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Environmental Control and Life Support System Analysis of STS-1

9-psia Extravehicular Activity Configuration

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Lyndon B. Johnson Space Center

Houston, Texas

SHUTTLE PROGRAM

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM ANALYSIS OF STS-1

9-PSIA EXTRAVEHICULAR ACTIVITY CONFIGURATION

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CONTENTS

TABLES

Figures

SYMBOLS AND ACRONYMS

ARS	Atmospheric Revitalization System
ATCS	Active Thermal Control System
BTU	British Thermal Unit
CFM	Cubic Feet per Minute
CO_2	Carbon Dioxide
ECLSS	Environmental Control and Life Support System
ECS	Environmental Control System
EPS	Electrical Power System
EVA	Extra-Vehicular Activity
FES	Flash Evaporator System
FT^3	Cubic Foot
GET	Ground Elapsed Time
GPC	General Purpose Computer
GSE	Ground Support Equipment
HR	Hour
HX	Heat Exchanger
H2O	Water
IMU	Inertial Measuring Unit
KW	Kilowatt
LiOH	Lithium Hydroxide
LB	Pound
MET	Mission Elapsed Time
MR	Metabolic Rate
NH_3	Ammonia
N.Mi	Nautical Miles
N_2	Nitrogen
O_2	Oxygen
PLB	Payload Bay
PSI	pounds per square inch
PSIA	pounds per square inch, absolute
PPO_2	Partial Pressure of Oxygen
PTC	Passive Thermal Control
QL	Metabolic Rate of Latent Heat Production
SECURE	Shuttle Environmental Consumables Usage
SEPS	Spacecraft Electrical Power Simulator
SODB	Shuttle Operational Data Book
STS-1	Space Transportation System - Flight 1
TD	Touchdown
ZLV	Positive Z Axis Oriented to the Local Vertical
^oF	degrees Fahrenheit

ECLSS ANALYSIS OF STS-1 9-PSIA EVA CONFIGURATION

by G. J. Steines

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1.0 SUMMARY

The capability of the Orbiter Environmental Control and Life Support System (ECLSS) to support vehicle cooling requirements in the event of cabin pressure reduction to 9 psia has been evaluated in accordance with the analysis request of reference 1. This was accomplished using the Orbiter versions of the Shuttle Environmental Consumables Usage Requirement Evaluation (SECURE) program (Reference 2), and using heat load input data developed by the Spacecraft Electrical Power Simulator (SEPS) program. This report defines the SECURE model used in the analysis, presents the timeline and ECLSS configuration used in formulating the analysis, presents the results of the analysis and summarizes the conclusion which may be drawn from these results. There are no significant thermal problems with the proposed mission. There are, however, several procedures which could be optimized for better performance: setting the cabin HX air bypass and the interchanger water bypass to the zero flow position is of questionable efficacy; the cabin air pressure monitoring procedure should be re-evaluated; and the degree of equipment power down specified for this analysis appears to be excessive. Consumables requirements have been evaluated and no problems were noted.

2.0 INTRODUCTION

Flight crew evaluation of the EVA pre-breath activities indicates that there is some risk of inadvertent breathing of N_2 during the procedure. Further, there is no positive indication to determine that adequate denitrogenation has been achieved. In addition, the equipment is awkward to use and interferes with other pre-EVA activities (Reference 3).

An alternate approach to pre-breathing has been proposed, namely to depressurize the crew cabin to 9 psia. This approach offers several advantages, including the following:

a. It provides a pre-breathing atmosphere for both crewmen simultaneously, thereby facilitating any required emergency EVA by the second crewman.

b. It avoids the encumbrance of the Portable Oxygen System and the Service and Cooling Umbilical for pre-breathing, thereby permitting the crew to more effectively accomplish other pre-EVA tasks.

c. It provides positive denitrogenation.

d. It decreases the length of the EVA workday by as much as two hours.

It also has certain drawbacks, among which are the following:

a. It results in an oxygen concentration as high as 30% for 12 to 55 hours.

b. It necessitates that a portion of the Environmental Control and Life Support System N_2 be budgeted for cabin repressurization to 14.5 psia.

c. It requires that additional materials flammability testing and hardware test/analysis be performed.

d. It necessitates a procedural powerdown to maintain operational cabin and avionics temperature levels with reduced air cooling capability.

This analysis was performed to evaluate the adequacy of the equipment powerdown and equipment reconfiguration and the cooling capability of the ECLSS, in maintaining adequate thermal levels under the 9 psia conditions.

3.0 ECLSS MODEL DEFINITIONS

The Orbiter ECLSS, as modeled by the SECURE program, consists of the Active Thermal Control System (ATCS) and the Atmospheric Revitalization System (ARS). These systems maintain the cabin atmosphere gas proportions, temperatures and humidity; remove heat from the crew, avionics, and assorted equipment; transport the collected heat to the heat rejection devices; and reject the heat from the Orbiter. The system configuration analyzed is illustrated in figure 1. This configuration is based on data obtained from references 4 through 9. The following sections outline configuration details and operating characteristics of the ECLSS.

3.1 ATCS

The ATCS is comprised of a dual freon loop, coldplates in the midbody and aft avionics bays, heat exchangers and the heat rejection devices.

3.1.1 ATCS Characteristics

Specfic ATCS configuration parameters are itemized below.

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

b. The flow split between the fuel cell heat exchanger and the mid cold plates at node 1 is 87.1 / 12.9% respectively.

c. The freon flow split to the aft cold plates at node 99 is 10.45% in the interchanger mode; 8.0% in the payload mode.

d. The freon flow split to the payload HX at node 28 is 10.5% in the interchanger mode, 43.1% in the payload mode.

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

3.1.2 ATCS Operating 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 (0.hrs).

   (2) None from lift-off to 140,000 ft. (0.036 hr.).

   (3) By hi-load and topping flash evaporators from 140,000 ft. to radiator deploy (2.35 hrs.).

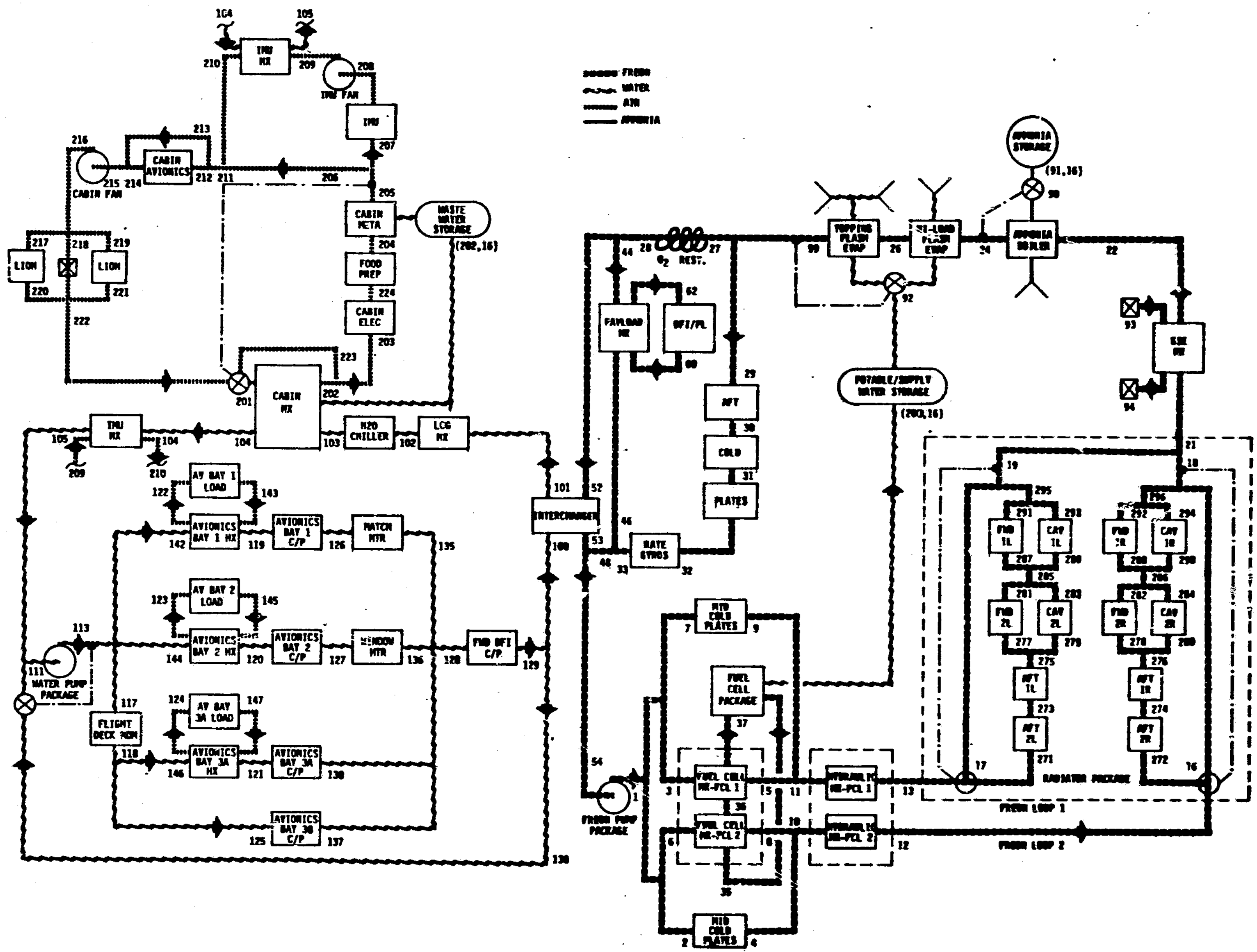

FIGURE 1.- ECLSS THERMAL MODEL SCHEMATIC

(4) By the radiators during on-orbit periods except for the deorbit rehearsal. Supplemental cooling is provided by the topping flash evaporator as required.

(5) By hi-load and topping flash evaporators during deorbit rehearsal (27.0 - 29.7 hrs.).

(6) By both flash evaporators from radiator retract (50.17 hrs.) to 120,000 ft. (54.36 hrs.), and as required until 85,000 ft. (54.40 hrs.) during descent.

(7) By the NH_3 boiler from 120,000 ft. through landing to GSE hookup (54.762 hrs.).

b. An 8 panel radiator is utilized with a bypass flowrate controlled to provide a discharge temperature of 38° F at nodes 18 and 19.

c. The flash evaporators utilize water with a heat dissipation capacity of 1010 BTU/lb. This accounts for an evaporator effectiveness of 99%. The water flow is controlled to provide a freon discharge temperature of 39°F at node 99.

d. The ammonia boiler utilizes NH3 with a heat dissipation capability of 520 BTU/lb. The NH3 flow is controlled to provide a freon discharge temperature of 35°F node 24.

e. The mission is initiated with five supply H_2O tanks loaded full and one loaded at 65% at lift-off. Potable water is maintained between 975 and 675 lb on orbit. The excess water is dumped overboard through the dump valves when necessary.

f. The freon flowrate is based on a 71 psia pump at 2540 lb/hr., and varies between 2650 and 2927 lb/hr/loop as a function of flow through the radiators and through the payload HX.

3.2 ARS

The ARS is comprised of a water loop, and an atmospheric loop. The water loop provides cooling and heat transport from the cabin heat exchanger and the avionics bays to the ATCS. The atmospheric loop provides for cooling of personnel and equipment on the flight and mid deck, for transport of the heat to the water loop, and for the control of the atmospheric gas consitituents. Avionics and electrical equipment are modeled as lumped nodes in the cabin and avionics bays, according to the method of cooling (see figure 1).

3.2.1 ARS Characteristics

Individual component performance parameters are as defined in the reference noted in section 3.0.

Specific ARS configuration and performance parameters are itemized below.

Water loop parameters:

a. The water pump flowrate is computed as a function of bypass valve position and the number of pumps operating, and varies between 1280 and 1641 lb/hr per loop.

b. The flow split at node 113 to avionics bays 1, 2, 3, and 3A is 24.2%, 24.0%, 47.3% and 4.5%, respectively.

Atmospheric loop parameters

a. The cabin volume is 2325 cubic feet.

b. The cabin fan provides a constant volume airflow of 307 CFM (1380 lb/hr @ 14.7 psia and 70°F).

c. Cabin pressure is controlled as follows:

   (1) Total pressure - 14.5 ± 0.2 psia

   (2) Oxygen partial pressure - 3.2 ± 0.05 psia

   (3) Cabin relief pressure - 15.5 psia

d. An air flowrate of 156 lb/hr (at 14.7 psia) is directed through the IMU's.

e. An air flowrate of 1140 lb/hr (at 14.7 psia) (node 212) is directed through the cabin avionics, with 240 lb/hr through the waste management compartment.

f. Maximum airflow bypass around the cabin HX is 71.4%.

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

f. Lithium Hydroxide (LIOH) canisters used to remove atmospheric CO_2 perform as follows:

   (1) Water of Reaction - 0.409 pound per pound of CO_2 absorbed.

   (2) Heat of Reaction - 876 BTU per pound of CO_2 absorbed.

g. One tank, with a usable capacity of 165 lbs., is assigned to waste water storage.

3.2.2 ARS Assumptions

The following assumptions regarding operation of the ARS are for nominal operations of the orbiter and ECLSS. Specific exceptions to these assumptions which apply to the time spent at 9 psia will be itemized in section 4. The nominal assumptions are presented below:

a. Water flowrate through the interchanger is set at 950 lb/hr/loop for 1 loop throughout the missions. Periodic cycling of the second water loop is not considered.

b. Cabin temperature is controlled to 70°F.

c. Atmospheric leakage from the pressurized cabin is 8.2 lb/day.

d. 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 value for QL

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

    or

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

    (4) Urine Production - 0.138 lb/man-hour

    (5) Crew water consumption is .344 lb/man-hour.

e. The LiOH canisters are not installed until 5.5 hrs MET, with one replaced a 12.25 hrs, and the other at 36.42 hrs. Both are removed prior to deorbit at 49.28 hrs MET.

f. The waste water tank is loaded to 97% (160 lb.) with purified H_2O prior to lift off for use in the flash evaporator in the event of a failure of the radiators to deploy properly. The tank will be dumped to 80% (132 lb) at 4.5 hrs MET, and again at 33.75 hrs MET.

4.0 ECLSS ANALYSIS FOR 9 PSIA MISSION

The primary purpose of this analysis was to provide an assessment of the ECLSS thermal performance and margins at 9 psia cabin pressure with the specified concurrent powerdown. Additionally, an assessment of the ECLSS related consumables was performed. The sections which follow discuss the guidelines and assumptions specific to the 9 psi part of the mission, over and above those for a nominal mission.

4.1 Analysis Definitions

The analysis was performed by superimposing a 9 psia, powered down equipment timeline on a nominal STS-1 mission timeline, beginning at 30:30:00 GET. For the atmospheric gas consumables analysis, however, a cabin repressurization was assumed to occur at 50 hrs.

It should be noted that the powerdown was developed from 8 psi contingency procedures in the Orbiter pocket check lists (Refs. 10 & 11) rather than being developed specifically for a 9 psia case, and thus may be overly conservative for this analysis.

Subsequent to the completion of the EPS analysis (Ref. 12), it was determined that GPC #1, in avionics bay 1, would remain powered up. The ECS analysis was accordingly rerun with this consideration, and the difference between the two cases is discussed in section 4.3.

Basic assumptions for the mission were:

a. A two man crew is assumed, working on a single shift basis.

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

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

   (1) A 150 n.mi. circular orbit at a beta angle of between -17^{o} and -27^{o}

   (2) A constant -ZLV attitude (PLB to the earth) for most of the mission, with a period (4.5 to 9.67 hrs. MET) at .2 degrees per second PTC.

   (3) A 40.3^{o} inclination.

d. A standard environmental heat load during entry, obtained from Ref. 6, is imposed on the orbiter cabin.

4.1.1 Analysis Timeline

A nominal STS-1 mission analysis was initiated at T-1 hr GET using SEPS tape X09507 (Ref. 13) to provide an equipment and heat load timeline.

At 30:30:00 GET, the 9 psia SEPS tape (X04589, Ref. 12) was substituted and used through the end of the mission. At 30:40:00 GET, the airlock vents were opened, and cabin pressure reduced to 9.0 psia. The 9 psia level was maintained until descent into the atmosphere during re-entry.

4.1.2 System Configuration

Nominal system configuration was assumed for this analysis except as follows:

a. at 30:40:0 GET, the water loop bypass valve was set to zero bypass.

b. at 30:40:00 GET, the cabin temperature control was disabled, and the HX air bypass forced to zero.

c. at 30:40:00 GET, a second cabin fan was turned on and left on.

It should be noted that the analysis did not attempt to model actual system operation in two pertinent respects:

a. Cycling of the second water loop every four hours was not included, as the resulting transients tend to make evaluation of the plotted results rather confusing. The omission will have inconsequential effects on the heat transfer analysis.

b. No attempt was made to model actual pressure control at 9 psia, as it would not contribute to a thermal analysis. Cabin pressure was allowed to vent to 9 psia, without regard to oxygen partial pressure and then modeled as though a 9 psi regulator was in the system, with the PPO2 controller was set to 3.2 psia.

4.2 ANALYSIS RESULTS

Thermal performance determined by this analysis of the ECLSS systems was generally adequate; no maximum temperature limits, with the exceptions of the IMU air discharge temperature, discussed below, were violated.

Table I presents a comparison of the maximum temperatures computed in this analysis to the specified system maximum temperature limits.

A thorough understanding of the effects of the reduced cabin pressure and avionics power levels may best be obtained by comparing the results of this analysis with the analysis of a nominal STS-1 mission (Ref. 14).

4.2.1 System Performance

Cabin total and partial pressures are shown on figure 2. Total pressure variations are due almost entirely to temperature effects. It is noteworthy that, after the cabin temperature drop to 60^{o}F (fig. 5) and subsequent increasing temperature after 42 hr GET, no additional O_2 or N_2 were required to maintain a cabin pressure of 9 psia through the end of the mission. This is a result of the quantity of gas (6.5 lbs of O_2) introduced into the cabin

TABLE I. ECS Maximum Temperature Limit Comparison

	NODE (Ref. fig.1)	MAX LIMIT (°F)	9 PSIA MAX. TEMP. (°F)
CABIN	205	77[1]	85
CABIN DEW POINT	205	61[2]	60
CABIN AVIONICS OUT	214	130	105
IMU AIR IN	207	73[3]	85
IMU AIR OUT	208	130[3]	135
AV BAY 1 AIR IN	122	73	67
AIR OUT	143	130	108
C/P IN	119	120	73
C/P OUT	126	130	84
AV BAY 2 AIR IN	123	73	67
AIR OUT	145	130	107
C/P IN	120	120	73
C/P OUT	127	130	85
AV BAY 3 AIR IN	124	73	61
AIR OUT	147	130	85
3A C/P IN	121	120	60
3B C/P IN	125	120	55
3A C/P OUT	138	130	68
3B C/P OUT	137	130	58
FUEL CELL COOLANT IN	37	140	80
MID BODY C/P IN	2,7	120	58
AFT C/P IN	31	120	72

1 90°F DURING ENTRY

2 84°F FOR 165 MINUTES

3 SODB LIMITS - SEE DISCUSSION IN SEC. 4.2.1

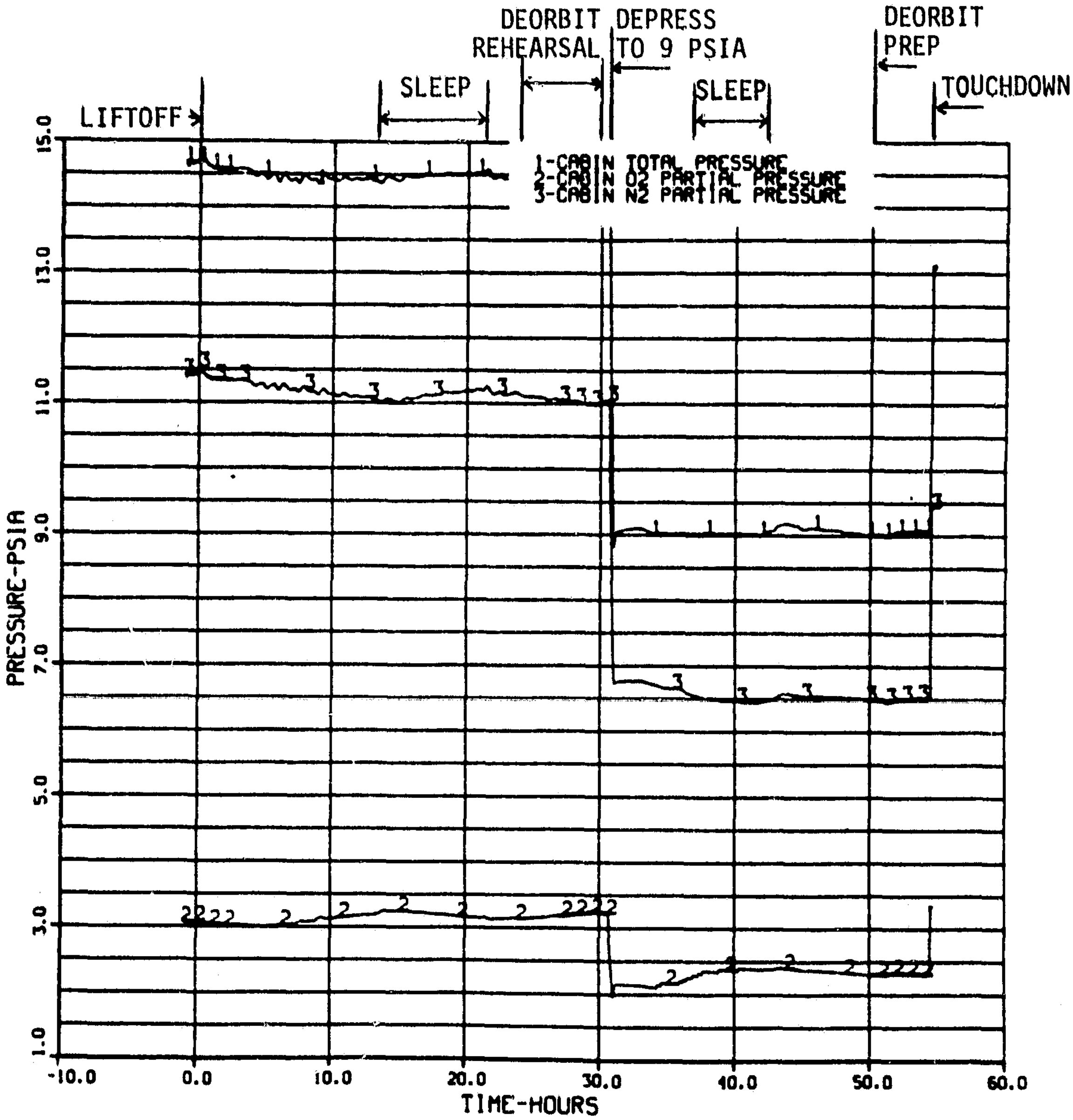

FIGURE 2 ORBITER CABIN PRESSURES

to maintain 9 psia while the temperature was decreasing between 33 and 38 hours GET. If the cabin pressure were being maintained by manual monitoring and control (as is planned), it would be necessary to anticipate the temperature profile in order to properly monitor the cabin pressure.

The electrical heat load imposed on the ECLSS and the heat rejection required of the radiators and flash evaporators are presented on figure 3. Comparison of this data to similar data for the nominal mission shows that, during most of the 9 psia portion of the mission, the heat loads were from 5000 to 10000 BTU/hr (≈1 to 2 KW) lower than the nominal. During deorbit prep and reentry however (≈50 hrs GET through TD) the heat load was not significantly reduced. This figure also shows, as expected, that the level of heat rejection contributed by the FES is reduced from that of the nominal mission.

Heat transfered from the cabin air loop to the ARS water loop, and from the water loop to the ATCS freon loop are shown in figure 4. The short term cycling (1.5 hr) is a system response to the radiator/FES interplay as the orbiter completes a revolution of the earth. This data indicates that, while the heat transfered to the freon loop is generally lower, reflecting the avionics power down, heat transfer from the air to the water loop ranges both above and below the nominal data. This is a result of the cabin HX air flow being fixed at zero bypass. Since the cabin temperature was not being controlled to 70°F, heat removal was not significantly reduced when the heat load was reduced; the temperature instead fell to 59°F (fig. 5).

Figures 5-7 display temperature profiles of the cabin air loop, the ARS water loop, and the ATCS freon loop. On figure 5, prior to 30.5 hrs., traces 1 and 2 show the effect of the cabin HX air bypass in trying to maintain a 70°F cabin temperature (trace 3). After 30.5 hrs, when the bypass is forced to zero, the cabin temperature falls dramatically in response to a reduced heat load. It should be noted that with the exception of the sleep period, cabin temperature cannot be maintained at 70°F, and rises rapidly during deorbit preparations.

When the water loop bypass is set to zero at 9 psia, the flowrate through the interchanger increases from 950 lb/hr to 1280 lb/hr. This causes the interchanger water discharge temperature (figure 6, trace 1) to operate approximately 4°F higher than it would for the nominal case. The water inlet flow to the avionics bays however, (trace 3) is approximately 4°F lower than nominal, dropping as low as 51°F and remaining below 55°F for almost the entire period. This offers some concern as to the possibility of condensation in the avionics bays.

The freon loop configuration is not changed for 9 psia operations, and the temperature levels (figure 7) are not changed except as they are affected by the lower heat load picked up at the interchanger (figure 4)./ The radiator inlet temperatures are as much as 10°F lower than in the nominal case.

The air flowrate through the cabin fans and heat exchanger are shown on figure 8, as are the cabin temperature and dewpoint. Flowrate variations are caused by changes to the air density as a result of temperature, pressure, and atmospheric makeup changes. The dewpoint, except for a sharp transient when

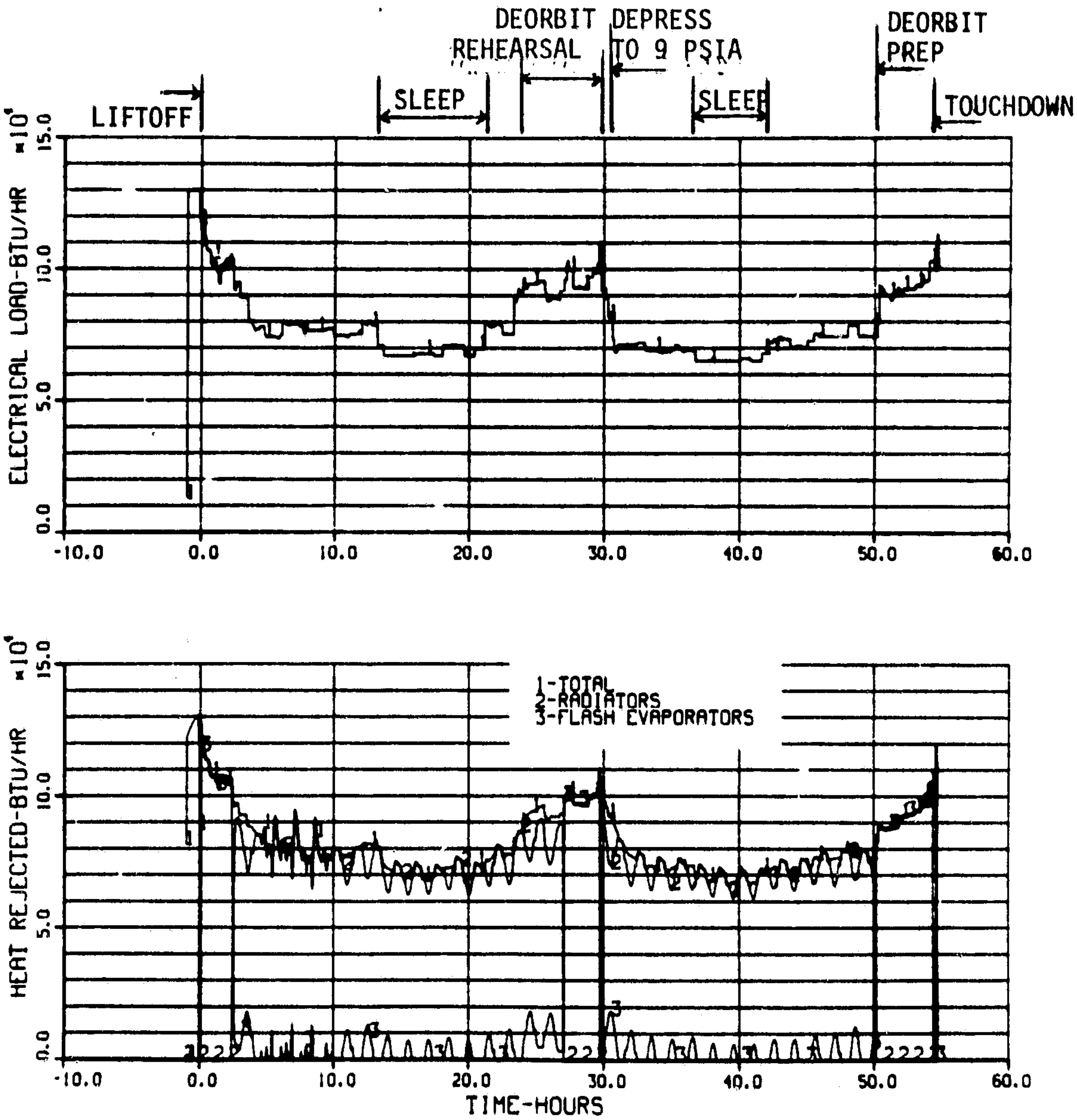

FIGURE 3 HEAT LOADS ON ECLSS

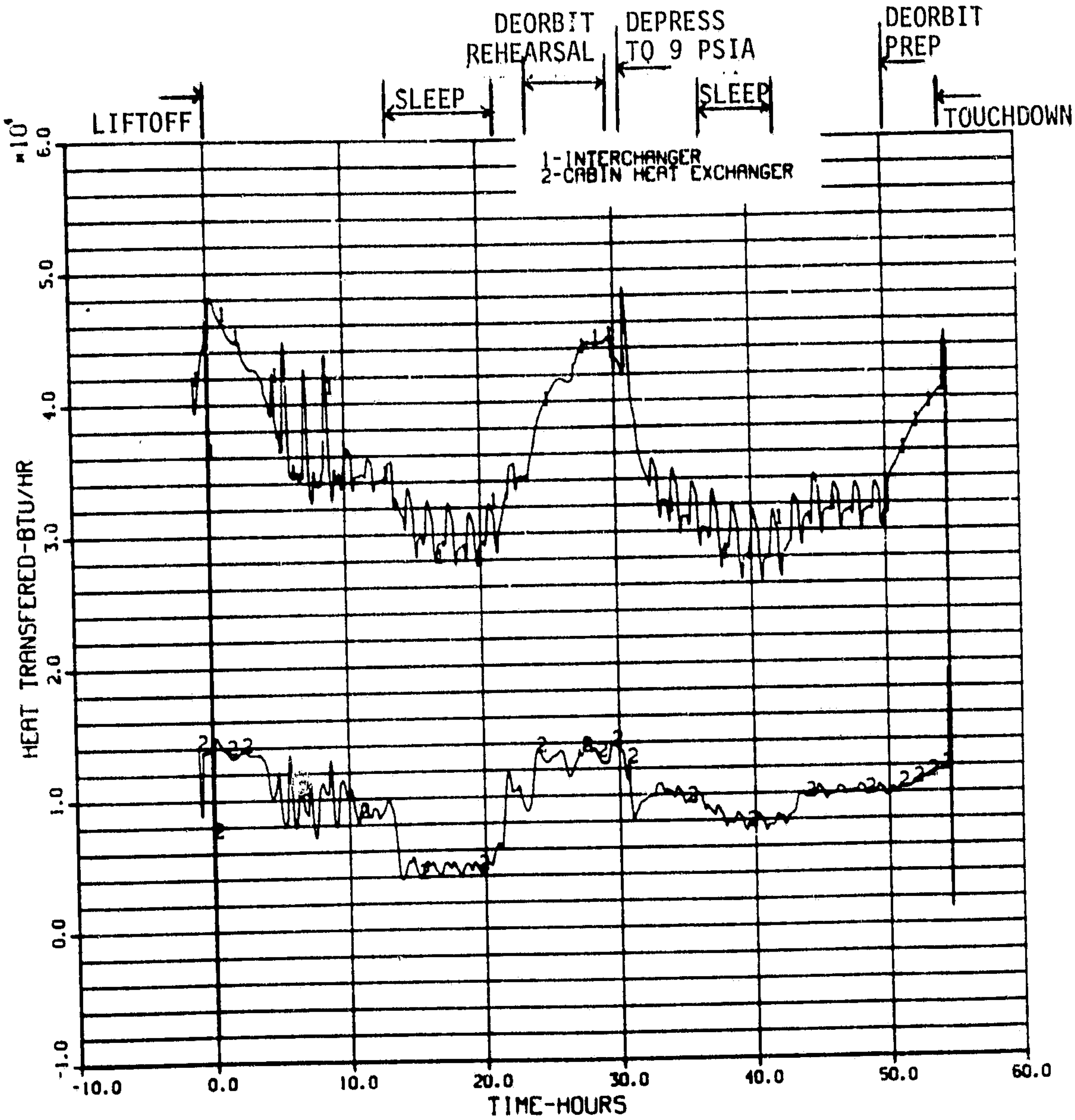

FIGURE 4   ATMOSPHERIC REVITALIZATION SYSTEM
HEAT TRANSFER RATES

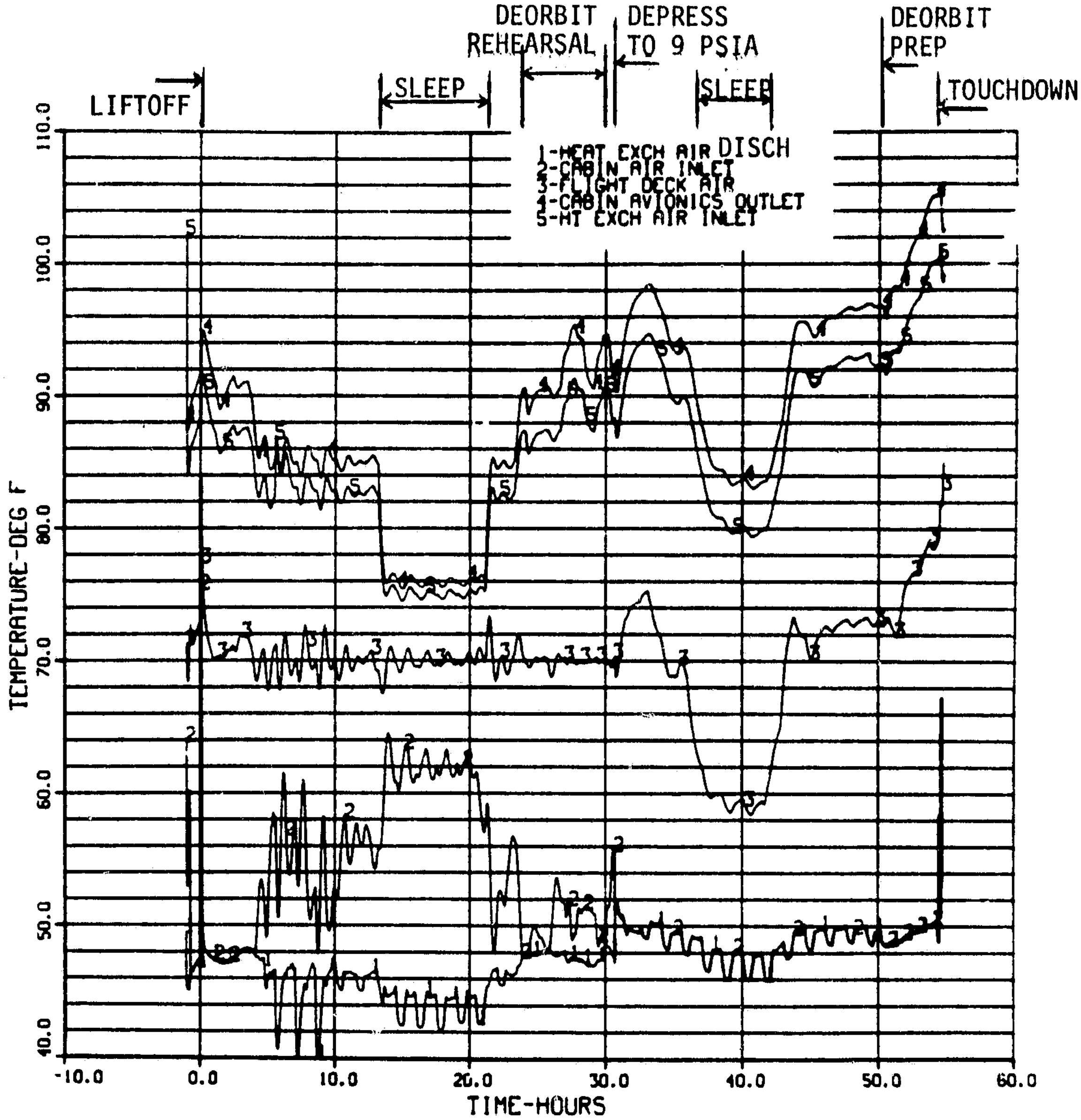

FIGURE 5 CABIN AIR LOOP THERMAL PROFILE

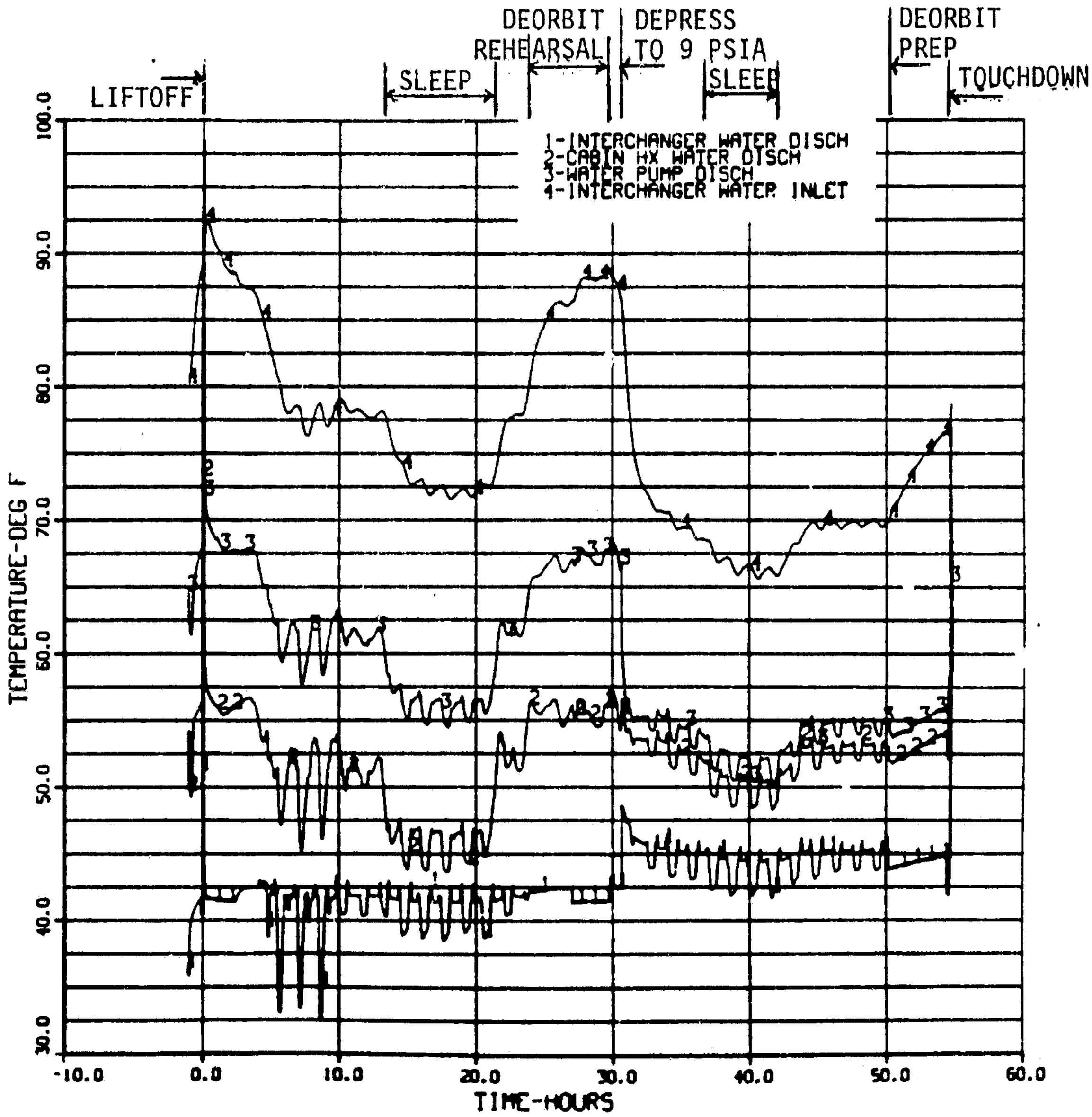

FIGURE 6 ARS WATER LOOP THERMAL PROFILE

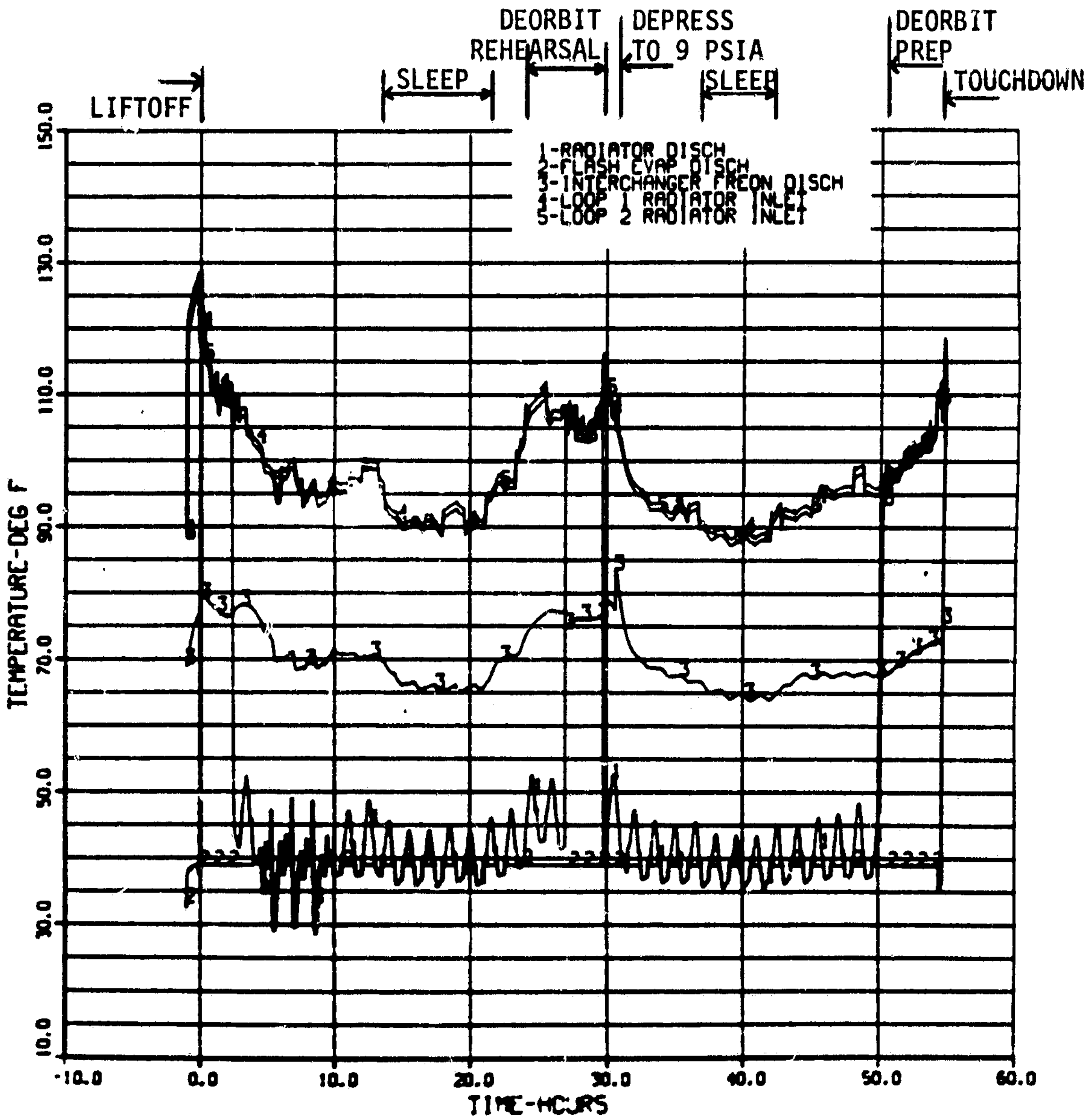

FIGURE 7   ATCS FREON LOOP THERMAL PROFILE

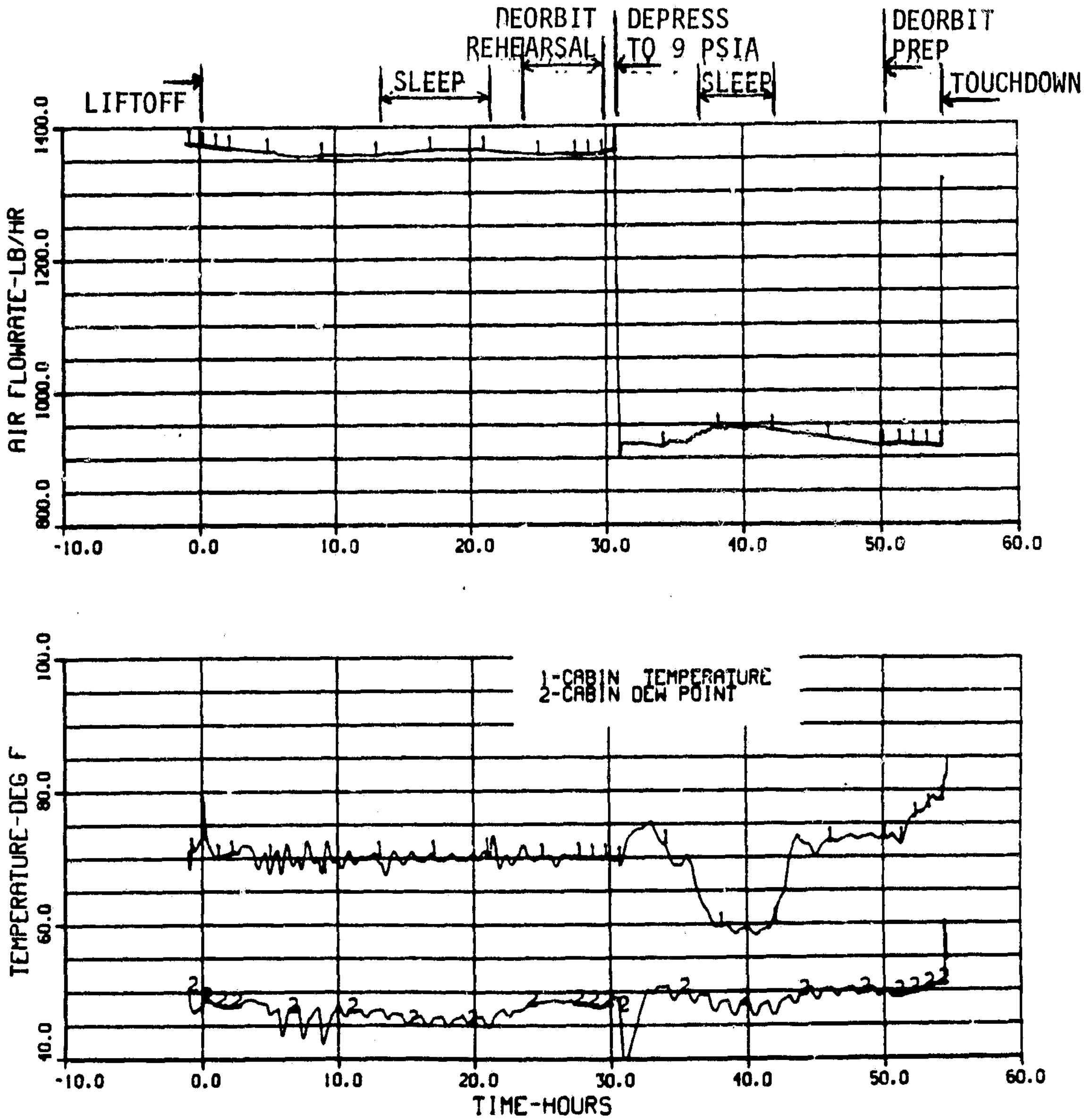

FIGURE 8 CABIN FLOWRATE AND TEMPERATURES

the cabin is vented, generally runs about 2°F higher than for the nominal case. The total flowrate through the 3 IMU's along with the IMU air inlet and outlet temperatures are presented on figure 9. The air outlet temperature (trace 2) exceeded the 130°F limit published in the SODB. However, the analysis does not model the operation of the IMU heaters, and it is expected that, at higher temperatures such as are seen in this analysis, there will be considerably less heater operation than was assumed for this analysis. Further, this 130°F air discharge limit is being superseded by a nonlinear air inlet temperature limit (Reference 15). This newer limit is shown on trace 4. Consequently, this apparent violation is not considered to be a problem.

The avionics bay temperatures (figure 10-13) were approximately 10°F lower than in the nominal case, primarily because the water bypass was set to zero, but also, partially because of the reduced heat loads. The air inlet temperature limits (trace 4 on figures 10-12, trace 5 on fig. 13) were determined by accepting the maximum air discharge temperature limit (130°) and multiplying the allowable temperature rise (35°F @ 14.7 psia) by the ratio of the change in air flowrate. This yields a limit of 72.8°F at 9 psia. Since the various items of avionics equipment are not individually modeled, the only way to assure adequate cooling for each item is to maintain the air inlet temperature below this limit. It is apparent from the data that a margin of 10 to 15°F was maintained on orbit, and at least 5°F during deorbit preparation. When the analysis was performed with GPC #1 also powered up, the bay 1 air inlet temperature prior to deorbit prep was increased approx. 5°F and the air discharge temperature about 20°F (figure 11). Inlet temperature however, remained at least 5°F below the limit.

It should be noted that the 72.8°F limit at 9 psia is based on a maximum air discharge temperature of 130°F. This limit is defined based on normal air pressure, density and flowrate. It has not yet been demonstrated that the 130°F limit is adequate at reduced pressures.

4.2.2 Consumables Evaluation

As was noted in section 4.2.1, the FES contributed less heat rejection at 9 psia than in the nominal case, consequently using less supply water. The resultant water level of 905 lb @ radiator retract (50.17 hrs.) shown on figure 14, compares to 885 lb @ 51.02 hrs on the nominal mission. Dumping of the supply water tanks is not required in either case.

Although a cabin repressurization is not reflected in the thermal analysis, repressurization was presumed to have occurred at 50 hrs for purposes of atmospheric gas consumables analysis. Results are presented in Table II. The negative N_2 margin shown there is not a concern, as it results from considering a contingency repressurization from 0 to 14.5 psia, which is no longer considered a requirement.

Consumables budgets were prepared for this particular analysis, and are presented in Tables II-VI. Contingency reserves were obtained from Reference 16.

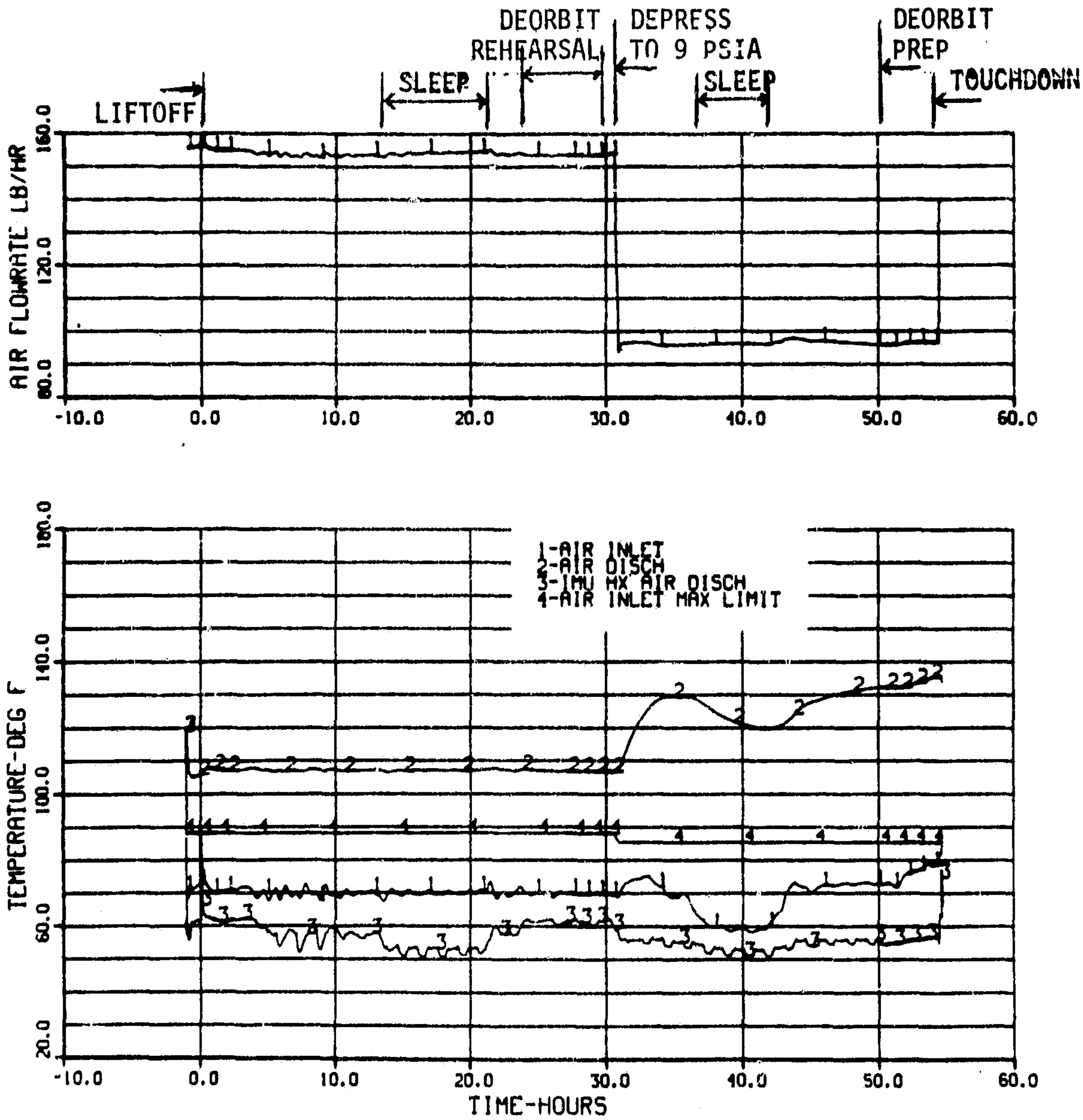

FIGURE 9 IMU THERMAL CONDITIONS

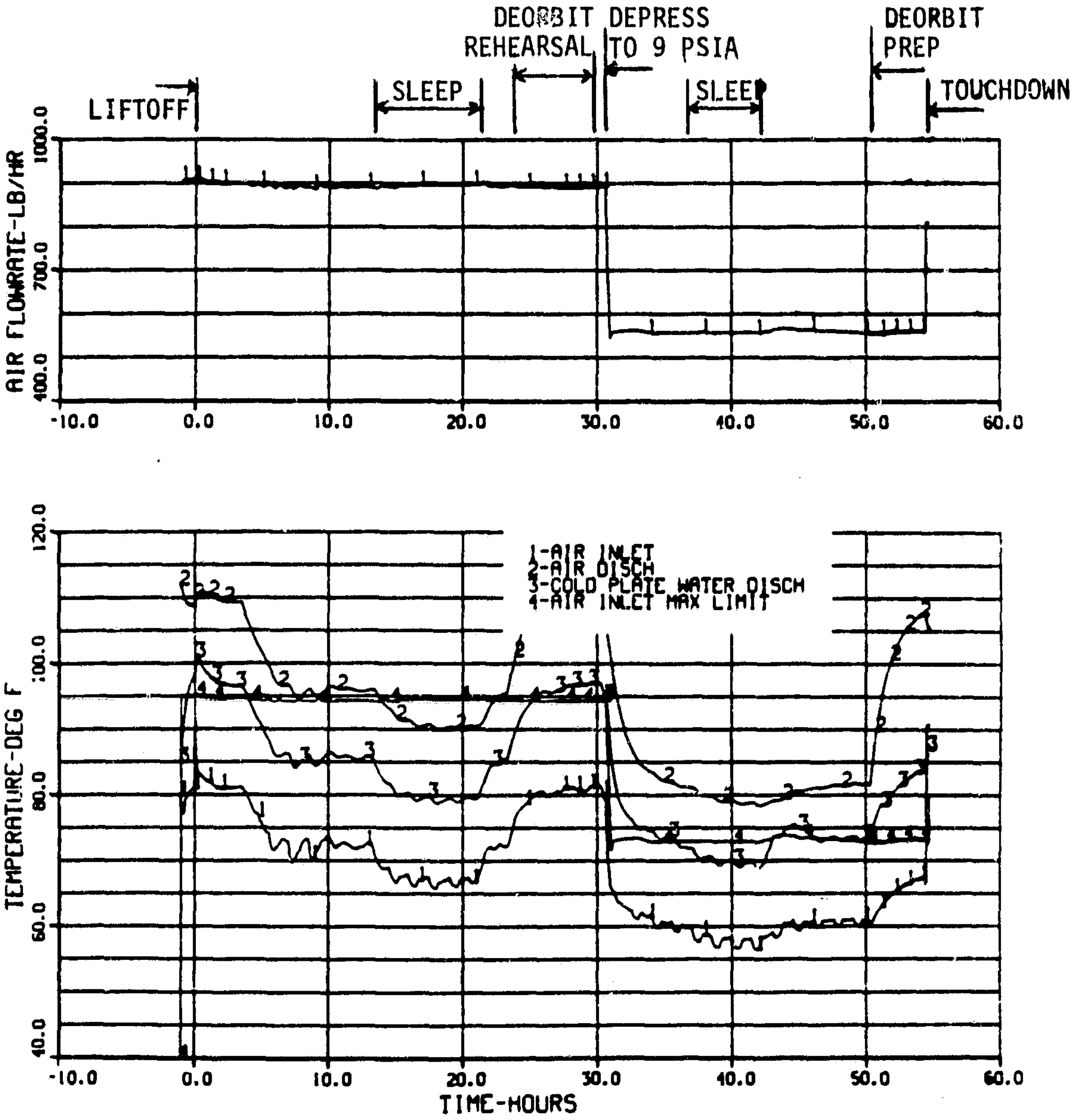

FIGURE 10 AVIONICS BAY 1 THERMAL CONDITIONS

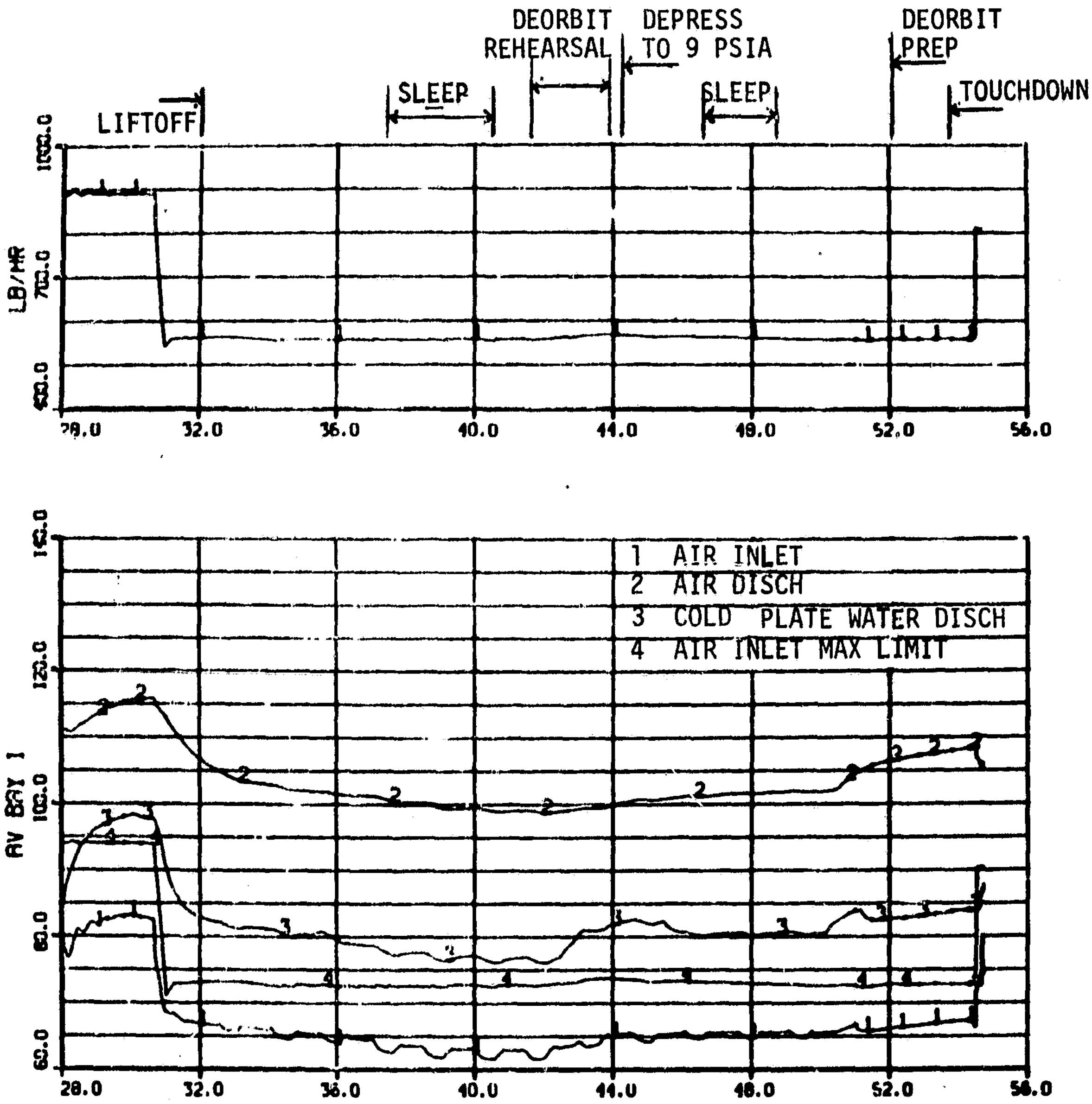

FIGURE 11 AVIONICS BAY 1 THERMAL CONDITIONS (4 GPC's)

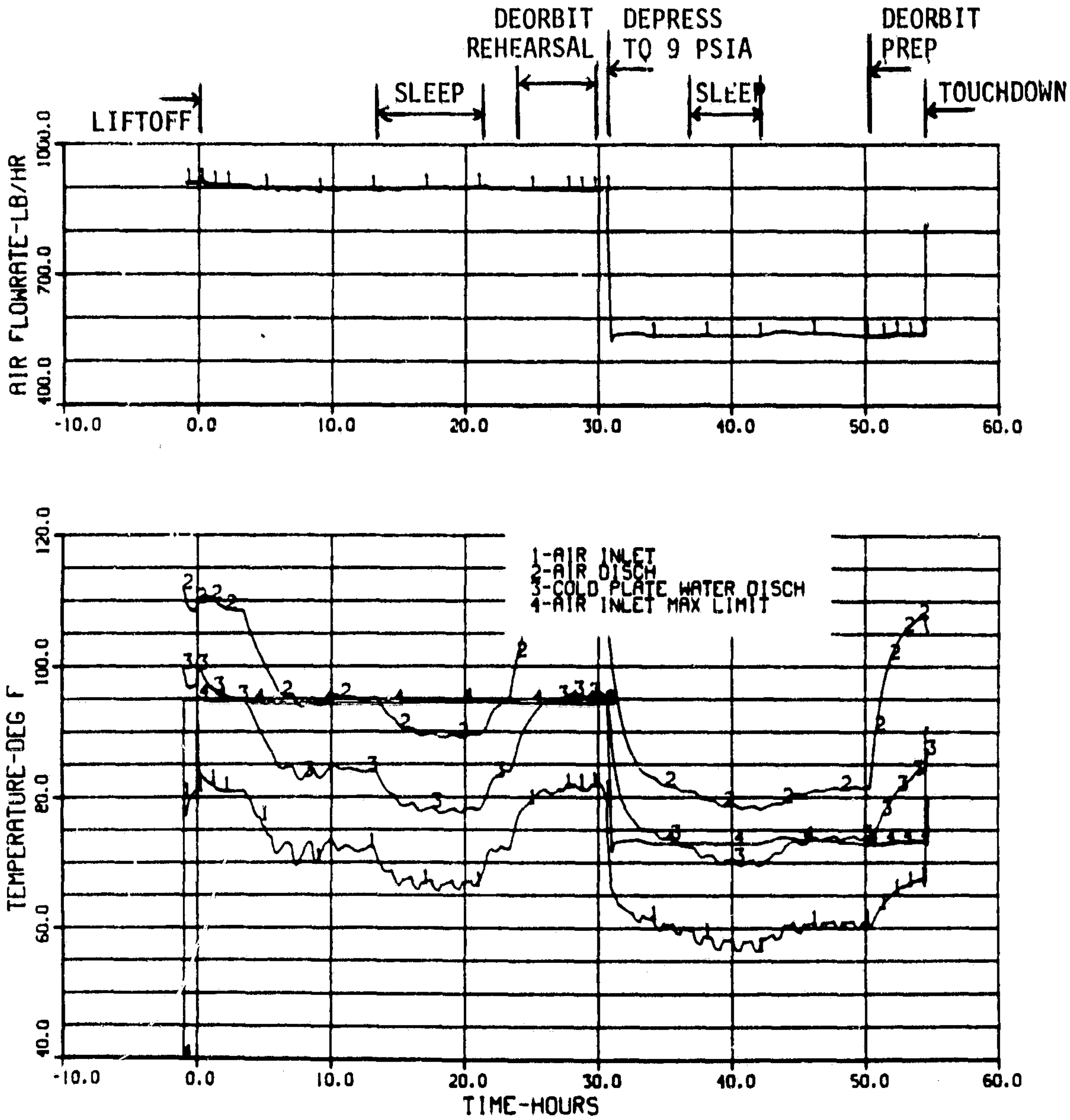

FIGURE 12 AVIONICS BAY 2 THERMAL CONDITIONS

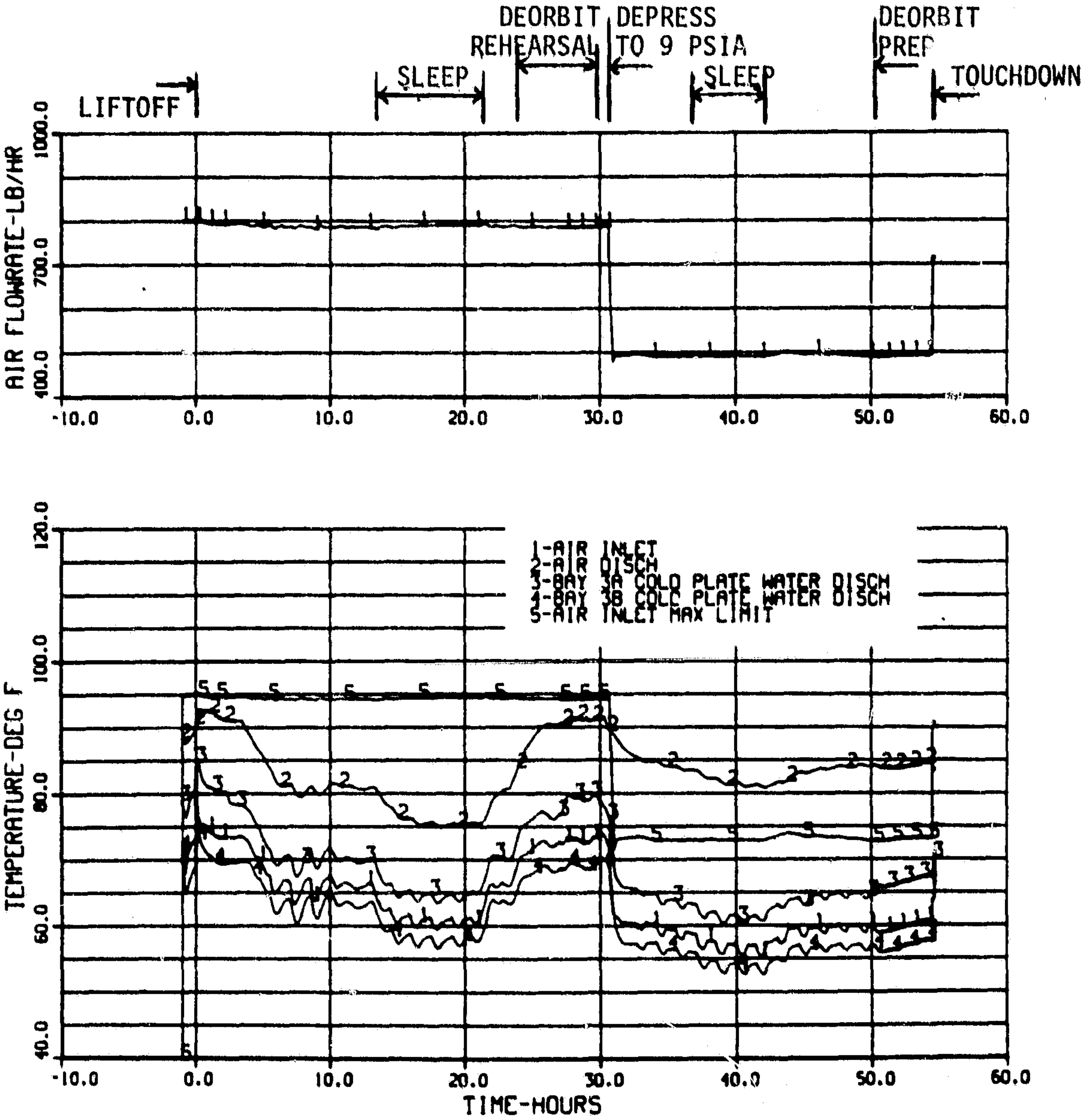

FIGURE 13 AVIONICS BAY 3 THERMAL CONDITIONS

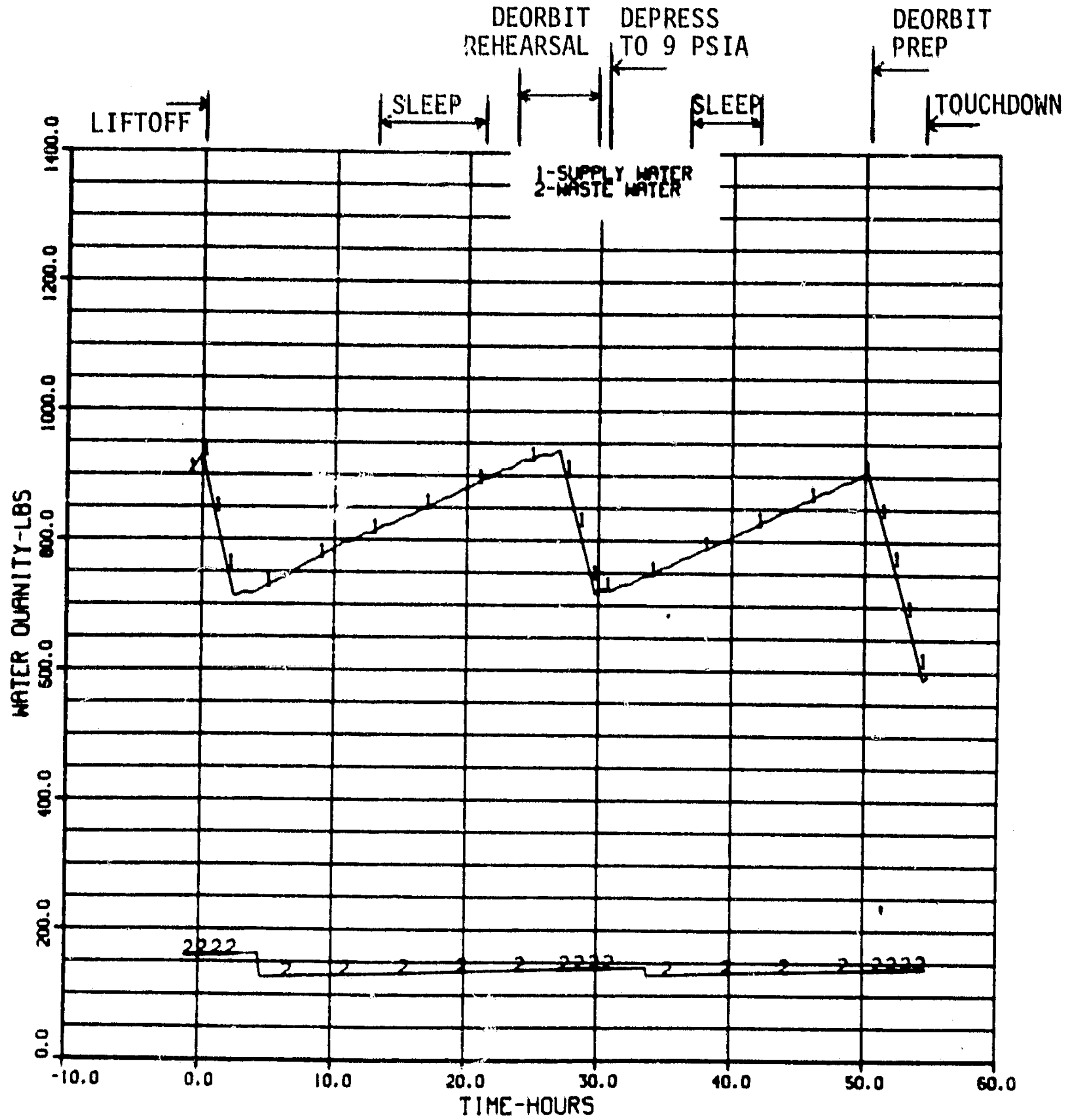

FIGURE 14 ORBITER WATER LEVELS

TABLE II

ECLSS ATMOSPHERIC GAS BUDGET

	CRYOGENIC OXYGEN (LB)		AUXILIARY OXYGEN (LB)		HI-PRESSURE NITROGEN (LB)	
Total Loaded		112.0[1]		66.0		262.2
Prelaunch Requirement	0		0		0	
Launch Load		112.0		66.0		262.2
Unusables: Residual	N/A[1]		11.0		26.0	
Available for Mission Planning		112.0		55.0		236.2
Reserves						
Measurement Error	N/A[1]		5.0		16.2	
Dispersion Allowance (10%)	2.8		0		7.8	
Contingency						
a) One day mission extension @ 14.5 psia	8.6±0.4		0		8.4±.4	
b) Cabin puncture[2]	26.9±1.3 (42.5±2.1)		29.0±1.4 (15.4±.8)		97.1±1.1 (135±6.5)	
c) Single cabin repress to 14.7 psia	0		41.8±2.1		131.6±6.6	
d) Single cabin repress to 8.0 psia	0		28.7±1.4		66.4±3.3	
e) Single cabin repress - 8 to 14.7 psia	0		13.1±.7		65.2±3.3	
f) One EVA @ 14.5 psia	7.5±.3		0		8.2±0.4	
Total Reserves[3]	40.9		48.9		162.2	
Available for nominal mission		71.1		6.1		74.0
Flight Requirement						
Leakage & Metabolic	12.2		0		11.9	
2 EVA's (at 9 psia)	9.4		0		9.3	
Cabin Repress (9-14.5 psia)	6.5		0		57.2	
	28.1		0		78.4	
MARGIN		43.0		6.1		-4.4[4]

1. Two cryogenic tank sets contain 1574 lb of Oxygen, 112 lb of which are allocated to the ECLSS; unuseable and measurement error are accounted for in the PRSD budget.
2. Parenthetical numbers are requirements for a leak occurring at 9 psia. If the 14.5 psia leak requirement plus the 9-14.5 psi repress requirement exceed the 9 psi leak requirement, the 14.5 requirement is used; if not the 9 psi leak requirement, reduced by the repress requirement is used.
3. Includes the worst single contingency.
4. Negative N_2 margin occurs only as a result of considering worst possible (and probably unrealistic) contingency.

TABLE III

ECLSS AMMONIA BUDGET - 9 PSIA

	AMMONIA (LB)	
Total Loaded		97.6
Prelaunch Requirement	0	
Launch Load		97.6
Unusables: Residual	2.0	
Available for Mission Planning		95.6
Reserves:		
Measurement Error	5.4	
Dispersion Allowance (10%)	7.5	
Contingency: None identified	0	
Total	12.9	
Available For Nominal Mission		82.7
Flight Requirement	75.0	
MARGIN		7.7

TABLE IV

ECLSS LITHIUM HYDROXIDE BUDGET - 9 PSIA

	LiOH (CANISTERS)	
Total Loaded		6
Prelaunch Requirement	0	
Launch Load		6
Unusables	0	
Available for Mission Planning		6
Reserves:		
Measurement Error	0	
Dispersion Allowance	0	
Contingency	1	
TOTAL	1	
Available For Nominal Mission		5
Flight Requirement	4	
MARGIN		1

TABLE V

ECLSS WASTE WATER BUDGET - 9 PSIA

ITEM	ORBITER WASTE WATER (LB)	
Total Capacity		168.3
Prelaunch Requirement	-1.0	
Offload	9.3	
Launch Load (95%)	8.3	160.0
Unuseable: Residual	3.3	
Available for Mission Planning		156.7
Reserves:		
Measurement Error	8.4	
Dispersion/Flight Planning Uncertainty[1]	0.	
Total Reserves	8.4	
Available for Flight Management		148.3
Flight Requirement:		
Water Generated	30.4	
Water Dumped	48.0	
Net Use	17.6	
Available for Cooling at EOM		130.7

[1] Since the waste water tank is periodically dumped to 80% (132 lbs), the analysis dispersion is limited to the 8.4 lb measurement uncertainty.

TABLE VI

ECLSS POTABLE/SUPPLY WATER BUDGET - 9 PSIA

	SUPPLY WATER (LB)	
Total Capacity (6 Tanks)		1009.8
Prelaunch Requirement [1]	-27.8	
Offload	112.6	
Launch Load		925
Unuseable: Residual	19.8	
Available for Mission Planning		905.2
Reserves		
Measurement Uncertainty	50.4	
Dispersion/Flight Planning Uncertainty (10%)	188.0	
Contingency:		
1) Loss of one tank at PLDB Close	156.8	
2) Miss Deorbit Opportunity [2] (1 Orbit wait)	123.8 ± 6.2	
3) PLBD Fail to open [3]	313.3	
Total Reserves [4]	551.7	
Available for Flight Management		353.5
Flight Requirements:		
Crew Use	38.4	
Ascent Rqmt.	262.4	
Onorbit Reqmt.	422.4	
Descent Reqmt.	384.1	
Water Dumped	0	
Less Water Generated	772.4	
Net Water Generated	334.9	
MARGIN		18.6

[1] Water generated by fuel cells prior to Launch.

[2] Contingency occurs at the end of nominal mission.

[3] Contingency includes a maximum of 3 hours of normal on-orbit operation prior to deorbit preparation, plus a nominal deorbit preparation and descent.

[4] Includes the larger of contingency 3 or 1 plus 2.

[5] Includes deorbit rehearsal.

5.0 CONCLUSIONS

It should be understood that the Orbiter equipment located in the cabin is designed with the understanding that it will be operated at normal atmospheric pressures. Operating with a 9 psia cabin introduces the possibility that some unanticipated factor may cause problems. For instance the performance of the LiOH canisters at reduced pressures is not known. It is arguable whether this should be condoned in a less-than-emergency situation.

Specific conclusions which may be drawn from this analysis are:

a. There are no thermal nor ECLSS consumables problems with the mission power and timeline analyzed.

b. The water temperature entering the avionics bays is sufficiently cold that the possibility of condensation should be evaluated.

c. The power down is probably overly conservative, at least relative to the avionics bays. Additional power due to GPC 1 in bay 1 was accomodated with no problems.

d. Setting the cabin heat exchanger air bypass to zero is of questionable value. The cold soak effect obtained during the sleep period does not appear to last long enough to justify the crew discomfort at 59°F.

e. The amount of water bypass around the interchanger should be evaluated. A better trade off of cabin vs. avionics bay temperatures might be obtained with some degree of bypass.

f. The current procedures for monitoring cabin pressure at 9 psia should be re-evaluated. These procedures assume pressure will decay due only to leakage and breathing. This analysis however, shows that temperature will have a significant effect, particularly if the cabin air bypass is set to zero.

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