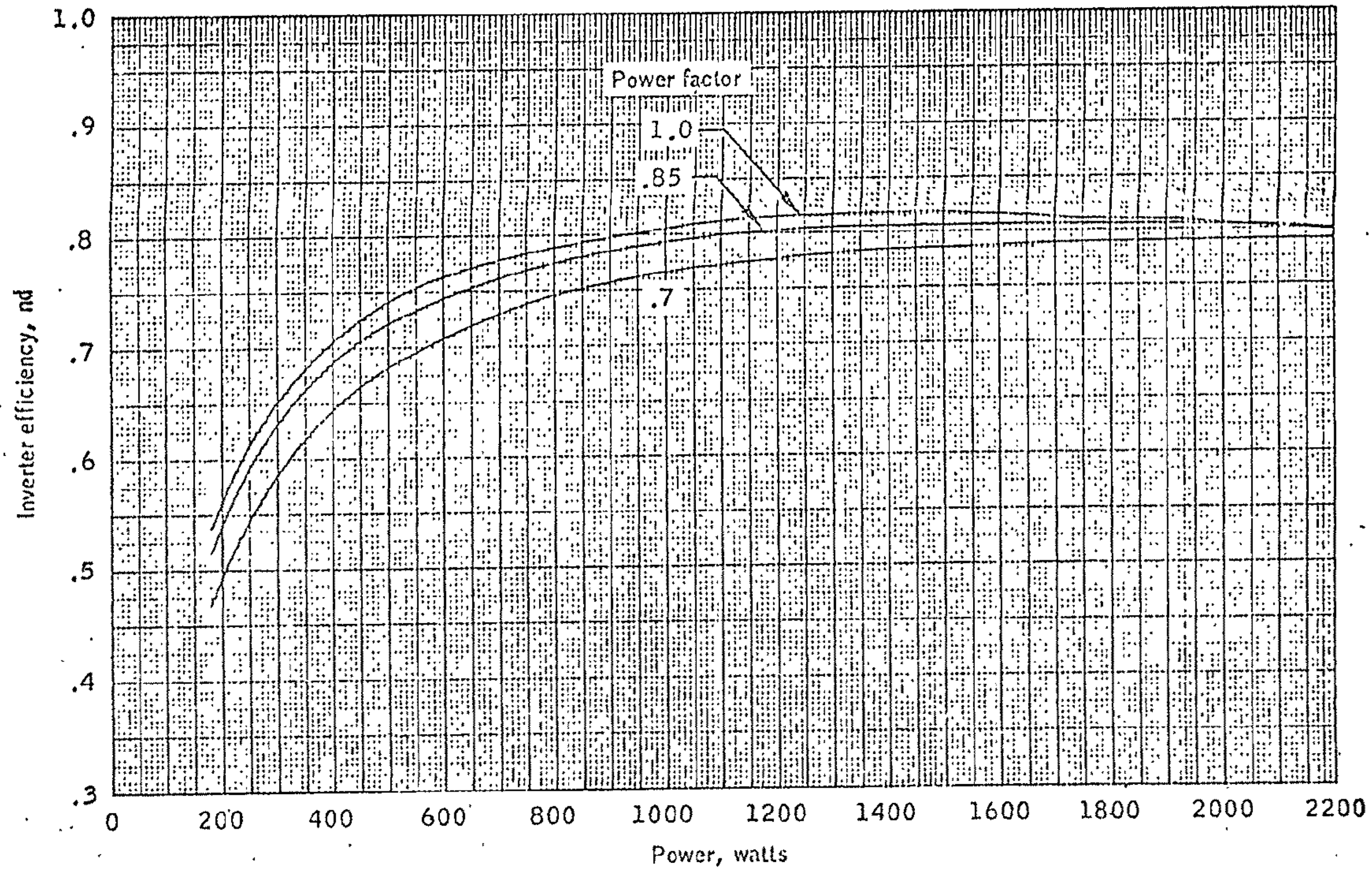

Figure 2.1-2 - Inverter characteristics.

2.2 ECLSS Characteristics

The ECLSS system performs the active heat transport and rejection required by the Space Shuttle, as well as providing for cabin atmosphere control and for management of potable and waste water. The system configuration analyzed is illustrated in figure 2.2-1. This configuration is based on data obtained from reference 3 and 7 through 14. In some instances, due to the preliminary nature of the spacelab configuration definition, it has been necessary to use undocumented data or arbitrary assumptions. Salient parameters of the ECLSS subsystems are outlined in sections 2.2.1 through 2.2.3.

2.2.1 <u>Active Thermal Control System (ATCS) Characteristics</u>.- Specific ATCS Configuration parameters are itemized below.

a. Individual component performance parameters are as defined in the references noted.

b. The flow split to the fuel cell heat exchanger mid cold plates is 94.9%/5.1% respectively.

c. The freon flow split to the aft cold plates at node 99 is 9%.

d. Three tanks, each with a usable capacity of 165 lbs, are assigned to potable water storage.

2.2.2 <u>Atmospheric Revitalization System (ARS) Description</u>.- Specific ARS configuration parameters are itemized in this section.

2.2.2.1 Water loop parameters:

a. The water pump flowrate is 950 lb/hr

b. The flow split at node 113 to avionics bays 1, 2, and 3 is 29.9%, 29.3%, and 40.8% respectively.

2.2.2.2 Atmospheric loop parameters:

a. The cabin volume is 2750 cubic feet.

b. The cabin fan provides a constant airflow of 1540 lb/hr.

c. 14.3% of the airflow is diverted to the spacelab.

d. Maximum bypass around the cabin HX is 75.4%.

e. 8.6% of the airflow is routed through each lithium hydroxide (LiOH) canister.

f. Two tanks, each with a usable capacity of 165 lbs, are assigned to waste water storage.

2.2.3 Spacelab ECLSS Description.- Specific Spacelab ECLSS configuration and performance parameters are itemized in this section.

2.2.3.1 Water loop parameters:

a. The entire experimental heat load is represented by a single node (61) of arbitrary mass and heat transfer coefficient.

b. The water flowrate is 500 lb/hr.

2.2.3.2 Atmospheric loop parameters:

a. The air flowrate is 1590 lb/hr.

b. The cabin ECLSS equipment and avionics are represented by nodes (72 & 77) of arbitrary mass and heat transfer coefficients.

c. 8.6% of the airflow is routed through each LiOH canister.

d. Oxygen for the cabin regulator is supplied from the orbiter system.

e. Nitrogen for the cabin regulator and experiment airlock is supplied from a spacelab provided GN2 tank.

f. 220 lbs/hr of airflow is received from the orbiter and is returned through the tunnel adapter.

g. The spacelab provides its own waste water storage with a 100.3 lb capacity.

h. The cabin volume is 785 cubic feet.

i. Maximum bypass around the cabin HX is 85%.

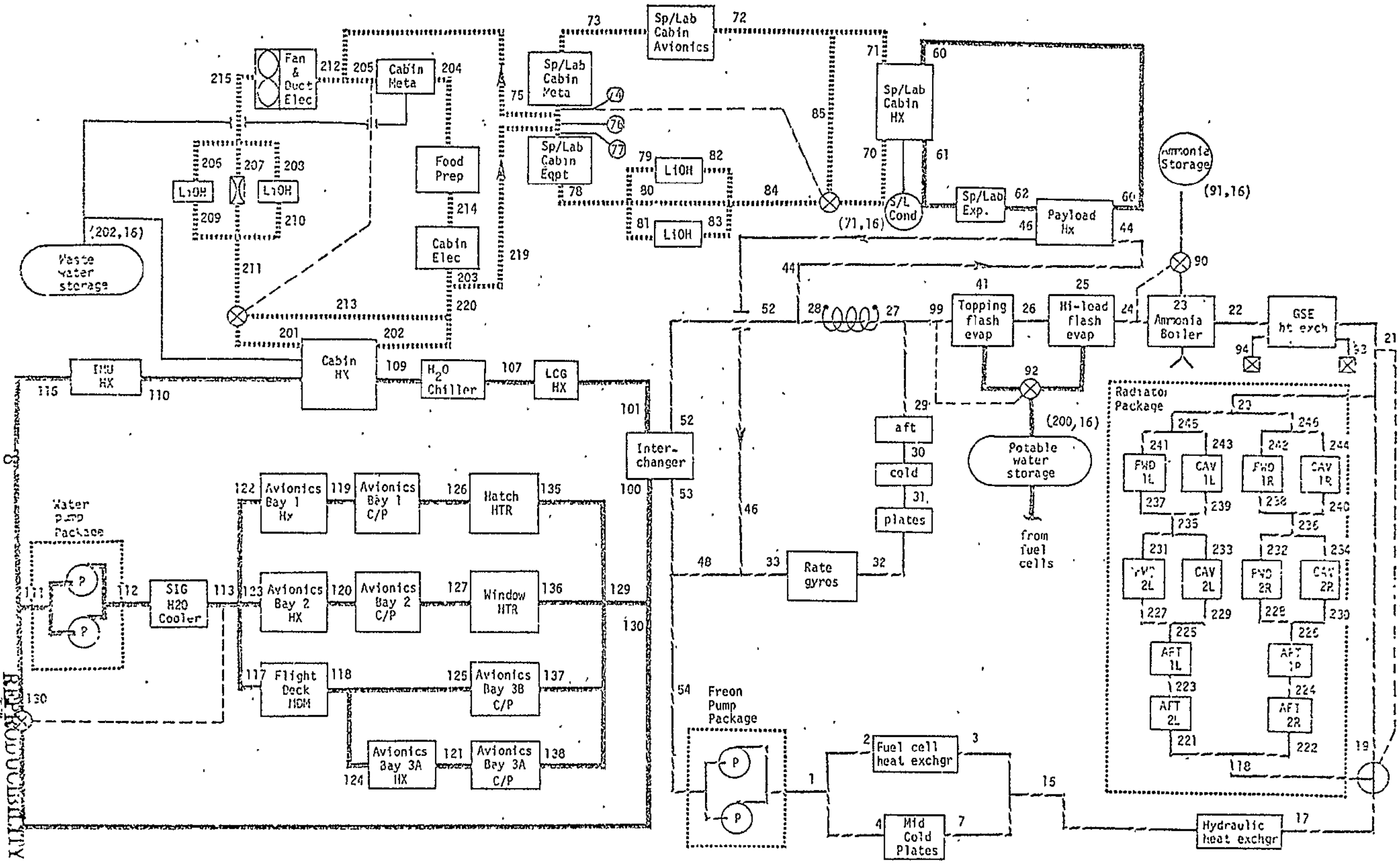

Figure 2.2-1 ECLSS Configuration Schematic

3.0 GUIDELINES AND ASSUMPTIONS

The guidelines used and the assumptions made, in the formulation of the EPS and ECLSS analyses, are the subject of this section.

3.1 EPS Guidelines and Assumptions

Guidelines and assumptions used in the formulation of the EPS analysis are enumerated below.

3.1.1 Guidelines.- EPS consumables analysis guidelines were as follows:

a. The major Spacelab 1 mission objectives and the general mission description were taken from reference 1.

b. The crew time line was derived from a proposed STS work-rest cycle, obtained informally from the Crew Training and Procedures Division.

c. The attitude time line, used for purposes of simulating orbiter TCS heater operation, was coordinated with Crew Systems Division. The time line used is presented in table 3.1-I.

d. A beta angle of 30 to 35 degrees was used for purposes of simulating orbiter TCS heater energy requirements.

e. The usage of orbiter chargeable electrical equipment was in accordance with the draft version of the Orbiter Electrical Equipment Utilization Baseline Document (ref. 6).

f. Management of the orbiter EPDS configuration was in accordance with Flight Control Division requirements, as follows:

(1). The spacelab was supplied 1.0 KW from main bus C from power transfer internal until 30 minutes after OMS-2.

(2). Main buses A, B, and C were isolated from power transfer internal until 20 minutes after OMS-2, at which time main buses B and C were interconnected.

(3). Thirty minutes after OMS-2, spacelab power was switched from main bus C to fuel cell 3.

(4). The spacelab power allocation was increased incrementally from 1.0 KW to 7.0 KW over the interval from OMS-2 plus 30 minutes to OMS-2 plus 1.0 hour.

(5). One hour after OMS-2 fuel cell 3 was removed from main bus C and dedicated to the spacelab.

(6). Spacelab powerdown commenced 3.0 hours prior to deorbit and followed the reverse of the preceding steps.

g. The following H2 tank characteristics and reserve allocations were used in estimating the Spacelab 1 tank set requirements:

(1). Usable H2 - 89.1 lbm per tank set

(2). Measurement Error - 3.5 lbm per tank set

(3). Prelaunch Requirement - 1.3 lbm per tank set

(4). 24 HR Launch Hold Reserve - 0.8 lbm per tank set

(5). Flight Planning Uncertainty - 10% of flight requirement

(6). Deorbit Reserve - Twenty four hours at nominal on-orbit orbiter power level, with payload at descent power level.

3.1.2 Assumptions.- The following assumptions were made in the formulation of the EPS consumables analysis:

a. Since no payload crew requirements were defined, it was assumed that the payload requirements would not conflict with the STS crew work-rest cycle (see section 3.1.1, b).

b. Where insufficient heater data was available to simulate a particular attitude, the rate of energy consumption was assumed to be the average of the available data (see table 3.1-I).

c. The following orbiter electrical equipment was used in direct support of payload requirements:

(1). One airlock light remained on continuously during the crew workday.

(2). The MSS PCM recorder was on 10% of the time when on-orbit.

(3). The Payload Bay TV, the S-Band FM system, and one additional Audio Terminal Unit were on during a 2.5 hour payload activation period, for 30 minutes every 24 hours on-orbit, and during a 2.5 hour payload closeout period.

TABLE 3.1-I. EPS ANALYSIS - ATTITUDE TIMELINE

INTERVAL (HRS:MIN)	ATTITUDE[1]	REQUIREMENT
000:43 - 012:00	-XSI, +Z toward earth[2]	Stellar Viewing
012:00 - 024:00	-ZLV, X-POP	Earth Viewing
024:00 - 043:00	-XLV (-15°), -ZVV (-15°)[2]	Stellar Viewing
043:00 - 048:00	-ZLV, Y-POP	Earth Viewing
048:00 - 059:30	-Z away from sun/earth[2]	UV Galactic Camera Exp
059:30 - 076:00	-ZLV, Y-POP	Earth Viewing
076:00 - 080:00	+XLV[2]	
080:00 - 128:00	-XSI, +Z toward earth[2]	Stellar Viewing
128:00 - 140:00	-ZSI	Solar Viewing
140:00 - 149:00	-YLV, -XVV[2]	
149:00 - 152:00	-ZLV, Y-POP	Earth Viewing
152:00 - 163:00	-XSI, +Z toward earth[2]	Stellar Viewing

1 - Dynamic Body Coordinate System

2 - Insufficient heater data available to properly simulate this attitude.

3.2 ECLSS Guidelines and Assumptions

The following general assumptions were used in performing the ECLSS consumables analysis:

a. A five man crew is assumed, with one or two crewmen (as a function of work shift) in the spacelab when it is powered up and active.

b. All biological and hygenic functions are assumed to occur in the orbiter cabin.

c. All members of the crew are assumed to be functioning at a nominal metabolic rate of 450 BTU/hr.

3.2.1 ATCS Assumptions.- Assumptions regarding operation of the ATCS are as follows:

a. Heat rejection is provided as follows:

(1). By the GSE HX from power up until lift-off

(2). None from lift-off to 140,000 ft (0.038 hrs)

(3). By Hi-load and Topping flash evaporator from 140,000 ft to radiator deploy (1.5 hrs)

(4). By the radiators during on-orbit periods, with supplemental cooling from the topping flash evaporator as required.

(5). The hydraulic heat exchanger is assumed to reject an average of 4000 BTU/hr during all on-orbit periods.

(6). By both flash evaporators from radiator retract to 100,000 ft during descent.

(7). By the NH3 boiler from 100,000 ft through landing to GSE hookup.

b. An 8 panel radiator is utilized with freon flowrate through it controlled to provide a discharge temperature of 38°F at node 21.

c. The flash evaporators utilize water with a heat dissipation capacity of 990 BTU/lb which has the flow controlled to provide a freon discharge temperature of 37°F at node 99.

d. The ammonia boiler utilizes NH3 with a heat dissipation capacity of 500 BTU/lb which has the flow controlled to provide a freon discharge temperature of 34°F at node 24.

e. Potable water is maintained between 236 and 470 lb. When it is necessary to dump water, the radiator control temperature is reset to 60°F and the extra heat is rejected through the topping flash evaporator, thus using the excess water.

f. The freon flowrate is based on a 68 psid pump at 2540 lb/hr, and varies as a function of flow through the radiators and through the payload HX (see ref. 14).

g. The flow split to the payload HX/interchanger at node 28 is optimized per mission phase: 7.3% to the payload HX during non-sortie operations, 43.6% for sortie operations.

3.2.2 ARS Assumptions.- Assumptions regarding operations of the ARS are as follows:

a. Water flowrate through the interchanger is optimized (see section 3.2.1, g.) per mission phase: during sortie operations it is fixed at 600 lb/hr, during non-sortie operations it is controlled to provide 63°F at the water pump discharge.

b. Cabin temperature is controlled to 70°F.

c. Cabin pressure is controlled as follows:

(1). Total pressure - 14.7 +/- 0.2 psia

(2). Oxygen partial pressure - 3.2 +/- 0.25 psia

(3). Cabin relief pressure - 15.5 psia

d. Atmospheric leakage from the pressurized cabin is 10 lb/day.

e. Metabolic requirements and production as a function of Metabolic Rate (MR) are as follows:

(1). O_2 Requirement - 0.0739 lb/man-hour at 450 BTU/hr

(2). CO_2 Production - 0.0882 lb/man-hour at 450 BTU/hr

(3). H_2O Production - The larger of:

$$QL = (MR - 430 + (10 + .001MR)(T-60))/1050$$

or

$$QL = (.22MR + 2.6(T-60))/1050 \text{ lb/man-hour}$$

(4). Urine Production - 0.1458 lb/man-hour

f. Lithium Hydroxide (LiOH) canisters used to remove atmospheric CO_2 are changed out alternately, one every 12 hours, and perform as follows:

(1). Water of Reaction - 0.409 lb/lb of CO_2 absorbed

(2). Heat of Reaction - 876 BTU/lb of CO_2 absorbed

g. No consideration was given to environmental heating of the cabin or avionics.

3.2.3 Spacelab Assumptions.- Assumptions regarding Spacelab ECLSS operation as follows:

a. The experiment airlock is used once each day, requiring 3.08 lbs of GN_2 each time.

b. Spacelab lithium hydroxide canisters are identical to those in the orbiter, but are changed alternately every 32 hours.

c. Spacelab cabin heat exchanger performance is identical to the orbiter cabin HX.

d. Atmospheric leakage from the pressurized cabin is 3 lbs/day.

e. Cabin temperature and pressure control are identical to orbiter cabin.

4.0 SPACELAB 1 CONSUMABLES ANALYSES

This section identifies the computer programs and data bases utilized in performing the EPS and ECLSS analyses, delineates the specific input data used, and presents the results of the analyses.

4.1 EPS Consumables Analysis

The EPS analysis was performed using the SEPS analysis computer program (ref. 2), operating with input data derived from the SOURCE Data Base (ref. 15). The SOURCE Data Base is a magnetic tape file containing a composite of all orbiter electrical equipment, along with activity blocks explicitly defining the usage of that equipment. The data base provides the capability to select, as input to the associated program, the equipment complement of any desired orbiter along with the usage of that equipment as a function of specific flight parameters. The SEPS program models the orbiter electrical power generation and distribution systems, and, working to a predefined electrical equipment time line, generates circuit analysis data based on a nodal solution technique.

4.1.1 Analysis Definition Data.- In order to perform an EPS Consumables analysis, an orbiter must be selected and certain specific flight parameters must be defined as input to the SOURCE Data Base. In addition, a flight time line must be formulated for use with the analysis program, in this case SEPS. The definition data used in this analysis is as follows:

a. SOURCE Data Base Input Data

(1). Orbiter - OV-102 (Operational Configuration)

(2). Crew Size/Shift Description - Five crewmen/two shifts

(3). Mission Duration - 6 - 9 days

(4). Nominal Site Coverage - 12 to 15%

(5). Payload - Spacelab

b. The Spacelab 1 EPS analysis time line is shown in figure 4.1-1.

4.1.2 Analysis Results.- The results of the Spacelab 1 EPS consumables analysis are as follows:

a. Table 4.1-I presents the energy requirements of the Spacelab 1 flight, as analyzed. These results were taken directly from the SEPS computer program, and are predicated upon a three cryogenic tank set orbiter. The numbers shown represent the actual energy consumed by the various subsystems from power transfer internal to EOM. They do not include additional tank set requirements and do not account for uncertainties or reserve allocations. This table indicates the major energy consuming subsystems and reveals that the total energy requirement is in excess of 3719 KWH.

b. Table 4.1-II is a tabulation of the major energy consuming equipment, listed in order of decreasing percent of energy consumed. Several observations may be made from this table:

(1). Excluding the payload, the TCS heaters represent the major item of energy consuming equipment, in this analysis.

(2). Over 80% of the total energy requirement is consumed by a relatively small number of components.

(3). The major portion of the high energy consuming equipment, excluding payload, either cannot be managed or is essential to basic orbiter operation.

c. Figures 4.1-2 through 4.1-6 present total power, fuel cell current, source power, source current, and source voltage for Spacelab 1, as analyzed.

d. A review of figure 4.1-4 reveals that the average power demands from fuel cells 1, 2, and 3 are approximately 7.5, 7.8, and 7.1 KW, respectively. These values exceed the fuel cell continuous rating of 7.0 KW, but are within the capability of the fuel cells (ref. 3; para 3.4.4.1, 2). The primary effect of operating at these levels is an increase in the rate of fuel cell degradation (ref. 16).

e. A further review of figure 4.1-4 indicates that fuel cell 2 may operate for extended periods with a power demand exceeding 8.0 KW. This violates the purge constraint of reference 3, paragraph 3.4.4.1, 7.

f. The average fuel cell power level for the 165.97 hour Spacelab 1 flight, as analyzed, is 7.65 KW per fuel cell. This power level and mission duration translate into a requirement for 347.5 lbm hydrogen (ref. 3, figure 4.4.1-5). This number represents the hydrogen quantity consumed during the analysis (i.e. from pwr xfr int to EOM). It does not account for loading and flight planning uncertainties and includes no reserve allocations. When these are taken into account, the results are as shown in table 4.1-III.

g. Tapes created in the performance of this analysis are itemized in table 4.1-IV.

4.1.3 Analysis Uncertainties.- The following major analysis uncertainties should be considered when interpreting the results of this analysis:

a. Much of the flight planning data, used as input to this analysis, was of a very preliminary nature.

b. The steady-state loads, used in this analysis, represent the payload allocation, rather than the actual payload power profile (see section 2.1.5).

c. Instantaneous power levels may be significantly higher than those indicated in figures 4.1-2 and 4.1-4 (orbiter and payload peak power effects were not analyzed).

d. Fuel cell degradation cannot be quantitatively assessed from this analysis.

e. TCS heater energy may deviate significantly from that indicated by this analysis (limited TCS heater input data).

4.1.4 Analysis Conclusions.- The following conclusions may be drawn from the analysis:

a. The Spacelab 1 mission may require fuel cell operation at levels above the fuel cell continuous rating.

(1). Primary effect is increased rate of fuel cell degradation.

(2). Power or purge management may be required.

b. A minimum of five cryogenic tank sets are required.

c. When loading and flight planning uncertainties and reserve allocations are taken into consideration, five tank sets provide a negligible H2 margin.

d. Attempts to reduce energy requirements by revising the utilization of electrical equipment must, to be effective, focus on a small number of components most of which are either unmanageable or are vital to basic orbiter operation.

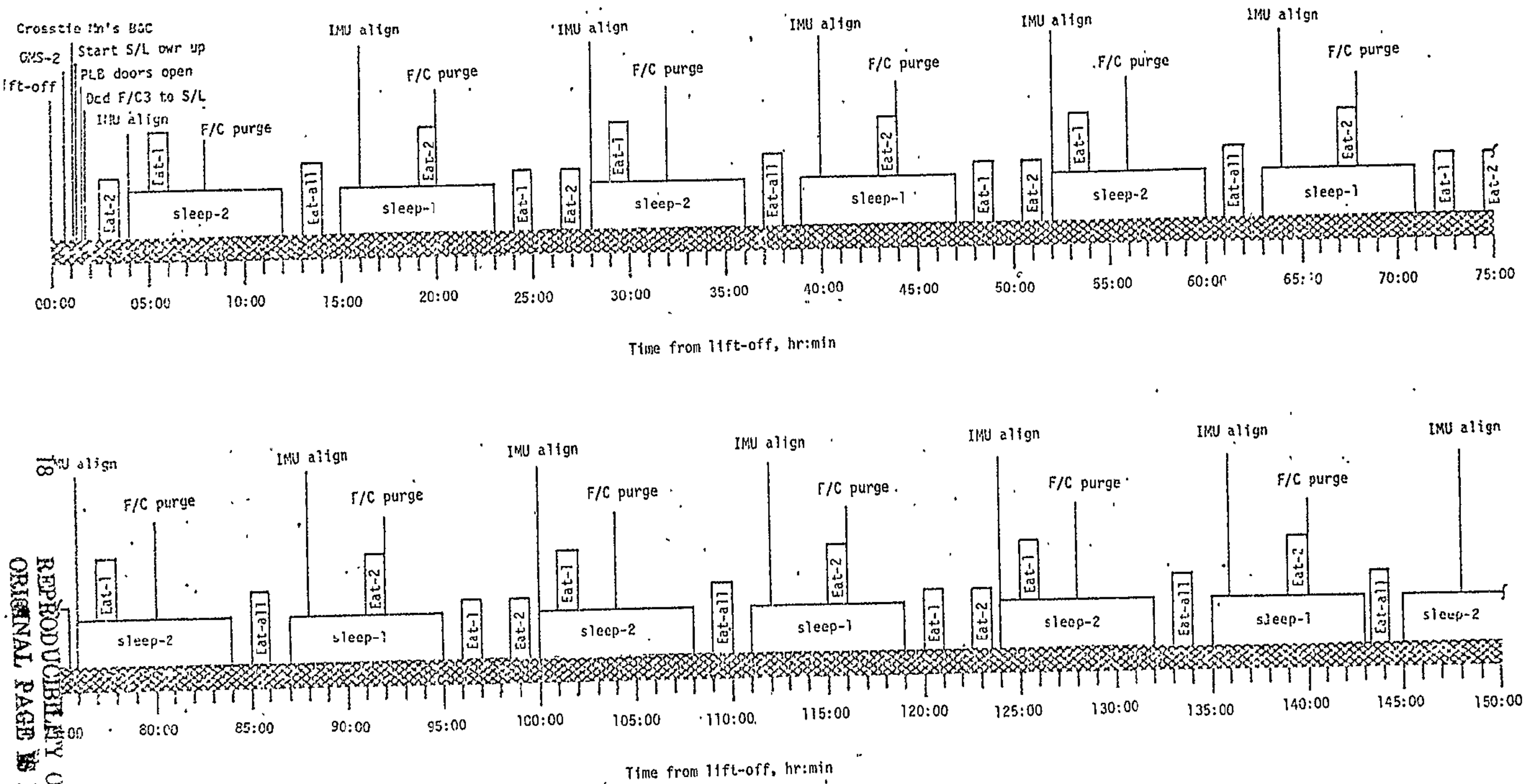

Figure 4.1-1.-EPS Consumables analysis time line for Spacelab 1.

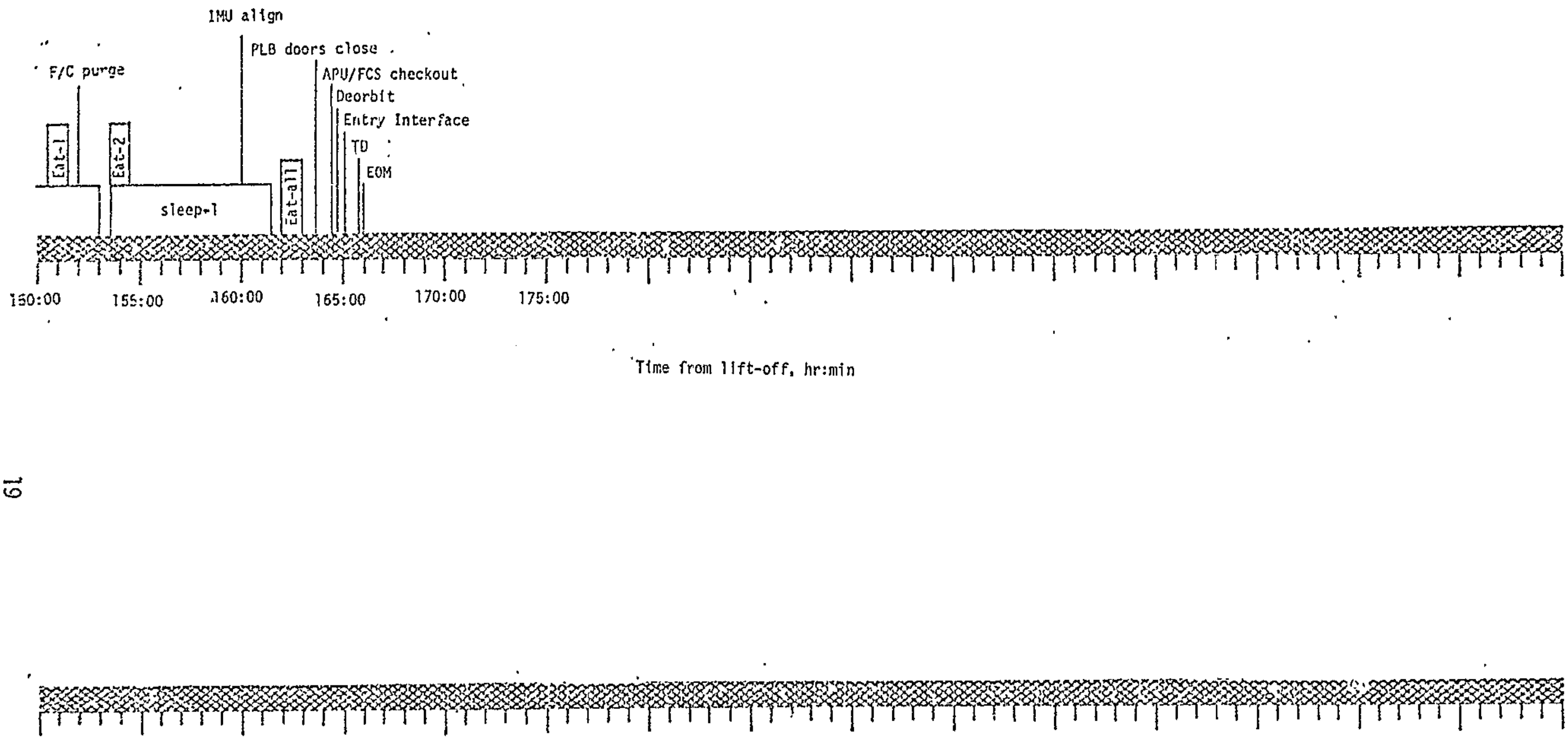

Figure 4.1-1 - Concluded.

4.1-I FLIGHT ELECTRICAL ENERGY REQUIREMENTS FOR SPACELAB 1

NUMBER	DESCRIPTION	KWH CONSUMED[1]	PERCENT[1]
1	GUIDANCE AND NAVIGATION	.78099822+02	2.2144563
2	COMMUNICATIONS	.93065337+02	2.6387912
3	DISPLAYS AND CONTROLS	.18171287+03	5.1523194
4	OPERATIONAL FLIGHT INSTRUMENTATION	.83905065+02	2.3790592
5	DEVELOPMENT FLIGHT INSTRUMENTATION	.00000000	.0000000
6	ELECTRICAL POWER DIST AND CONTROL	.22711987+03	6.4397976
7	DATA PROCESSING	.47064751+03	13.3448237
8	PAYLOAD MANAGEMENT	.12769233+04	36.2061119
16	SOLID ROCKET BOOSTER	.15575065+00	.0044162
20	MAID PROPULSION SYSTEM	.30535583+01	.0865811
21	ORBITAL MANEUVERING SYSTEM	.11023027+03	3.1254889
22	REACTION CONTROL SYSTEM	.77224431+02	2.1896354
30	POWER GENERATION SYSTEM	.11761942+03	3.3350020
31	CRYOGENICS SYSTEM	.77959980+02	2.2104912
32	AUXILIARY POWER UNIT.	.21210548+02	.6014077
40	ENVIR CONTROL AND LIFE SUPPORT	.57114490+03	16.1943448
50	HYDRAULICS POWER SYSTEM	.13599109+03	3.8559157
51	DOCKING AND CARGO HANDLING	.14477452-01	.0004105
52	MECHANICAL SYSTEMS AND LANDING	.74244162+00	.0210513
60	CREW SYSTEMS	.21424716-02	.0000607
		.35268169+04	

TOTAL KWH CONNECTED TO BUS	3489.3620
TOTAL KWH AT THE LOAD BUS	3526.8169
LINE LOSSES (KWH)	192.5021
TOTAL KWH AT SOURCE TERMINALS	3719.3191
ADD. KWH REQ. BY CRYO HEATERS	.0000

1: Must be adjusted to reflect actual cryogenic tank set requirements

TABLE 4.1-II. MAJOR ELECTRICAL ENERGY CONSUMING EQUIPMENT

EQUIPMENT	ENERGY (KWH)	PERCENT OF TOTAL (%)	ACCUMULATED PERCENTAGE (%)
Payload	1252	32.85	32.9
TCS Heaters	349	9.16	42.0
GPC's	338	8.88	50.9
Power Distributors[1]	200	5.25	56.1
Freon Pumps	194	5.10	61.2
Cryo Heaters[1]	193	5.06	66.3
OFI	174	4.56	70.9
Avionics Fans	134	3.53	74.4
Orbiter Line Losses	124	3.26	77.7
FCP Operation	112	2.93	80.6
Cabin Fan	105	2.76	83.3
CRT's	102	2.67	86.0
Ku-Band/S-Band PM	82	2.15	88.2
Miscellaneous ECLSS	74	1.95	90.1
Payload Line Losses	68	1.79	91.9
H2O Pumps	58	1.51	93.4
Flight Critical MDM's	54	1.41	94.8
IMU's	44	1.14	96.0
Cabin Lights	42	1.11	97.1
Other D&C	38	0.99	98.1
Reaction Jet Drivers	33	0.87	98.9
Misc. Small Components	40	1.08	100.0
TOTALS	3810	100.00	

[1] Adjusted to reflect actual cryogenic tank set requirements (5 tank sets)

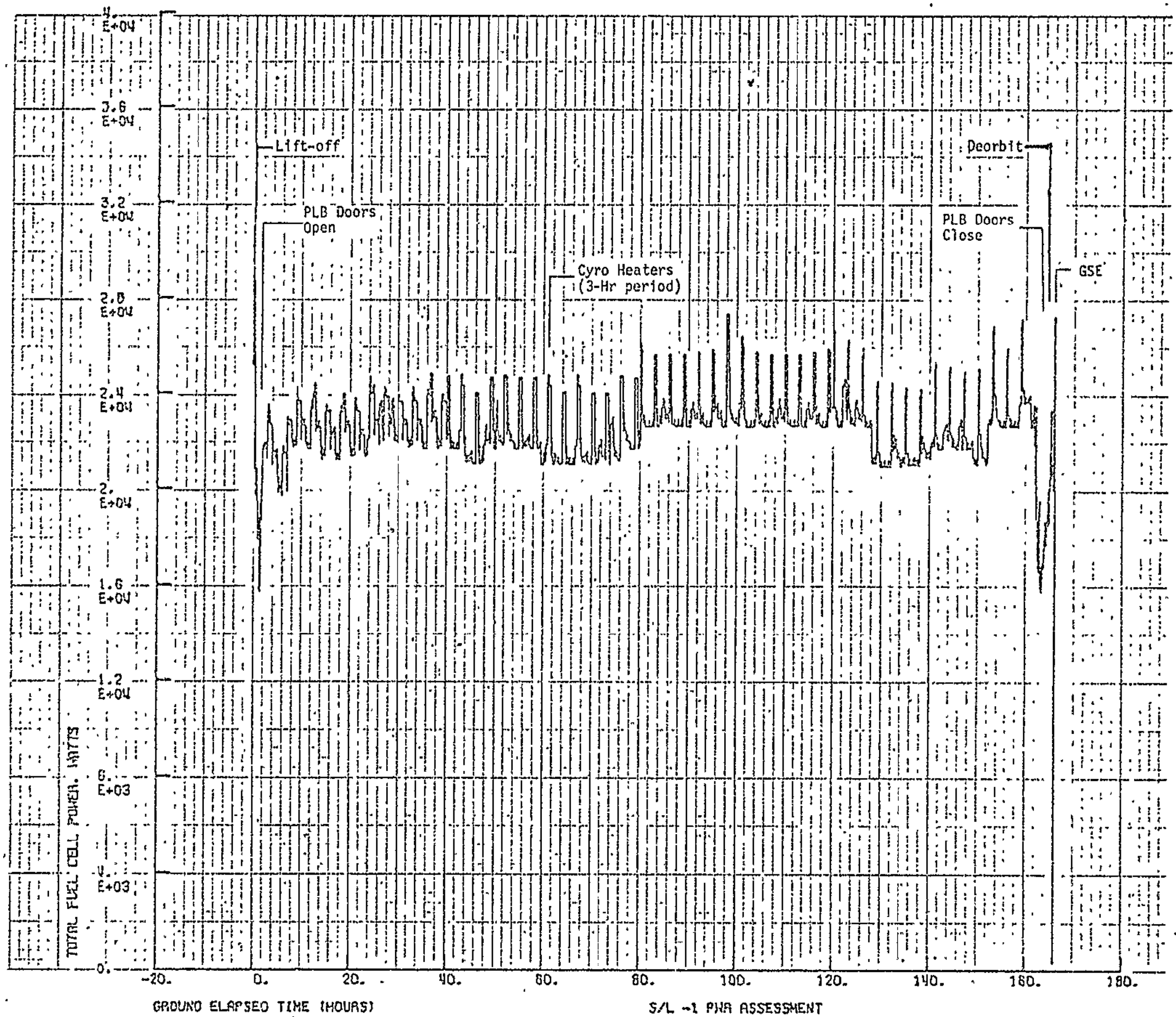

Figure 4.1-2. - Total power for Spacelab 1.

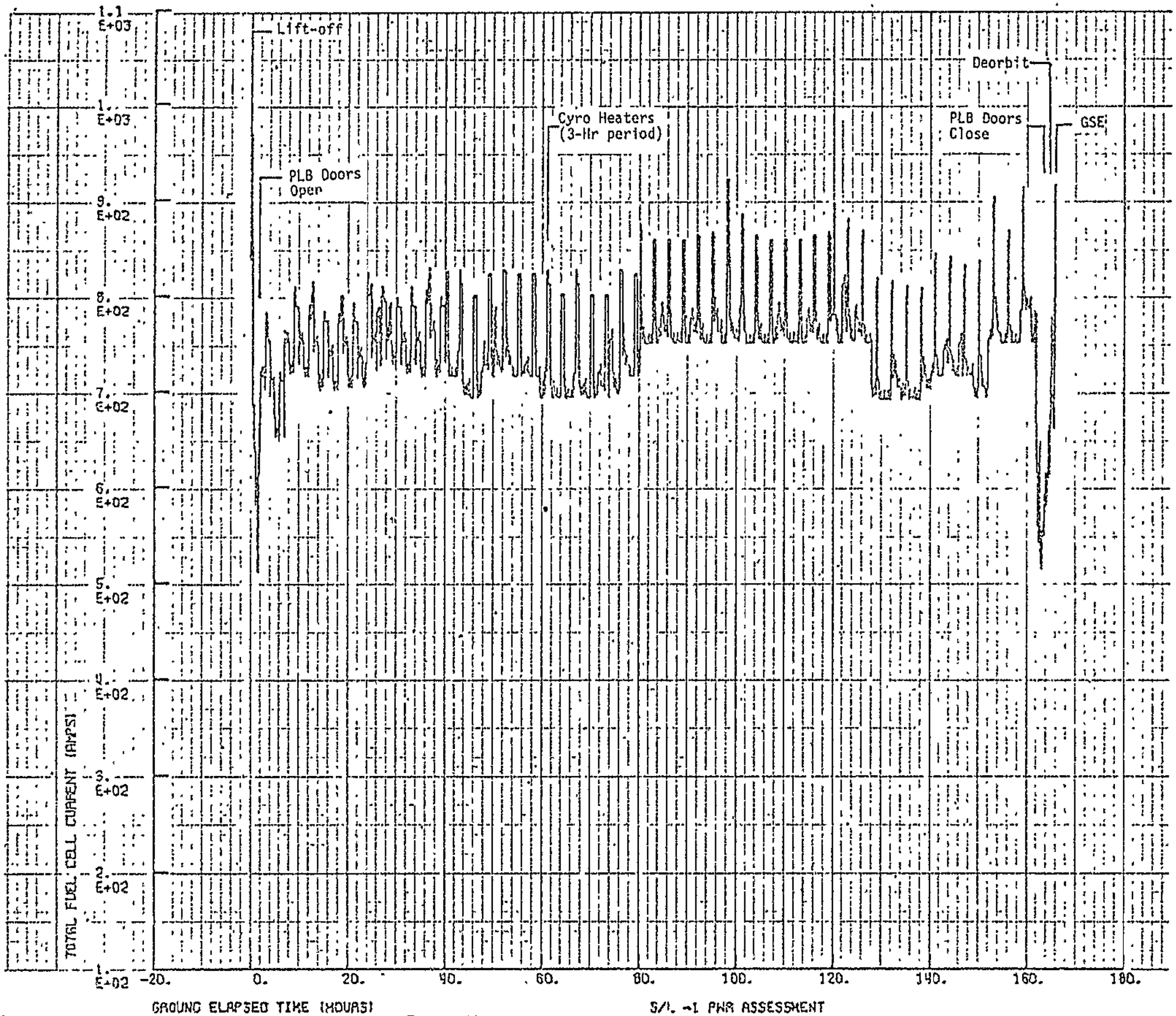

Figure 4.1-3. - Total fuel cell current for Spacelab 1.

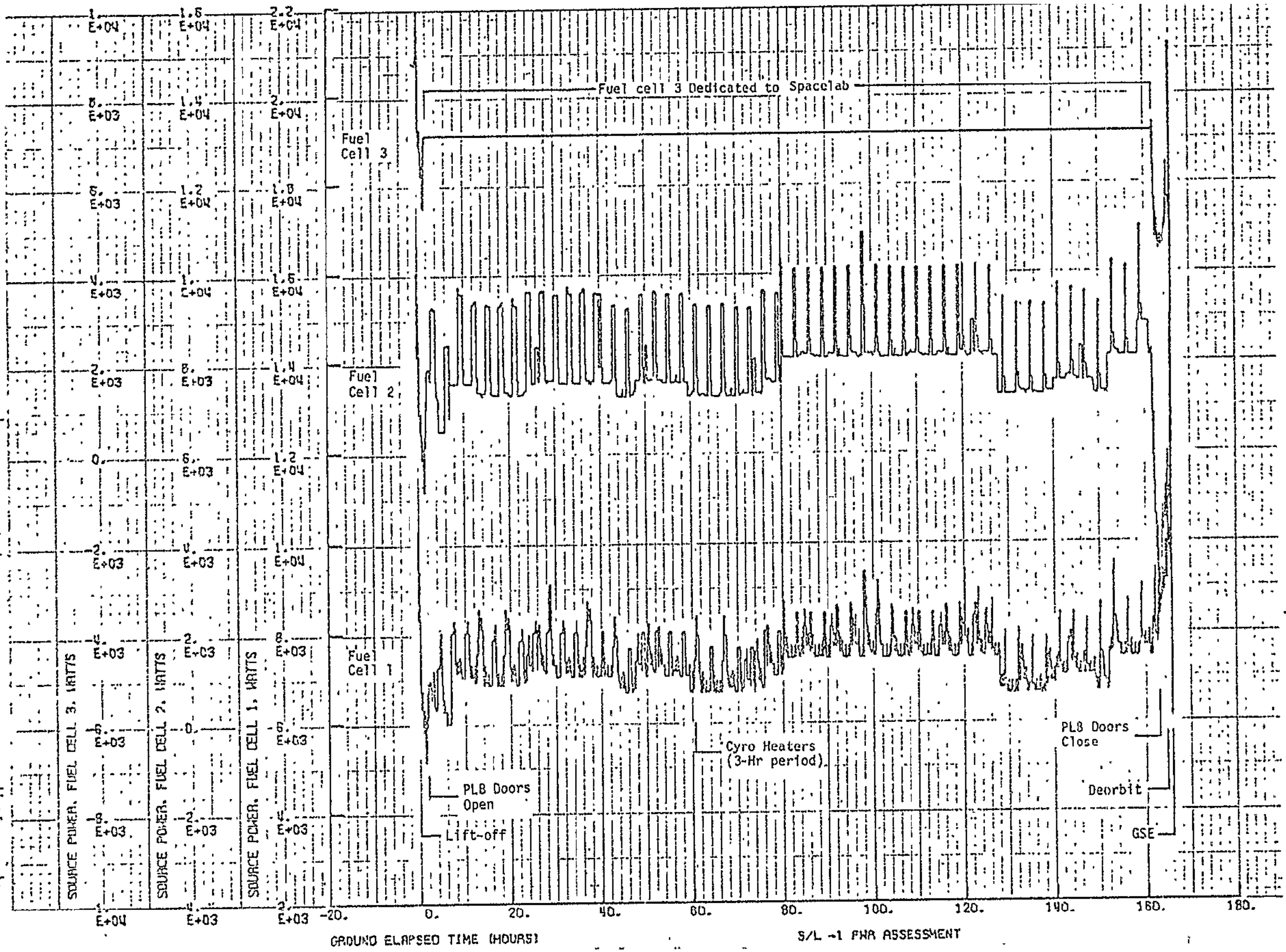

Figure 4.1-4. - Fuel cell 1, 2, and 3 source power for Spacelab 1.

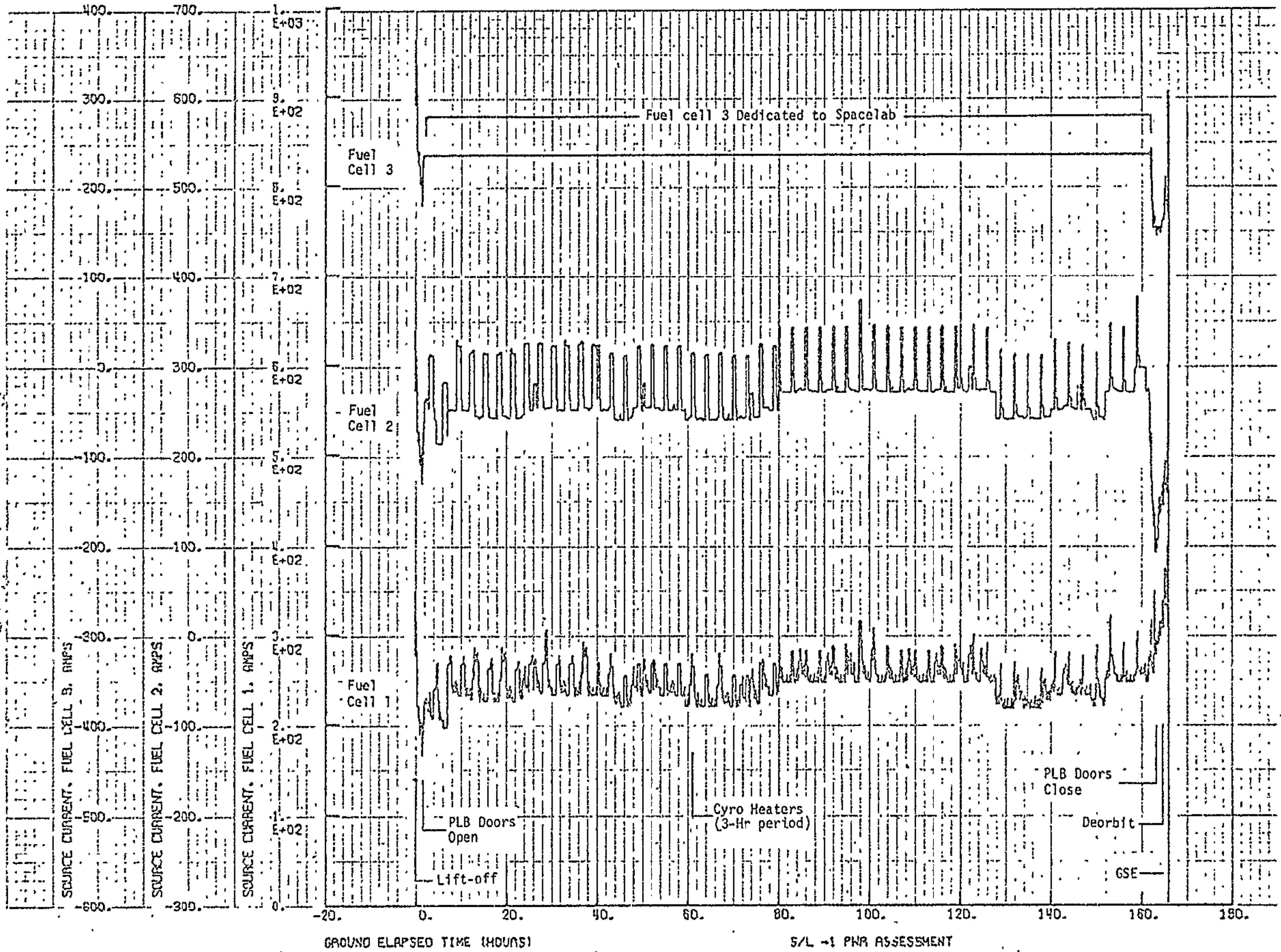

Figure 4.1-5. - Fuel cell 1, 2, and 3 source current for Spacelab 1.

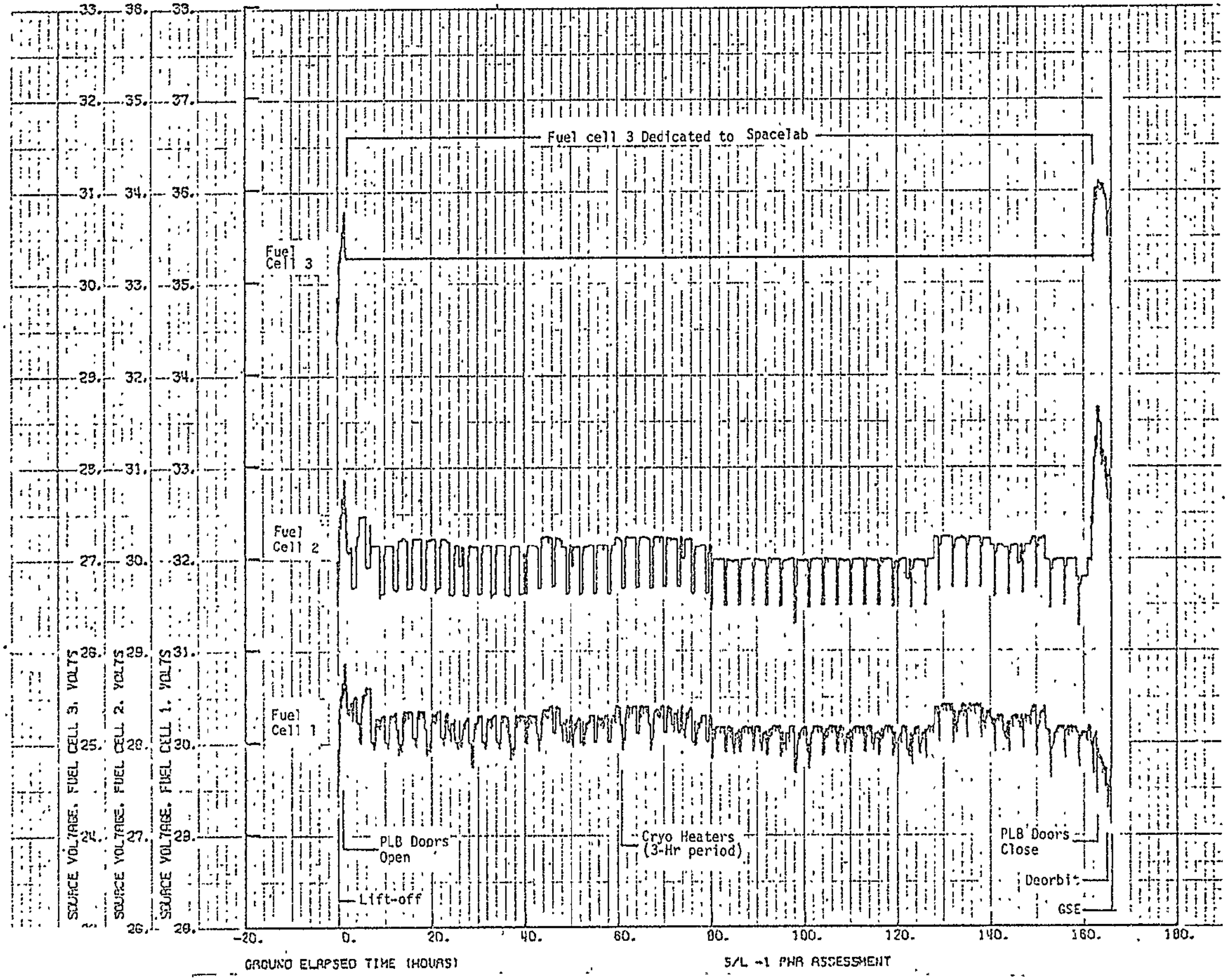

Figure 4.1-6. - Fuel cell 1, 2, and 3 source voltage for Spacelab 1.

TABLE 4.1-III. EPS ESTIMATED TANK SET REQUIREMENTS FOR SPACELAB 1

ITEM	ENERGY (KWH)	H2 QUANT (LBM)	REMARKS
MISSION REQUIREMENTS:			
Flight	3810	347.5	1). Avg power = 7.65 KW/FC 2). H2 quantity at 0.091 lbm/KWH
Deorbit Reserve	389	34.6	1). Energy at 5.40 KW/FC for 24 hrs 2). H2 quantity at 0.089 lbm/KWH (Assumes payload at descent pwr level)
Flight Plan Uncertainty	381	34.7	
SUBTOTALS	4580	416.8	Indicates five H2 tanks, minimum
PREFLIGHT REQUIREMENTS:			Tank set dependent
Prelaunch	-	6.5	
24 Hr Launch Hold	-	4.0	
Measurement Error	-	17.5	
TOTALS	4580	444.8	
USABLE H2 - 5 TANKS		445.5	89.1 lbm/tank
MARGIN		0.7	

TABLE 4.1-IV

EPS ANALYSIS TAPE INFORMATION

TAPE TYPE	TAPE NUMBER
DATA	X11761
INTERFACE 1	X11823
INTERFACE 2	X13271
PLOTS	X13132

4.2 ECLSS Consumables Analysis

Consumables analysis of the ECLSS was performed through the use of the Shuttle Environmental Consumables Requirements Evaluation Tool (SECRET) computer program. This program employs a nodal technique utilizing the Fortran Environmental Analysis Routines (FEAR) of reference 17. The SECRET program models ECLSS performance continuously throughout the duration of a mission and outputs consumables usage, based on the input data itemized in section 4.2.1.

4.2.1 Analysis Definition Data.- Data input to the SECRET program, to define the mission, were as follows:

a. The orbiter heat load time line is as defined by the electrical power system consumables analysis (section 4.1) on tape X13271.

b. The crew activity time line is as shown in figure 4.1-1.

c. Incident heat flux on the radiators is calculated as a function of orbiter attitude and position in space, based on the following:

(1). An orbital trajectory computed as a result of an 0900 launch on 15 June 1980, at a 57° launch azimuth from KSC, to a 155 nautical mile circular orbit. The resultant beta angle is approximately 35 degrees.

(2). An attitude time line as presented in table 3.1-I.

4.2.2 Analysis Results.- The results of the Spacelab 1 Mission ECLSS analysis are presented in tables 4.2-I through 4.2-V and in figures 4.2-1 through 4.2-8.

4.2.3 Analysis Conclusions.- The results of the Spacelab 1 Mission analysis indicate no problems in the required ECLSS support. Two items, however, are worthy of note:

a. No attempt was made to differentiate the two sources, orbiter and spacelab, of GN2. It seems likely that, on a mission, management of these sources might be required in order to ensure adequate GN2 in the spacelab bottle for experiment purposes.

b. The topping flash evaporator is in use during a high percentage of the on-orbit time. In the analysis, no attempt was made to constrain the timing or rate of water vapor venting. On a given mission, constraints may be required as a function of the particular experiment requirements. This must be considered in flight planning of future specific missions.

TABLE 4.2-I

ECLSS ATMOSPHERIC GAS BUDGET

	CRYOGENIC OXYGEN (LBS)		AUXILIARY OXYGEN (LBS)		Hi-Pressure NITROGEN (LBS)	
Total Loaded		224[1]		66		265[2]
Prelaunch Requirement	0		0		.14	
Launch Load		224		66		264.86
Flight Requirement	85.1		0		89.01	
Unusables	16.8		11		50[2]	
Residual		122.1		55		125.85
Reserves						
Measurement Error	8.4		5		20	
Dispersion Allowance	8.5		0		4.5	
Contingency:						
a) one day mission extension	5.7±.3		0		7.8±0.4	
b) Cabin puncture	17.0±.9				112.3±5.6	
c) Single cabin repress to 14.7 PSIA	0		39.7±2.0		138.7±7.0	
d) Single cabin repress to 8.0 PSIA	0		44.1±2.2		70.0±3.5	
e) one EVA	6.3±.3		30.3±1.5		8.2±0.4	
Total Reserves[3]	34.8		51.3		170.2	
Margin		87.3		3.7		-44.35[4]

[1] 4 Cryogenic tank sets

[2] Includes one spacelab tank

[3] Includes worst single contingency

[4] Negative N_2 margin occurs only as a result of considering worst possible contingencies.

TABLE 4.2-II

ECLSS AMMONIA BUDGET

	AMMONIA (LBS)
Total Loaded	97.6
Prelaunch Requirement	0
Launch Load	97.6
Flight Requirement	74.5
Unusables	2
Residual	21.1
Reserves	
Measurement Error	1.0
Dispersion Allowance	3.7
Contingency:	
None identified	0
Total	4.7
Margin	16.4

TABLE 4.2-III

ECLSS LITHIUM HYDROXIDE BUDGET

	LiOH (canisters)
Total Loaded	23
Prelaunch Requirement	0
Launch Load	23
Flight Requirement	22
Unusables	0
Residual	1
Reserves	
Measurement Error	0
Dispersion Allowance	0
Contingency	1
Total	1
Margin	0

TABLE 4.2-IV

ECLSS POTABLE WATER BUDGET

	POTABLE WATER (LBS)	
Total Loaded		471.8
Prelaunch Requirement	-3.06[1]	
Launch Load		474.86
Flight Requirement		
Crew Use	197.3	
Ascent Rqmt.	129.2	
Descent Rqmt.	174.7	
Excess H_2O Dumped[2]	2797.79	
Less H_2O Generated	2934.19	
Total Requirement	364.8	
Unuseable	9.9	
Residual		100.25
Reserves		
Measurement Error	25.3	
Dispersion Allowance	25.0	
Contingency:		
Loss of one tank at Payload Bay Doors Close	118 ± 5.9	
Total Reserves	174.2	
Margin		61.8[3]

1 Some water is generated by the fuel cells prior to launch.

2 Excess water dumped is comprised of water used for supplemental cooling, as well as water dumped for quantity management purposes.

3 Management of potable water levels to a minimum of 236 lb. prior to the time of the potential contingency will maintain a margin of (236-174.2) 61.8 lbs.

TABLE 4.2-V

ECLSS WASTE WATER BUDGET

	ORBITER WASTE WATER (LBS)		SPACELAB WASTE WATER (LBS)	
Total Capacity		336.6		100.3
Unuseables	6.6		0[1]	
Prelaunch Requirement	.35		.01	
Launch Capacity		329.65		100.29
Flight Requirement	178.45		60.09	
Residual Capacity		151.2		40.2
Reserves				
Measurement Error	17		5.0[1]	
Dispersion Allowance	8.9		3.0	
Contingency:				
One day mission extension	30.5 ± 1.5		$5.6\pm.3$	
Total Reserves	42.9		13.9	
Margin		108.3		26.3

[1] Spacelab waste water tank unuseables are not known. An allowance is included in the measurement error which is estimated at 5% of tank capacity.

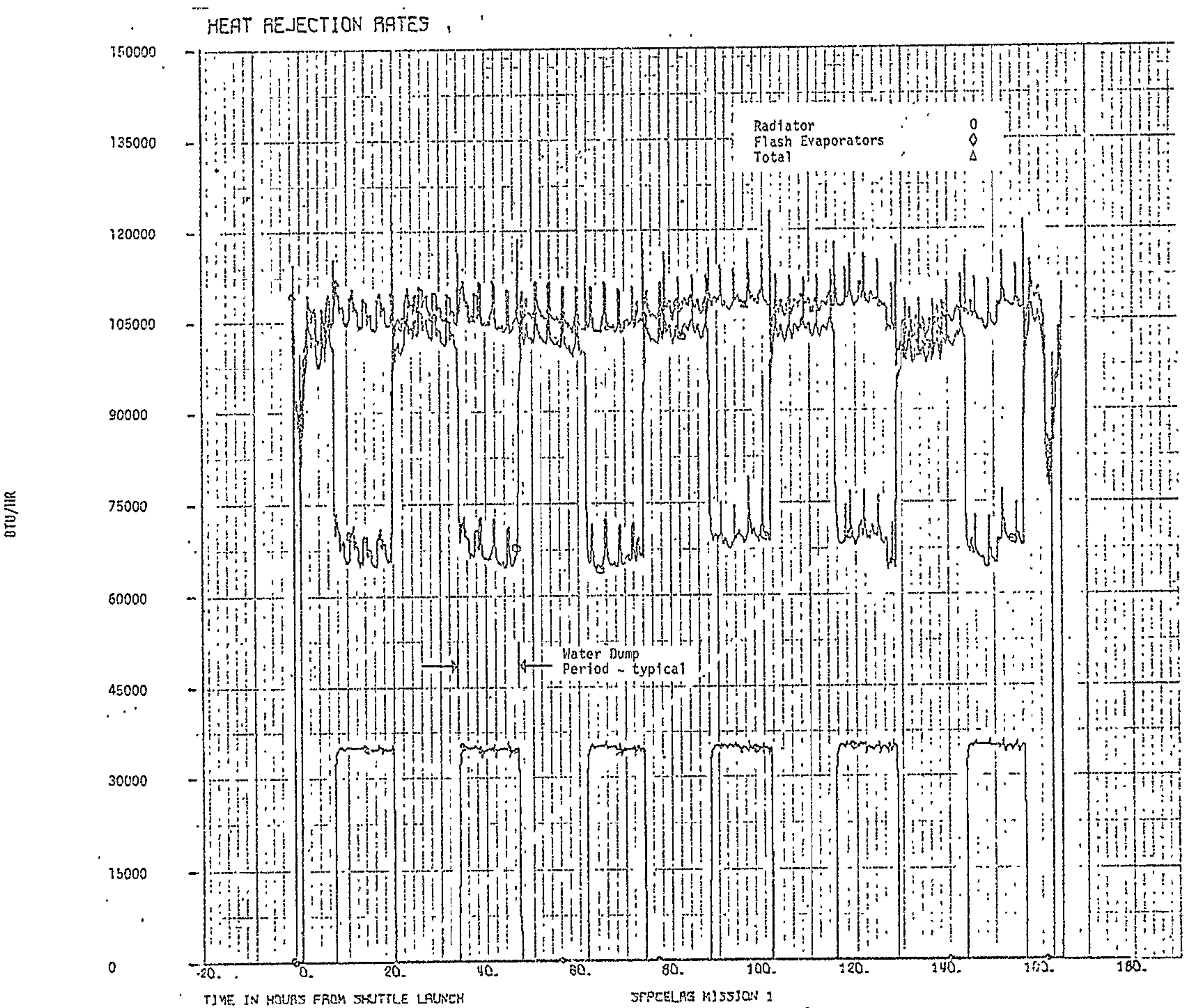

Figure 4.2-1 ECLSS Heat Rejection Rates

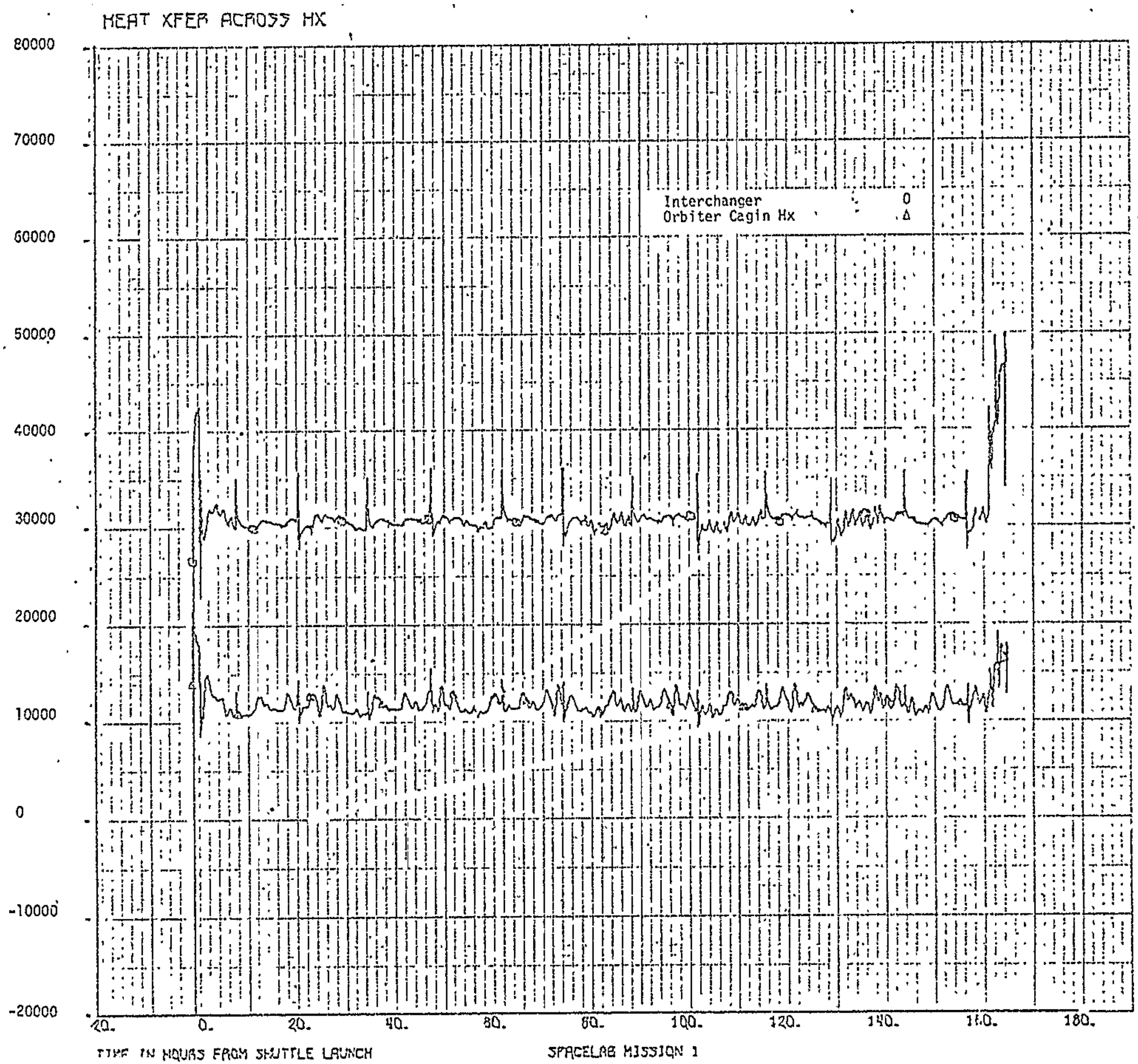

Figure 4.2-2 Atmospheric Revitalization System Heat Transfer Rates

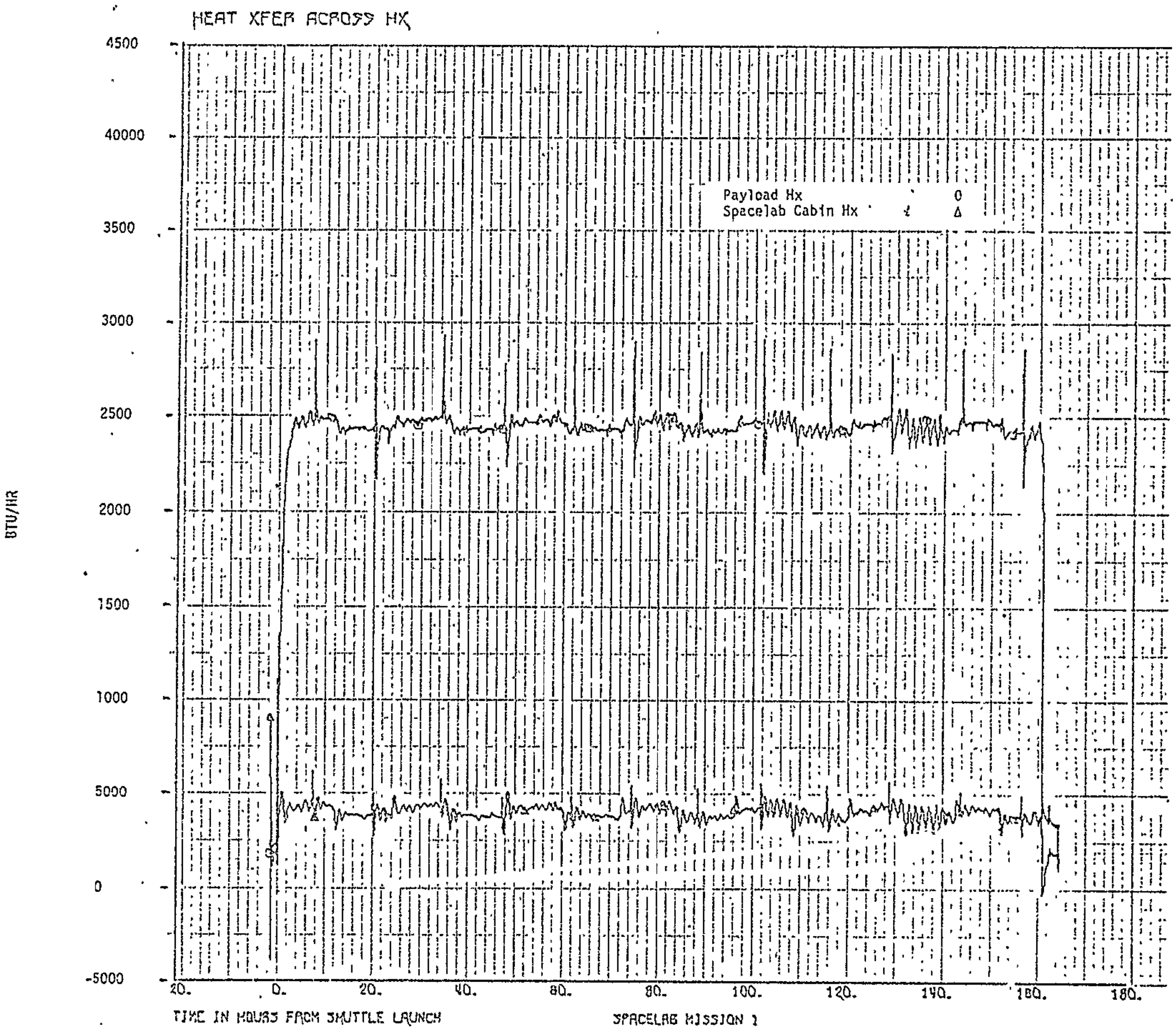

Figure 4.2-3 Spacelab Heat Transfer Rates

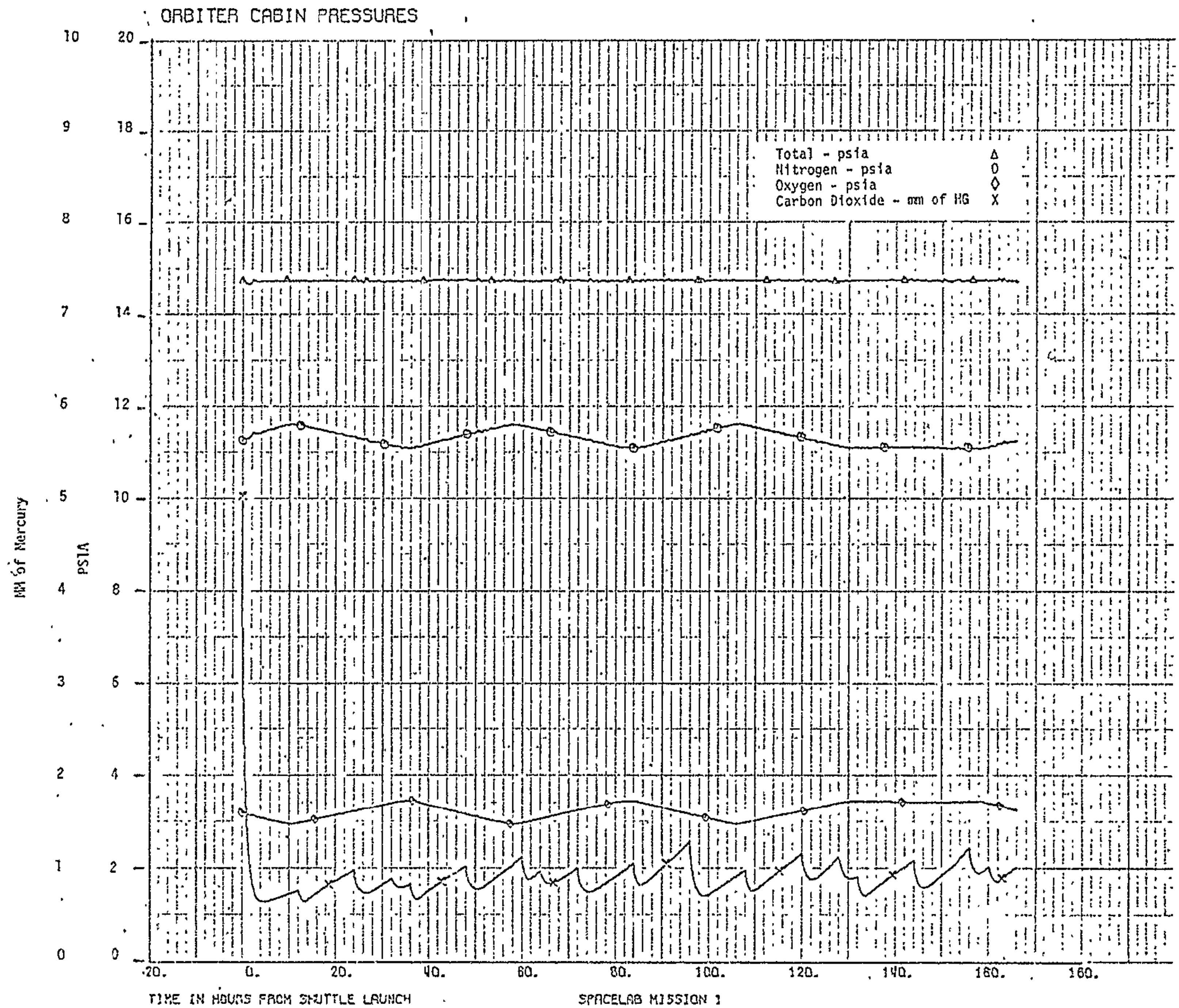

Figure 4.2-4 Orbiter Cabin Atmospheric Pressures

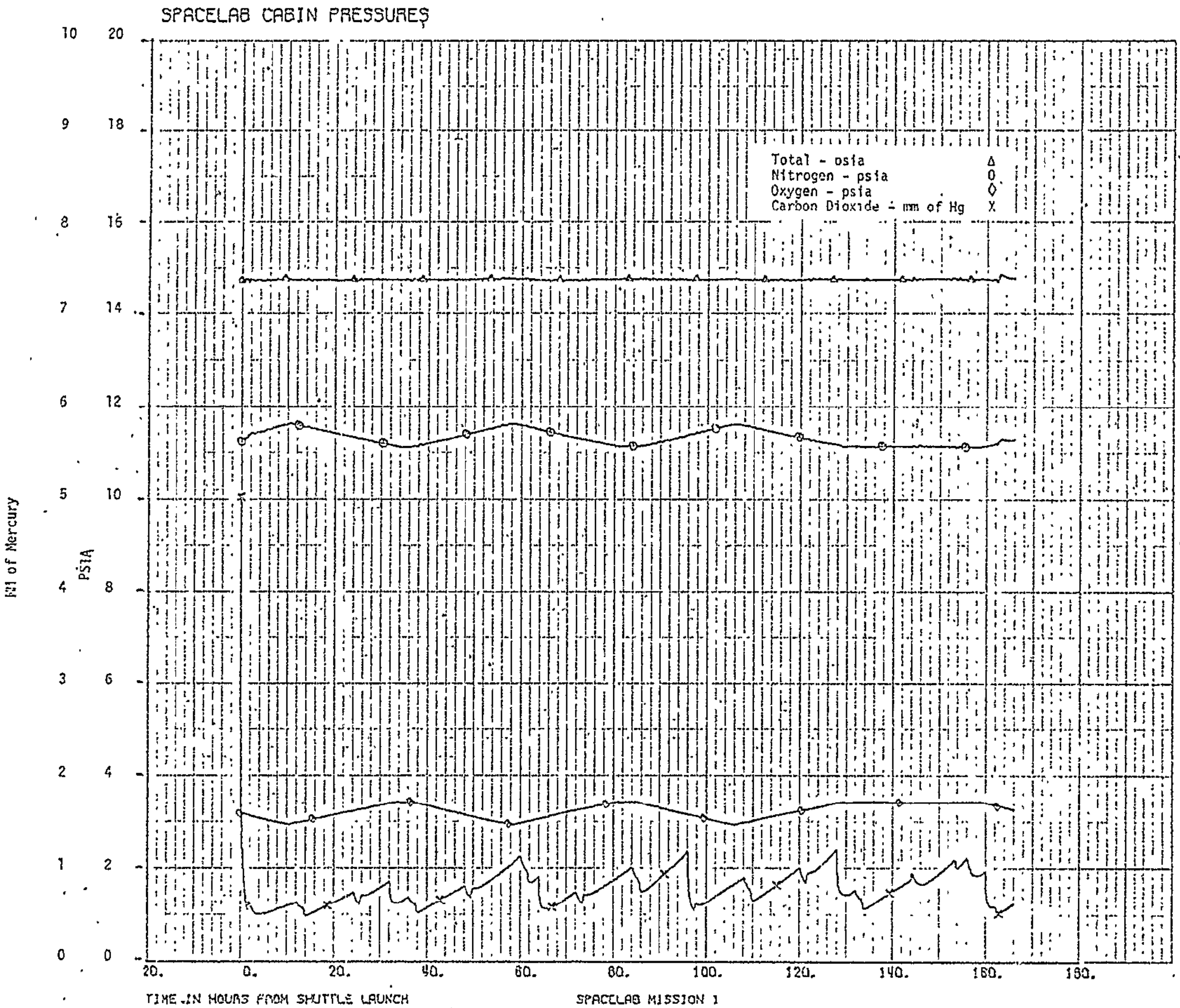

Figure 4.2-5 Spacelab Cabin Atmospheric Pressures

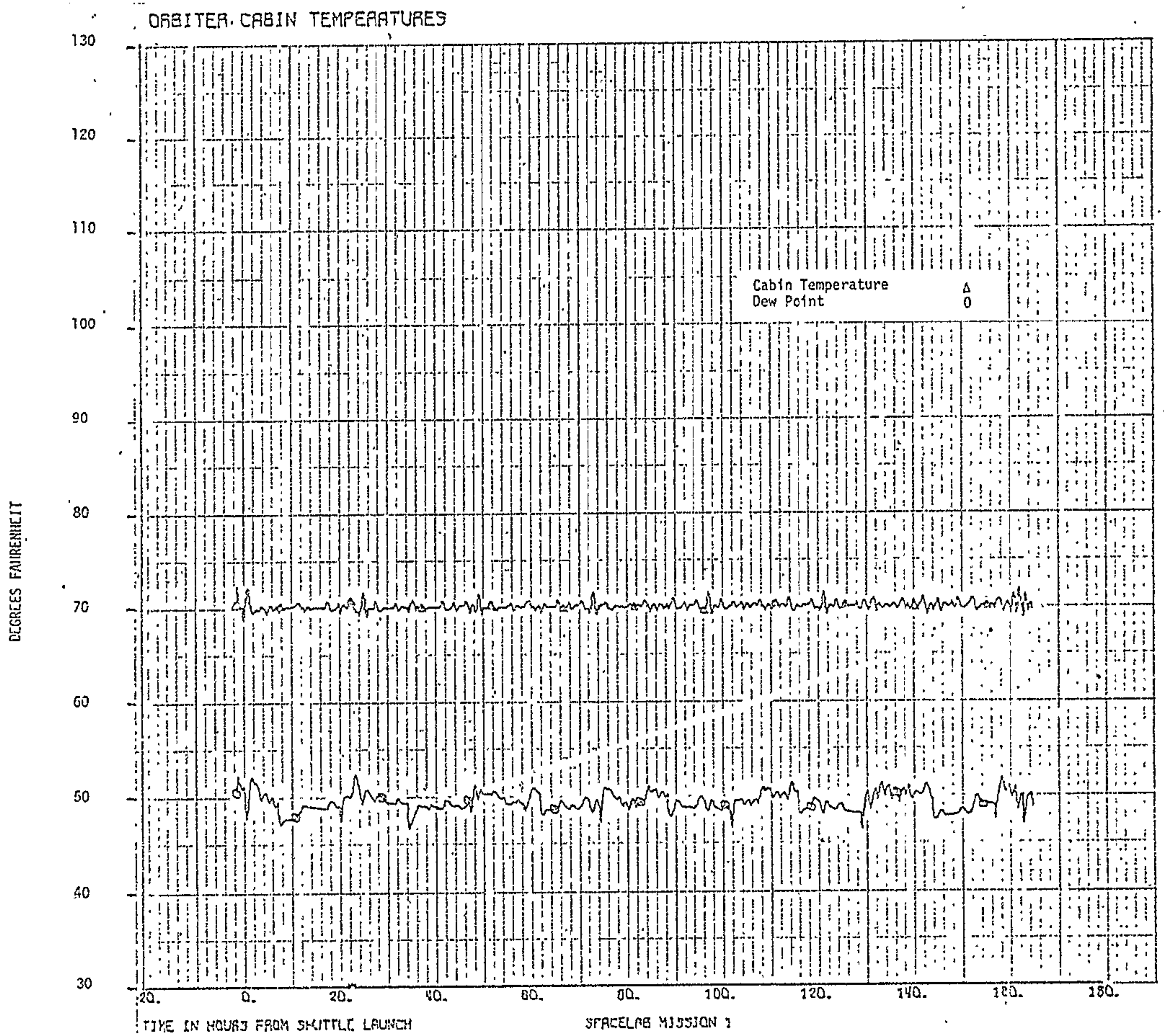

Figure 4.2-6 Orbiter Cabin Temperatures

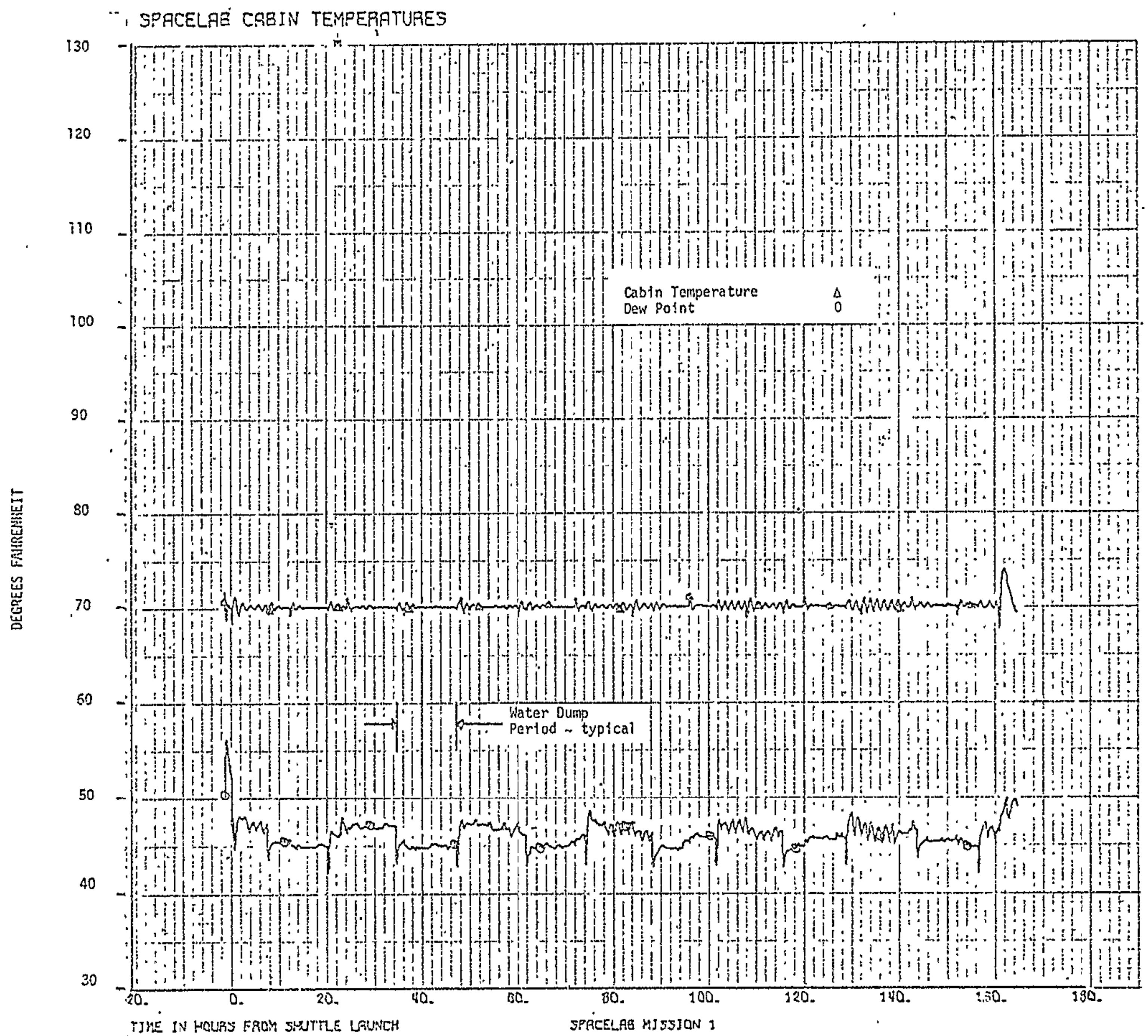

Figure 4.2-7 Spacelab Cabin Temperatures

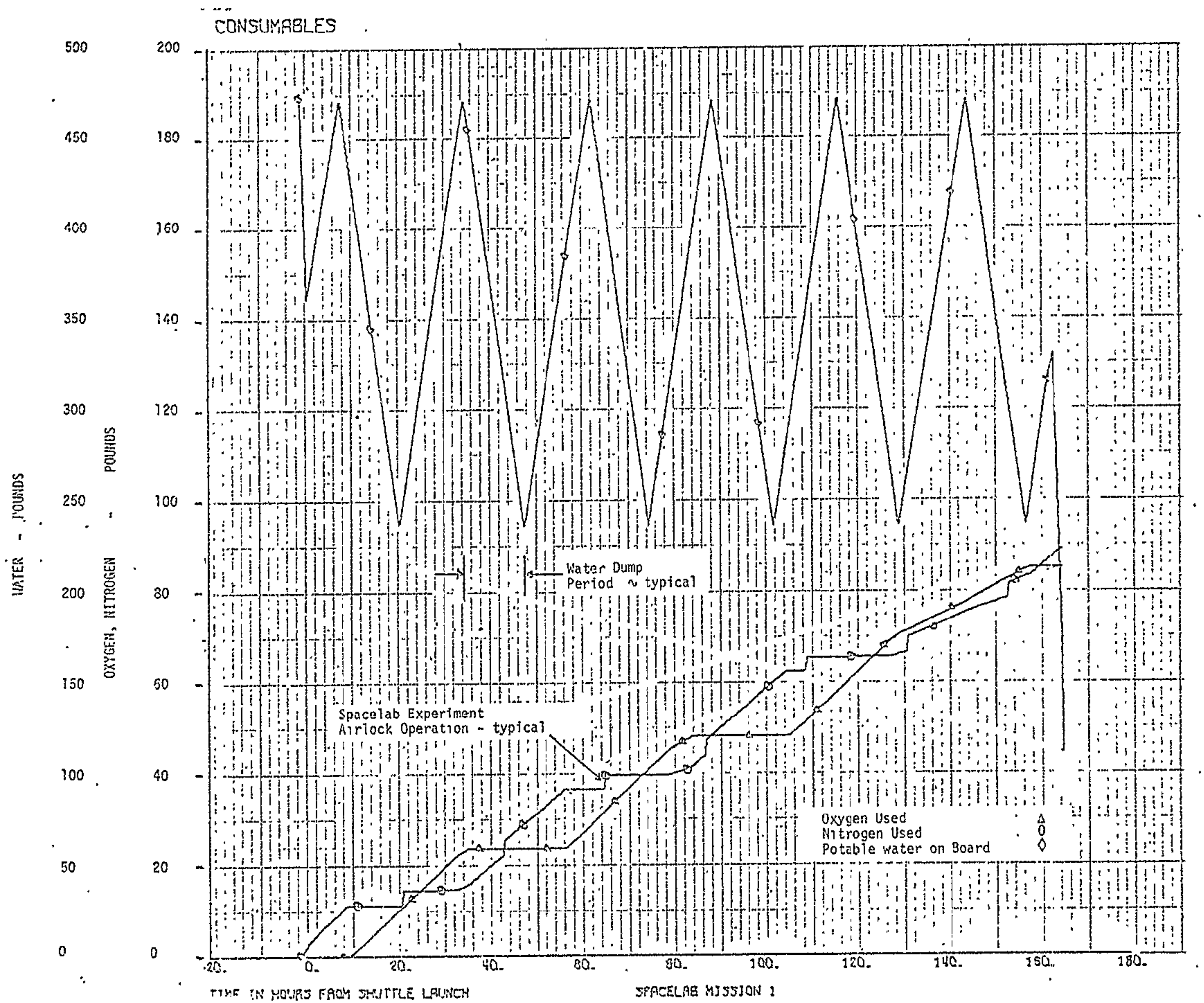

Figure 4.2-8 Spacelab Mission Consumable Profiles

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