

STS-4 Orbiter Mission Report

September 1982



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

STS-4 ORBITER

MISSION REPORT

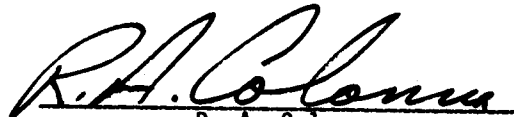
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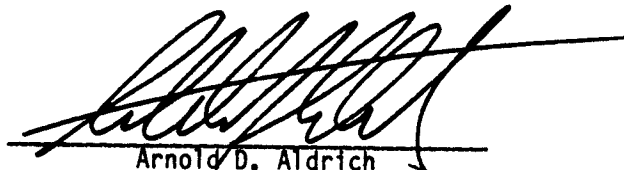


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1.0 INTRODUCTION/SUMMARY

The STS-4 Orbiter mission report presents a summary of the evaluation and analysis of the Orbiter subsystems performance. Likewise, the report presents a discussion of and the resolution for all Orbiter and Government furnished equipment anomalies, and a discussion of the flight test objectives accomplished.

The successful STS-4 mission was flown as planned with the launch on June 27, 1982, and the landing on July 4, 1982. The crew for the fourth orbital flight test was Captain T. K. Mattingly, Commander, and Henry W. Hartsfield, Jr., Pilot.

Major activities during the fourth orbital flight test included remote manipulator system operations with a 900-lb payload (Induced Environment Contamination Monitor). This flight also included the first Department of Defense payload (DOD 82-1). All of the Orbiter services required by the Payload Integration Plan, annexes, etc. were supplied as planned with one exception. The wiring harness between the crew cabin area and the GAS (Get-Away Special) experiment was not satisfactory, but the crew were successful in working around this problem and activating the GAS experiment.

All spacecraft systems operated satisfactorily throughout the STS-4 mission with only minor problems that did not impact the results of the mission. The sequence of events for the flight is presented in table 1-1.

The crew report of STS-4 is published as Appendix A to this report. It is available by request from R. W. Frické, mail code WC6 at Johnson Space Center.

Standard units of measurement are used throughout the report. Unless otherwise specified, all given times are referenced to G.m.t. (Greenwich mean time), with lift-off specified as 178:14:59:59.8 G.m.t. (day:hour:minute:second). All weights are referenced to earth gravity.

TABLE 1-1.- STS-4 SEQUENCE OF EVENTS

Event	Planned* G.m.t.	Actual G.m.t.
APU activation (1)	178:14:54:57	178:14:55:07
(2)		178:14:55:08
(3)		178:14:55:08
MPS start command (Engine 3)	178:14:59:54	178:14:59:53.2
MPS 90 percent thrust (Engine 1)	178:14:59:57.4	178:14:59:57.5
SRB ignition command from GPC (lift-off)	178:15:00:00	178:14:59:59.8
Main engine throttledown to 68 percent thrust	178:15:00:29.8	178:15:00:36.6
MPS throttleup to 100 percent thrust	178:15:00:51.2	178:15:00:50.7
Maximum dynamic pressure	178:15:01:05	178:15:01:14.8
SRB separation command	178:15:02:05	178:15:02:10.8
MPS throttledown for 3g acceleration	178:15:07:36	178:15:07:38.4
3g acceleration	178:15:07:36.6	178:15:07:39.8
Main engine cutoff (MECO) command	178:15:08:31.2	178:15:08:32.5
External tank separation	178:15:08:49.2	178:15:08:50.6
OMS-1 ignition	178:15:10:34	178:15:10:33.8
OMS-1 cutoff	178:15:12:07	178:15:12:01.8
APU deactivation (1)	178:15:15:00	178:15:14:28
(2)		178:15:14:31
(3)		178:15:14:34
OMS-2 ignition	178:15:40:51	178:15:37:40.8
OMS-2 cutoff	178:15:42:22	178:15:39:25.8
Payload bay doors start opening command		178:16:40
Payload bay doors open		178:17:00:52
OMS-3 ignition	178:19:29:00	178:19:29:13.8
OMS-3 cutoff	178:19:29:36	178:19:29:45.8
OMS-4 ignition	178:20:14:00	178:20:14:11.8
OMS-4 cutoff	178:20:14:36	178:20:14:43.8
Mono Disperse Latex Reactor (MLR) activation	178:21:30:00	178:22:14:59
Continuous Flow Electrophoresis System (CFES) activation	179:11:25:00	179:11:25:00
MLR Deactivation	179:17:10:00	179:17:55:00
GLOW Activation	179:15:30:00	179:15:25:00
CFES Deactivation	179:19:50:00	179:19:50:00
DFES Activation	181:10:45:00	181:10:45:00
Getaway Special (GAS) Activation	179:11:25:00	181:11:15:00
CFES Deactivation	181:19:09:00	181:19:09:00
Begin second payload bay door operation		181:17:48:09
Port door failure to latch problem		181:17:57:00
Port door reopened		181:19:56:56
Begin third payload bay door operation		182:10:43:38
End third payload bay door (successful) operation		182:11:13:10
OMS-5 ignition		182:18:33:00
OMS-5 cutoff		182:18:33:17
Begin final payload bay door operation		185:11:47:14
End final payload bay door operation		185:12:11:03
APU 1 activation	185:15:12:00	185:15:27:00
Deorbit maneuver ignition	185:15:17:00	185:15:10:00
Deorbit maneuver cutoff	185:15:19:--	185:15:12:53.5
APU activation (2)	185:15:30:00	185:15:04:48
(3)	185:15:30:00	185:15:28:00
Entry interface (400,000 ft)	185:15:44:00	185:15:40:23
End blackout	185:16:01:00	185:15:56:47
Terminal area energy management	185:16:12:00	185:16:03:20
Main landing gear contact	185:16:14:00	185:16:09:39.9
Nose landing gear contact	185:16:14:30	185:16:09:52.8
Wheels stop	185:16:16:30	185:16:10:44
APU deactivation completion	185:16:30:00	185:16:30:46

2.0 ORBITER SUBSYSTEM PERFORMANCE

2.1 PROPULSION SYSTEMS

2.1.1 Main Propulsion System

The MPS (main propulsion system) performance was satisfactory during all prelaunch and mission activities. The scheduled activities from start of chilldown to SSME (Space Shuttle Main Engine) ignition, including the planned hold periods, were conducted essentially as planned with lift-off occurring at the planned time. At T-3 hours, the LO₂ bleed valve was cycled closed in a special test. The "A" close microswitch worked according to specification, but the "B" close microswitch required 77 seconds to close. As a result, a decision was made to mask across both switches at T-9 minutes to preclude a possible launch scrub (Section 5.0, flight test problem report 2).

The GH₂ concentration in the LH₂ T-0 umbilical was less than 2 percent, except for a brief period when it went to 2.5 percent. Overall, these GH₂ concentrations were well below the 4-percent redline. The hazardous gas concentration in the aft fuselage never exceeded the established redline of 500-ppm GH₂.

Figure 2-1 contains the main engine inlet pre-start propellant conditions and ICD (Interface Control Document) start box requirements. The conditions were within the pre-start box.

Ignition of the main engines was commanded at 178:14:59:53.229 G.m.t. with engine no. 3 starting first as planned. Guidance-commanded MECO (main engine cutoff) occurred at 178:15:08:32.509 G.m.t. The total thrusting time on each of the main engines was approximately 8 minutes, 33 seconds, which includes approximately 7 seconds for the start transient plus burn time prior to SRB (solid rocket booster) ignition command. The LO₂ low-level cut-off was unexpectedly triggered after the MECO command was given.

The overall operation of the Orbiter propellant feedlines were satisfactory during ascent. The operating band for feedline temperatures and pressures were within the ICD requirements, as shown in figure 2-2, for mainstage operation of the Shuttle main engines. The feedline data for STS-4 compared very favorably with the data from both STS-1 and STS-3. A failure in the propellant feedline area was noted during the postflight inspection at DFRF (Dryden Flight Research Facility). The LO₂ 17-inch disconnect flow tube (liner) was damaged (bent inward). Section 5.0, flight test problem report 21 discusses this condition.

The propellant dump from the Orbiter feedlines was initiated 2 minutes after MECO and continued for 3 minutes and 2 seconds. Within a few minutes after the dump was completed, the Orbiter feed system was vacuum inerted by opening the fill and drain valves for a period of approximately 12 minutes and 40 minutes. Also, as in all previous flights, post-dump pressure rises in both feed systems and aft end "snow" particles were observed indicating incomplete elimination of propellants during the dump.

The MPS (main propulsion system) helium system performed satisfactorily while on-orbit and from entry through post-landing operations. The excessive usage observed during the STS-3 post-landing engine purge was not experienced on this flight, probably as a result of the replacement of a defective LO₂ POGO recirculation check valve.

Two failures involving temperature transducers that went off-scale high during ascent were noted. One of these transducers, MPS engine 2 GH₂ pressure outlet temperature, has failed on every flight. The second instrument that failed was the MPS engine 3 LH₂ temperature transducer. Section 5.0, flight test problem report 6 contains a discussion of both failures.

Engine 1 ○ Engine 2 △ Engine 3 □

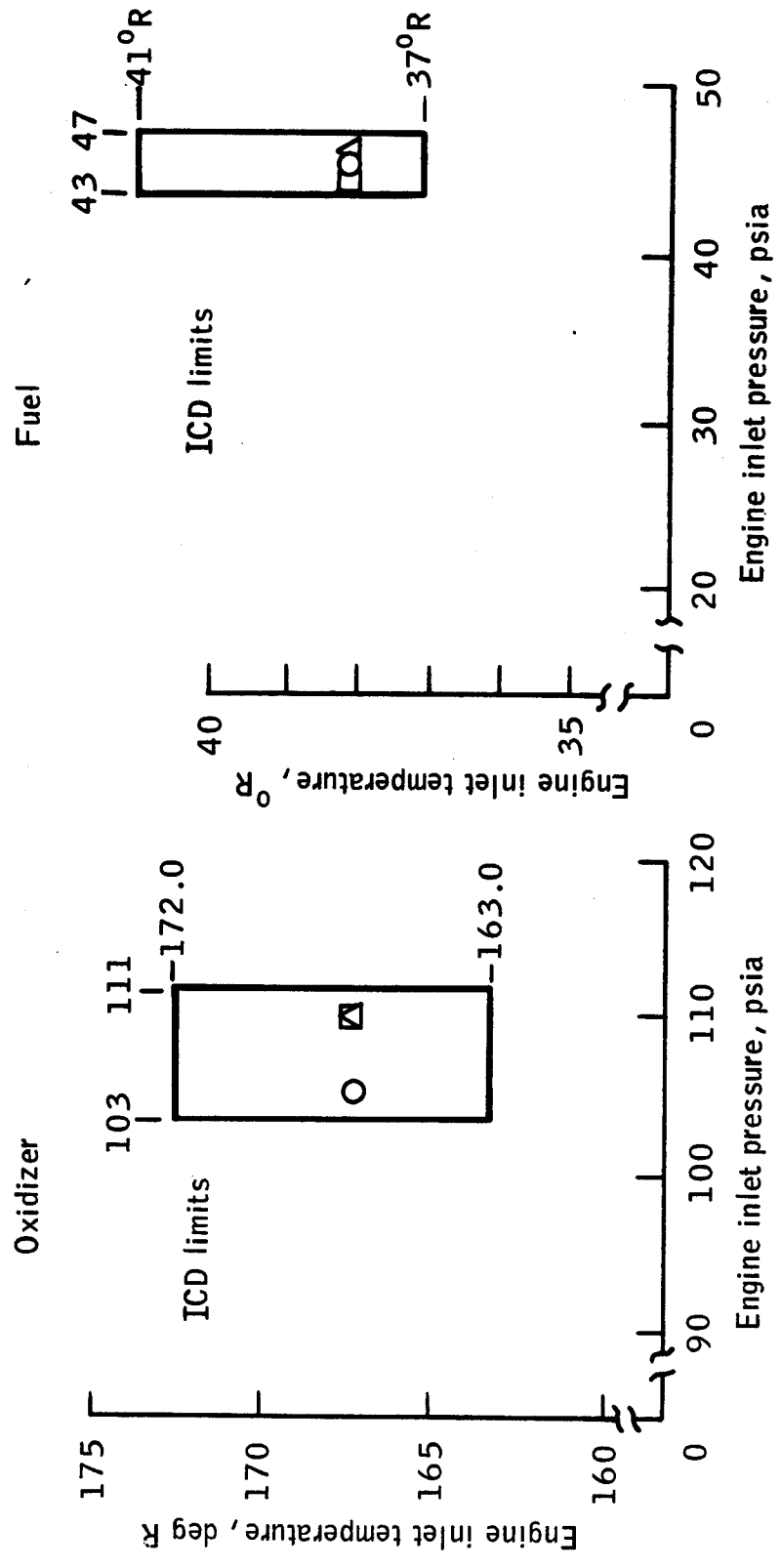


Figure 2-1.- Prestart propellant conditions.

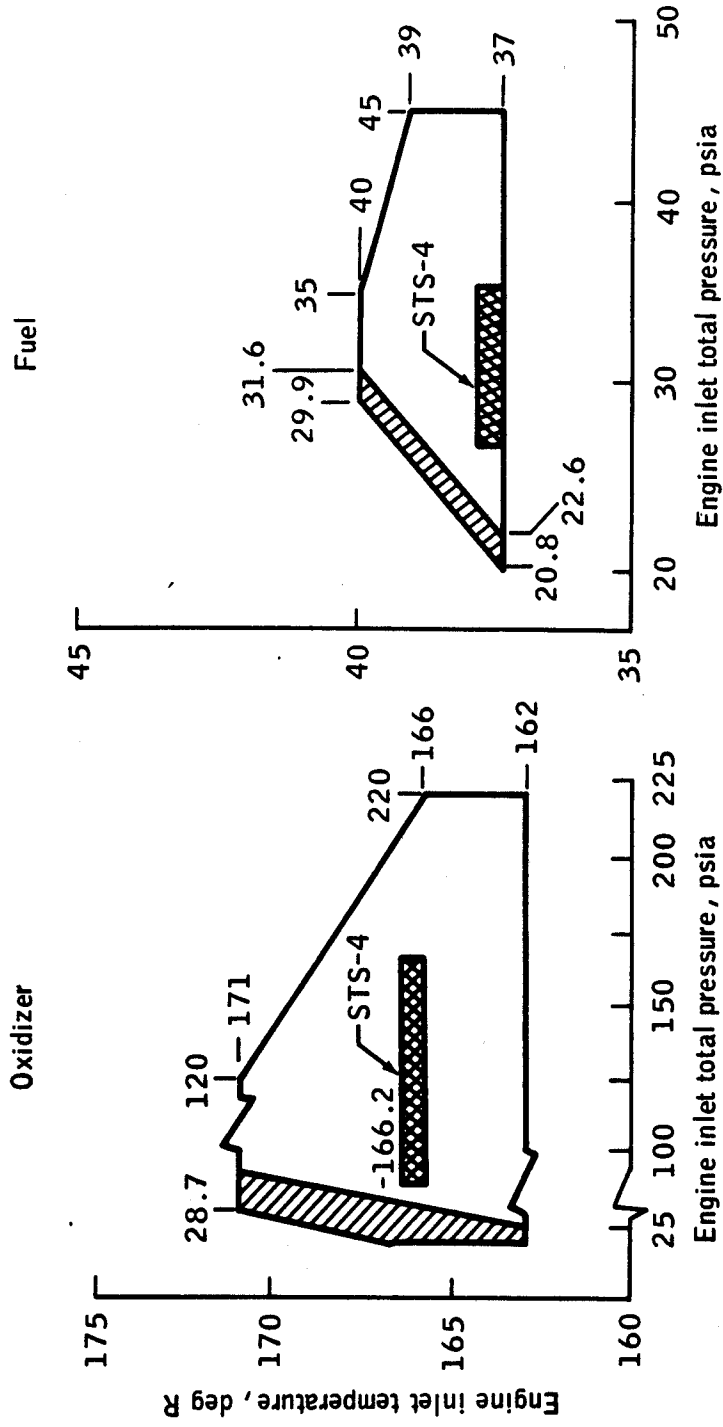


Figure 2-2.- Engine propellant inlet conditions (mainstage operation) .

Data were obtained in support of all 14 MPS FTR's (Flight Test Requirements). The eight FTR's considered closed at this time are:

- 41VV002 - Performance of MPS helium system;
- 41VV003 - Performance of liquid oxygen pressurization system;
- 41VV004 - Performance of liquid hydrogen pressurization system;
- 41VV005 - Propellant conditions at liquid oxygen inlet and external tank discharge within specifications;
- 41VV006 - Propellant conditions at liquid hydrogen inlet and external tank discharge within specifications;
- 41VV007 - Performance of liquid oxygen and hydrogen feedline relief valve;
- 41VV009 - Events between MECO and external tank separation follow planned sequence;
- 41VV024 - Performance of longitudinal oscillation (POGO) suppression system.

The six FTR's not considered complete include five that require assessment of performance involving residuals and loading accuracies. These FTR's are:

- 41VV010 - Establishing timeline for post-MECO automatic propellant dump;
- 41VV011 - Establishing close tolerance on liquid oxygen residuals;
- 41VV012 - Establishing close tolerance on liquid hydrogen residuals;
- 41VV013 - Evaluate the analytically established vacuum inerting sequence and timeline;
- 41VV019 - Develop from flight data the procedures to fulfill liquid oxygen loading accuracy requirements;
- 41VV023 - Verify and assure MPS performance is within limits.

2.1.2 Orbital Maneuvering Subsystem

The OMS (orbital maneuvering subsystem) was used for six firings during the STS-4 mission, and OMS propellants were supplied to the reaction control subsystem from both the left and right pods. One firing was made with a single engine (left pod); the remainder were dual-engine firings. A comparison between planned and actual ignition times, firing time, and ΔV (differential velocity) for each of the six OMS maneuvers is shown in table 2-I. All of the OMS maneuvers were performed in the normal feed mode. All data reviewed from these firings indicate normal system performance.

Extended tail-to-sun Orbiter attitudes resulted in OMS engine feedline temperatures that exceeded the FDA (fault detection annunciator) limits (the limits were reset to avoid alarms) and approached the OMS engine qualification limit of 125° F.

The OMS-to-RCS interconnect was used 6 times during the mission; the propellant supplied to the RCS was calculated at 692 lbm from the left pod and 1072 lbm from the right pod.

Table 2-II shows the calculated engine performance based on observed tank and engine inlet pressures. Engine performance was as expected, and valve timing and start and shut-down transients were normal. The engine pneumatic systems functioned normally during the flight. Due to the lower-than-expected left-engine pneumatic-bottle pressure at launch, the pneumatic pressure on that side reached approximately 1350 psia after the deorbit firing. This is the lowest GN₂ pressure experienced during the first four flights, but was still 150 psi above the flight redline, and pneumatic pack operation was not affected.

TABLE 2-I.- STS-4 OMS FIRING DATA

Event	Planned			Actual		
	Time of ignition, day:hr:min:sec, m.e.t.*	Firing Duration, sec	ΔV , ft/sec	Time of ignition, day:hr:min:sec, m.e.t.*	Firing Duration, sec	ΔV , ft/sec
OMS-1	00:00:10:34	94.1	152	00:00:10:33	88	153
OMS-2	00:00:37:39	104.2	175	00:00:37:41	104	174.1
OMS-3	00:04:29:12	36.5	62	00:04:29:13	32	54.2
OMS-4	00:05:14:13	36.2	62	00:05:14:13	32	54
OMS-5	N/A	N/A	N/A	04:03:33:00	17**	15
Deorbit	06:22:41:49	175.6	315	07:00:10:00	171	309

*m.e.t. = mission elapsed time

**One engine firing

TABLE 2-II.- OMS ENGINE PERFORMANCE SUMMARY

Left OMS Engine							
Maneuver no.	Calculated					Observed	
	I _{sp} , sec	Mixture ratio	W _{tot} , lbm/sec	P _c , percent	T _{regen} , F	P _c , percent	T _{regen} , F
OMS-1	314.7	1.664	19.02	103.9	225	102.7	232
OMS-2	314.7	1.661	19.16	104.7	223	103.4	232
OMS-3	314.8	1.670	19.18	104.3	223	103.7	232
OMS-4	314.7	1.661	19.18	104.8	222	103.4	232
OMS-5	314.6	1.665	19.18	104.7	217	103.4	226
Deorbit	314.7	1.665	19.26	105.2	218	104.0	229

Right OMS Engine							
Maneuver no.	Calculated					Observed	
	I _{sp} , sec	Mixture ratio	W _{tot} , lbm/sec	P _c , percent	T _{regen} , F	P _c , percent	T _{regen} , F
OMS-1	314.3	1.672	19.16	104.5	225	103.4	233
OMS-2	314.4	1.672	19.28	105.2	225	102.1	233
OMS-3	314.4	1.672	19.28	105.2	225	103.7	232
OMS-4	314.4	1.672	19.29	105.2	224	102.7	233
Deorbit	314.4	1.672	19.47	106.2	221	105.3	229

2.1.3 Reaction Control Subsystem

The RCS (reaction control subsystem) performed well during STS-4. One major anomaly, a leaking oxidizer valve on thruster F1L, and several minor anomalies (water behind the paper covers prelaunch; cool down on thruster F1F, and a bias between leak detectors on vernier thruster R5D) were encountered, but none were serious enough to impact the mission. Postflight inspection of the vernier thrusters showed wearout of the thrust chamber coating on thrusters R5R and F5L (Section 5.0, flight test problem 33).

Shortly before launch, water was discovered behind the covers on thrusters F1L and F3D, apparently because of improper installation of these covers. (Section 5.0, flight test problem report 22). Water in the thruster was a concern because of the possibility of its freezing during ascent and blocking the chamber-pressure transducer port, the thruster would be erroneously deselected by the RM (redundancy management). A decision was made that there was an insufficient amount of water trapped behind the covers to present a problem. Injector temperature sensors on F3D cooled to about 48° F during ascent, apparently because of water in the chamber, but it caused no problem during external tank separation. No cool down was noted on F1L.

For the first 1 1/2 hours of the flight, primary thruster F1F slowly cooled to 58° F and then warmed back up to a temperature where the thruster heater cycled off (Section 5.0, flight test problem report 6F). This is believed to be caused by a faulty thermal barrier seal between the engine and the Orbiter skin. This faulty barrier allowed water to penetrate into the can which surrounds the thruster and to soak the insulation. The cooling was caused by the evaporation/sublimation of this water in a vacuum. After it warmed up, the thruster performed normally.

The overall propellant usage for STS-4 was very close to the predicted amount. Deviations in the flight plan, i.e., the addition of the "shopping list" item Loaded RMS/PRCS Interaction test, the deletion of the LIA test, the higher consumption during the unloaded RMS/PRCS test and the rearrangement of the thermal FTO's, all contributed to differences between the planned and actual consumption. A tabulation of propellant used from the RCS as a function of flight phase follows:

QUANTITY OF PROPELLANT USED, LB

Mission phase	Left RCS	Right RCS	Forward RCS
Ascent	204	217	167
On-orbit	772	732	1576
Deorbit to entry interface	153	167	164
Entry	583	505	-

In addition, the aft RCS also consumed propellant from the OMS tanks. In the interconnect configuration, the RCS consumed 692 lbm from the left OMS tanks, and 1072 lbm out of the right OMS.

Several FTO's (flight test objective) were accomplished by the RCS and these were the loaded and unloaded RMS/PRCS Interaction tests, thermal tests involving several 30-second firings of the -X thrusters, a minimum dead-band PRCS test, and the contamination mapping and plume flow field measurement experiments. All were successfully performed and no problems were encountered.

During the STS-3 mission, the leak detectors on thruster F5L developed a bias of about 40° to 50° F between the measurements. Troubleshooting on the ground during turnaround failed to duplicate the phenomenon. This bias was again seen during STS-4 on F5L, and a smaller bias (25° F) was seen on thruster R5D. (Section 5.0, flight test problem report 6D). These biases caused no mission impact.

Another discovery was made after STS-4 concerning verniers. Since STS-1, it has been known that the aft down-firing verniers were only delivering 55 to 60 percent of their rated thrust due to plume impingement on the vehicle. Inspection of the body flap after the STS-4 flight disclosed that, due to the plume impingement, a large area of tile had been severely eroded. (Section 5.0, flight test problem report 29.) Testing is planned at WSTF to evaluate several tile coatings in an attempt to alleviate this problem.

Shortly after the OMS-1 maneuver, thruster F1L developed an oxidizer leak and the RM automatically deselected the thruster. The leak apparently stopped, and the leak detector on the thruster began to warm up. Approximately 3 hours later, the crew closed forward manifold 1 isolation valves. During day 3 of the mission, a decision was made to reactivate that manifold and try to fire F1L to determine if it would operate normally. A staged representation was performed. F1L was fired, and performed normally, with no indication of a leak for the duration of the mission. However, during the night following the flight, the thruster began leaking oxidizer again. Section 5.0, flight test problem report 5 discusses this problem.

For the first three flights, leg A of the RCS helium pressurization system was used exclusively while on orbit, which meant that the leg B regulators had seen very little use. In an effort to get more time on these components, about half way through STS-4, the pressurization path was changed from leg A to leg B. This procedure is planned for all future flights.

Another reason for switching to leg B was that since STS-2, the regulator on that path in the forward oxidizer system had been locking-up high, a phenomena which had not occurred during the qualification program. By using it on orbit, it was seen that although it did have the unexplained high lock-up (257 to 258 psia versus the 253 maximum requirement), and a correspondingly high-regulated pressure (255 versus 245 ±3 psia) the regulator performed consistently, and showed no additional degradation.

Before STS-4, a concern existed in that the coating on the vernier thruster nozzle and combustion chamber could fail due to thermal cycling. Without the coating, the nozzle quickly erodes (burns through) causing hot gas to enter the interior of the vehicle. Postflight inspection of the vernier thrusters showed coating degradation on R5R and F5L. (Section 5.0, flight test problem report 33.)

2.2 POWER SYSTEMS

2.2.1 Auxiliary Power Unit Performance

The performance of the APU's (auxiliary power unit) was acceptable STS-4. The APU's were started 5 minutes before launch and were shut down after the MPS dump. The on-orbit flight control system checkout was performed with APU 1. For entry, APU 2 was started at deorbit firing ignition time minus 5 minutes and APU's 1 and 3 were started at entry interface minus 13 minutes.

APU OPERATING TIMES

Flight phase	APU, hr:min:sec		
	1	2	3
Ascent	0:19:21	0:19:23	0:19:26
On-orbit checkout	0:05:52	--	--
Entry	<u>1:02:49</u>	<u>1:25:54</u>	<u>1:02:46</u>
Total run time	1:28:02	1:45:17	1:22:12

Fuel consumption for the mission was 199 lb for APU 1, 217 lb for APU 2, and 184 lb for APU 3. The fuel consumption was determined from the PV (pressure-volume) gaging which is inaccurate. Actual usage will not be known until servicing for STS-5 when the residuals are offloaded.

Performance of all 3 APU's during the various mission phases was normal with the exception of the APU 3 lubrication system pressure (section 5.0 flight test problem report 5), a leak in the APU 3 seal cavity drain line (section 5.0, flight test problem report 15), and a slight leak in the APU 1 fuel system (section 5.0, flight test problem report 23); however none of these problems affected the APU's ability to provide power to the hydraulic pump.

The FP/GGVM (fuel pump gas generator valve module) water cooling system maintained the pump and GGVM below the 200° F limit during post-shutdown soakback. Both the primary and secondary water systems were exercised.

The thermal control system heaters for the APU fuel, lubrication oil, and water systems maintained temperatures within critical limits throughout the on-orbit APU non-operational periods. Both systems A and B were exercised.

A thermal DTO (detailed test objective) was performed to determine if the fuel feedline heaters could be safely turned off for entry to protect against a failed-on heater. At 42 hours mission elapsed time, the APU 1 feedline heaters were turned off. In 3 hours, the APU 1 fuel test line temperature (V46T0183A) 1 reached 37° F and the heaters were again turned on. Based upon this test, a decision was made to leave the heaters on for entry and accept the risk of a failed-on heater.

2.2.2 Hydraulic Subsystem

Hydraulic system operation was normal. WSB (water spray boiler) 3 incorporated a 0.80-inch diameter steam vent nozzle insert, and all 3 WSB's had a 5 lb preload of water. The lubrication oil warmup rates during prelaunch were similar to previous missions except system 3. The APU 3 had a high lubrication oil pressure indicating particle plugging of the lubrication oil filter and/or WSB lubrication oil tubes. This caused a reduced flow rate of the lubrication oil. WSB performance after lift-off is shown in figures 2-3, 2-4, and 2-5. Flashoff of water occurred 1 minute after lift-off and the lubrication oil temperature dropped as shown in the following table.

COMPARISON OF LUBRICATION OIL TEMPERATURE
OUT OF WATER SPRAY BOILER

Event	System, °F		
	1	2	3
APU Start	73	75	73
Lift-off	185	190	180
Minimum	125 (2.9 min)	127 (3 min)	125 (4.4 min)
MECO	249	240	178
Maximum	257	257	277

As can be seen in the table, the system 3 lubrication oil temperature increase, after flashoff, was much less than systems 1 and 2. This results from more water being retained in the boiler because of the reduced orifice size, causing less violent boiling. Also, it is believed that the heat load was less on APU 3.

WSB's 1 and 2 performed as expected, reaching the lubrication oil control point of 253°F just after MECO. Lubrication oil temperature control was normal. The boiler temperatures were at, or below, freezing for over 1 minute (system 1 - 7 minutes, 20 seconds to 9 minutes 2 seconds elapsed time and system 2 - 7 minutes, 31 seconds to 9 minutes, 29 seconds elapsed time) prior to spray control, and no freeze-up occurred.

The APU 3 lubrication oil temperature, after reaching 178° F at MECO, dropped 10° F due to excess water in the boiler passing over the lubrication oil tube bundle as it exits the boiler. The slope of the lubrication oil temperature profile, after MECO, matches systems 1 and 2 after flashoff, indicating that most of the free water was dumped. The lubrication oil temperatures passed through the control point (253° F) as the boiler temperature reached the triple point and no cooling occurred. It was concluded that WSB 3 froze up at 178:15:12:45 G.m.t. A theory existed that the freeze-up would not occur in zero g. The WSB 3 thawed 1 minute later and drove the lubrication oil temperature down to 230° F. This undershoot is typical of the WSB design and similar to WSB 3 on the STS-1 flight.

FCS (flight control system) checkout was conducted as planned at 184:07:54:55 G.m.t. with hydraulic system 1. System performance was satisfactory.

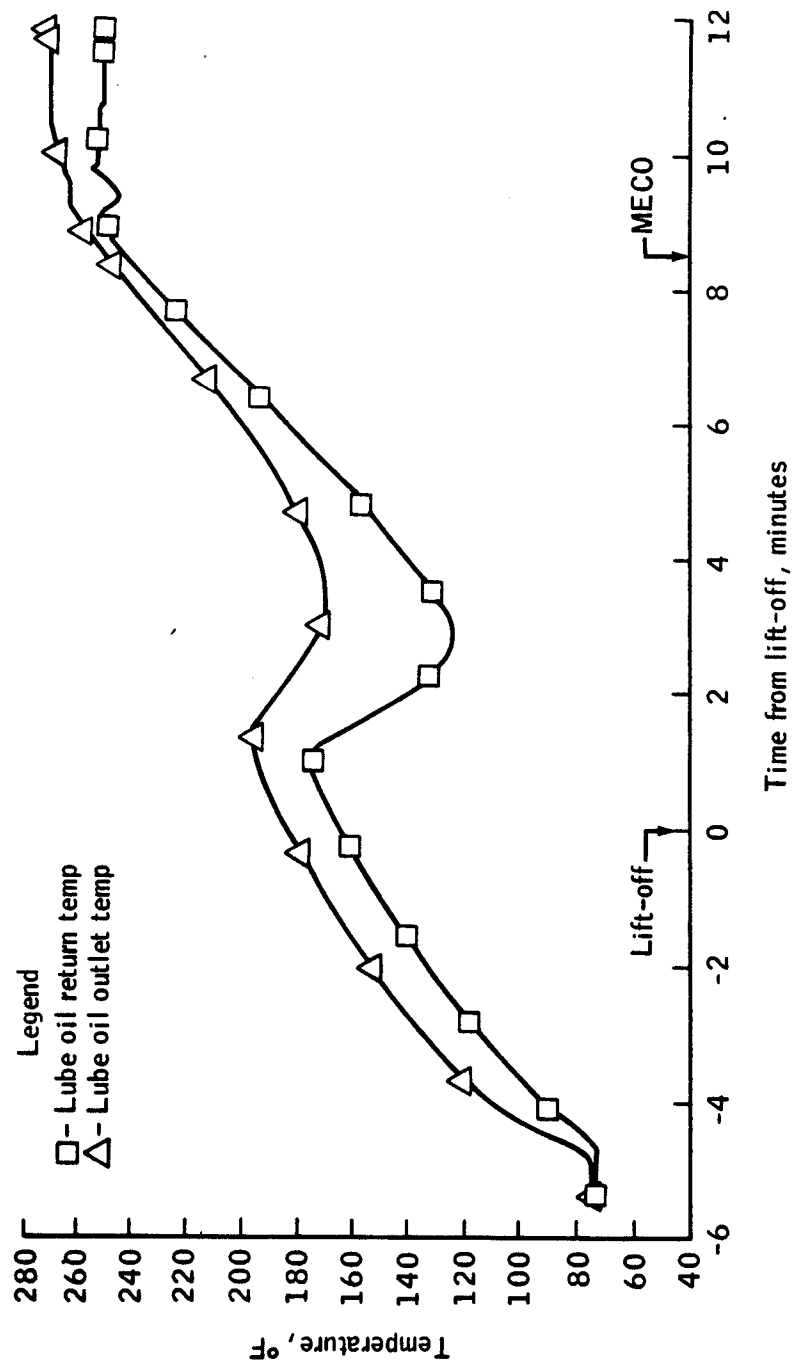


Figure 2-3.- Water spray boiler 1 performance.

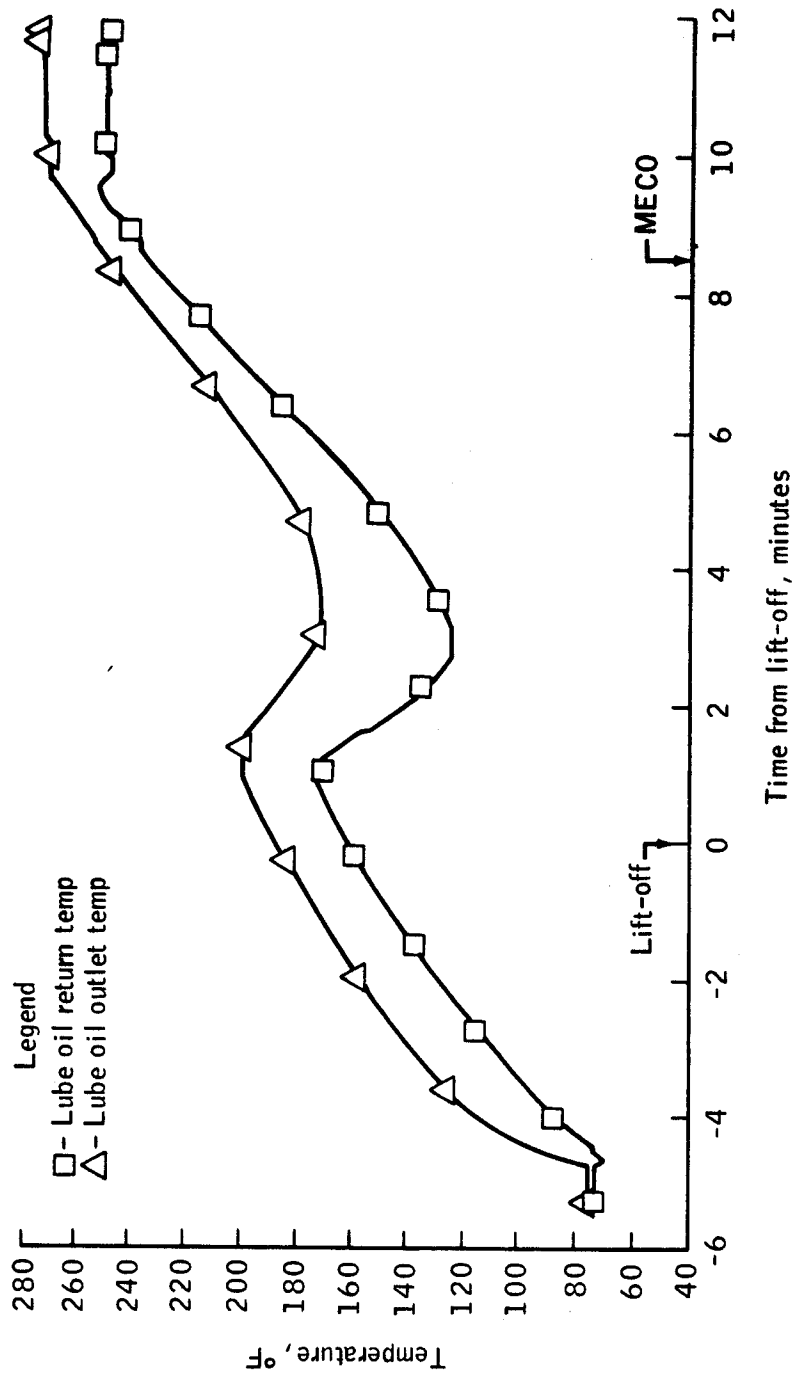


Figure 2-4.- Water spray boiler 2 performance.

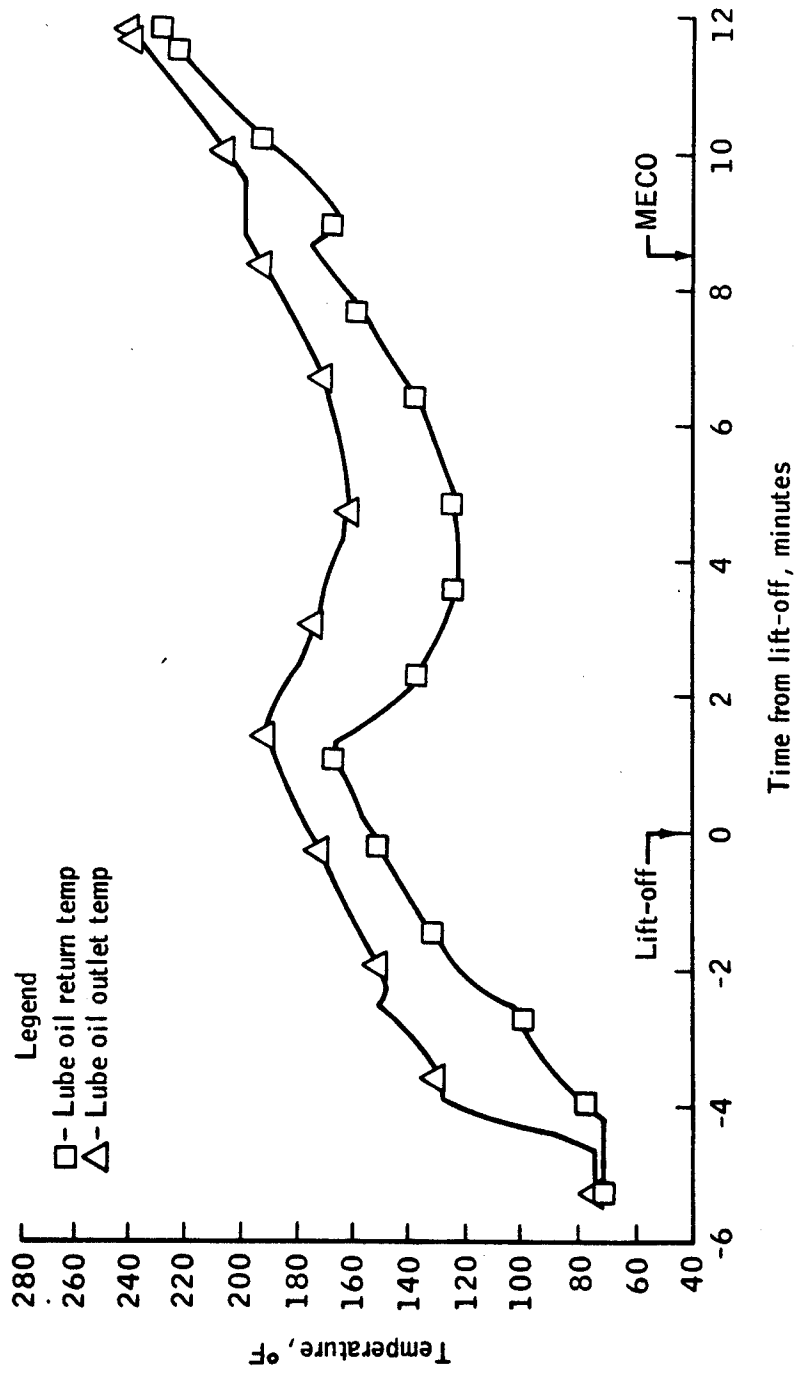


Figure 2-5.- Water spray boiler 3 performance.

2.2.3 Power Reactant Storage and Distribution

During the mission, the PRSD (power reactant storage and distribution) supplied 224 lb of hydrogen to the fuel cells and 1778 lb of oxygen to the fuel cells and environmental control.

During the flight, DTO (detailed test objective) 445-03 (Low Density Stratification Test) was completed. This DTO demonstrated low density/high flow performance. Additionally, PRSD tanks were depleted to residual quantities for the first time.

Three anomalies occurred in the PRSD system. The H₂ tank 2 quantity went from 94.4 percent to 42.7 percent early in the mission (Section 5.0, flight test problem report 6A).

During the first 24 hours of the mission, it was noticed that H₂ tank 4 quantity was lagging tank 3 by an increasing amount (see fig. 2-6). The two tanks were being managed identically so that their quantities should have matched within 5 percent. A heater failure was suspected when it was noted (27 hours m.e.t.) during a heater cycle, tank 4 pressure rose at half the rate of tank 3 (Section 5.0, flight test problem 7).

It was noted at 183:21:18 G.m.t. that H₂ tank 2 heater B was not coming on with heater A during a heater cycle. Event monitors indicated heater A-on and heater B-off with cabin switches for A and B both in the AUTO position (Section 5.0, flight test problem 16).

2.2.4 Power Generation System

The FCP's (fuel cell powerplant) satisfactorily provided all electrical power for the Orbiter during the mission. Their performance at startup was identical to that observed on STS-3; however, when the prelaunch conditioning loads were applied to the fuel cells at T minus 20 minutes, the condenser exit temperature for fuel cell 1 shifted downward 8° F from the STS-3 control temperature which was already 6° F low. This shift did not impact the mission. This problem is discussed in section 5.0, flight test problem report 3.

At about 130 hours elapsed time, the fuel cell 2 water relief valve heater B should have come on. The no. 1 and 3 relief valve heaters did cycle, but no. 2 did not come on (Section 5.0, flight test problem report 30).

The average power level over the mission was 15.2 kW at a 494 A rate. Performance was above predicted values for all 3 fuel cells from startup at 178:07:28 G.m.t., 178:07:50 G.m.t., and 178:08:12 G.m.t., respectively, through shutdown at 187:06:49 G.m.t., 187:06:14 G.m.t., and 187:06:37 G.m.t., respectively. Total mission operating times were 215 hours, 21 minutes; 214 hours, 24 minutes; and 214 hours, 25 minutes for fuel cells 1, 2, and 3, respectively. Total hours on the power sections are 516 hours; 631 hours, 49 minutes; and 546 hours, 44 minutes for fuel cells 1, 2, and 3, respectively.

For the first four flights, the following flight test objectives were accomplished:
FTR V45VV006-Fuel cell powerplant subsystem performance
FTR V45VV010-Fuel cell purging capability
FTR V45VV011-Fuel cell powerplant vent port and vent line entry thermal environment

There are no flight test objectives remaining to be accomplished, thus the fuel cells are qualified for operational flights.

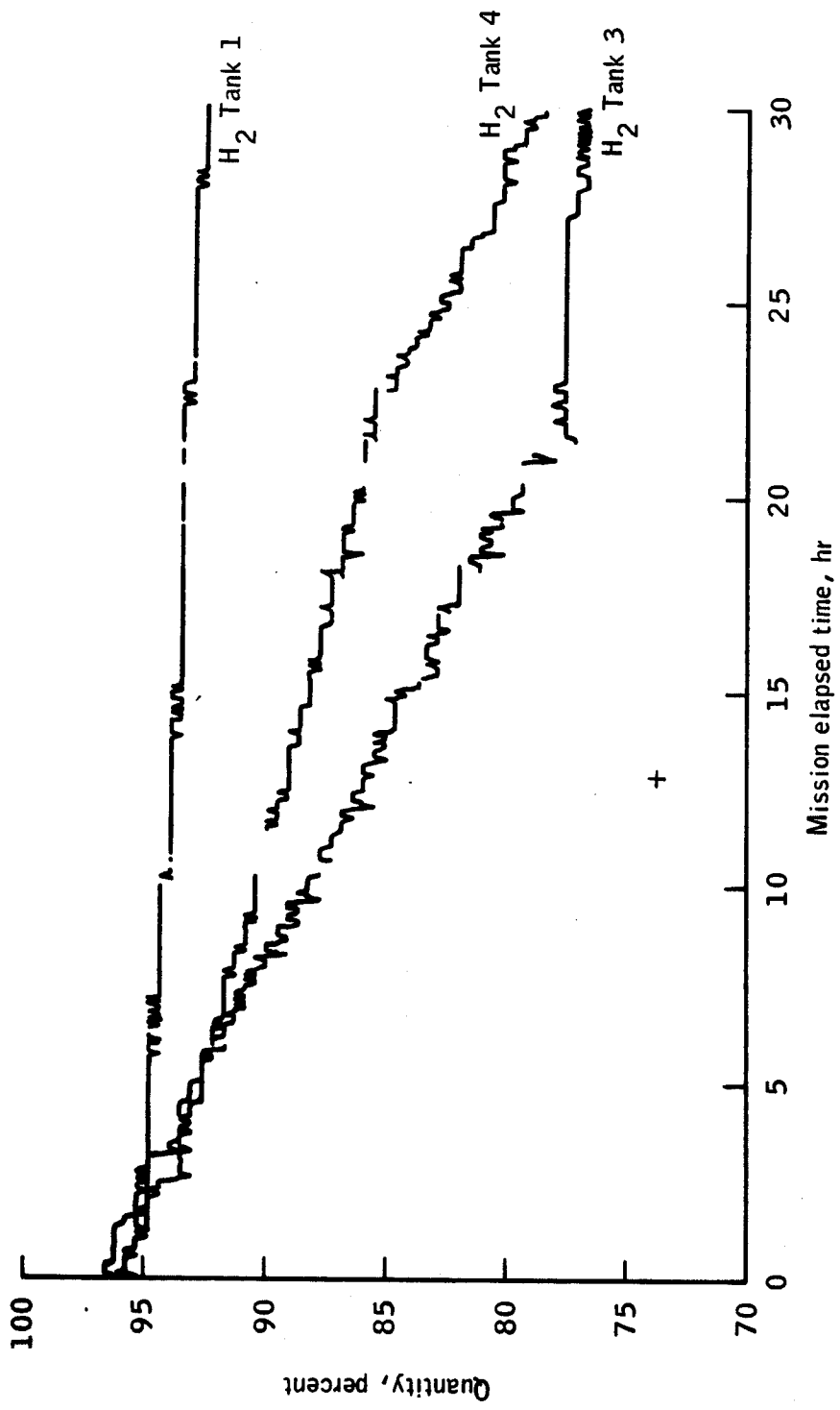


Figure 2-6.- Hydrogen tank quantity differences.

2.2.5 Electrical Power Distribution and Control

EPDC (electrical power distribution and control) performance during STS-4 was normal. All of the Orbiter bus voltages were well within design limits throughout all mission phases.

On-orbit, the get-away special (GAS) experiment activation was initially unsuccessful due to a discontinuity in an Orbiter wiring harness (Section 5.0, flight test problem report 9). The crew was able to wire around the wire discontinuity and activate the GAS experiment. The second problem was a failed heater "B" control circuit on the hydrogen tank 2, on-orbit (Section 5.0, flight test problem report 16).

2.3 AVIONICS SUBSYSTEMS

2.3.1 On-Orbit Flight Control Performance

Performance of the flight control system using the primary RCS was normal with the exception of higher-than-expected propellant usage during the primary RCS narrow deadband test (FTO 477-01). FTO 477-01 was performed as planned and the capability to maintain a ± 0.1 deg/axis attitude deadband was demonstrated. However, propellant usage during the test was more than double the preflight predictions.

Performance of the flight control system using the vernier RCS was essentially as expected based upon the actual usage of the system. However, the vernier RCS was called upon to operate outside the design envelope in damping large residual angular rates (> 0.4 deg/sec) from primary RCS firings and maneuvering at rates greater than 0.2 deg/sec. The effects were readily apparent from visual inspections of the Orbiter after the flight. First, extensive damage of the thermal tiles on the top of the body flap directly beneath vernier thrusters L5D and R5D was observed (Section 5.0, flight test problem report 29). The damage appears to have been caused by erosion of the tiles because of exhaust plume impingement from these two thrusters. Further, visual inspection of the vernier thrusters revealed that the thermal coating in the throats of two of them (F5L and R5R) had eroded down to the metal beneath the coating in at least one place (Section 5.0, flight test problem report 33).

Flight control system test objective (FTO 477-02 - Passive Gravity Gradient Attitude Hold) was performed in two parts, as planned. However, the first part (on flight day 1) was unsuccessful because of a negative roll torque having a magnitude of 4 to 6 ft-lb during the sunlight portion of each orbit and dropping to less than 0.5 ft-lb during the darkness portions. One possible source was water sublimation from the thermal tiles on the underside of the wings such that the integrated effect was a negative roll torque. (Section 7.0, flight test problem report 19.) In any event, the disturbance appeared to have disappeared by the time the test was repeated on flight day 2. Although the test time was shortened from 12 hours to 6 hours, the test was reasonably successful. The vehicle response was bounded by oscillations in each axis with peak amplitudes reasonably close to preflight predictions. The peak amplitudes could probably have been reduced by reinitializing vehicle attitude, but it was decided not to do so and obtain long-term trend data instead.

2.3.2 Entry/Landing

The guidance, navigation and control subsystem performance during entry and TAEM (terminal area energy management) was normal and generally as predicted. Likewise, the autoland performance was satisfactory. The autoland engaged, acquired and flew the outer glide slope very well. The vehicle was on the navigated reference state when the commander took over near 2000 feet for the manual preflare and landing.

2.3.2.1 Autoland Engage and Tracking.- The engagement transient was very mild and occurred at about 9600-ft altitude. The vehicle was damping a low -amplitude pitch oscillation on prefinal, and the body flap went to trail. At engage, autoland pitched the vehicle up slightly and the glide slope was acquired. TAEM had set-up a good transition. The vehicle was right of centerline and rolled left to -4° . The wings slowly came level over a 10-second period and remained there (within $\pm 1^\circ$) until manual takeover.

Judging from the absence of significant vehicle and surface motions, tracking down the outer glide slope was very precise and uneventful. The autoland was in control for 50 seconds.

2.3.2.2 Speed Control.- The speedbrake channel remained on manual throughout the entry and landing phase. The speedbrake was generally near the 55° position with maximum excursions to 65° and 27° . The speed brake was in the process of regaining 55° from the excursion to 27° as the vehicle descended through 4500 feet altitude. The speed brake was retracted manually from 50° at 2500 feet with the velocity very near 285 KEAS. The velocity increased to a maximum of 292 KEAS 14 seconds later during the preflare. The landing velocity and distances past the threshold are discussed in Section 2.9.

2.3.3 Guidance Navigation and Control Hardware Performance

2.3.3.1 Star Tracker/Crewman Optical Alignment Sight/Navigation Base.- The star tracker, COAS (crewman optical alignment sight), and navigation base hardware functioned normally throughout the flight. All IMU (inertial measurement unit) alignments were completed successfully. The three FTO's planned for this flight were successfully completed. Two FTO's were on the shopping list and have now been scheduled for STS-5.

FTO 474-01 (Navigation Base Stability) was successfully accomplished. Two test sequences were performed, one after each period of x-axis perpendicular to orbit plane in passive thermal control and tail-to-sun thermal attitude. The test, which consisted of back-to-back IMU alignment sightings with star-pair reversal in between, showed that the navigation base is insensitive to thermal cold soaking, with no angular deviations greater than the expected data noise. The -Y star tracker required 14 minutes to acquire its star (no. 57) during the first phase of the navigation base stability test. At first, it seemed that the star tracker was attempting to acquire particles or background noise in the field-of-view. The -Y star tracker has a known sensitivity problem which was waived for the first four flights. The star was finally acquired and the test completed when the crew maneuvered the Orbiter to place the star in a different area of the field-of-view.

FTO 473-01 (Star Tracker Operations during Water Dumps) was successful. Results confirmed predictions that the star trackers would experience difficulty with star acquisition during water dumps. The -Y star tracker was unable to acquire its star at all, and the -Z star tracker did acquire its star at least twice. Time-critical IMU alignments should not be scheduled during daylight water dumps.

FTO 473-03 (Forward Station COAS Calibration) was carried out successfully with the data agreeing well with previous flights. The crew experienced some difficulty with pointing the COAS at the star due to an unknown control disturbance (venting) in progress at the time (Section 5.0, flight test problem report 19).

FTO 473-02 (Star Tracker Threshold Level Verification) was a "shopping list" item and was not performed on this flight. It is currently scheduled on STS-5 as a priority "C" test.

FTO 473-04 (Aft Station COAS Calibration) was a "shopping list" item and was not performed. It is currently scheduled for STS-5.

2.3.3.2 IMU Performance.- All three IMU's performed normally throughout the flight. The preflight calibration parameters were all less than 0.7 sigma. Preflight alignment was good. There were five gyro bias updates made during the flight. The largest update was +0.032 for the IMU 2 X axis and this was as expected because of to the warm-up characteristics of the gyro. No updates were required the last day and a half of flight. Three accelerometer bias updates were made; the largest was 50 μ g (1 sigma) for IMU 3 Z-axis the first day.

2.3.4 Communications and Tracking

The communications and tracking system provided satisfactory command, data and voice transmissions for the complete mission. The teleprinter operation was flawless and the RF Nav aids provided good data throughout the landing phase.

2.3.4.1 S-Band Network Equipment.- The Orbiter phase modulation equipment operated within its design limits for all of the mission. The string 2 network signal processor, transponder, and power amplifier were configured in the STDN (Spaceflight Tracking and Data Network) high-power, high-frequency mode for the entire mission with no problems. Main engine data were transmitted in real-time over the frequency modulation equipment and later television (real-time and playback), and OI (operational instrumentation) recorder dumps were transmitted with no problems.

2.3.4.2 UHF Transceivers.- The EVA/ATC (extravehicular activity/air traffic controller) UHF (ultra high frequency) transceiver provided good voice communications with the Orbiter in conjunction with the S-band PM system. The UHF frequency was changed for the first time on-orbit from 296.8 MHz to 259.7 MHz to take advantage of the higher ground antenna gain. This frequency change led to an out-of-configuration situation for the first portion of the EMU (extravehicular mobility unit) demonstration. This was later corrected. The crew reported noisy voice communications during the first part of the EMU demonstration, however this noise disappeared later. This problem has been attributed to a loose fit between the airlock adapter plate and the EMU (Section 5.0, flight test problem report 34). The plate restrains the EMU when not in use as well as during donning and doffing, and the loose fit is as designed to enable easy removal and replacement.

During the landing phase, errors in coordination between DFRF (Dryden Flight Research Facility) and GDS (Goldstone) led to more than 7 minutes of garbled uplink voice. When BUC (Buckhorn) handed the S-band to GDS, DFRF did not release the UHF. This resulted in two simultaneous uplink UHF transmitters. The problem continued throughout the GDS pass until 3 minutes after the S-band handover. When the misconfigurations were corrected, and the DFRF UHF uplink was dominant, the voice communications improved for the final landing phases.

2.3.4.3 Audio Distribution.- The crew used the WCCU (Wireless Crew Communication Unit) with the MHS (Mini-Headset) for most of the mission. The commander reported some trouble keeping the MHS on due to cable stiffness. In general, the audio quality was very good and there were no ADS (Audio Distribution System) hardware problems.

The WCCU system provided good on-orbit voice communications. During a live TV pass, the pilot reported that his audio was intermittent and that he had exchanged unit "C" for unit "B". Prior to exchanging the units, the unit "B" batteries were checked and were to be good (section 5.0, flight test problem report 27).

2.3.4.4 Teleprinter.- The teleprinter provided clear messages throughout the mission with no anomalies or failures.

2.3.4.5 Television.- The CCTV (closed circuit television) system was used extensively during the STS-4 mission. There were cameras mounted at the four payload bay locations (A, B, C, and D), at the wrist and elbow locations on the RMS, and two were in the cabin.

There were three CCTV-related problems reported during STS-4. A description of each of the problems follows.

The onboard-recorded video tapes could not be properly synchronized with the console monitor 2 when playback in the "direct" source mode was attempted (Section 5.0, flight test problem report 8).

The rewind function of the VTR failed. This failure was verified during postmission KSC testing and at JSC after return of the VTR for analysis and repair. However, during inspection of the unit at JSC the function had become operative (Section 5.0, flight test problem report 12).

The video from the mid-deck TV input location was intermittently degraded - i.e., reduced high-frequency response and "smearing" of the scene content (Section 5.0, flight test problem report 26).

2.3.4.6 RF Navigation Aids.- A discussion of the performance of the navigation aids is contained in the following subparagraphs.

2.3.4.6.1 TACAN: Prior to lift-off, the TACAN units were turned on and the unit 2 bearing went into an oscillation of about ± 20 degrees. This was first believed to be caused by the gantry surrounding the spacecraft, but this condition persisted after lift-off. On-orbit tests and entry data did not show this condition, and 13 TACAN on-orbit tests were successfully made in support of DTO's (detailed test objectives) over sites in Africa, Australia, Mexico, Hawaii, Central America, Wake Island, and the United States. The most successful lock-on with respect to range was Wake Island on revolution 97 when all three units were tuned to the same channel. Acquisition occurred at a range rate of 7920 knots, and was lost at about 10,234 knots.

The TACAN units were turned on for entry and solid range lock-on for unit 1 occurred at approximately 185:15:57:42 G.m.t. on the lower antenna at 368.15 nmi. A subsequent continuous loss-of-lock starting at 185:15:58:24 G.m.t. caused the antenna to switch to the upper antenna at 185:15:58:36 G.m.t. back to lower antenna at 185:15:58:48 G.m.t., and finally to the upper antenna at 185:15:58:59 G.m.t. at a range of 250.5 nmi. This lock-on was maintained throughout the remainder of the mission. Unit 2 acquired solid range lock-on at approximately 185:15:58:11 G.m.t. on the lower antenna. A continuous unlock condition occurred on unit 2 range at 185:16:01:47 G.m.t. and the antenna was switched from lower to upper at 185:16:01:58 G.m.t. at about 83.25 nmi. Lock was reacquired on the unit 2 lower antenna position and was maintained throughout the remainder of the mission. Unit 3 locked on in range at approximately 185:15:57:53 G.m.t. (349.8 nmi.) with the lower antenna and maintained this antenna position for the remainder of the flight. All range and bearing data were locked on and tracking prior to the incorporation into the navigation state at approximately 185:15:59:26 G.m.t. (approximately 133,000 ft).

Unit 2 bearing had several intermittent 40-degree sector errors starting at 185:16:00:36 G.m.t. and ending at 185:16:01:29 G.m.t. None of these errors were consecutive for up to 10 software passes and therefore unit 2 bearing was not failed as has occurred on previous flights. The in-cone flag was set at 185:16:04:56 G.m.t. and bearing data was inhibited from being incorporated into the navigation MLS (Microwave Landing System) data when it came on-line at 185:16:07:41 G.m.t. prior to the spacecraft coming out of the in-cone flag at 185:16:08:27 G.m.t. Some 40-degree sector errors did occur in units 1 and 2 after MLS incorporation, but were obviously not passed on to navigation.

2.3.4.6.2 Microwave Scanning Beam Landing System: The performance of the MSBLS (microwave scanning beam landing system) navigation units was satisfactory and their data output supported the autoland portion of the landing. The three functions (azimuth, elevation and distance) for all three Navsets were properly locked as follows:

	Time, G.m.t.	Average data
Azimuth	185:16:07:04	14.7 degree
Elevation	185:16:06:41	15.2 degree
Distance	185:16:06:57	14.1 nmi.

The three functions met the selected criteria as follows:

	Time, G.m.t.	Selected Value
Azimuth	185:16:07:40	3.5 degree
Elevation	185:16:07:40	15.3 degree
Distance	185:16:07:00	13.9 nmi.

As expected, azimuth-angle differences between the three units were noted, with the most probable cause being the errors introduced by the MSBLS ground-station azimuth-antenna cross-polarization radiation (a change to the MSBLS ground-station azimuth antenna to reduce this cross-polarized radiation has been approved for STS-6).

2.3.4.6.3 Radar Altimeter: Radar altimeter 1 locked on at an altitude of 5515 feet and unit 2 at 5173 feet and both tracked very well through touchdown. There were no indications in the data of any influence of the landing gear on the altitude readings. Consequently, the modification to stop landing gear interference will be incorporated into the remaining altimeters for subsequent vehicles.

2.3.4.7 Flight Test Objectives.- All test objectives were accomplished except for measuring inflight antenna patterns for S-band and UHF. This item was scheduled for STS-2; however, only a portion of the requirement was completed and the test was rescheduled for STS-4. The test was partially completed, but it will require some tests on STS-5 to complete the test objective.

2.3.5 Data Processing Subsystem

Data processing subsystem hardware performance was essentially normal during the flight with only procedurally induced anomalies. A postlanding problem was noted with a stuck keyboard switch on the CDR keyboard. This is not an unanticipated failure in long-life switch assemblies (Section 5.0, flight test problem report 20).

2.3.6 Backup Flight System

The BFS (backup flight system) performed as expected during all phases of the STS-4 mission. Postflight data showed the BFS tracked PASS nominally during all mission major modes.

During deorbit preparations, the crew observed the payload bay door talkback change from closed to barberpole while initializing the BFS (Section 5.0, flight test problem report 18 discusses this occurrence).

2.3.7 Displays and Controls

The performance of the D and C (displays and controls) system on STS-4 was satisfactory. The requirements of FTR 71VV002 (Inertial Measurement Unit Performance and Alignment Verification) were successfully completed during STS-4.

The cabin interior lighting and payload bay lighting were adequate for all mission phases. However, the crew reported that the starboard, forward port and forward bulkhead floodlights were inoperative. Section 5.0, flight test problem report 11 discusses this anomaly.

The flight displays and controls worked properly during all mission phases, except switch 53 (Orbit DAP Control Auto Select Switch) on panel C3A6 experienced a failure of contact A. Subsequent activation during the flight indicated that the contact failure had cleared; however, the RM flag remained latched (Section 5.0, flight test problem report 14).

2.3.8 Instrumentation and Recorders

2.3.8.1 Operational Instrumentation.- The OI (operational instrumentation) subsystem performed satisfactorily for STS-4. There are no FTO's for the OI subsystem. Three measurements failed during STS-4. The following subparagraphs list each failure.

PRSD measurement V45Q2205A dropped from a 94.4 percent to a 42.2 percent reading at 178:22:03:21 G.m.t. The PRSD subsystem signal conditioner was replaced for STS-4 and will be replaced for STS-5 (Section 5.0, flight test problem report 6A).

MPS measurement V41T1301C read off-scale high for 2 minutes starting at 178:15:06:33 G.m.t. before returning to normal (Section 5.0, flight test problem report 6B).

MPS measurement V41T1261A was reading 60 to 100° F high for 3 minutes starting at 178:15:05 G.m.t. On each of the previous flights, it failed off-scale high for several minutes (Section 5.0, flight test problem report 6C).

2.3.8.2 Development Flight Instrumentation.- The DFI (development flight instrumentation) system performed satisfactorily except for the loss of PCM recorder data on tracks 1 through 7. The wideband ascent recorder operated satisfactorily during ascent and the OMS-1 and -2 maneuvers. The wideband mission recorder operated satisfactorily during ascent, the OMS-1 through -5 maneuvers, selected RCS firings, and during the deorbit maneuver, entry and landing. The PCM recorder operated during ascent, the OMS-1 through -5 maneuvers, and during the deorbit maneuver, entry and landing.

On-orbit, the PCM recorder generally remained in the low- or high-sample rate mode except for selected DTO's. However, due to an apparent short circuit in the recorder/reproduce electronics, the playback tape heads for tracks 1 through 7 were dc magnetized and this caused data erasure (See section 5.0, flight test problem report 28). Unfortunately, tracks 1 through 7 contained the ascent and entry data as well as a portion of the on-orbit data. Good on-orbit data were obtained on tracks 8 through 14 from 181:15:60:00 G.m.t. to 185:11:38:48 G.m.t., with resetting to track 1 prior to the deorbit maneuver.

Approximately one percent of the 3500 DFI measurements had newly discrepant conditions during this flight. These will be repaired where accessible prior to STS-5. The extended DFI/DATA system (38 payload vibration and acoustic measurements) operated satisfactorily via the OEX recorder during ascent and entry.

2.3.8.3 Recorders.- The AF (Air Force) payload contractor reported that only 4 minutes of good data were obtained from the payload recorder. Postflight testing verified that only 4 minutes of data existed on the tape. Subsequent tests of the recorder and associated wiring verified that the recorder was functioning properly, indicating that the data did not reach the recorder. The AF payload had already been removed from OV-102 prior to the discovery of this data loss; consequently no further testing could be performed.

2.3.9 Redundancy Management

The RM (redundancy management) performance was satisfactory, with significant events occurring within the RCS and GN and C RM areas. In all cases, RM successfully provided the best source data to all users (selection filtering) while maintaining a comfortable margin of component performance evaluation when compared to the RM fault detection thresholds.

An RCS leak alert and thruster deselect was experienced early in the mission (178:15:16:38 G.m.t.) as a result of RM detection of the thruster (F1L) oxidizer temperature going below the RM threshold. Subsequent on-orbit troubleshooting procedures indicated the leak condition had cleared, and the thruster was reselected for use with no further flight problems (Section 5.0, flight test problem report 4).

It was also noted that vernier RCS thruster F5L repeated the anomalous characteristic observed on STS-3 in that the oxidizer temperature used for RM leak detection appeared to have a thermal lag in response compared to the fuel measurement on that same thruster. A similar characteristic was also noted on this flight on vernier thruster R5D, except that fuel measurement appeared to experience the slow response (Section 5.0, flight test problem report 6D).

During on-orbit operations (182:12:12 G.m.t.) the GN and C switch RM deselected the "A" contact of the forward orbital DAP control auto pushbutton switch. Subsequent on-orbit troubleshooting determined all contacts (3) in that switch were performing properly (Section 5.0, flight test problem report 14).

2.4 ENTRY AERODYNAMICS

2.4.1 Performance and Trim

Preliminary analysis of the entry aerodynamic performance characteristics show similar results as measured on the first three flights. The hypersonic lift-to-drag ratio was close to predictions and consistent with previous flights. Trim analysis, as evidenced by the body flap position at the higher Mach numbers, confirmed the pitching moment difference noted on all earlier flights. This difference is now attributed to real gas effects not properly accounted for in the original predictions.

2.4.2 Flight Test Requirements Accomplished

During entry on STS-4, five programmed test input (PTI) maneuvers and two push-over/pull-up (POPU) maneuvers were planned. All maneuvers were completed with PTI's executed at Mach 24.9, 21.8, 17.2, 15.4, and 2.9, and POPU's executed as scheduled at Mach 14 and 8. Preliminary aerodynamic data extraction results show excellent results from these maneuvers with all STS-4 flight test requirements met.

2.4.3 Stability and Control

Results have been obtained for lateral-directional aerodynamic data extraction for STS-4 entry. In addition to PTI and bank reversal data that were analyzed, several cases of transient incidental motion were also identified and analyzed. Figures 2-7 through 2-11 show examples of the results obtained.

Figure 2-7 shows the side force (Y) produced by the RCS engines versus Mach number. The values determined are close to the data book values, indicating reliable data book values for the side force due to RCS (reaction control system) engines.

Figure 2-8 presents the corresponding rolling moment from the side-firing engines. As on STS 1 through 3, the flight results are consistent, reliable and different from the predictions. This difference has been identified as a wind tunnel scaling problem and the aerodynamic data base has been changed accordingly.

Figure 2-9 shows the coefficient of roll due to aileron deflection versus Mach number. Above Mach 10, the derived data are more positive than the data book values, indicating a greater amount of aileron effectiveness for roll above Mach 10. However, below Mach 5, the derived data are less positive than the data book values, indicating less control effectiveness. These results do not concur with STS-3 results (see figure 2-10). This is apparently due to an elevon setting of 5° on STS-4 compared to 3° on STS-3. Figure 2-11 shows the coefficient of yaw due to aileron deflection versus Mach. The flight data are more negative than data book values.

2.4.4 One-Quarter-Hertz Oscillation

As on the previous three flights, an unplanned lateral directional oscillation occurred in the transonic Mach regime. The amplitude was small and the frequency was again about one-quarter hertz. A conclusive cause and effect has not been found. If the problem is of an aerodynamic nature, the most likely explanation is a dynamic flow separation/attachment phenomena not measurable by standard wind-tunnel testing techniques.

The amplitude and phasing of this oscillation does not lead to aerodynamic identification using existing flight extraction techniques. On STS-5 and subsequent, specific maneuvers will be executed by the computer that should lead to accurate identification of the aerodynamic stability and control derivatives.

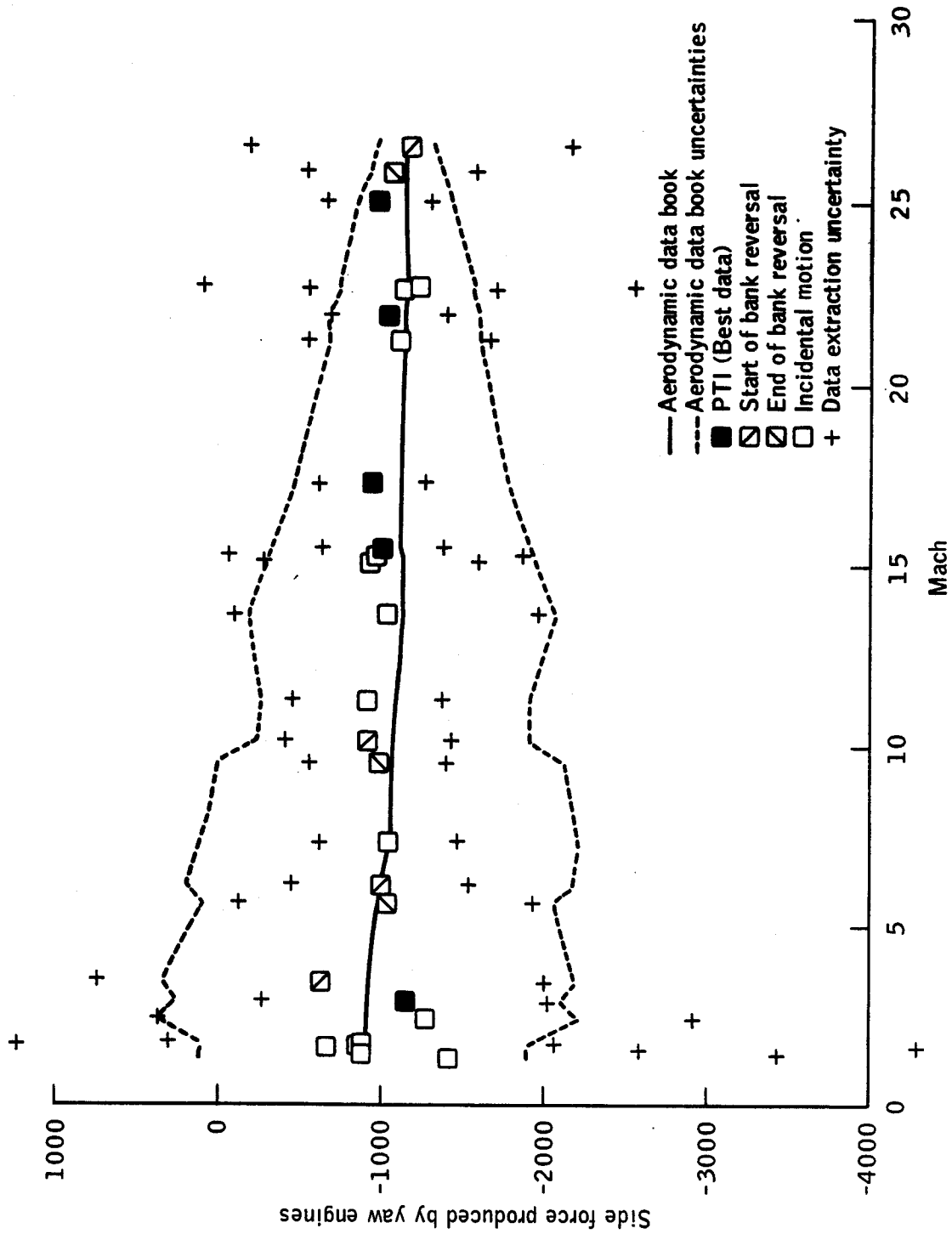


Figure 2-7.- Side force produced by RCS engines versus Mach number.

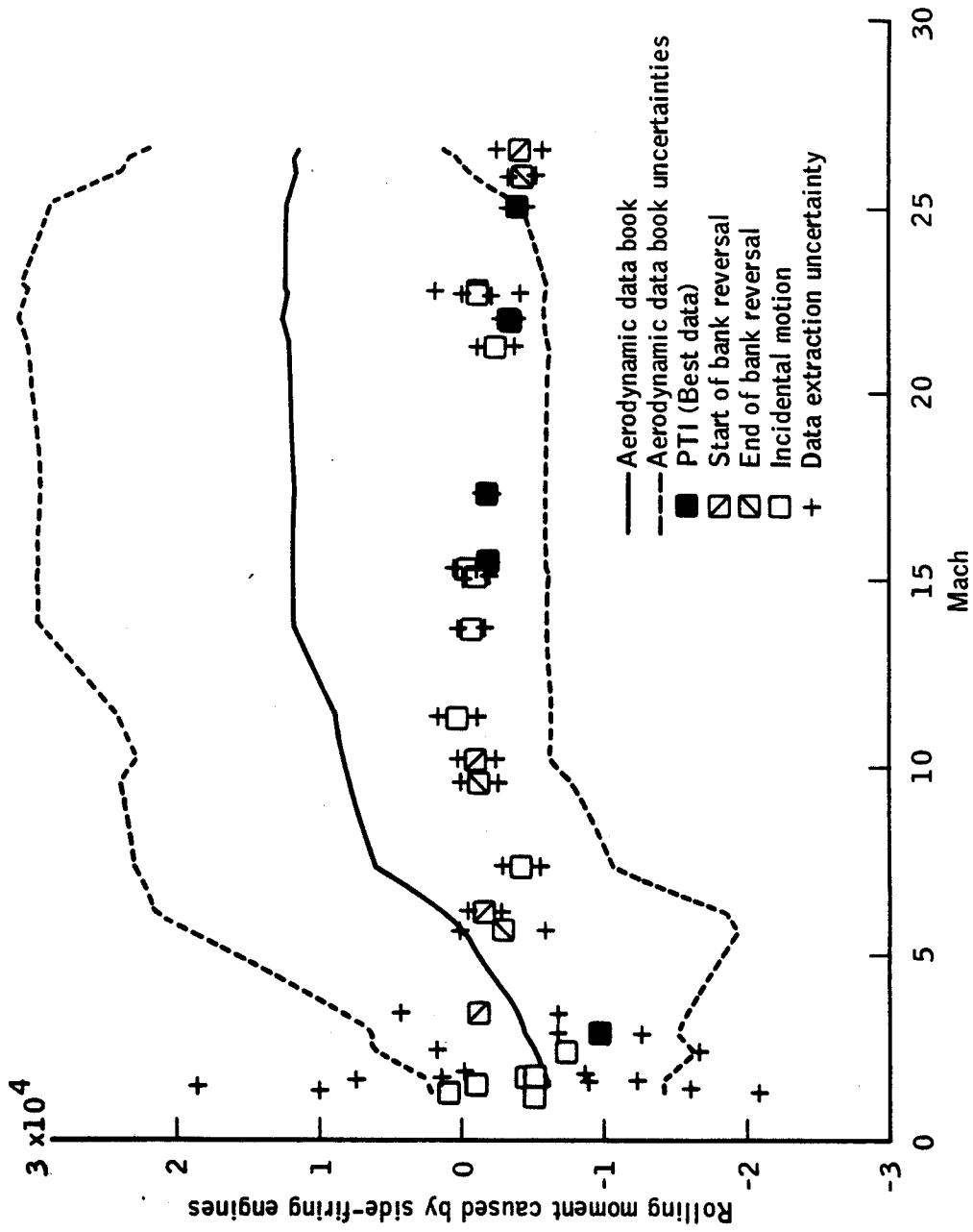


Figure 2-8.- Rolling moment caused by side-firing engines versus Mach number.

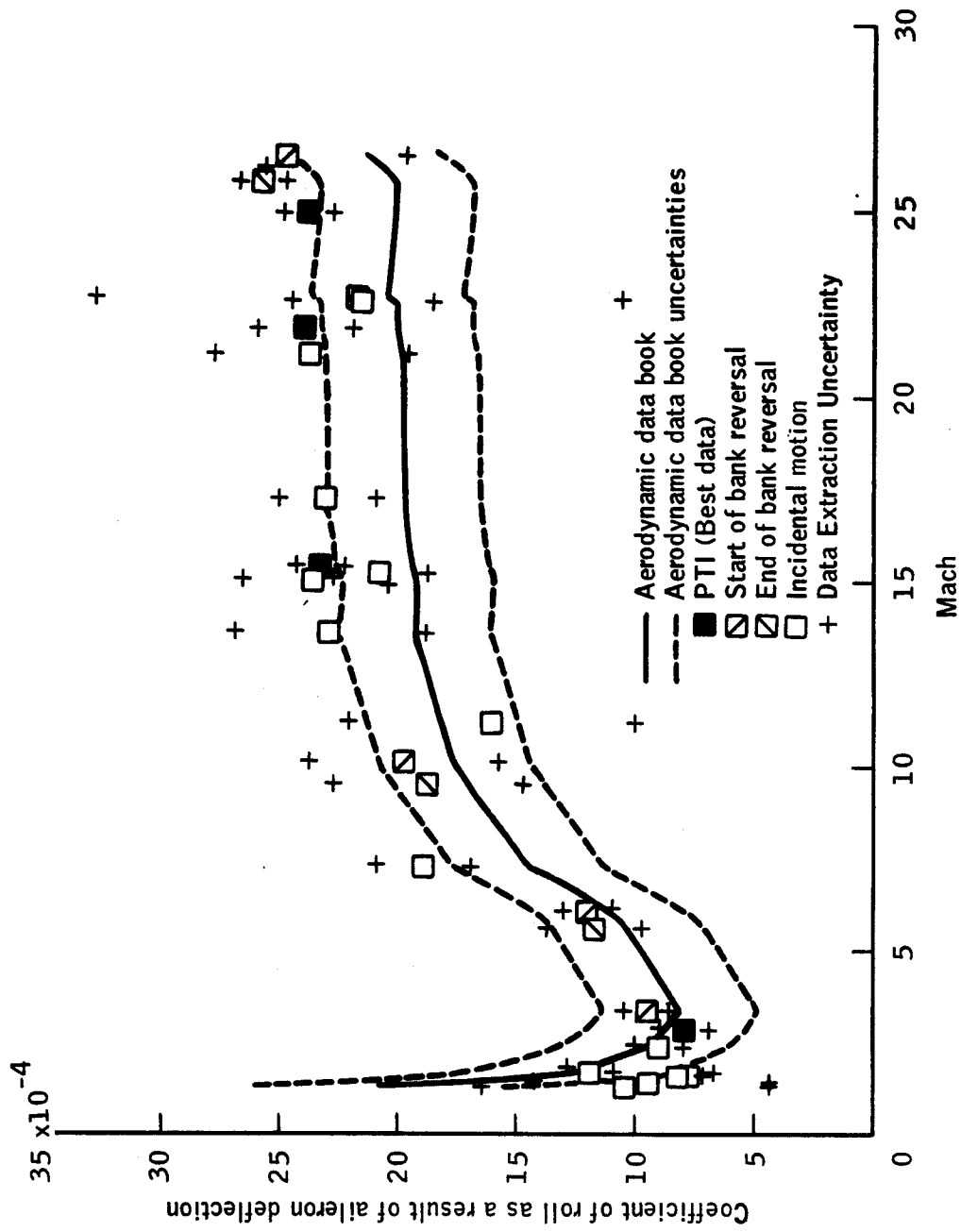


Figure 2-9.- Coefficient of roll due to aileron deflection versus Mach number for STS-4.

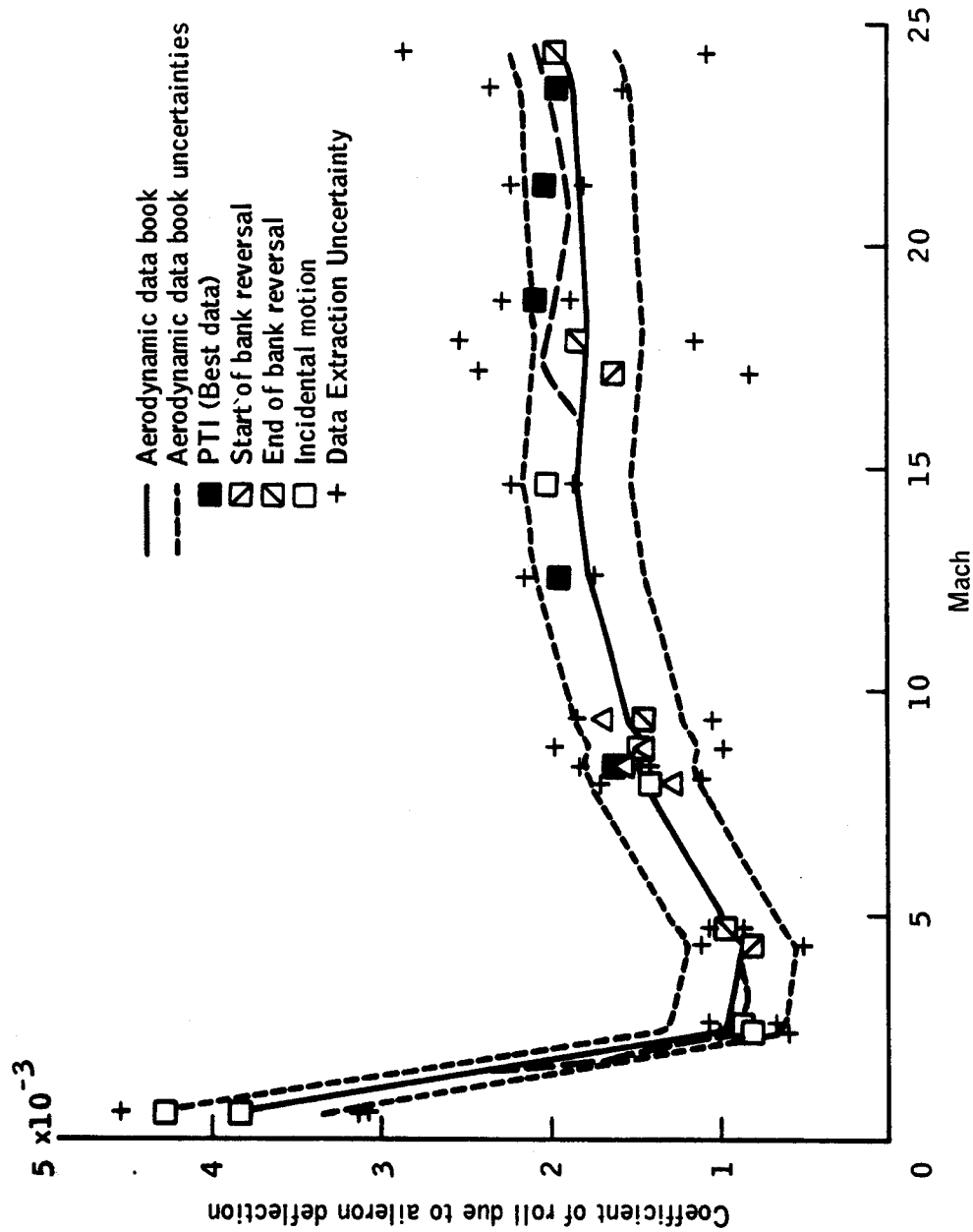


Figure 2-10.- Coefficient of roll due to aileron deflection versus mach number for STS-3.

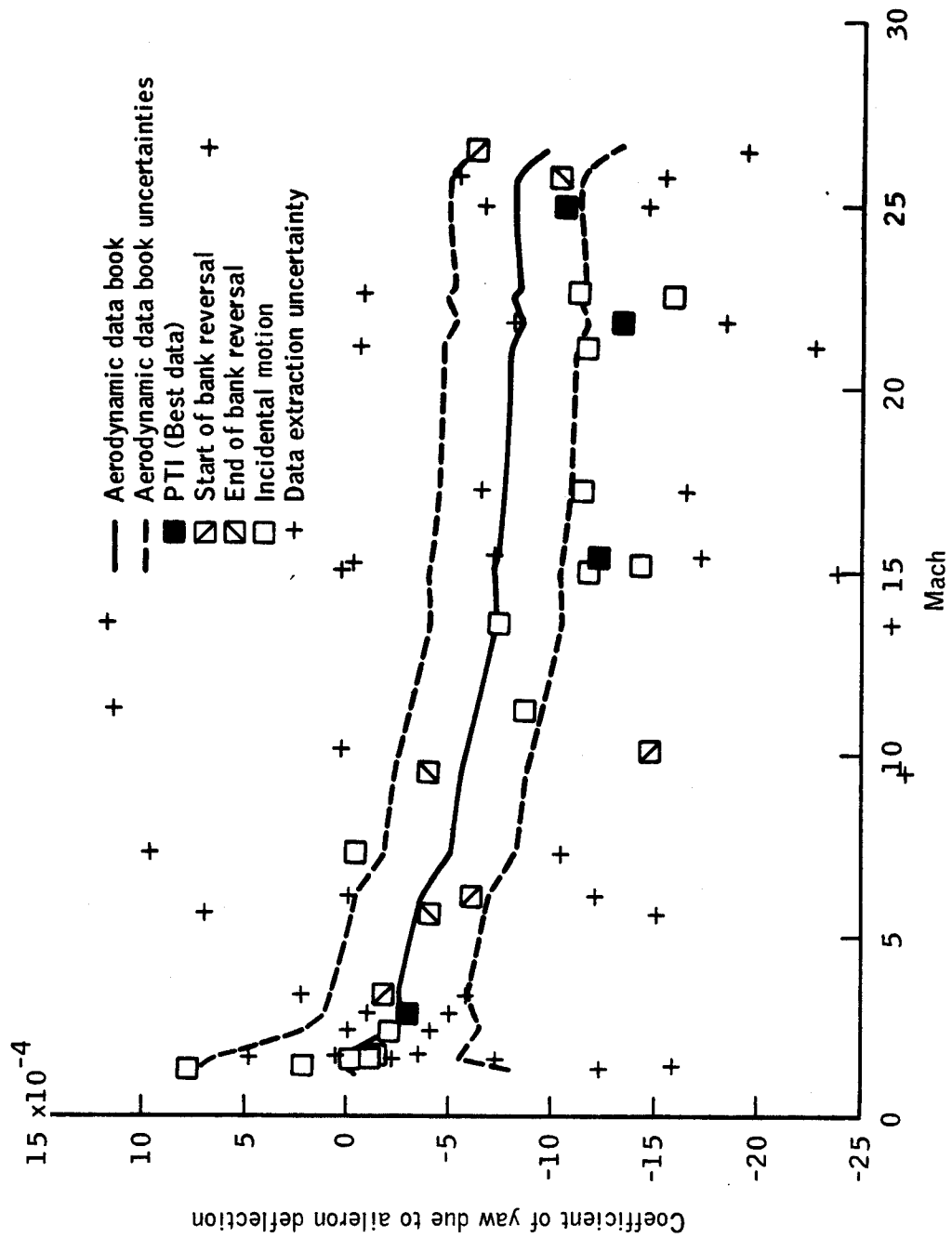


Figure 2-11.- Coefficient of yaw due to aileron deflection versus Mach number.

2.5 DESCENT TRAJECTORY

The entry targeting appeared completely normal. Entry interface (400,000-ft altitude) was reached at a range-to-runway distance of 3810 nmi. compared to a predicted range of 3807 nmi. The Orbiter transitioned to closed-loop guidance (0.176g load factor) at a range of 2798 nmi. and a velocity of 24444 ft/sec, with a left roll being commanded 21 seconds later. Entry proceeded normally until a velocity of 13500 ft/sec where a manual angle of attack sweep was performed. During this pitch maneuver, the roll angle drifted from 60° to approximately 40° and this caused the vehicle to loft 10000 ft above the preflight predicted altitude. Figures 2-12, 2-13, and 2-14 show the roll angle, altitude and altitude rate compared with the preflight predictions. When auto guidance was reengaged at 12000 ft/sec, it responded to the loft and produced an 85° roll angle. This resulted in a sink rate in excess of 550 ft/sec during the recovery maneuver. During the loft, the Orbiter deceleration was below the desired level and this produced a range error of 15 nmi. As shown in figure 2-15, all of this error was removed by guidance by the time a velocity of 6000 ft/sec had been attained.

The terminal area energy management phase (2500 ft/sec) was achieved at a range of 59.5 nmi. and an altitude of 81208 ft. The preflight predictions were 59.0 nmi. and 80463 ft. Control stick steering (CSS) mode was again selected at 44582 ft for the left turn around the heading alignment circle. Just prior to the turn (33870 ft altitude), the speed brake was moded to manual and this mode was maintained through the remainder of the flight. The automatic flight control mode was reengaged at 18,400 ft with the Orbiter 10,000 ft to the left of the runway centerline. Heading alignment performance was excellent, as shown in figure 2-16.

All critical parameters were within autoland acceptance limits, so the automatic moding occurred at an altitude of 10,000 ft. The CSS mode was engaged at 2300 ft with gear deployment at 420 ft. Gear touchdown was 948 ft past the runway threshold at an equivalent airspeed of 204 knots. The nose gear touched at 4988 ft. A braking deceleration of approximately 7.5 ft/sec² from 120 kts to 50 kts produced a rollout distance of 9878 ft with the vehicle stopping at 10826 ft past the runway threshold. Landing events are depicted in figure 2-17.

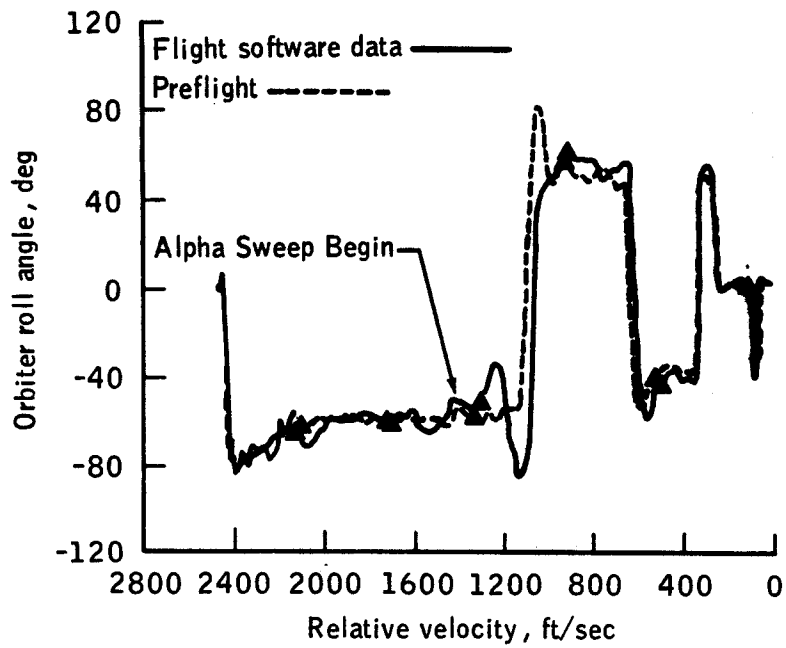


Figure 2-12.- Entry roll performance.

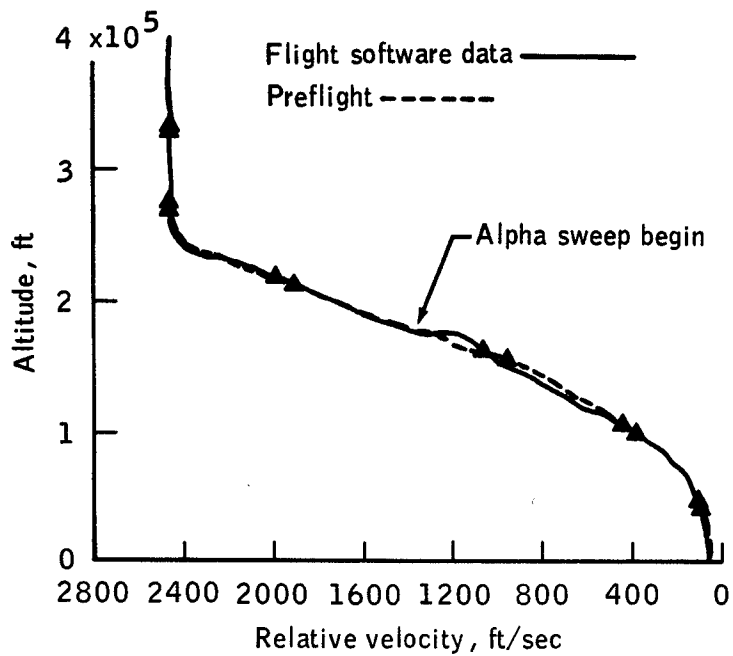


Figure 2-13.- Entry altitude profile.

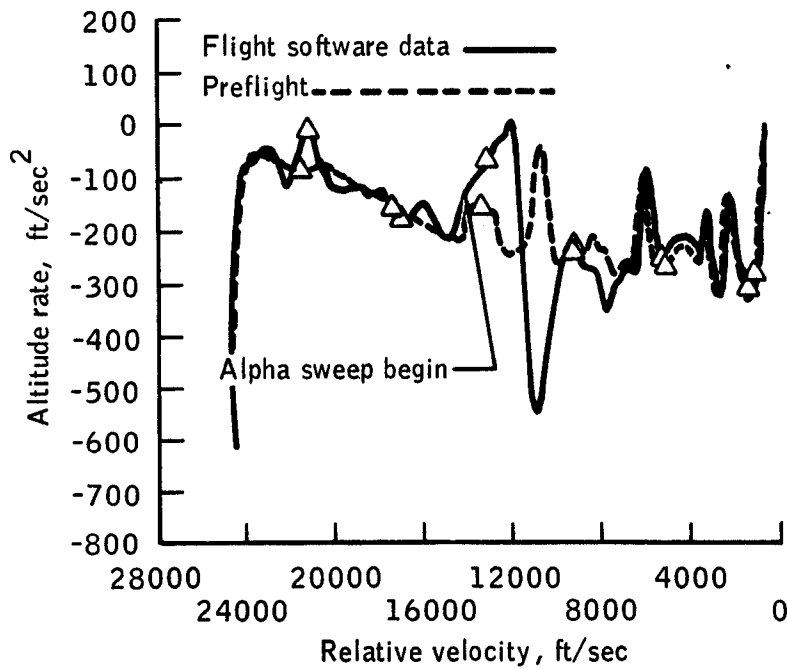


Figure 2-14.- Altitude rate performance.

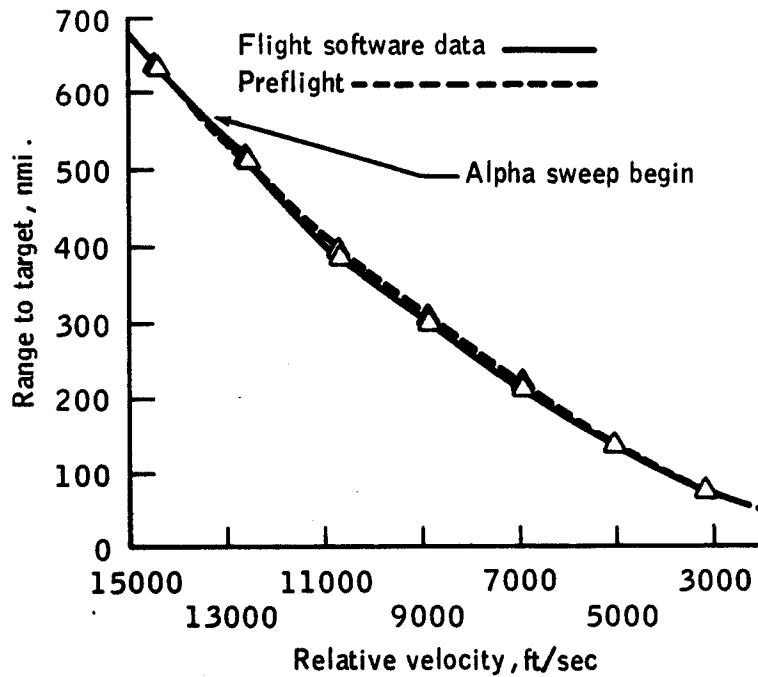


Figure 2-15.- Entry ranging.

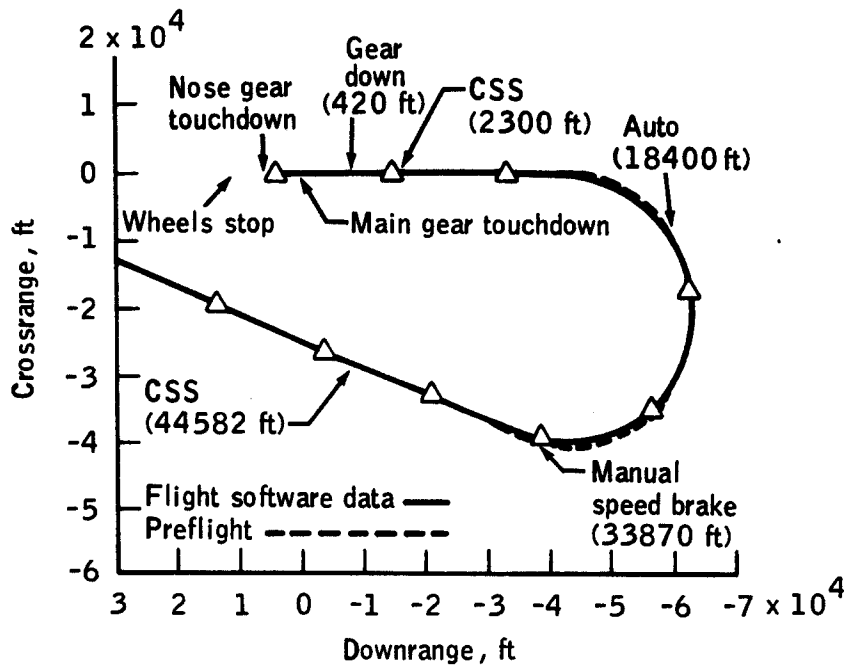


Figure 2-16.- Heading alignment groundtrack.

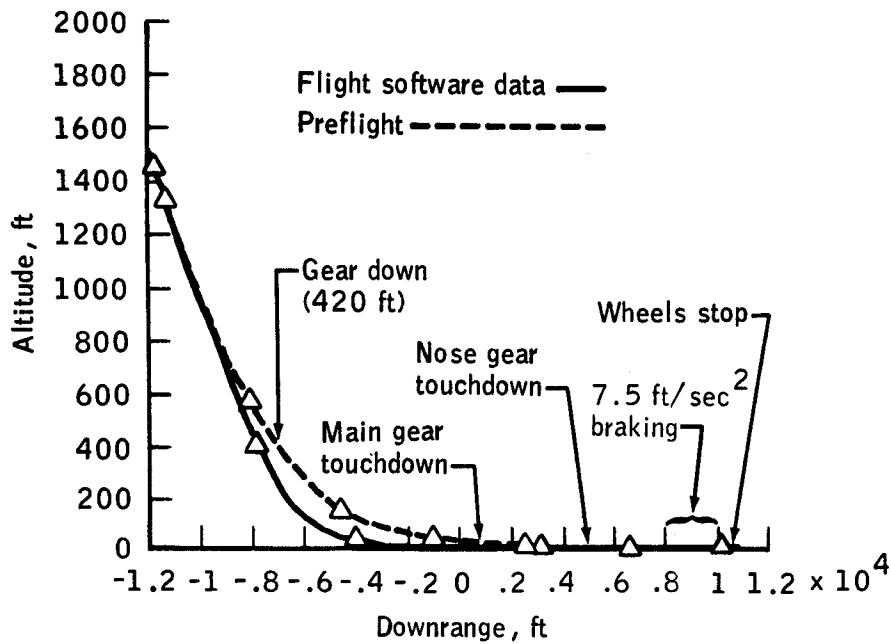


Figure 2-17.- Final flare.

2.6 ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM

2.6.1 Active Thermal Control Subsystem

The ATCS (Active Thermal Control Subsystem) performance was satisfactory in meeting STS-4 mission objectives. There were several off-nominal or unplanned aspects of subsystem operation which are discussed in the following paragraphs.

The STS-4 data collection portions of FTR 63VV001 (Active Thermal Control System Performance) and 63VV003 (ATCS Flash Evaporator Sub-Subsystem) are expected to be satisfied upon review of flight data. Data covering FTO 462-01 (Radiator Surface Coating Inspection) and FTO 466-01 (Radiator Performance Test) are being reviewed. FTO 462-01 was completed, but the deployed radiator performance portion of FTO 466-01 was not completed.

Prelaunch, the Freon coolant loop 1 payload heat exchanger Freon flow rate indication was erratic. During operation with the flow proportioning modules in the payload position, the flow rate indication was normal, but when the FPM's (flow proportioning modules) were in the interchanger position, the indication had larger and more rapid fluctuations than observed on previous flights. However, no launch commit criteria were violated during prelaunch operations.

During ascent, unexplained cooling of the Freon coolant loops occurred momentarily, as seen on all previous flights. The flash evaporator outlet temperature on Freon coolant loop 1 exceeded 100° F during the ascent no-cooling transient, triggering a caution and warning alarm (Loop 2 temperature was lagging slightly and did not exceed 100° F). The topping flash evaporator steam duct starboard nozzle temperature fell to 23° F, triggering a fault message. This low temperature was caused by freezing of rain water in the nozzle during ascent. The ice later cleared by sublimation causing no problem with flash evaporator operation.

After the first payload bay door opening, the forward radiator panels were left stowed. They were later deployed for 6 hours of the bottom-to-sun attitude period, as part of FTO 466-01. During initial movement of the flow proportioning modules to the payload position, a caution and warning alarm was triggered because the interchanger flowrate indication on Freon coolant loop 2 was less than 1200 lb/hr for about 2 seconds (Loop 1 response was slower than loop 2 and the flow rate indication did not drop below 1200 lb/hr). This momentary decrease in flow is normal during FPM movements.

While on orbit, the flash evaporator primary B controller was tested in the topping and full-up modes to verify proper operation. The port and starboard radiator panel surfaces were scanned with the remote manipulator arm camera to verify the coating bond for FTO 462-01. Defects in the bonding were seen on the port aft and port mid-aft panels, however, these defects were not significant enough to warrant corrective action since the coating will be changed on STS-6. To determine the hydraulics subsystem's long-term cooling effect on the Freon coolant loops, hydraulic circulation pumps were operated for 2 continuous hours of the tail-to-sun attitude period. Data indicated that the long term cooling effect resulting from pump operation is negligible.

Data from the mission indicated small leaks of Freon from both coolant loops. The leak rate was less than 1 lb/day for each loop, and this low leak rate created no problem.

During the deorbit preparations when the high load flash evaporator duct B heaters were activated, data indicated that the Zone A heater had failed. The B heaters had been used 4 days previous to the bottom-to-sun payload bay door test and had worked normally. The

Zone A temperature measurements rose very slowly while the Zone B and nozzle measurements rose quickly in the normal manner (fig. 2-18). Additional description of this anomaly is given in section 7.0, flight test problem report 17.

Radiator flow was begun at about 135,000 ft altitude during entry. This was about 1 minute later than expected. The flash evaporator was switched off at 120,000 feet altitude before the radiator cooling had reached the flash evaporator outlet temperature sensor. This caused the flash evaporator outlet temperature to exceed 65° F and trigger a caution and warning alarm.

During the four orbital test flights, data were collected on 19 of 21 ATCS functional test objectives.

Data were obtained on radiator performance with the forward radiator panels stowed to satisfy a portion of FTO 466-01; however, data were not obtained for the deployed radiator portion of FTO 466-01. This latter configuration was subsequently not deemed mandatory for completion of the FTO. Also data on radiator performance with forward radiator panels stowed for FTO 266-01 during STS-2 was not accomplished, but the test objective was deleted post-flight.

Major ATCS test objectives still to be accomplished consist of obtaining radiator performance data with the forward panels stowed and the Orbiter in a side-to-sun attitude which is scheduled for STS-5, and collecting radiator thermal capacity data with a large mass payload and a warm payload bay and this is scheduled for STS-9.

2.6.2 Air Revitalization Subsystem

The performance of the ARS (Air Revitalization Subsystem) was satisfactory during all mission phases of STS-4.

None of the ARS launch commit criteria were violated during prelaunch operations.

Manual cabin air temperature control procedures were limited to pinning of the cabin heat exchanger air bypass valve, with no water flow adjustments required. The crew adjusted the air bypass valve as needed to maintain a comfortable cabin environment during the various attitudes of STS-4. More than adequate avionics cooling was maintained through all configurations, attitudes and activities of the flight.

The FPM valves on the ATCS Freon loop were positioned to payload to provide warmer temperatures in the cabin during the long attitude holds in tail-to-sun and bottom-to-sun. This action proved effective in allowing simple adjustment of one valve by the crew during the flight to maintain comfortable cabin temperatures.

Some condensation was observed on aft windows just as on STS-3. The condensation increased slightly when shades were installed.

Further data were collected on cold-mission thermal performance supporting FTR 61VV001. The objective of FTR 61VV001 to evaluate subsystem performance was completed. FTR 61VV002 ARS ATCO (Ambient Temperature Catalytic Oxidizer Performance) was partially completed through chemical analysis of the catalyst and through gas analysis of a cabin atmosphere sample taken during the flight. This sample will be tested for carbon monoxide to verify acceptable levels. This FTR requires two additional flights to finalize catalytic oxidizer performance evaluation.

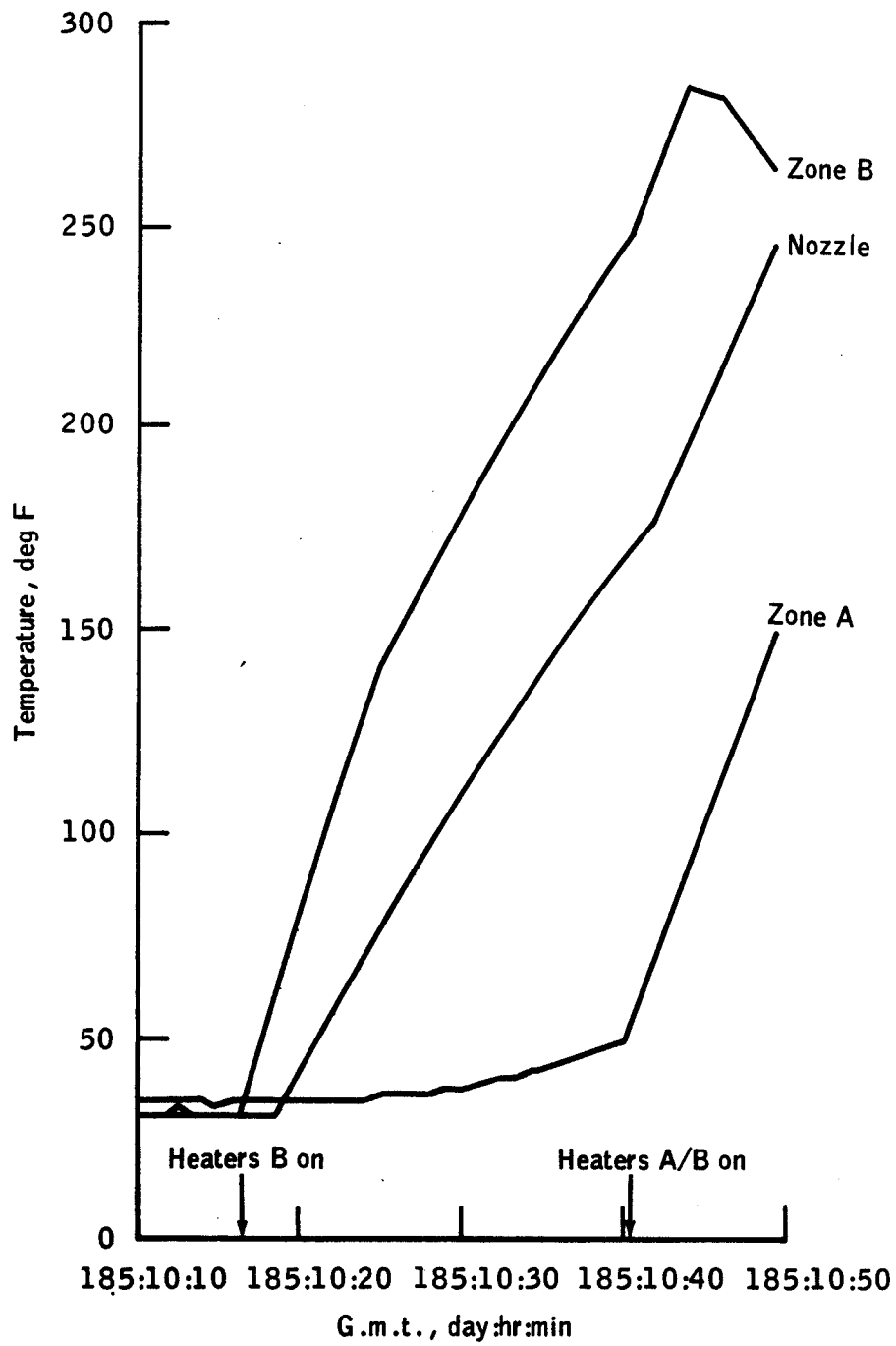


Figure 2-18.- High load flash evaporator subsystem duct heater anomaly.

The cabin PPCO₂ (Partial Pressure of Carbon Dioxide) remained at or below 0.8 mm Hg for all mission phases except ascent and entry when LiOH cartridges were not installed. The peak PPCO₂ value observed on ascent was about 4.3 mm Hg and the peak for entry and post-landing, prior to hatch opening, was about 4.2 mm Hg. The maximum normal limit is 7.6 mm Hg.

The redundant components of the ARS were checked out to verify on-orbit operation. All backup fans and pumps operated normally. After the redundant component checks, an inspection for free water in the air exit duct from the cabin air-to-water heat exchanger and slurper assembly was completed. A second duct inspection was made later in the flight. Both inspections showed no free water in the duct. The cleaning of the slurper section of the cabin heat exchanger after STS-3 may have prevented the free water from recurring during STS-4.

A variation in PPO₂ readings occurred during ascent and entry (Section 5.0, flight test problem report 25). Subsequent evaluation of these variations indicate that PPO₂ sensor response was normal during the transient temperature conditions.

During the four orbital test flights, all scheduled ARS FTO's were accomplished. ARS test objectives still to be accomplished consist of repeating the catalytic oxidizer performance evaluation on STS-5 and STS-6.

2.6.3 Air Revitalization Pressure Control Subsystem

The ARPCS (Air Revitalization Pressure Control Subsystem) performance during STS-4 was identical to that of STS-3 in that system performance was normal with the exception of the nitrogen leak from the GN₂ system in the tail-to-sun attitude. The cabin pressure shell leak rate remained far below the specified rate as expected from previous performance. During ascent, the dP/dt again exceeded the -0.05 psi/min alarm point, activating the Klaxon alarm. This limit has been exceeded during each of the first four flights and is caused by the normal cabin pressure increases. A change is being implemented to establish a higher Klaxon alarm actuation rate and this will alleviate the problem.

There were no configuration or hardware changes to the ARPCS since STS-3. The STS-4 portion of FTR 61VV001 is expected to be satisfied as the leak in the GN₂ system proved to be repeatable at the same temperature and to the same leak rate in the tail-to-sun attitude. This leak did not affect the ability of the ARPCS to provide cabin pressure control and PPO₂ control for the crew environment.

None of the ARPCS launch commit criteria were violated during prelaunch operations.

During the cold tail-to-sun attitude, the GN₂ leak was observed to start at the same temperature range and at the same rate as noted on STS-3. The later evidence included a difference between vent line temperatures (upstream and downstream of the N₂ vent line tie-in) and increased heater duty cycles on the vacuum vent line. The ARPCS had no new anomalies during the STS-4 mission.

During the four orbital test flights, all FTO's were completed.

2.6.4 Airlock Support Subsystem

The Airlock Support Subsystem had no anomalies during the EMU demonstration for STS-4. DTO 463 (Airlock and EVA Systems Demonstration) was completed as planned. Major test objectives still to be accomplished consist of the demonstration of all procedures required during a normal airlock egress. This test is scheduled for STS-5.

2.6.5 Water and Waste Management Subsystem

None of the WWMS (Water and Waste Management Subsystem) launch commit criteria were violated during prelaunch operations.

The potable and supply water system performance was normal during all STS-4 mission phases. Four supply water tanks were flown on STS-4, as opposed to six on previous flights. Tank quantity management by supply water dumps maintained adequate amounts of water onboard.

Waste management and collection was satisfactory. The waste collector slinger speed was lower than normal during the flight, but the slinger motor circuit breaker did not open (Section 5.0, flight test problem report 24). Postflight inspection showed no impediment to slinger motion, and slinger motor or gear degradation is suspected as the cause of the low slinger speed. Urinal air flow degraded during the flight from the normal 8 cfm, and the urinal prefilter was cleaned once during the flight, which improved the air flow. The postflight inspection showed 30 percent clogging of the prefilter.

No smoke alarms occurred, and the fire suppression bottles were not used. During the smoke detector selftest, the alarm activation was later than the crew expected due to the variation in the time it takes the detector logic to complete the self-test, but all smoke detection circuits were verified to be operative.

No test objectives covering water, waste management, or smoke detection and fire suppression subsystems were required during the four orbital test flights, and none is scheduled for the operational flight phase.

2.7 CREW STATION AND EQUIPMENT

2.7.1 Hand-held Flight Crew Camera

The cameras provided for STS-4 were from previous programs or previous Shuttle flights. Overall, the cameras operated satisfactorily providing good documentation of the onboard activities and observations.

2.7.2.1 16mm System.- Eighteen of the 19 film magazines were used with satisfactory photography and camera operation. Some overexposure occurred during flight-deck sequences because of sunlight shafting through the window. Sequences could be improved by more use of the bracket mounting on future flights. The 16mm camera system provided for the NOSL (Nighttime/Daytime Optical Survey of Lightning) operated satisfactorily and provided satisfactory photographic data.

2.7.2.2 35mm System.- One 35mm camera, which was used for operational photography, operated satisfactorily and provided excellent photographic documentation. All photographs were taken in the AEC (Automatic Exposure Control) mode and the interior pictures were exposed using an electronic flash. A second unit was used with a special 55mm lens to photograph the CFES (Continuous Flow Electrophoresis) experiment and the auxiliary photo light was used for lighting. Results of CFES photography were excellent.

2.7.2.3 CRT (Cathode Ray Tube) Hardcopy System.- The CRT hardcopy camera, which is an instant development camera, was not used on STS-4.

2.7.2.4 70mm Systems.- Three 70mm Hasselblad cameras were used, and each camera operated satisfactorily. Much of the photographs were taken through the forward windows and were affected by the haze on the external pane that has been building up with each successive mission. This haze produces light scatter which reduces contrast and sharpness. Some underexposures were noted and the cause is unknown.

2.7.2 Mounted Cameras

2.7.3.1 16mm Camera.- Two high-speed cameras, mounted in the umbilical well, satisfactorily recorded solid rocket booster and external tank separation from the Orbiter. Some parts of the film sequence were affected by an unfavorable sun angle during part of the separation sequence. A third high-speed 16mm camera, mounted in the crew cabin, was used to record debris as viewed through window 4. This camera operated satisfactorily, but certain parts of this sequence were affected by an unfavorable sun angle.

Five 16mm-cameras with automatic exposure control were used to record PDRS (Payload Deployment and Retrieval System) operation. These cameras performed satisfactorily. Photography was slightly affected by the formation of ice crystals on the viewing ports of the environmental enclosures. These crystals are attributed to the outgassing of the film moisture and chemicals and subsequent deposit on the glass.

2.7.3.2 35MM Camera.- One 35mm camera was mounted in the right umbilical well and recorded the view of the external tank at separation. This camera functioned satisfactorily and provided excellent photographs of the tank. However, an unfavorable sun angle affected the last one-third of the film.

2.7.3 STS-1 Through STS-4 Summary of Photography

The hand-held and mounted cameras supported both documentation and operational requirements for each of the OFT (orbital flight test) flights. All FTO's were accomplished even though some hardware anomalies occurred. A total of 48 test objectives were planned for the OFT program. Of that total, two were deleted and 46 were completed. As a result, no major or minor test objectives for cameras remain open.

2.7.4 Ancillary GFE and Flight Crew Compartment

The suction-cup shoes for IVA (intravehicular activity) foot restraint were used and evaluated. The restraints were usable in some areas, but could not be totally evaluated because of scratches in the deck.

The food freezer flown first on STS-4 was considered a most worthwhile addition by the crew.

The additional trash bags onboard were quite useful. Wet trash was generated in greater than anticipated quantities.

Stowage locker fasteners continue to become misaligned; however, closure of the locker doors did not require use of the alignment tool.

Restraints for use of the waste collection subsystem were not adequate. Use of the urinal required too much time and requires design improvement. Body cleaning facilities also need improvement. Difficulty was encountered in removing soap from washcloths. The limited number of washcloths and towels onboard restricted the crew's use of these items.

The crew had to shout in the mid-deck to communicate. Turning the cabin fans off solved this problem. Without the cabin fans on, the crew compartment was extremely quiet.

The kneeboard used by the Pilot failed. The plastic-molded eyeloop that retains the pencil broke. Also, the flight crew complained of shadows across the writing surface from cabin lights. All other ancillary equipment performed satisfactorily.

2.8 STRUCTURES

2.8.1 Flutter/Buffer

Examination of response data from lifting and control surface instrumentation yielded no indication of flutter during entry (FTR 08VV010) (Lifting Surface - Control Flutter - Descent). Low-level control surface buffet (FTR 08VV012) was detected in the transonic region; however, this was anticipated. Response to SPTI (structural programmed test inputs) was detected on all surfaces during both ascent and entry. The maximum accelerations noted on the lifting and control surfaces during STS-4 entry were essentially the same as noted on STS-1, -2, and -3 and all were within design limits. Structural PTI's were repeated due to loss of data (recorder failure) on STS-3. SPTI data were obtained successfully on STS-4.

2.8.2 Stress Evaluation

Review of airframe and control surface strain data indicate that stress levels are similar to those measured on previous flights and that no areas of the structure experienced strains in excess of design values.

Strain data were obtained for the first time on STS-3 on the bottom skin of the midfuselage at station X=880 in., the region of highest predicted stress due to combined thermal and mechanical loading during entry. Strain data recorded at this location during STS-3 indicated stress levels higher than anticipated from preflight predictions. This was due primarily to higher-than-expected thermal stresses. For STS-4, to enable a more accurate determination of skin bending, strain gages were added to the top of stringers at locations corresponding to the bottom skin strains that measured on STS-3. During STS-4 entry peak stresses on the lower midfuselage occurred approximately 3 minutes before touchdown with the maximum measured compressive stress of 11,200 psi occurring at span station Y=90 in. Approximately 2/3 of this stress was induced by thermal gradients and 1/3 was induced by mechanical loading. At this location on the airframe, the allowable buckling stress is 16,700 psi, thus yielding a positive margin of safety. At the time of peak stress, the normal load factor (N_z) was 1.34 g's. If the mission placard of $N_z=2.0$ g's had been attained at this time during entry, an estimated compressive stress of 12,800 psi would have been encountered. This corresponds to a negative margin of safety of 7 percent based on a factor of safety of 1.4 and an allowable stress of 16,700 psi.

2.8.3 Entry Flight Loads

Entry loading conditions were within design limits for the Orbiter and within flight restrictions established for the STS-4 mission. The maximum vertical load factor experienced during the STS-4 entry was 1.8 g compared to a flight restriction of 2.0 g. The maximum load factors measured in the Orbiter payload bay are presented in the following table along with comparative values for STS-1, STS-2, and STS-3.

ENTRY LOAD FACTORS

	<u>STS-1</u>	<u>STS-2</u>	<u>STS-3</u>	<u>STS-4</u>
N_x	0.4/~0	0.4/~0	0.3/~0	0.4/~0
N_y	0.1/-0.15	±0.2	<±0.1	<±0.1
N_z	1.65/~0	1.9/~0	1.6/~0	1.8/~0

Maximum dynamic pressure during STS-4 entry was 282 psf at Mach 0.5 (the maximum allowable was 375 psf at Mach numbers ≤ 5.0).

Landing gear vertical velocities at touchdown were within flight restrictions and were typical of touchdown velocities encountered on STS-1 and -2, but were significantly lower than those experienced on STS-3. Main gear vertical impact velocity was approximately 1.0 ft/sec versus a 6 ft/sec restriction, and nose gear impact velocity was 5.4 ft/sec versus an 11.0 ft/sec design limit. A summary of vehicle responses at the time of nose gear impact based on accelerometers located in the crew cabin and mid fuselage are presented in table 2-III.

2.8.4 Window Cavity Conditioning System

The window dessicant system functioned normally. No frost or fog was observed by the crew on the inner cavity window surfaces during the flight.

TABLE 2-III.- ORBITER RESPONSE AT TOUCHDOWN

X ₀ Location, Description	Main gear impact, g		Nose gear impact, g	
	STS-4 h ~ 1 ft/sec	Design h ~ 6 ft/sec	STS-4 h ~ 5.4 ft/sec	Design h ~ 11 ft/sec
513, Crew cabin (NY)	0.13	-	0.11	0.21
513, Crew cabin (NZ)	1.20	-	1.52	4.08
823, Left Longeron (NZ)	1.30	2.4	1.42	2.79
973, Left Longeron (NZ)	1.28	2.7	1.42	2.23
973, Right Longeron (NZ)	1.30	-	1.36	2.07
979, Keel (NY)	0.10	0.6	0.12	0.42
1294, Bulkhead (NX)	0.07	0.6	0.26	0.84
1294, Bulkhead (NY)	0.11	-	0.13	0.23
1294, Bulkhead (NZ)	1.26	-	1.25	1.92

2.9 MECHANICAL SYSTEMS

All mechanical systems functioned satisfactorily during STS-4 except for one operation of the payload bay door and some inboard brake failures.

2.9.1 Purge, Vent, and Drain

All purge and vent system requirements were satisfactorily accomplished with no anomalies during the STS-4 flight.

After landing, the crew commanded the vent doors to the postlanding purge position configuration and the postlanding purge to the Orbiter was initiated 34 minutes after touchdown.

A postlanding inspection of the wing vent relief doors showed both the ascent and descent relief doors remained closed. Both the left-hand and right-hand relief doors opened on STS-2 but have remained closed on STS-1, 3, and 4.

Comparisons of predicted and measured Orbiter compartment pressure data during ascent show good correlation.

2.9.2 Orbiter/External Tank Separation and Umbilical Devices

The Orbiter/ET separation subsystem (i.e. umbilical separation and retract, Orbiter/ET structural separation and umbilical door closure) performed normally during STS-4.

2.9.3 Payload Bay Doors and Radiators

The initial and final PLBD (payload bay door) operations were normal. However, following a bottom-to-sun attitude of approximately 32 hours duration during the performance of FTO 451-03 (payload bay door cold-case performance), anomalous operation occurred. Upon closure of the port door, both forward and aft ready-to-latch indications were obtained as was the forward port door 1 closed indication. At this time both door drive motors were turned off. Twenty-five seconds later, the port door forward and aft bulkhead latches were initiated. Since the aft door closed indication (close indicator 2) had not been obtained at the time the bulkhead latches were initiated, the software turned on the number 2 motor of the PLBD power drive unit, which operated until the aft door closed indication was achieved after 13 seconds of run time. The forward and aft bulkhead latches continued to operate, and after 17 seconds a motor stall occurred on the aft latch motors. At 24 seconds, the forward bulkhead latches indicated latched. However, a latched indication was terminated (Section 5.0, flight test problem report 13). It was decided to thermally condition the doors in a PTC (passive thermal control) attitude for 10 hours followed by 2 hours in tail-sun. This simulated the entry day procedure. Following thermal conditioning, door operations were successfully completed.

2.9.4 Manipulator Positioning Mechanism

The RMS (remote manipulator system) positioning mechanism was used twice and performed normally during the STS-4 mission. The crew reported that the MPM (manipulator positioning mechanism) functioned satisfactorily during deployment and stowage operations. The MPM actuation times were within two motor predicted time requirements.

The MRL (manipulator retention latches) actuation times were normal, i.e., within predicted two-motor operation times.

2.9.5 Startracker Doors

The startracker door actuation mechanisms performed normally during the STS-4 mission (i.e., doors open/closed when commanded).

2.9.6 Air Data Probes

The air data probe deployment mechanisms performed normally during the STS-4 mission.

2.9.7 Landing/Deceleration Subsystem

The landing/deceleration system performed normally during the STS-4 deployment, landing, and rollout.

2.9.7.1 Landing Gear Deployment.- Deployment of the landing gear was initiated at an air speed of 294 KEAS (knots estimated air speed), an altitude of 406 feet, and 20 seconds before touchdown. All landing gear were down and locked 14.3 seconds before touchdown. The deployment time of 6 seconds was well within the design requirement of 10 seconds.

2.9.7.2 Landing and Rollout.- Touchdown occurred at 185:16:09:39.9 G.m.t., at a sink rate of less than 1 ft/sec and 948 feet beyond the threshold. Nose-wheel touchdown took place 12.7 seconds later and 4988 feet from the threshold. Table 2-IV provides detailed performance values regarding speed during landing. Figure 2-19 shows the time history of the ground speed during landing. Nose-wheel steering was not engaged during the rollout.

Braking was initiated at 132 knots ground speed with a moderately hard level being held for approximately 20 seconds, resulting in an average deceleration of about 7.5 feet/second/second. Following deceleration to approximately 40 knots ground speed, brake pressure was relieved somewhat and the remainder of the landing roll was completed at a lower deceleration rate. The total ground roll distance was 9878 feet.

The braking FTO of a deceleration in the range of 8 to 10 feet/second/second was attempted but not achieved. Postflight examination of the brake commands and the resulting brake pressures revealed large and small amplitude pressure fluctuations. The large amplitude fluctuations were the result of crew commands while the small amplitude fluctuations resulted from hydraulic system supply and return pressures. There were no obvious indications of anti-skid activity.

Postflight inspection of the brakes revealed damage to the two inboard brakes (Section 5.0, flight test problem report 31). The damaged brakes will be refurbished and two new inboard brake assemblies will be installed for STS-5.

Postflight inspection of the tires revealed main gear tire tread wear, but very little wear on the nose tires. The two right-hand main tires had small cuts through one to three layers of cord (17 layers total), and will be replaced with new tires for the next flight. All tire pressures were normal following the landing.

2.9.8 Aerothermal Seals and Thermal Barriers

The aerothermal seals and thermal barriers performed satisfactorily during the STS-4 mission. Postflight inspection revealed slight to moderate damage to the following thermal barriers:

TABLE 2-IV.- LANDING/DECELERATION SUBSYSTEMS PERFORMANCE

Parameter	Velocity, knots	
	Equivalent air speed	Ground relative velocity
Main gear touchdown	199.5	195.7
Nose gear touchdown	164.9	161.2
Braking initiated		132.0
Nose wheel steering	none	none

Touchdown points from threshold:

Left main, ft	1021
Right main, ft	948
Distance from main to nose wheel contact, ft	4040
Distance from nose contact to brake initiation, ft . . .	1919
Braked roll, ft	3919
Braked duration, sec	42
Pitch rate at nose wheel contact, deg/sec	3.3
Sink rate at main gear touchdown, ft/sec	<1
Total roll out, ft	9878
Roll-out duration, sec	61

Note: Touchdown occurred 14 feet left of runway centerline and the Orbiter was stopped on the centerline.

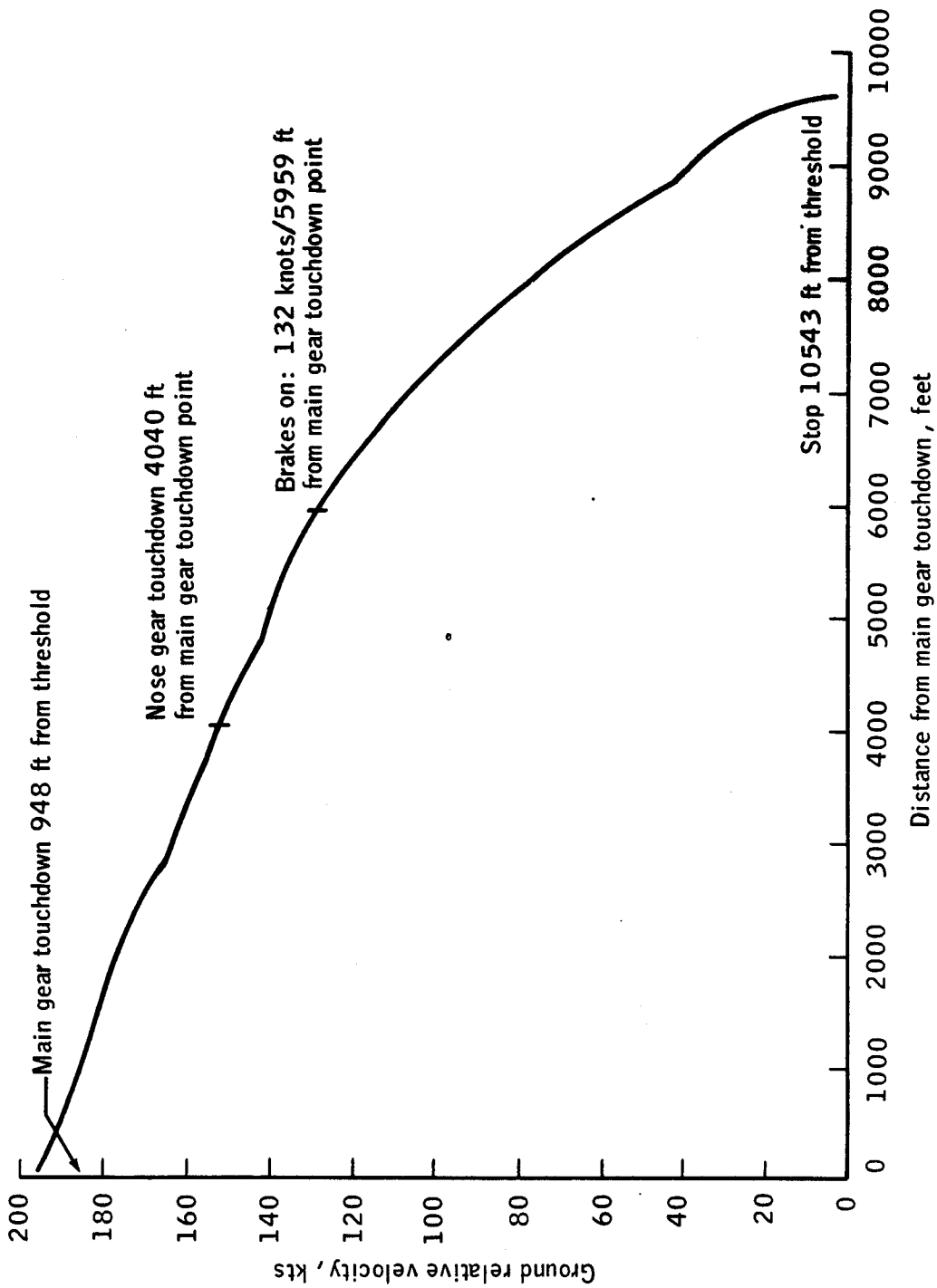


Figure 2-19. - STS-4 rollout time history.

The nose landing-gear door forward thermal barrier fabric was torn and frayed on the left side at the outer mold line for approximately 10 inches and on the right side for about 3 inches near the corner. The aft barrier was damaged at both corners. The forward and aft barriers were replaced. The left-hand hinge line barrier had a small hole (1/2-inch diameter) and fraying, requiring a patch.

The left-hand main landing gear door had a bad tear in the outer cover of the forward barrier. This tear was about 10 inches long and was located at a previously patched section. This section was frayed, burnt, and came loose when touched during inspection at the landing site. Several frayed and torn areas were found on both the right- and left-hand main landing gear doors' thermal barriers. This damage was caused by excessive RTV applied to flow restrictors which adhered to the thermal barriers during entry and tore during the opening of the landing gear doors. All damaged sections of the main landing gear door thermal barriers will be repaired by patching.

The external tank umbilical doors' thermal barriers have two (2) small frayed areas requiring patches, one on the right inboard barrier and the other on the left door forward barrier.

The ingress/egress hatch has an 8-inch tear in the thermal barrier near the aft portion of the hatch hinge. The damaged section will be repaired prior to STS-5 roll-out.

The payload bay door environmental seal was cut through the Teflon tube at the aft port bulkhead centerline splice. This damage was caused by the interference of the door structure with the seal, and will require replacement of a portion of the Teflon tube.

Some fraying occurred to the left- and right-hand vent door number 2 thermal barriers and to the aft portion of the vertical tail split line thermal barrier. Both damaged sections will be repaired.

The extent of the damage was typical of that experienced during previous flights.

2.9.9 Crew Escape System

The crew system ejection seats provided the crew with support and constraint, vertical positioning, back-angle positioning for ascent, oxygen and ventilation connections for suited operations, and communications and biomedical connections. No difficulties were reported during the STS-4 mission.

2.9.10 Airlock Hatch A

During the STS-4 mission, the EVA crewman performed an airlock/middeck preparation task. In the process of performing this task, airlock hatch A had to be opened and stowed. While performing this task, the flexible airlock vent duct was torn by the hatch's uplock fixture as the hatch was rotated toward the stowed position (Section 5.0, flight test problem report 32).

2.10 THERMAL

2.10.1 Thermal Control System

2.10.1.1 Prelaunch and Ascent.- All thermal control system temperatures were maintained within limits during prelaunch and ascent. Post-ascent observations by the crew and postflight inspection have shown that the payload bay liner, flown for the first time, maintained its contamination seal integrity. The maximum pressure differential across the liner was approximately 0.024 psid as compared to the ultimate design pressure of 0.14 psid.

During ascent, several hydraulic line temperature sensors in the nose landing gear exhibited drastic decreases in temperature (the largest decrease was from 77° F to 4° F) and this has not occurred on previous flights. Several hours were required for the temperatures to recover. It is expected that the decay resulted from rain penetration into the wheelwell during prelaunch operations.

2.10.1.2 On-Orbit.- The Attitude Hold Thermal Response (FTO 412-01), was planned with two major attitude-hold periods, 67 hours of tail-to-sun SI (solar inertial) and 33 hours of bottom-to-sun solar inertial followed by 10 hours of PTC (passive thermal control) (four revolutions per hour roll about the x-axis with the x-axis perpendicular to the solar vector). As a result of real-time prioritizing of the attitude sequences to accommodate moisture bakeout of the TPS (thermal protection system) tiles, the bottom sun attitude was flown first for approximately 22 hours and 55 minutes (180:22:20 G.m.t. to 181:21:15 G.m.t.) followed by 10 hours of PTC and 60 hours and 42 minutes of tail sun SI (182:07:20 G.m.t. to 184:20:02 G.m.t.). As a result of this reordering, a postflight as-flown-timeline analysis will be required to make a direct comparison of predictions to flight data.

During the bottom-to-sun SI attitude, all forward fuselage bondline measurements appeared to reach equilibrium, except for the upper forward RCS compartment bondline temperature. This particular bondline location is influenced by the port-side feed system heater cycling during the bottom-to-sun period.

Compared with the STS-3 tail-to-sun orbital rate data, the forward fuselage bondline equilibrium temperatures are generally warmer (except the bottom and side hatch areas) during the STS-4 tail-to-sun SI, as was expected. Table 2-V presents the initial and final bondline temperatures, as well as the initial response rate of seven representative areas during the three mission phases of interest. Midfuselage bondline temperatures at several representative locations at the end of the two major test attitudes along with predictions are summarized in Table 2-VI. Bottom bondline maximum temperatures in the bottom sun attitude ranged from 68° F to 122° F.

The DFI longeron retention fitting minimum temperatures were -10° F at the end of the bottom sun attitude and -30° F at the end of the tail-sun attitude. The temperatures appeared to be steady-state at the end of tail-to-sun attitude. Predictions for these attitudes were -15° and -45° F, respectively (Fig. 2-20). Minimum temperatures for the DFI keel fitting were +10° F in bottom-sun and -30° in tail-sun.

Table 2-VII summarizes the aft-fuselage thermal response to the bottom-to-sun, tail-to-sun, and PTC attitudes. Overall, the aft fuselage was warmer than predicted, and this is consistent with previous flights. In the bottom-to-sun attitude, the aft structure was 10 to 20° F warmer than predicted except for the base heat shield which was approximately 7° F cooler than predicted. In the tail-to-sun attitude, the base heat shield reached 88° F as compared to a predicted 48° F.

Of particular interest during the STS-4 mission was the response of the main landing gear strut actuators and dump valve (during the tail-to-sun SI attitude) which reached -24° F and -28° F, respectively, as compared to the minimum allowable limit of -35° F. Adequate data were obtained to support definition of the hold-time constraint to prevent exceeding -35° F.

TABLE 2-V.- ATTITUDE HOLD THERMAL RESPONSE - FORWARD FUSELAGE

Description	Measurement no.	Bottom-to-sun				PTC				Tail-to-sun			
		Initial temperature, °F	Initial transient rate, °F/hr	Equivalent temperature, °F	Initial temperature, °F	Initial transient rate, °F/hr	Equivalent temperature, °F	Initial temperature, °F	Initial transient rate, °F/hr	Equivalent temperature, °F	Initial temperature, °F	Initial transient rate, °F/hr	Equivalent temperature, °F
Upper cabin X530 bondline	V09T1524	11	-2.9	-4	-4	3.1	a	20	-2.0	a	-5		
Upper FRCS bondline	V90T9462	19	-1.3	12b	7	7.1	a	46	-4.9	a	10		
Lower X560 bondline	V90T1624	20	5.1	121	121	-5.1	a	72	-2.5	a	-7		
Starboard cabin bondline	V31T9004	-19	-1.0	-28	-28	5.0	a	7	-1.7	a	-39		
Starboard FRCS bondline	V09T1510	26	-2.7	18	18	8.1	a	50	-4.6	a	12		
Port X480 hatch bondline	V09T9334	14	-1.0	10	10	4.5	a	39	-4.1	a	0		
Port cabin bondline	V31T9003	-8	-2.1	-20	-20	3.1	a	10	-2.7	a	-28		

^aEquilibrium was not reached after 10 hours of PTC.
 bTemperature gradually decreasing.

TABLE 2-VI.- MID FUSELAGE BONDLINE TEMPERATURES AT THE BEGINNING AND END OF MAJOR STS-4 MISSION PHASES

Measurement location and no.	Bottom-to-sun				Tail-to-sun			
	Initial temperature, °F	Initial transient rate, °F/hr	Final temperature, °F	Predicted final temperature, °F	Initial temperature, °F	Initial transient rate, °F/hr	Final temperature, °F	Predicted final temperature, °F
Bottom fuselage								
V09T9504 (X=777, Y=-52)	-10	15.0	122	105	50	-10.0	-47	-25
V34T9116 (X=1030, Y=0)	1	9.3	70	58	39	-4.5	-47	-50
V34T9117 (X=1214, Y=-2)	14	10.7	68	50	44	-4.5	-27	-42
Wing bottom								
V09T9147 (P, X=1280, Y=-240)	-9	9.0	37	12	24	-6.0	-47	-39
V09T9146 (S, X=1280, Y=-240)	-12	6.8	37	23	29	-8.0	-50	-43
Wing top								
V09T9177 (P, X=1280, Y=-240)	-22	3.3	21	-5	19	-10.0	-51	-59
V09T9148 (S, X=1280, Y=-240)	-24	2.8	21	10	21	-9.3	-58	-35
Fuselage side								
V34T9108 (P, X=850, Y=-105)	-9	4.2	21	39	24	-4.0	-47	-51
V34T9109 (S, X=850, Y=-105)	-20	4.9	39	40	35	-10.0	-62	-50
V34T9112 (P, X=1215, Y=-105)	11	-5.0	16	15	34	-4.0	-27	-29
V34T9113 (S, X=1215, Y=-105)	8	-3.3	16	15	34	-4.0	-32	-30

TABLE 2-VII.- AFT FUSELAGE THERMAL RESPONSE

Measurement no. and location	Bottom-to-sun				Recovery PIC			Fall-to-sun		
	Start temperature, °F	Start rate, °F/hr	End of attitude temperature, °F	Start temperature, °F	Start rate, °F/hr	End of attitude temperature, °F	Start temperature, °F	Start rate, °F/hr	End of attitude temperature, °F	
Bottom fuselage V09T1702 (X=1390, Y=-1)	Actual	10	57 to 62	60	-6	39	39	1.2	26 to 29	
	Predicted	16	17	40 to 48	44	7	6	-0.2	14 to 16	
Port side V09T1724 (X=1410, Z=340)	Actual	1	14 to 19	14	4	26 to 31	29	-4	14 to 19	
	Predicted	6	0.2	4 to 12	11	8 ^a	10	-15 ^b	0 to 7	
Starboard side V09T1720 (X=1410, Z=340)	Actual	-4	9 to 14	11	14	23 to 32	29	-3	9 to 14	
	Predicted	5	2	4 to 12	9	5	8	-5 ^b	-2 to 3	
Base heat shield V09T1616 (Y=-6, Z=393)	Actual	47	14	14	0.8	19	19	6	88	
	Predicted	48	-9	20 to 22	21	0.6	8	12	44 to 48	

^aA sharp rise followed by a slow decline.

^bA sharp decline followed by a slow rise.

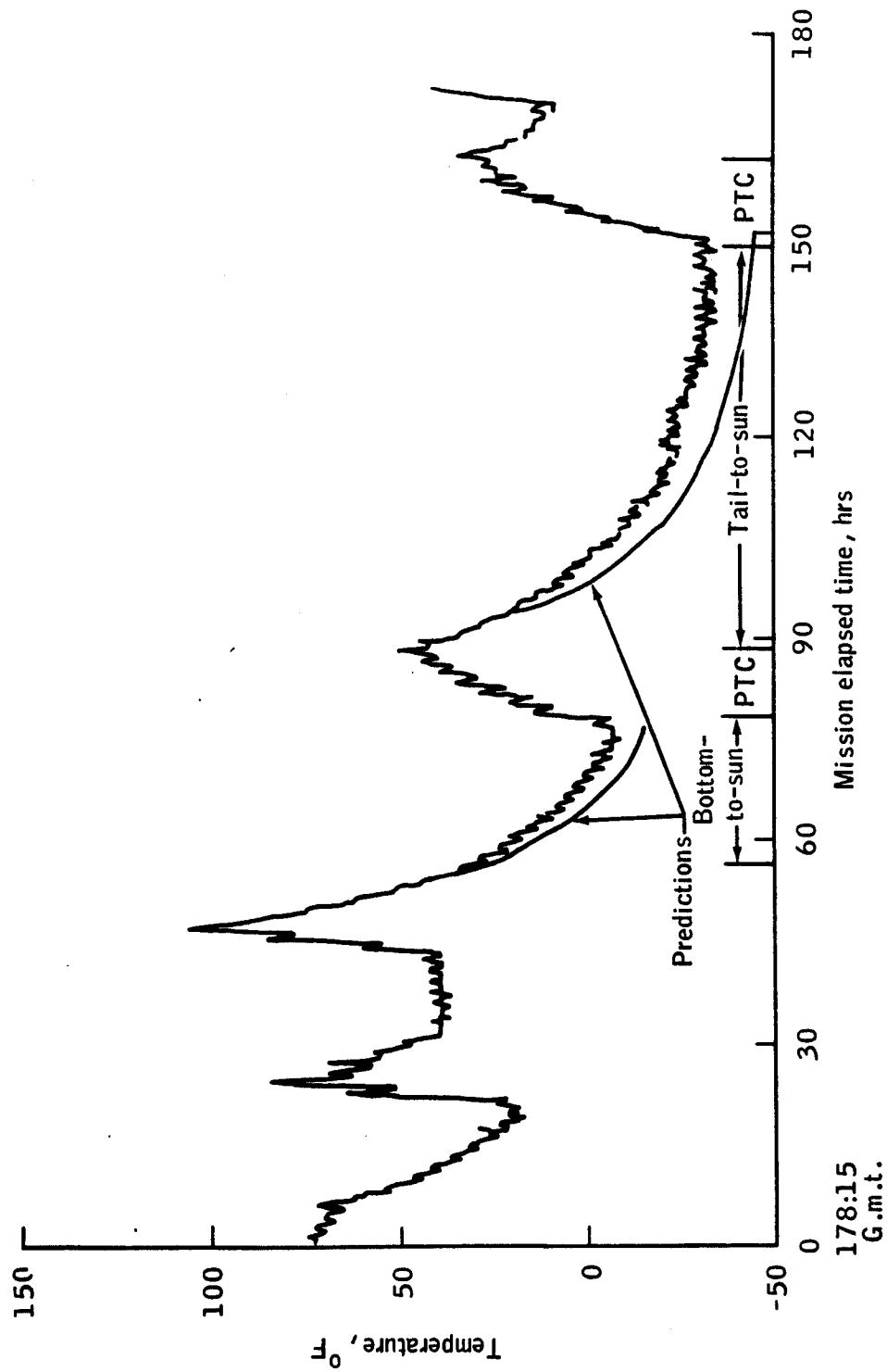


Figure 2-20. - Flight data versus predictions for DFI longeron retention fitting.

A summary of pertinent temperatures for payload bay door closures for both STS-3 and 4 is provided in Table 2-VIII. A review of the thermal conditions for successful and unsuccessful door closures indicates that the only major difference between success and failure is the average temperature gradient between the bottom midfuselage bondlines and the sill longerons. The data indicate that unsuccessful closures occur for negative gradients from top to bottom greater than approximately -50° F. There is no obvious dependence on seal temperatures.

The concern evidenced on STS-3 that the OMS engine feedlines could exceed their 145° F limit for a high beta angle tail-to-sun attitude was further substantiated by STS-4 flight data. Extrapolation of STS-3 data indicated an equilibrium temperature of approximately 120° F which was obtained during the long tail-to-sun attitude flown on STS-4 (Fig. 2-21). Extrapolation to high beta angle conditions indicate a possible equilibrium temperature of 200° F. Adequate data for definition of the constraint were obtained.

A summary of thermal control system heater performance shows that heater duty cycles were less than predicted as a result of structural temperatures being warmer than predicted. The forward RCS compartment heaters performed as expected and maintained all components within temperature limits. The heater configuration change was intentionally delayed until 184:06:30 G.m.t. to obtain long-term performance on a single heater system (system A) to support a decision on relocating the heater thermostats. The unexpected high duty cycles and long heater "on" times experienced on STS-1 through -3 caused concern over the possibility of overheating components or bulk propellant. The long continuous operating times in the tail-to-sun attitude provided the necessary data to determine a requirement to relocate the thermostats for a reduction in heater operating times and duty cycles.

The RCS thruster heaters maintained temperatures except for thrusters F1L and F1F. A large drop of the oxidizer injector tube was seen early in the flight and this is indicative of an oxidizer leak, which was verified. Figure 2-22 shows both oxidizer and fuel injector tube temperatures for thruster F1F decreasing to the expected heater operating temperature of approximately 59° F and recovering over a period of approximately 15 hours before the heater turned off. This response is believed to have resulted from ice in the nozzle from rain prior to launch.

All OMS pod temperatures were maintained within limits. The minimum aft RCS bulk propellant temperatures were 73° F and 74° F, respectively, for the port oxidizer and starboard fuel, which satisfied the entry limit of 70° F.

The Star Tracker Cold Soak Thermal Response (FTO-412-02) was initiated at 180:19:04 G.m.t. Adequate data were obtained to verify cold soak performance.

Four RCS thruster firing thermal soakback tests were planned for STS-4 (FTO's 412-05, 412-06, 412-07, and 412-08). The ARCS thermal soak back test, FTO 412-08, which required a 100-second continuous firing of thruster L1A was not performed as a result of the timeline changes associated with the TPS water bakeout problem. Table 2-IX compares predicted maximum engine temperatures with actual flight test data for the three FTO's that were accomplished. The data will be used to correlate thermal models for analytical definition of any engine firing constraints which might exist.

To determine if the APU fuel and water lines would start freezing within 3 hours after the heaters were turned off in an environment similar to that prior to entry (DTO 414-01) a test was conducted. A successful demonstration would have proved that the heaters could be switched off for entry. The test showed that freezing would start well before 3 hours. As a result of this DTO, the APU fuel/water line and tank heater switches were enabled for entry (B system "AUTO", A system "OFF"). The stagnant fuel and water line heaters operated throughout entry and maintained normal temperatures.

TABLE 2-VIII.- PAYLOAD BAY DOOR CLOSURE TEST SUMMARY

	STS-3 Attitude, °F (door closure status)			STS-4 Attitude, °F (door closure status)			
	Tail sun (Problem) -90(s111) 50(aft dr)	Top SI + PTC (Success) -77(s111) 44(aft dr)	Nose SI (Success) -35(s111) 96(fwd dr)	Top sun (Success) +50(fwd dr) 120(aft dr)	End of mission Top SI + PTC (Success) 7(fwd dr) 44(aft dr)	Bottom SI + PTC (Success) -4(s111) 47(aft dr)	End of mission Tail SI + PTC + 3hr tail SI (Success) -14(fwd dr) 49(aft dr)
Motors							
Door structure	-70/+40	-24/+62	-47/-19	+57/+190	-60/1	-52/21	-60/1
582 frame	-67/-47	-47/-32	-17/+34	+39/+75	4/15	-12/6	-22/49
Aft bulkhead seal support	-24	-2	-4	+65	19	6	21
Seal (s111)	-120/-110*	0/+29*	-62/-110*	+55/150*	0	-32	-27
Average sill longeron	-62	-37	-27	+85	+28	2	-6
Average midbottom fuselage bondline	+15	+9	-23	+21	+36	37	10
Bottom to top gradient	-77	-46	-4	+64	-8	-35	-16

*Seal temperature cycle

TABLE 2-IX.- FORWARD RCS THRUSTER F3F HOT SOAK FIRING TEST SUMMARY^a

Flight test objective	Description	Maximum hot soak temperature, °F						
		Injector tube			Valve body		Valve seat	
		Oxid ^b	Fuel ^c	Pred ^d	Oxid ^e	Pred ^d	f	Pred ^d
412-05	30-second continuous firing	131	135	156	98	90	114	128
412-06	2 engines F3F/F2F 30-second continuous firing	130	135	156	96	92	111	130
412-07	5 Cycle 30-second/30 min on/off	171	176	196	126	118	150	156

^aAll component temperatures were below upper allowable limits

^bV42T1505

^cV42T1506

^dV42T9105

^eArithmetic average of injector tube and valve body

^fAverage of V42T1506 and V42T9105

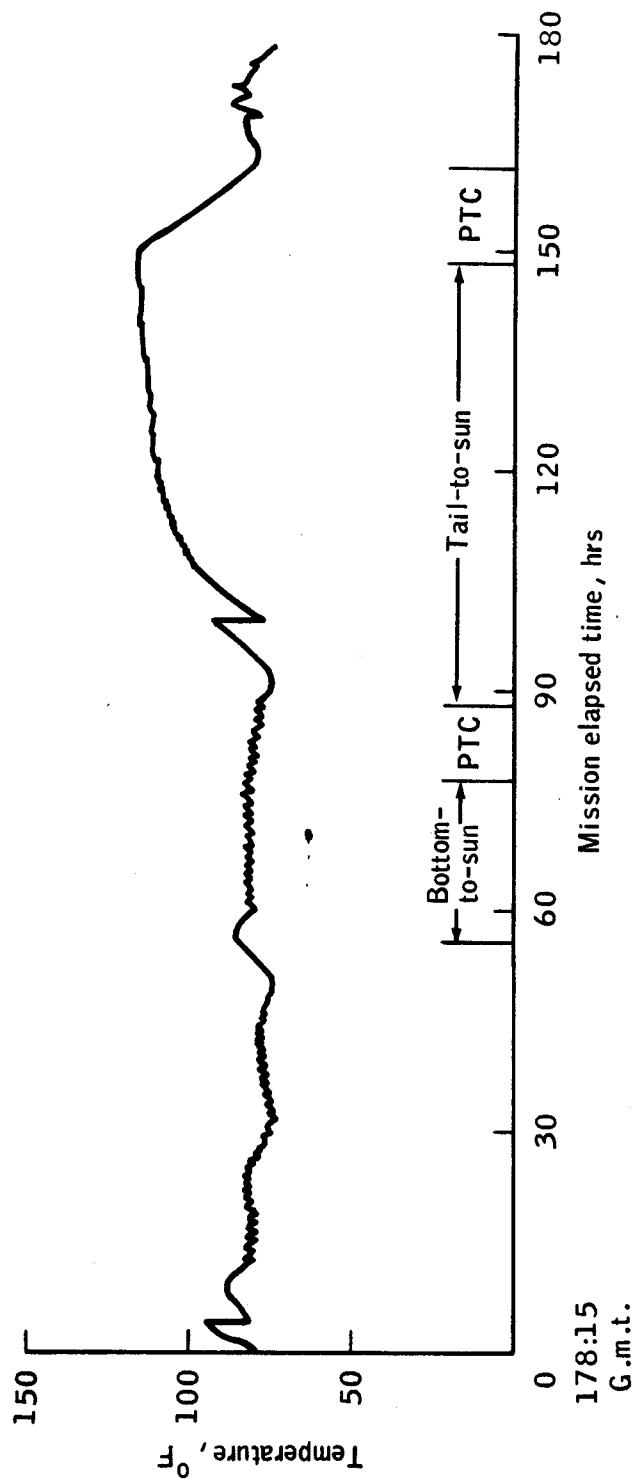
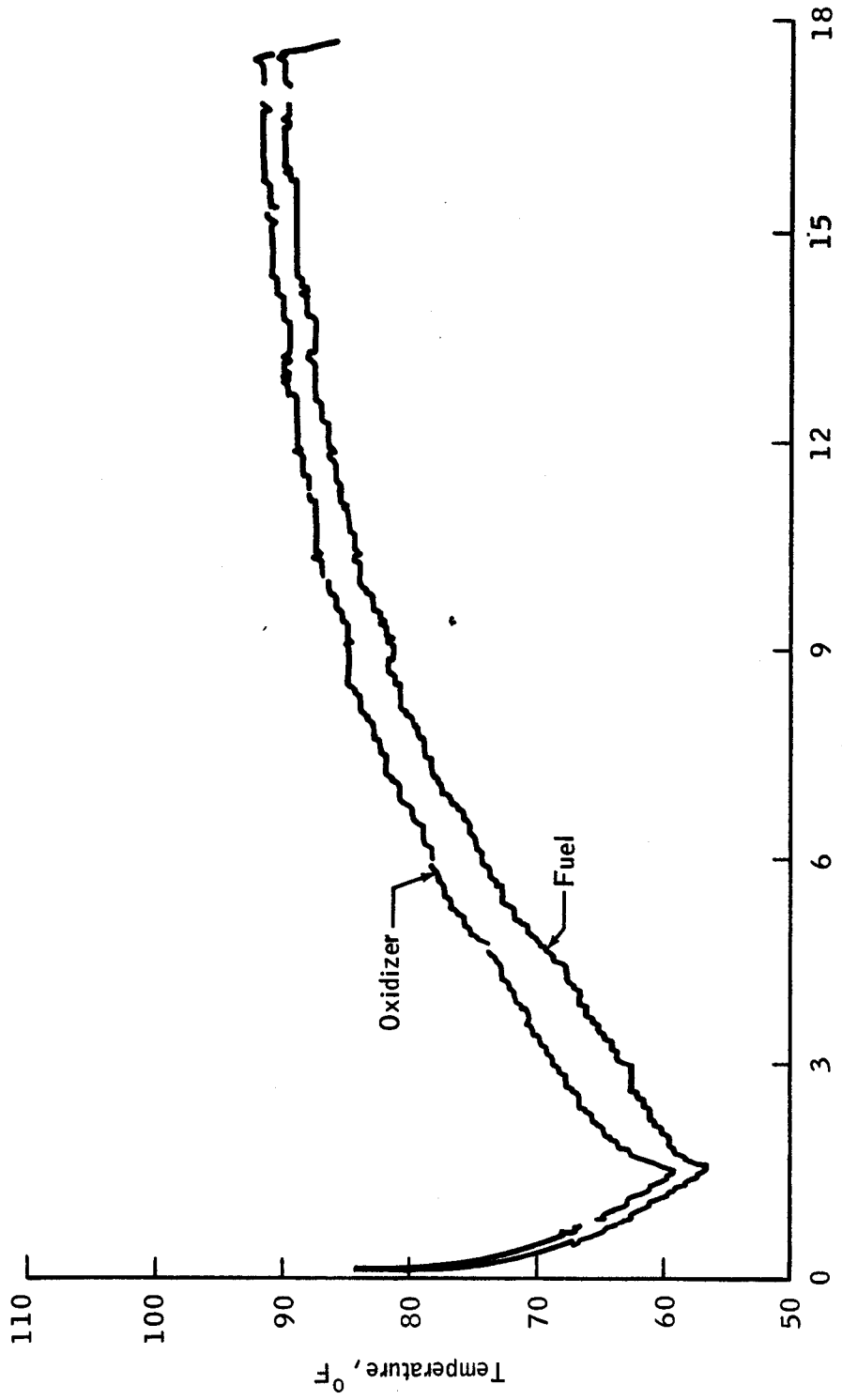


Figure 2-21.- Port OME fuel line flight data.



178:15
G.m.t.

Mission elapsed time, hrs

Oxidizer

Fuel

Temperature, °F

Figure 2-22.- Engine F1F oxidizer and fuel injectors.

Hydraulic System Warmup (FTO 444-01) was accomplished during the long tail-to-sun SI attitude. The objective was to inhibit circulation pump operation on system 1 to allow the system to cool as much as possible prior to FCS checkout to demonstrate system warmup from cold conditions. Table 2-X summarizes component temperatures of interest prior to and following FCS checkout.

Hydraulic System Timer Mode Operation (DTO 444-02) was accomplished during the long tail-to-sun SI attitude hold period. Data were obtained for systems 2 and 3 in the GPC timer mode. The originally planned 4-percent duty cycle was decreased to 2.4 percent in real time to reduce elevon actuator heating from the systems 2 and 3 circulation pump operation.

Figure 2-23 shows the timer mode thermal response for the ROEL (right outboard elevon) actuator and the system 2 ROEL actuator return line. The response of the system 1 REIL (right inboard elevon) actuator return line, which is located under the actuator insulation, is also shown. It can be seen that the 2.4-percent duty cycle was not adequate to maintain line temperatures above the desired 0° F. This points out the delicate balance which must be achieved to meet minimum temperatures while minimizing circulation pump run time.

Hydraulic system midbody and landing gear lines are isolated from circulation pump flow. The nose landing gear extend (supply) line temperature displayed a colder temperature and higher decay rate than nearby structure. The colder bias had been noticed during STS-3 and was suspected to have been caused by the fact that it was located within the hydrogen tank 3 insulation compartment, but the extent of this possible effect had not been determined. On STS-4, the sensor eventually exceeded the fault detection limit of -50° F (changed to -65° F in real time) at approximately 183:14:00 G.m.t. (Section 7.0, flight test problem report 6E). Real-time assessment revealed that flow out of hydrogen tank 3 was influencing the line temperature.

The crew was required to observe elevon positions (DTO 446) at various times during the flight to determine the effect of circulation pump operations and FCS checkout on elevon positions. The data will be used to support thermal analysis predictions and to evaluate the effect of elevon positions on hydraulic and bondline temperatures. Table 2-XI summarizes the crew observations which indicate that the left inboard and both right elevons tend to drift to an "up" position while the left outboard drifts to a down position.

2.10.1.3 Entry Post-Landing.- The maximum entry bondline temperatures, as on previous flights, occurred on the starboard OMS pod (233° F) and the bottom midfuselage (180° F).

From the available data the entry/postlanding thermal soakback on systems was in general minimal (10° F to 15° F) as experienced on previous flights. No hydraulic circulation pump operations occurred post-landing since none of the bondline temperatures in the vicinity of hydraulic components exceeded 240° F.

2.10.2 Thermal Protection Reusable Surface Insulation

The night before launch a severe hail storm occurred at the launch pad damaging the surface of a number of tiles (Section 5.0, flight test problem report 1). An inspection of the Orbiter surface showed no damage that would restrict a safe entry and therefore, the launch proceeded as planned. The T+4 minute DFI surface temperature data indicated that many instrumented tiles had entrapped water. Subsequent ascent temperature response data of all DFI measurements conclusively showed water in many instrumented tiles. Figures 2-24 and 25 show some typical wet tile temperature responses for STS-4 as compared to STS-3. These data confirmed the prelaunch decision to place the Orbiter in a solar inertial attitude

TABLE 2-X.- FCS CHECKOUT HYDRAULIC SYSTEM WARMUP
(FTO 444-01)

System 1 component	Sensor identification	Initial Temperature, ° F		Final Temperature, ° F	
		Predicted	Actual	Required	Actual
Reservoir fluid	V58T0101	29	33	-	88
Main Pump	V58T9101	89	88	-	195
Rudder speed brake PDU	V57T0014	-12	16	-	63
Return line	V58T1006	-35	0	35	105
Body flap PDU	V57T0018	48	64	-	92
Return line	V58T9144	30	43	35	109
Left inboard elevon actuator	V58T0830	11	18	-	55
Return line	V58T0157	-20	18*	35	97
Right inboard elevon actuator	V58T0930	10	15	-	55
Return line	V58T0159	-21	13*	35	100
Left outboard elevon actuator	V58T0880	0	3	-	42
Return line	V58T9261	-27	-8	35	93
Right outboard elevon actuator	V58T0980	4	4	-	43
Return line	V58T9262	-28	-27	35	91

*These temperature sensors are mislocated under the actuator insulation.

TABLE 2-XI.- CREW OBSERVATIONS OF ELEVON POSITION

Time, G.m.t./m.e.t.	Elevon position observation			
	Lower outboard elevon	Lower inboard elevon	Right inboard elevon	Right outboard elevon
179:12:06/21:06	DL ^a	U ^b	UL ^c	T ^d
180:18:50/51:50	UL	U	U	UL
182:20:00/101:00	DL	FU ^e	DU	U(~20°)
184:07:52/136:52	18.3°(FD) ^f	-33.5(FU)	-33.5(FU)	-33.5(FU)
184:08:00/137:00	0°(T)	0°(T)	0°(T)	0°(T)
184:14:51/143:51	T	FU	FU	U(~10°)

^aDL = Down a little
^bU = Up
^cUL = Up a little
^dT = Trail
^eFU = Full up
^fFD = Full down

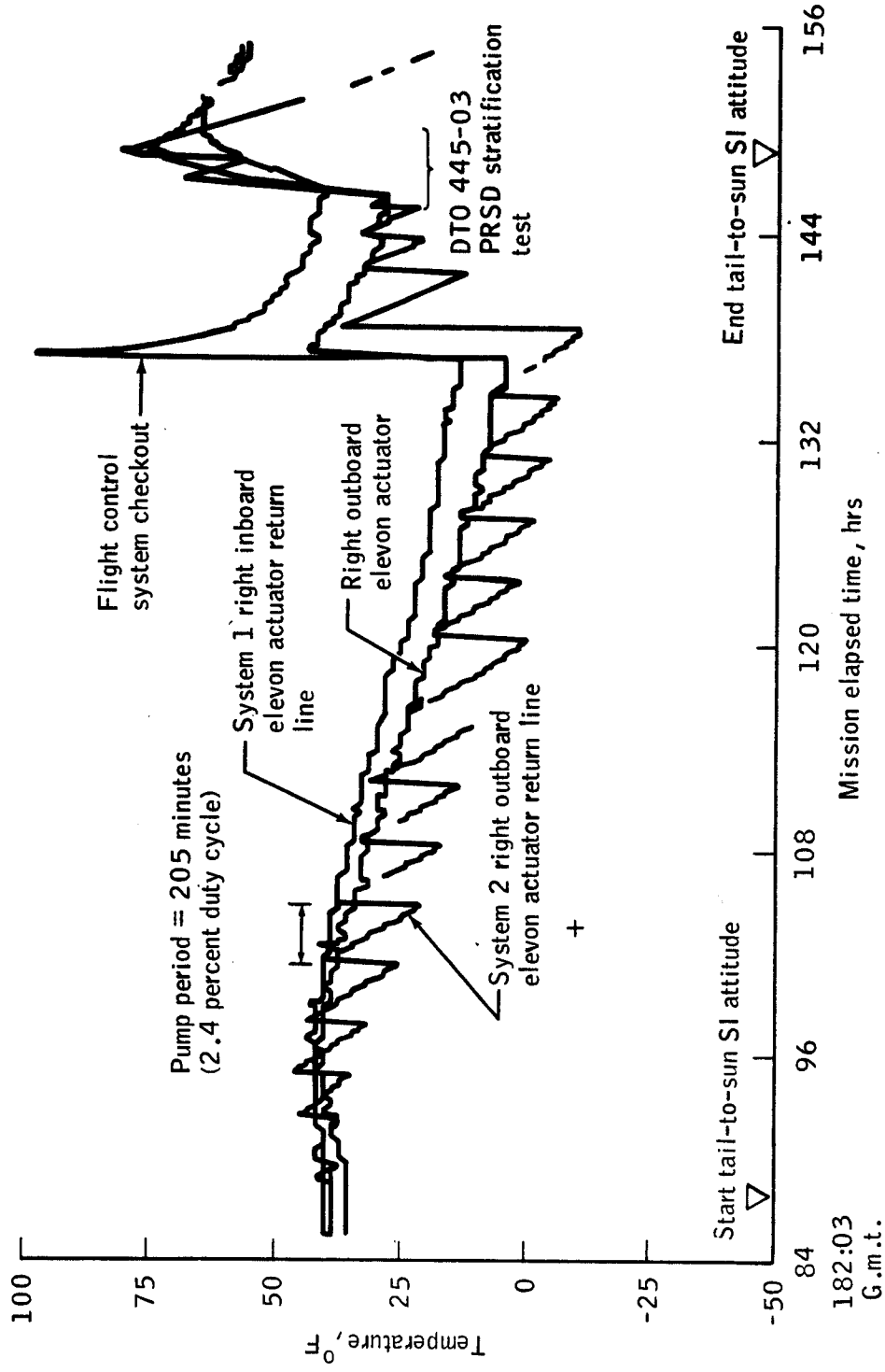


Figure 2-23.- Right wing hydraulics.

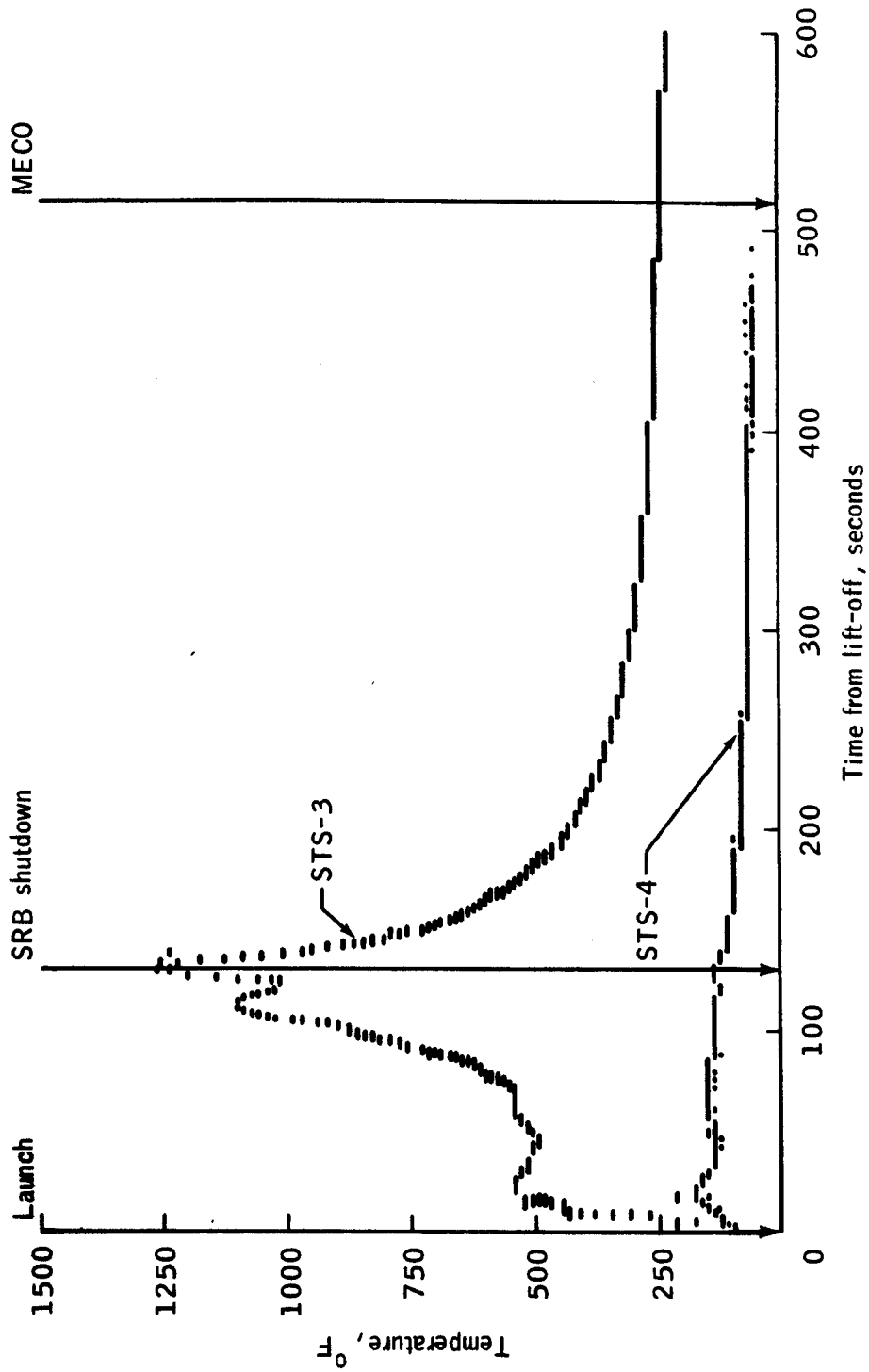


Figure 2-24.- Wet tile temperature response.

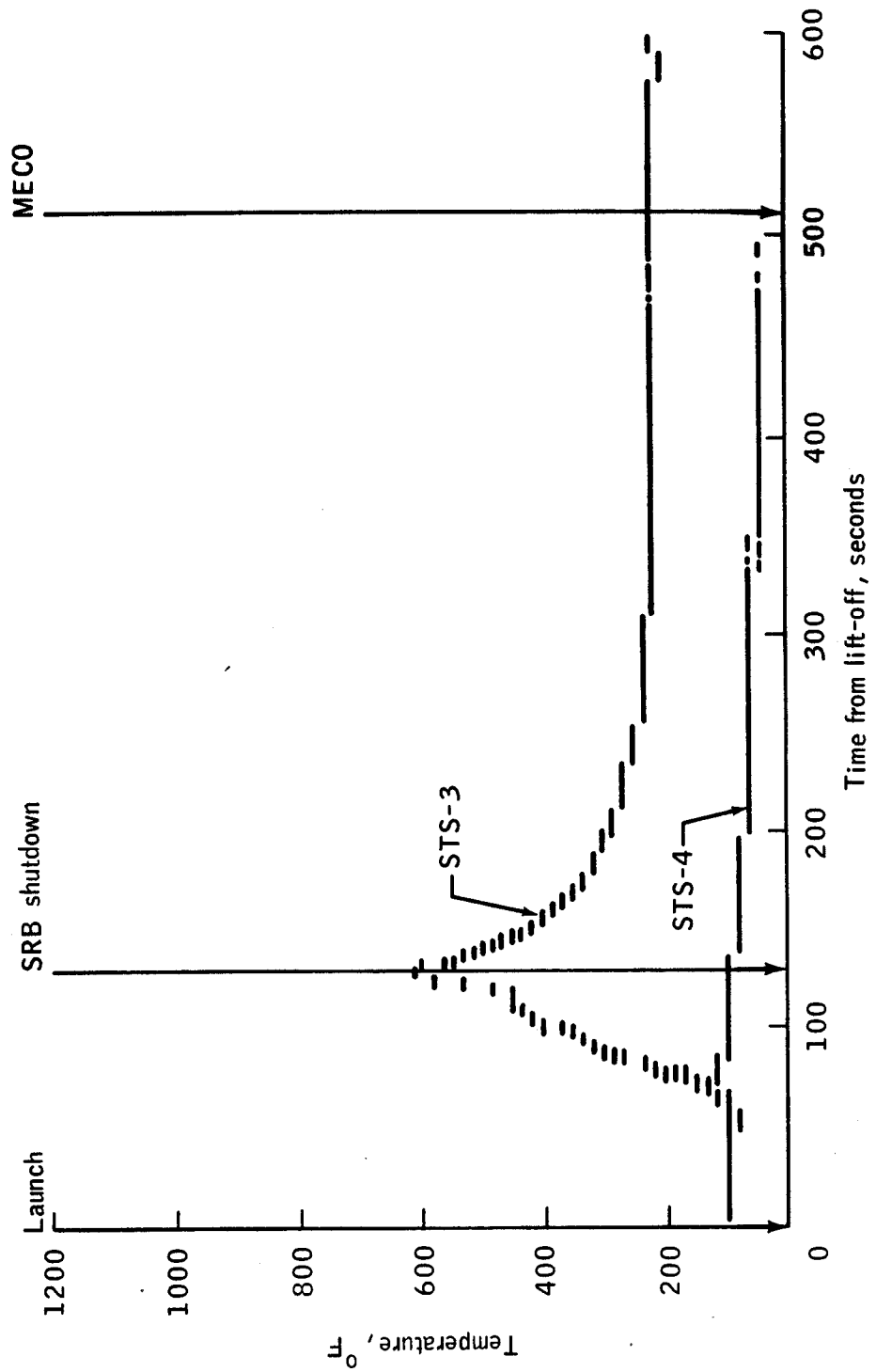


Figure 2-25.- Wet tile temperature response.

with the bottom toward the sun to dry the tiles prior to reaching a cold condition that would fracture the tiles as occurred during STS-2. This bottom sun attitude was maintained for almost 12 hours after which the normal planned attitudes were resumed. Subsequent data of indepth tile temperatures from remote sites indicated that some DFI tiles still may have contained some water and therefore, a second solar inertial bottom-to-sun attitude was established for 23 hours after which the data conclusively showed no water or ice to exist. After landing twenty representative tiles were removed and an inspection showed no evidence of any water/ice damage. In addition, extensive sidewall coating inspections showed no evidence of ice damage. One of the areas where the worst hail damage occurred was the right side of the forward fuselage as shown in figure 2-26 after landing. Another of the worst hail damaged areas was the lower right wing. This area was repaired prior to lift-off and suffered no adverse effects during entry.

The DFI data were not obtained over the complete entry profile as on STS-1. However, the peak bondline temperatures that were obtained after blackout were similar to those observed on the previous three flights. Even though the tile surface temperatures were higher than on previous flights, the entry time was approximately 100 seconds less, thereby resulting in a net reduction in the heat load that affects the aluminum structural temperature response. Figure 2-27 compares the maximum measured structural temperatures during entry for STS-1, 2, 3, and 4. The differences in temperatures from flight-to-flight result primarily from the differences in initial temperature prior to entry and, secondarily from the slight differences in entry trajectories and elevon and body flap deflection histories. Figures 2-28, 2-29, and 2-30 compare the STS-3 and 4 temperature time histories at three DFI plug locations on the Orbiter lower surface.

Continued excessive tile-to-tile gap heating occurred, unexpectedly equivalent to STS-1, and this was contrary to the expectation that less and less gap heating would occur as reported in the STS-3 Orbiter Mission Report. Seven tiles had slumped as a result of this gap heating effect and one location on the OMS pod required structural repairs because of an over-temperature condition that occurred to the graphite epoxy. The increase in occurrences and severity may have been the result of earlier transition and higher turbulent heating than experienced during the STS-2 and 3 entries.

The FRSI on the midfuselage side, PLBD side and OMS pod, again experienced higher heating resulting in scorching of the FRSI similar to the previous flights (see figure 2-31).

Severe coating abrasion and loss of tile coating and recession of LI-900 was noted on the upper body flap outboard edges. This was caused by repeated firing of the aft RCS downward firing vernier engines (L5D and R5D). (Figure 2-32 shows this affect.) This erosion appeared cumulative and the direct result of excessive use of the aft vernier engines during the long attitude hold periods of STS-3 and 4. No thermal degradation occurred during entry since the entry environment in this region is minimal.

One tile was lost off the forward part of the right-hand OMS pod. No thermal damage occurred in this thermally benign region in front of the pod next to the payload bay door. Postflight investigations indicate that the tile was not properly bonded to its aluminum carrier plate due to its shape and interference with the pod thermal barrier. Only 20 percent of the SIP footprint was bonded to the carrier plate. Other tiles with similar geometry and thermal barrier interference will be inspected prior to STS-5 to insure proper bonding.

2.10.3 Leading Edge Structural Subsystem

2.10.3.1 Nose Cap.- The DFI data obtained during entry indicate generally that STS-4 was slightly cooler than STS-3. Table 2-XII presents a comparison of the STS-4 nose cap flight data with the STS-1, -2, and -3 flight data. These data, along with other data, indicate no degradation in the nose-cap performance for the initial four flights.

TABLE 2-XII.- COMPARISON OF STS-1, 2, 3, AND 4 LEADING EDGE STRUCTURAL SYSTEM AND NOSE CAP DATA

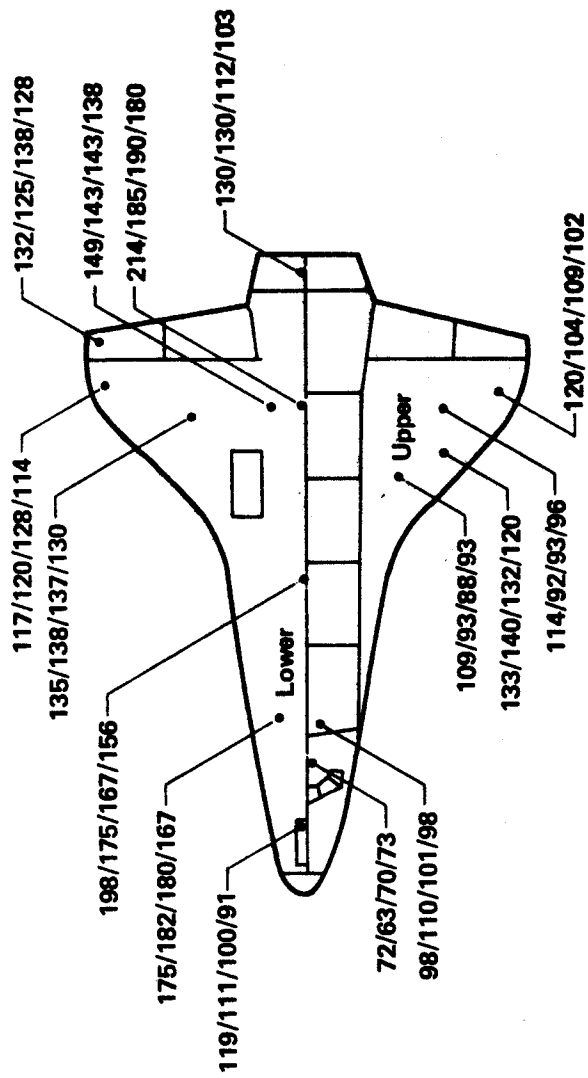
Sensor no. V09T(P)----A	Component location	STS-1 maximum temperature, °F	STS-2 maximum temperature, °F	STS-3 maximum temperature, °F	STS-4 maximum temperature, °F
9941	Lower centerline support link	a	725	720	701
9942	Lower centerline bulkhead	185	178	162	153
9943	Lower centerline HRSI/RCC TB (thermal barrier)	a	a	a	a
9944	120 centerline bulkhead	170	170	155	154
9945	120 centerline support line	700	710	640	631
9946	120 centerline HRSI/RCC TB	a	a	a	a
9947	Upper centerline support link	350	360	353	351
9948	Upper centerline HRSI/RCC TB	a	a	a	a
9949	Bulkhead HRSI	1750 ^b	2000	1980	1865 ^b
9950	Bulkhead HRSI bondline	180	172	160	154
9951	Bulkhead HRSI	1150 ^b	1190	1180	1227 ^b
9952	Lower centerline support link	610	610	570	543
9955	Stagnation RCC	1360 ^a	1450 ^a	1450 ^a	1380 ^a
9956	Lower centerline RCC	a	a	a	a
9957	Lower tangential RCC	1075 ^a	1200 ^a	1190 ^a	1124 ^a
9958	Upper centerline RCC	700 ^a	860 ^a	860 ^a	822 ^a

^aSensor inoperative or data questionable.

^bMaximum value at start of data.



Figure 2-26 . - Hail damage to right side of forward fuselage .



STS-1/STS-2/STS-3/STS-4 .°F

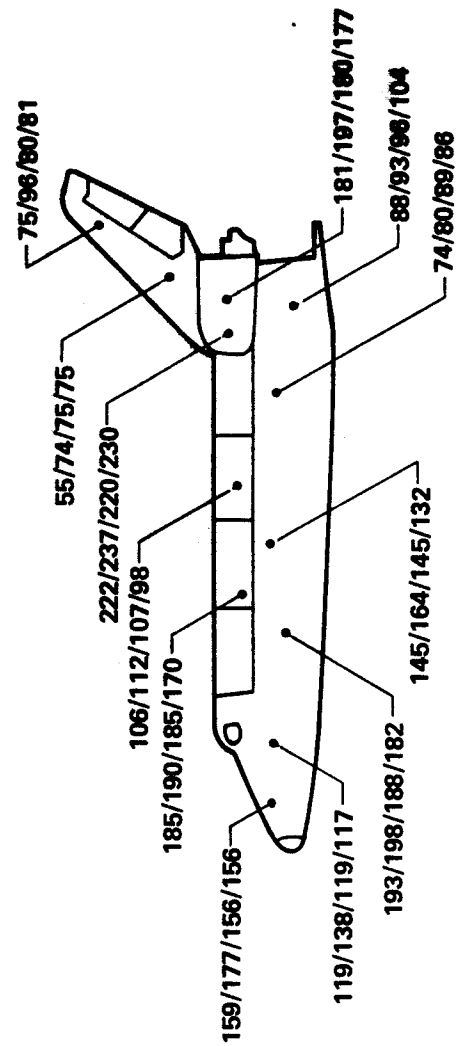


Figure 2-27.- STS-1, STS-2, STS-3, and STS-4 peak entry structure temperature comparisons.

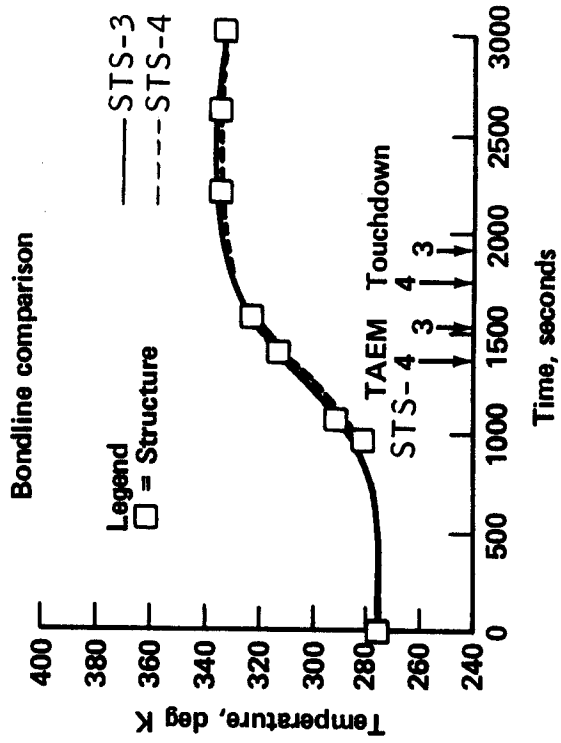
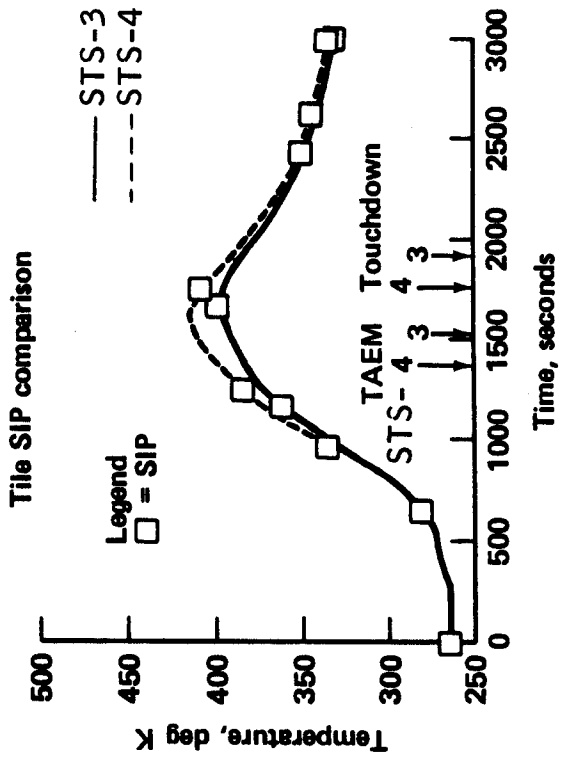
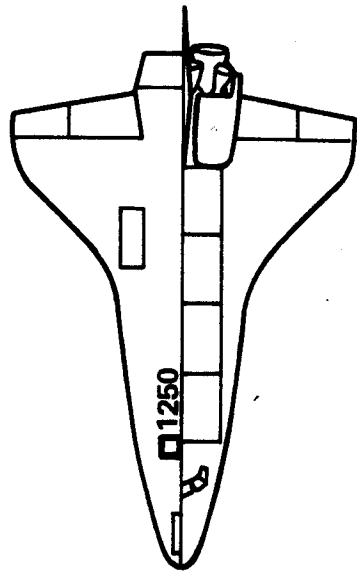
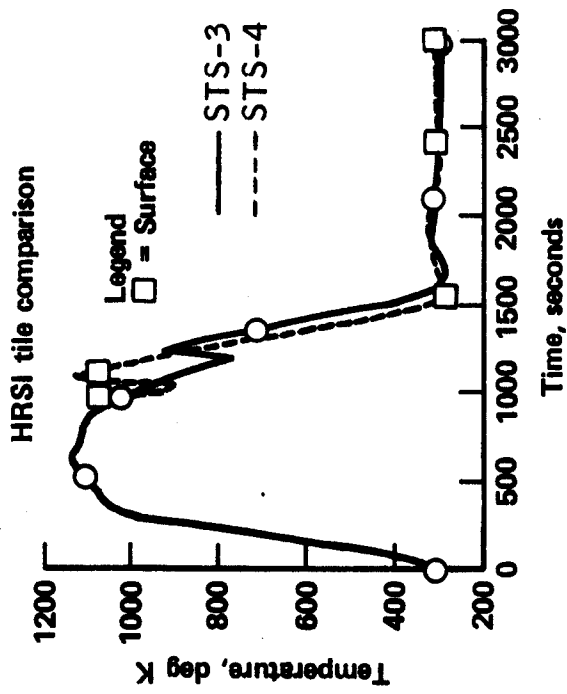


Figure 2-28.- Comparison of analysis and actual temperature data at station 1250.

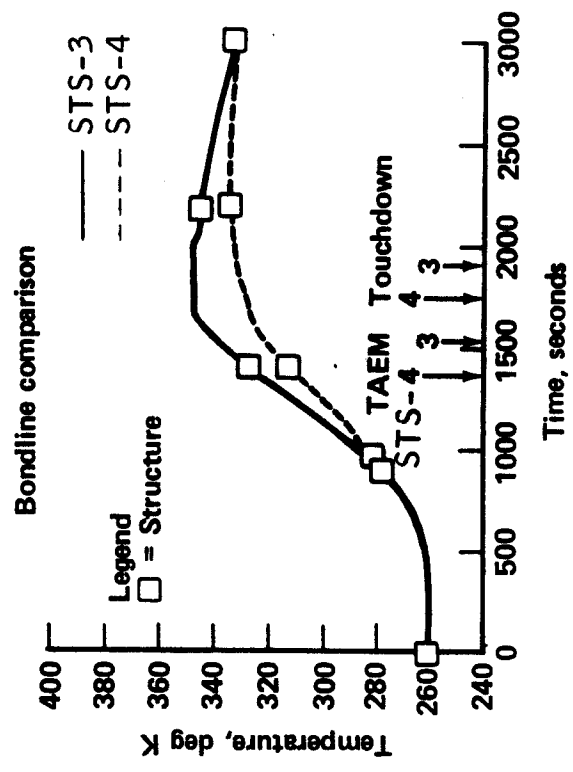
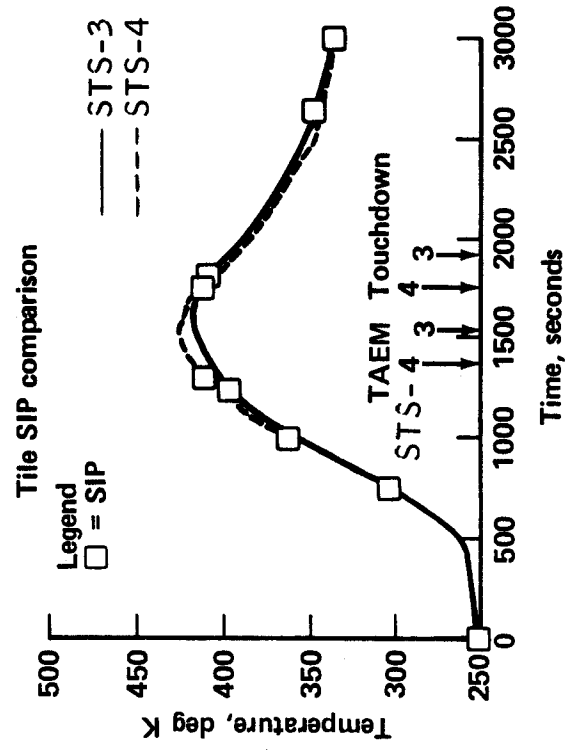
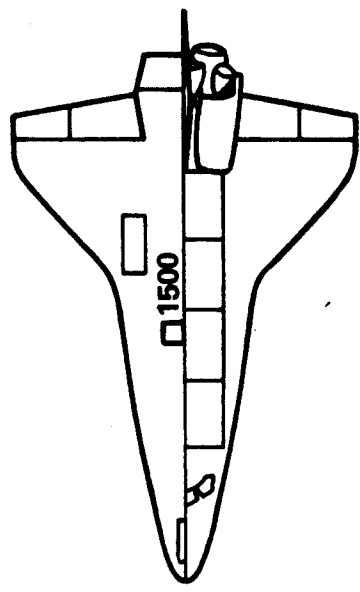
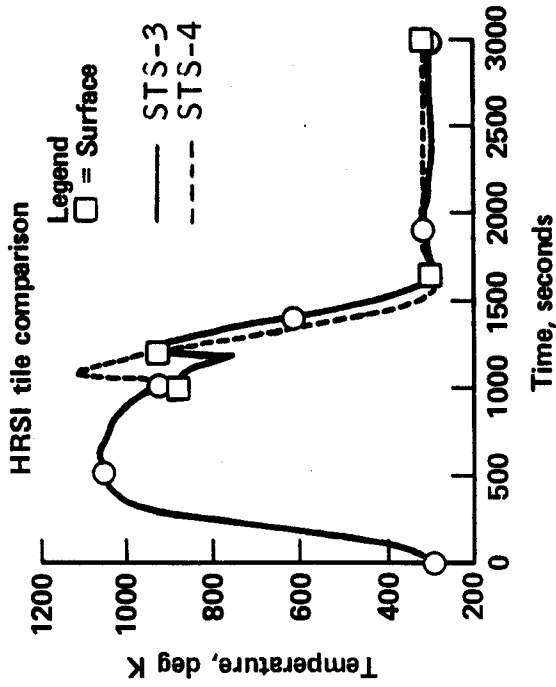


Figure 2-29.- Comparison of analysis and actual temperature data at station 1500.

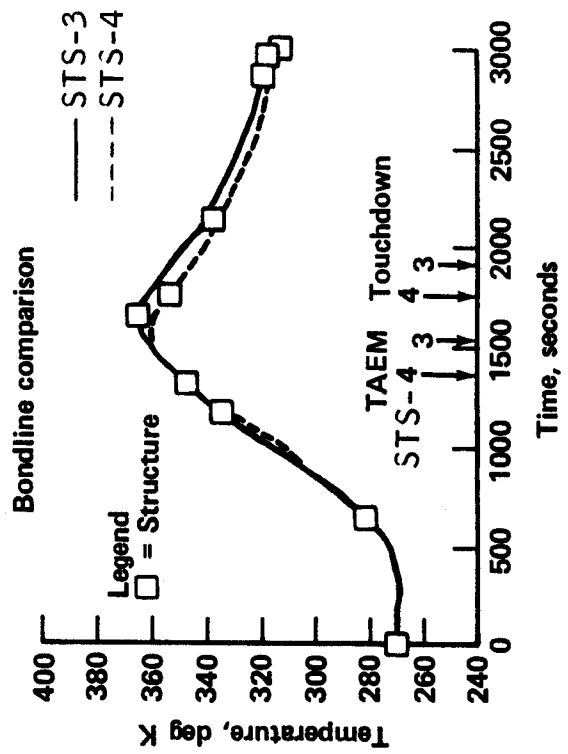
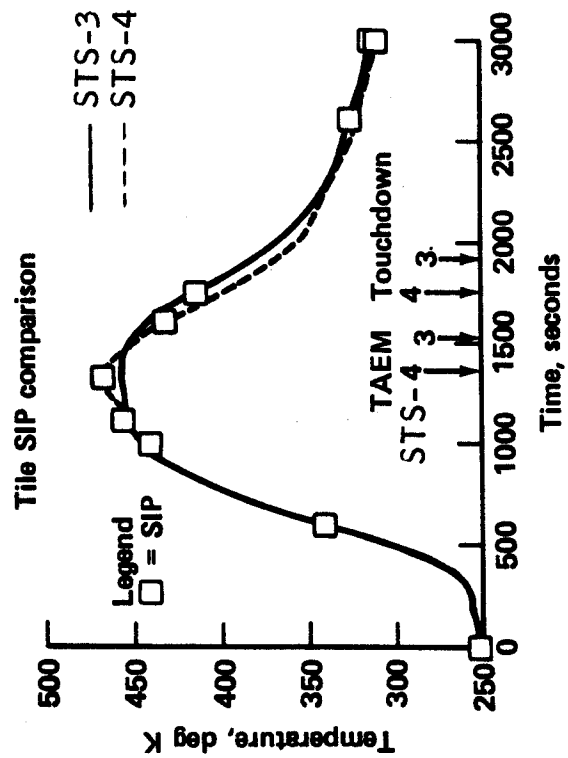
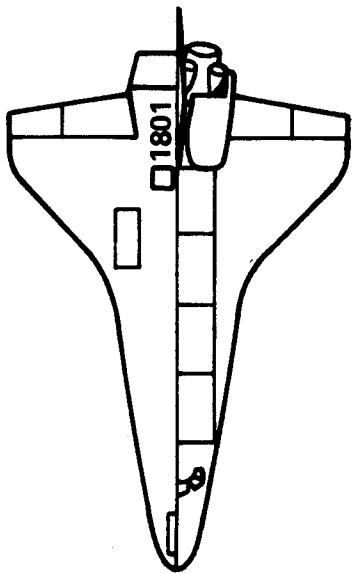
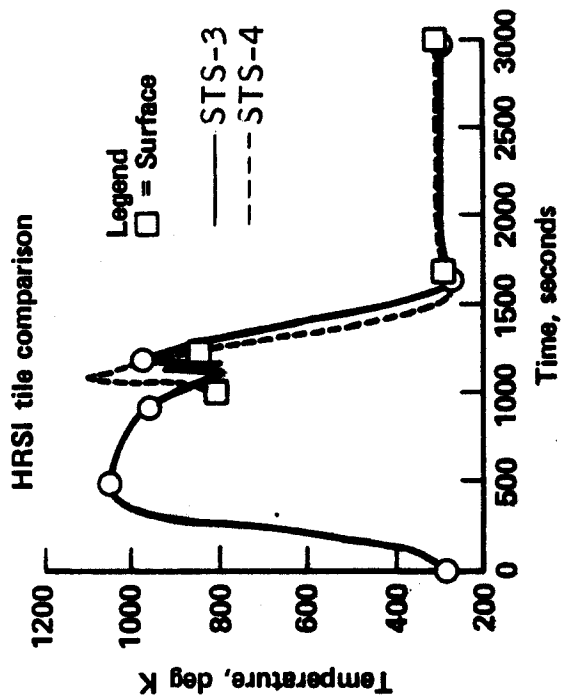


Figure 2-30. - Comparison of analysis and actual temperature data at station 1801.



Figure 2-31 . - Areas of scorching on midfuselage , payload bay door , and OMS pod .



Figure 2-32.- Coating degradation on body flap upper-surface tiles.

The nose-cap external surface was examined visually for evidence of cracks, chips, etc., and no evidence of these conditions was found except for two surface coating abrasion areas in the lower right-hand portion of the nose cap. No repairs will be made for STS-5. Also, there was evidence (i.e., contamination/residue) of numerous impacts on the nose cap.

The nose-cap bulkhead door was removed to inspect the internal conic insulation blankets and clean/calibrate the four (4) nose-cap radiometers mounted in the bulkhead door. With the door removed, the exposed hot surface of the conic insulation blankets was inspected. The blankets were in excellent condition i.e., pliable, no fraying, no evidence of quartz thread/AB312 cloth embrittlement, and no blanket separation at polyimide joints or at the RCC mating surface. Some black discoloration of the blankets was evident but less than that seen on the nose cap certification test. The lower centerline polyimide cone sections and blanket support brackets had a black deposit similar to that seen on the certification hardware.

The nose cap bulkhead door tiles were in excellent condition, but had white/black deposits over the tile surface from outgassing of the internal insulation blanket organic binder. This deposit is similar to that found from the nose-cap certification test. A black deposit was found on the filler bar in and around the lower half of the door tile perimeter, but with no indication of filler-bar overtemperature. Indication of flow between the bulkhead structure and door closeout was evident based on deposits on the aft surface of the bulkhead structure. The four nose-cap radiometer lens were covered with a black deposit. The radiometer temperature measurements of the RCC shell have been suspiciously low for the STS-1, -2, -3 and -4 flights. The lack of available radiometer data has hindered the verification of nose-cap entry aerodynamic heating. The STS-4 radiometer lens calibration before cleaning indicated that the contamination was too thick to perform a post-flight calibration. Therefore, the data from STS-1, -2, -3 and -4 are not recoverable. After cleaning the lens, very good agreement between the DFI and the manufacturer's calibration curves was obtained. Based on these results, it is expected that the radiometers will provide good data for the STS-5 flight.

Several HRSI interface panel tiles were removed from the lower centerline 416 carrier plate to inspect slumped tiles at the RCC interface. Inspection of the interface cavity indicated some scorching/burning of the filler bar at the base of the slumped tiles. The interface-panel thermal barrier was brittle at the tile OML (outer moldline). Several HRSI tiles located aft of the interface panel tiles and forward of the nose landing gear door were also removed to inspect for tile slumping at their corner intersection.

2.10.3.2 Wing Leading Edge.- A summary of the wing leading edge DFI temperature data for the four flights are presented in Table 2-XIII. Comparing the STS-4 data with the STS-1, 2 and 3 flight data indicates that STS-4 had a slightly cooler entry. As can be seen from the table, no degradation in the thermal performance has occurred from the four flights.

The wing leading edge panels were examined externally for evidence of anomalies, chips, cracks, etc., from the STS-4 mission. Areas of discoloration can be seen on the RCC panels on both wings. These areas of discoloration are areas of coating rework and/or repair, and evidence of cumulative heating effects especially on RCC RH (right hand) and LH (left hand) panels 7 through 9. Numerous white contamination impacts can be seen on the RH wing panels with resulting impact damage to RH upper access panel tiles. A lesser number of impact marks can be seen on the LH wing with no impact damage on the LH upper access panel tiles.

TABLE 2-XIII.-- COMPARISON OF STS-1, 2, 3, AND 4 WING LEADING EDGE SUBSYSTEM FLIGHT DATA

V09T(P)-----A	Wing leading edge		STS-1 maximum temperature, °F	STS-2 maximum temperature, °F	STS-3 maximum temperature, °F	STS-4 maximum temperature, °F
	Location	Component				
9901	Panel 4	Lower clevis	170	196	175	159
9902	Panel 4	Lower spar bracket	162	187	175	167
9903	Panel 4	Lower IF interface panel	425	445	a	449
9904	Panel 4	Upper clevis	81	104	88	101
9905	Panel 4	Upper spar bracket	1260b	1300	1285	1249b
9906	Panel 4	Insulation surface	122	137	125	119
9907	Panel 4	Insulation bondline	1625b	1890	a	1652b
9909	Panel 4	Lower RCC temperature	915	875	a	a
9910	Panel 9	Lower clevis	295	305	320	295
9911	Panel 9	Lower spar bracket	1220	1205	1135	1164
9912	Panel 9	HRSI facing RCC	300	a	290	289
9913	Panel 9	Lower IF panel	--	--	--	--
9914	Panel 9	Upper clevis	267	250	220	209
9915	Panel 9	Upper spar bracket	1300b	1650	1640	1605b
9916	Panel 9	Upper HRSI facing RCC	270	a	317	314
9917	Panel 9	Upper IF panel	1975b	a	1810	1709b
9918	Panel 9	Insulation surface	1165b	1155	1125	1137b
9919	Panel 9	Insulation in-depth	889	900	835	888
9920	Panel 9	Insulation in-depth	400	411	383	385
9921	Panel 9	Insulation bondline	1840b	2025	1975	1830b
9922	Panel 9	Insulation surface	1675b	1750	1750	1645b
9923	Panel 9	Insulation surface	--	--	--	--
9924	Panel 9	Cavity pressure	2450b	2470	2460	2046b
9926	Panel 9	Lower RCC temperature	1390b	1920	1920	1609b
9927	Panel 9	Upper RCC temperature	580	570	550	550
9928	Panel 16	Lower clevis	257	270	265	260
9929	Panel 16	Lower bracket	425	435	430	436
9930	Panel 16	Upper clevis	2400a	2400a	2400a	2333a
9931	Panel 16	Insulation surface	215	197	192	177
9932	Panel 16	Insulation bondline	1890b	2170	2100	1876b
9934	Panel 16	Lower RCC temperature	565	570	510	469
9935	Panel 22	Lower clevis	169	177	175	148
9936	Panel 22	Lower bracket	1110b	1150	1140	1080b
9937	Panel 22	Insulation surface	122	122	127	117
9938	Panel 22	Insulation bondline	--	--	--	--
9939	Panel 22	Cavity pressure	1750b	1850	1840	1728b
9940	Panel 22	Lower RCC temperature	--	--	--	--

aSensor inoperative or data questionable.

bMaximum value at start of available data.

The post-ST5-2 design modification [addition of larger diameter (1/2") end panel stuffer to both panel ends] to the lower access panel was again successful in that no evidence of carrier panel structure (aluminum tube) overheating was evident. Although inspection of the interface panel tiles and horsecollar TB (thermal barrier) indicated that significant heating occurred at the access panel corners, there was no evidence of hot gas flow into the wing leading edge cavity and on the internal insulation blankets.

2.10.3.3 RCC - Forward External Tank Attachment.- The ST5-4 RCC external tank plates had the type "A" coating enhancement. As expected, under magnification, the surface had a glossy, granular appearance as opposed to the fabric weave pattern seen on the non-"A" enhanced ST5-1, 2, and 3 plates. The ST5-4 plates did not show any evidence of coating damage or flow of the Type A overcoat.

2.10.3.4 Windows (Thermal Panes).- The six windshield, two overhead and side hatch thermal panes were examined for evidence of buildup of the surface haze that has been observed after the previous flights. Windows 6, 1, and 5 have a minimal, but increased amount of external hazing. Windows 2 and 3 appear to have a thicker buildup of surface haze, but little reduction in visibility. Water droplet marks on window 2 have been enhanced by the haze buildup. Window 4 had the thickest haze deposit, but again visibility was not significantly reduced. Impact areas were observed on windows, but the impacts did not scratch or flaw the window surface. The left-hand overhead window had some haze, but less than the cleanest forward window (6). The right-hand overhead window exhibited less haze than the left-hand overhead window. The side-hatch window had a very light haze on the external thermal pane surface.

The contamination (hazing and impact deposit) could not be removed with the standard solvent. Disposition of this condition for ST5-5 was determined as no constraint.

2.10.3.5 Elevon/Elevon Ablators.- The ablators were examined for the ST5-4 heating effects. In general, the ablators appear to be comparable to the ST5-3 results. Both the right-hand and left-hand inboard ablators look very good with little separation of the ablator from the fiberglass along the miter joint. The outboard rib ablators appear to have surface recession/char thickness values similar to ST5-3. In contrast to the ST5-3 results, two surface recession cusps are visible on the rib ablators. The first cusp is approximately 12 inches long (starting 3.5 inches aft of hub seal) and the second cusp is approximately 6 inches long (starting 15 inches aft of hub seal). The fiberglass along the aft end of the tip ablators is peeled and separated from the ablator similar to that observed on other ST5 flights. The ST5-4 ablator hardware (4 ribs, 2 spills, 4 tips) have been removed for detailed sectioning to aid in ST5-4 heating/thermal performance evaluations.

2.10.4 Aerothermodynamics

The push over/pull up maneuvers planned during Orbiter entry at velocities of 14000 ft/sec and 8500 ft/sec were performed. However, the surface temperature data necessary for analyses of these maneuvers were not obtained until the middle of the first maneuver. Data were acquired from Vandenberg and Buckhorn at 959 sec after entry interface. An attempt will be made to get meaningful information from both maneuvers.

Boundary-layer transition was observed to occur earlier during ST5-4 entry than previous flights. This phenomenon will be investigated.

2.11 REMOTE MANIPULATOR SYSTEM

The RMS (Remote Manipulator System) flew on STS-4 as the last flight of a three-flight DDTE (design, development, test, and evaluation) program. The mission consisted of approximately 9 hours of testing of the RMS both loaded (with payload) and unloaded. The payload used for the loaded test was the IECM (Induced Environment Contamination Monitor) with a weight of about 850 pounds. The RMS appeared to satisfy all of its test objectives.

FTO 454-01 (RCS Plume Impingement Survey), however, was not successful due to a malfunction with the IECM sequencer. CCTV and DAC data appears to be very good. The crew reported that the handling characteristics were "crisp and smooth, just as was expected."

During STS-4, the RMS deployed and berthed an IECM, which interfaced with the Orbiter via a REM (retention engagement mechanism) to fulfill the requirements of FTO 455-01 (Payload Deployment and Berthing Performance). In general, the payload deployment and berthing operations went as expected.

Deployment and berthing of the IECM were no problem. The ready-to-latch indications were achieved immediately in one case, and easily achieved in a second case after an adjustment in payload roll was commanded. Payload digital displays were repeatable and were used to position the IECM above the REM in the high hover position and to align the payload with the REM at the top of the guides. CCTV cues, however, were the primary cues for payload position.

During STS-4, three of the payload bay lights failed (Section 5.0, flight test problem report 11). The crew reported that the remaining light was adequate for the RMS tasks, but that the lighting levels were marginal for visual night operations.

Electronic, CCTV, and DAC data that were acquired in support of FTO 452-03 (Unloaded Arm Response to PRCS Activity) appear to be adequate.

The FTO 452-02 (Singularity Management) data reviewed appeared to be of good quality, however, numerous dropouts have occurred in the data tape. The arm response to the hand-controller/rate hold switch inputs has some unexplained response characteristics which are being evaluated.

The FTO 455-03 (RMS Control System Evaluation) was not scheduled for STS-4, however, the crew were able to work the FTO into the timeline and perform this activity.

Electronic, CCTV, and DAC data acquired in support of FTO 455-02 (Loaded RMS/PRC Interaction Test) have been previewed. The hand-controller inputs appear to be pure and no effects of cross-coupling have been observed.

Anomalous EE (end effector) status indications were observed during EE checkout. These were mainly EE fail, uncommanded release, and incorrect talkback status. Section 5.0, flight test problem report 10 discusses this anomaly.

3.0 ENVIRONMENTS ANALYSIS

3.1 ACOUSTIC ENVIRONMENT

Acoustic and boundary-layer noise from the active transducers were reviewed for compliance with design specification criteria and previous flights. Data were reviewed for the time period from main engine ignition through the supersonic phase of flight. Data relative to the entry phase was not processed for review because the levels experienced on STS-1 were within the noise threshold of the transducers.

The processed data were overlaid with data obtained from previous flights and from ground test. The data comparison was found to be representative of the earlier flight data. The lift-off event remains as the predominant time for the highest noise level. The specification criteria was not exceeded at any time during the flight. The acoustic environment has remained constant from flight-to-flight during the four flight OFT program.

3.2 VIBRATION ENVIRONMENT

Vibration data analyzed from the STS-4 flight is in compliance with the design criteria and with previous flights. The Orbiter zones that had anomalies on previous flights are still showing the same anomalies. The anomalies are being studied to determine the effect on the mission-life duty cycle.

The APU system 3, which has been indicating a high level of vibration on previous flights, had the same amplitude of response on STS-4. However, the high response was present when the APU was turned on. Both the x-axis and z-axis measurements responded the same way. The unit was removed from the Orbiter and the z-axis transducer was found to be faulty. Further investigations are being conducted to determine the validity of the measured data.

4.0 BIOMEDICAL EVALUATION

The primary objective of the medical operations support is to assure the health and well-being of flight personnel during all phases of the mission.

4.1 EVALUATION OF CREW HEALTH

The preflight evaluation of crew health was performed at launch minus 32 days (May 24, 1982), launch minus 10 days (June 17, 1982), and launch morning. The crew was in excellent health throughout the preflight period.

Inflight, the pilot reported mild symptoms of space motion sickness which resolved within the first 48 hours of the flight. The crew slept well throughout the mission. Both crew members used the treadmill exerciser throughout the mission. A minor equipment malfunction required some inflight repairs, but did not prevent use of the exerciser. On entry morning, the crew completed a saltwater cardiovascular countermeasure protocol.

Postflight evaluation of crew health on landing day (July 4) and landing plus 5 days (July 9) found them to be in excellent health.

4.2 HEALTH STABILIZATION

A Level I Health Stabilization Program was successfully completed for the STS-4 mission. Briefings were given to personnel in the crew work areas. Instruction sheets and posters were also made available. A total of 305 primary contacts were identified and badged. No reports of illness were received from this group during the 7-day period immediately preceding the mission.

4.3 RADIATION

There were no unexpected exposures to radiation on STS-4. The projected radiation dose to the crew was 42 millirad. Thermoluminescent dosimeters (TLD) worn by the crew measured 39.12 ± 1.8 mrem (average). TLD's placed at various locations in the spacecraft to verify shielding calculations averaged 48.3 ± 4 millirad. The spacecraft passed through the South Atlantic Anomaly 42 times during the mission. Solar flare activity was minimal throughout the mission.

4.4 MOTION SICKNESS PROPHYLAXIS

Both crewmen underwent drug sensitivity testing and neurophysiological/vestibular evaluation preflight.

The commander was not required to and elected not to use prophylactic therapy. The pilot took one Scopolamine/Dexedrine tablet on the flight day 1 after OMS-1 as scheduled. He exhibited mild symptoms compatible with the diagnosis of space motion sickness on flight day 2 and took a second Scopolamine/Dexedrine tablet. He did not use medication for motion sickness the remainder of the flight.

4.5 TOXICOLOGY

The trace gas contaminants of the Orbiter cabin atmosphere were determined from one air cylinder collected inflight.

The STS-4 sample contained six compounds while the sample from STS-3 indicated the presence of 40 compounds in the crew compartment. It is highly probable that this reduction in the number of compounds is the result of having flown the ambient temperature catalytic oxidizer (ATCO) on STS-4.

None of the compounds detected in the STS-4 sample approached spacecraft maximum allowable concentration values. The combined effects of the six compounds did not represent any toxic effect for the crew.

4.6 MICROBIOLOGY

The STS-4 crew were microbiologically evaluated as part of the launch minus 30 day, launch minus 10 day, launch minus 2 day, and landing day medical evaluations. Both crewmen exhibited normal microbial flora in all collected samples.

Microbial evaluation of the Orbiter consisted of surface samples and air samples collected from designated sites throughout the flight-deck and middeck. Samples were collected on launch minus 30 days, launch minus 2 days, and landing day. Six different species of Aspergillus were isolated. No pathogenic bacteria were isolated.

4.7 BIOINSTRUMENTATION

The Orbiter bioinstrumentation system enabled real-time electrocardiographic (ECG) data on both crewmen during launch and entry to be displayed on the biomedical display units located in the Surgeon's console at the Mission Operations Control Room.

Good quality ECG's were obtained on both crewmen during launch and entry using this system.

5.0 FLIGHT TEST PROBLEMS

This section contains a copy of the approved resolution for each STS-4 problem.-4 that was closed prior to publication. Table 5-I summarizes the status of each problem at the time of report publication. Those actions not completed at the time of publication will be issued as a supplement to this report.

TABLE 5-I.- SUMMARY STATUS OF STS-4 PROBLEMS

No.		Status
1	Hailstone impacts on tile	Open
2	MPS liquid oxygen overboard bleed valve close indicator "B" failed	Closed
3	Fuel cell 1 condenser exit temperature shift	Closed
4	RCS engine FIL oxidizer leak indication	Open
5	APU 3 lubrication oil pressure oscillations	Open
6	Operational instrumentation failures (6)	Closed
7	Hydrogen tank 4 heaters not operating properly	Open
8	VTR onboard recorded tape frames out of synchronization during onboard playback on monitor 2	Open
9	Getaway special activation unsuccessful	Closed
10	RMS end effector capture, open, and close flags showed incorrect status	Open
11	Aft starboard, forward port and forward bulkhead floodlights failed	Closed
12	Crew reported VTR will not rewind	Closed
13	Aft bulkhead actuator on port payload bay door stalled during latch closure	Closed for STS-5
14	Orbit DAP control auto select switch failed contact "A"	Closed
15	APU 3 fuel cavity drain leakage	Closed
16	Hydrogen tank 2 heater B circuit failure	Closed for STS-5
17	High load flash evaporator duct heater system B, zone A, failed	Closed for STS-5
18	Payload bay door talkback incorrect	Closed
19	Vehicle torquing produced attitude excursions	Closed
20	Item entry key on left keyboard sticking	Closed
21	Liquid oxygen 17" disconnect flow liner damaged	Closed
22	Water intrusion in forward RCS thrusters	Open
23	APU 1 fuel tank pressure decay	Closed
24	Waste management system slinger speed slow	Closed for STS-5
25	PP02 sensors erratic during entry	Closed
26	Middeck TV camera operation erratic	Closed
27	Wireless crew communications unit "B" cutting out	Closed
28	DFI PCM recorder lost data on tracks 0 through 7	Closed
29	Upper body-flap tile degradation by aft vernier RCS plumes	Closed for STS-5
30	Fuel cell 2 relief valve heater auto B inoperative	Closed
31	Right- and left-hand inboard brake rotors damaged	Closed for STS-5
32	ECLSS airlock vent duct damaged	Closed
33	Degradation of vernier RCS engine nozzle coating on engines R5R and F5L	Closed for STS-5
34	Communications noisy while donning EMU	Open

Statement of problem: MPS LO₂ Overboard Bleed Valve Close Position Indicator Switch "B" Failed.

Discussion: During STS-3, the MPS LO₂ bleed valve (PV-19) close switch "A" (V41X1580X) was slow in closing. This is a redundant switch, which can cause a launch scrub if both switches "A" and "B" fail. The valve was changed out for STS-4 and was checked during the tanking test. The "B" switch (V41X1581X) did not work. The switches were adjusted and tested again at T-3 hours during tanking for flight. The "A" switch worked, but the "B" switch required 77 seconds to close. It was decided that the valve worked; consequently both switches were masked out in OPS-1 at T-11 minutes to preclude a launch scrub. The KSC data indicated, at launch, that both switches were closed in approximately 1.3 seconds. Because of the tolerance of the telemetry data, the switch actuation may or may not have been in the required time of less than 1 second when the RSLS (redundant set launch sequencer) checked at T-7 seconds for LO₂ bleed valve closure.

The valve position indicator can be affected by cryogenic temperatures. The probable cause of the failure is a malfunctioning position indicator.

For STS-5, the MPS LO₂ bleed valve close position indicator check has been masked out in the GPC mass memory. A new LO₂ bleed valve will be installed in OV-102 during the major modification period.

Conclusions: The probable cause of the failure is a malfunctioning valve position indicator.

Corrective action: For STS-5, the MPS LO₂ bleed valve close position indicator check has been masked out in the GPC mass memory. A new LO₂ bleed valve will be installed in OV-102 during the major modification period.

APPROVED

W.J.S. 7/14

A. Aldrich

9-20-82

Date

Effect on subsequent missions: None.

M. C. Buchanan 9-13-82 R. J. Ward 9/13/82

Personnel assigned: M. Buchanan/EP2; R. J. Ward/WA2

Resolution: CLOSED for STS-5 09/15/82

Statement of problem: Fuel Cell 1 condenser exit temperature was 12°-15°F below normal control range throughout the flight.

Discussion: When the STS-4 prelaunch conditioning loads were applied to the fuel cells at T-20 minutes, the TCE control point shifted downward 8° to 133°-134°. Analysis showed an acceptable margin of an additional 8° and a decision was made to proceed with the launch. The fuel cell 1 TCE continued to operate in the 133° control range and did not impact the STS-4 mission.

Postflight the subcontractor verified the 133°-134° control point for the actuator. During disassembly of the actuator, a small amount of FC-40 coolant was collected from the boot when the actuator piston was removed. Entrapment of fluid in this region has caused TCE control calibration shifts in the past; the fix was to provide a relief slot along the length of the piston to enable any fluid that was trapped to flow out as the copper/wax compound expanded and pushed the piston outward. On this particular unit, however, the slot was very shallow with rounded edges near the end of the piston, allowing the viton boot to conform to the shallow groove and block the flow of fluid through the groove. Inspection records showed that this unit was one of the three TCE cartridges that were polished and assembled by the production department and apparently was overpolished after the groove was machined. The other two actuator assemblies processed by the production department were screened out by normal fuel cell ATPs. The vendor had no formal specifications or inspection procedures that might have caught the defect prior to assembly in the affected units.

The viton boot thickness was checked and found to be within tolerance. A calibration check showed TCE control identical to the original ATP, thus confirming the fluid entrapment scenario. A total of 12 thermal control valve cartridges were inspected and all were acceptable with nominal tolerances for the machined groove.

Conclusions: The machined slot on the actuator piston was overpolished by the thermal control valve cartridge vendor. The shallow region of the slot was blocked by the viton boot as the copper/wax compound expanded, resulting in premature piston motion and creating the resultant temperature control band shift.

Corrective action: The vendor has implemented formal cross-sectional tolerance limits on the groove machining and polishing operations and established a new mandatory inspection point to assure proper configuration of the piston prior to final assembly and calibration.

A change to prelaunch fuel cell procedures has been initiated to operate the fuel cells at high power for approximately 10 minutes as soon as possible after fuel cell activation. This will provide early visibility into steady-state fuel cell thermal performance on all flights. The OV-099 fuel cells will be operated during the FRF test, providing early assessment of fuel cell performance for that vehicle.

A future change will provide two more relief slots along the length of the piston, equidistant from the original slot. This change is effective for the 3-substack fuel cells which will be added after STS-5.

APPROVED

[Signature]
A. Aldrich

[Signature]
Date

Effect on subsequent missions: None, 8/31/82

Personnel assigned: *[Signature]* F. Plauche/EP5; C. Walsh/SC6

Resolution: CLOSED 09/01/82

Statement of problem: Operational Instrumentation Failures

Discussion: Operational instrumentation failures include the following:

- a) PRSD H₂ tank 2 quantity shift (V45Q2205)- The indicated quantity was 42.2 percent should have been 94.4 percent. A similar problem occurred on STS-3. No problem was found in the vehicle wiring. After extensive troubleshooting the signal conditioner was replaced and returned to the vendor for failure analysis. Contingency loading procedures will be used if required. The quantity can be tracked using the other tank indications should a failure occur.
- b) MPS engine 3 LH₂ inlet temperature measurement (V41T1301) failed off-scale high for 2 minutes from T+6 to T+8 minutes. The vibration environment exceeds the specification. The probe has been replaced with a new design.
- c) Main engine 2 GH₂ pressurant temperature (V41T1261) shift. The measurement was on scale but read high for 3 minutes from T+5 to T+8. Data from this measurement is not essential. Fly as is for STS-5.
- d) RCS R5D Injector oxidizer (V42T3525) or fuel (V42T3526) temperature bias. A similar problem occurred on VRCS jet F5L on STS-3 and STS-4. Inaccessible. Fly as is. Should the temperature bias result in an RM deselect, a software patch is available.
- e) Flow out of LH₂ CRYO tank 3 influences decay rate of midbody hydraulic line temperature (V58T1143). Insulation installation results in transducer responding to cryogenic flow. Fly as is for STS-5.
- f) RCS FIF injector temperatures (V42T1501) ox and (V42T1502) fuel were slow to respond during ascent. The problem is attributed to water intrusion from rain during prelaunch operations. Inspection did not reveal a leak source. Fly as is.

Conclusions: See above.

Corrective action: See above.

APPROVED

[Signature]
A. Aldrich

9-27-82
Date

Effect on subsequent missions: None.

Personnel assigned: *Ad. Hernandez for* F. Rotramel/EH4; *Robert R. Rice* T. Davies/EP5; *C. Walsh* C. Walsh/WC6 *9/2/82*

Resolution: CLOSED 09/22/82

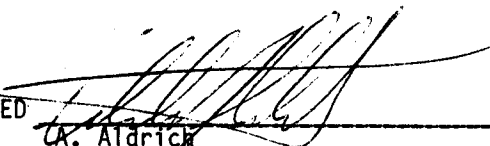
Statement of problem: Get Away Special (GAS) Activation Unsuccessful.

Discussion: Planned activation of the GAS was unsuccessful at 178:21:53 G.M.T. After inflight troubleshooting, the GAS was activated at 181:11:29 G.M.T. Deactivation was delayed until postflight. A broken wire was found at a crimp point of a pin in a jumper cable at the on-orbit station distribution panel located behind panel A12 on the aft flight deck.

The wire was probably broken during removal of a Data Processing System (DPS) camera bracket mounted near the wire. The camera is used to monitor DPS displays during ground checkout. The bracket was removed after successful completion of the GAS end-to-end functional checkout.

Conclusions: A wire in a jumper cable at the on-orbit station was probably broken when checkout personnel removed a nearby DPS monitor camera bracket after completion of GAS checkout.

Corrective action: GAS checkout for STS-5 and subsequent will be done after closeout of panel A12.

APPROVED  9-3-82
 G. Aldrich Date
 8/31

Effect on subsequent missions: None.
 8-25-82 8-25-82
 Gary D. Meester L. J. Moon R. J. Ward 8/25/82

Personnel assigned: G. Meester/PH; L. Moon/EH5; R. J. Ward/WA3

Resolution: CLOSED 08/26/82

Statement of problem: Aft Starboard Forward Port and Forward Bulkhead Floodlights Failed.

Discussion:

During STS-4, the crew reported that the aft starboard, forward port, and forward bulkhead floodlights in the payload bay were not operating. A review of the downlink bus current measurements confirmed the failures. Testing after the flight determined that that two channels within the floodlight electronics assembly had failed and one lamp assembly (fwd bulkhead) had failed. Failure analysis by the light manufacturer confirmed that the failures were due to known problems with approved redesigns in progress. The electronics assembly had been redesigned because inadequate venting may have caused corona on STS-1. The lamp had been redesigned to reduce anode heating because thermal stress at high anode temperatures curtailed lamp life during qualification and extended life testing.

Conclusions:

The electronic assembly failures were caused by inadequate venting of the box which resulted in corona. The corona caused electronic parts degradation which eventually resulted in a failure. The lamp assembly failure was caused by multiple thermal stress of the anode end of the lamp that resulted in a broken (cracked) glass envelope.

Corrective action:

Effective on STS-5, the electronic assemblies have been modified to include a larger, more porous vent that will significantly decrease the box venting time from 27 minutes to 2.6 seconds. The lamp fix consisted of modifying the lamp structure to reduce anode heating. Additional fixes are under review to significantly increase lamp life.

APPROVED

[Signature]
A. Aldrich

9-8-82
Date

Effect on subsequent missions:

None.

Personnel assigned: A. J. Farvas/EH5; R. J. Ward/WA3

A. J. Farvas 9/7/82 R. J. Ward 9/7/82 R. J. Ward 9/7/82

Resolution: Closed 09/07/82

Statement of problem: Video Tape Recorder (VTR) Rewind Function Failed.

Discussion: Midway through the mission, the rewind function of the VTR failed. This failure was verified during postmission testing at KSC and at JSC after the VTR was returned for analysis and repair. However, during inspection of the unit at JSC the rewind function became operative. No cause for the failure was uncovered. The SY-10 printed circuit board was removed and the rewind microswitch that is located on the board was replaced. The suspect microswitch was X-rayed and cut open, but no problem was found. The SY-10 board will be run extensively in the crew trainer recorder in an effort to repeat and identify the inflight rewind failure.

Conclusions: The loss of the VTR rewind function was probably caused by an intermittent electrical problem on the SY-10 printed circuit board.

Corrective action: The VTR used for STS-4 was removed from OV-102 and the SY-10 printed circuit board was replaced. Another flight VTR has been installed on OV-102 for STS-5.

APPROVED

[Signature]
A. Aldrich

9-28-82
Date

Effect on subsequent missions: None.

Bernard C Embrey Jr 9-27-82 *Robert J. Ward* 9/27/82

Personnel assigned: B. C. Embrey/EE2; R. J. Ward/WA3

Resolution: CLOSED 09/29/82

Statement of problem: Aft Bulkhead Actuator on Port Door Stalled During Latch Closure.

Discussion: During the door closure test following approximately 20 hours with the Orbiter in the bottom-to-sun attitude (cold case), the aft port bulkhead latch gang failed to reach the fully latched position. A survey using the payload bay TV cameras showed that the aft corner of the 22-inch breather panel at the Orbiter centerline was deflected outward approximately 7 degrees. The forward and aft latches were returned to an unlatched position, the door was opened, and the Orbiter was oriented to a passive thermal control attitude for 10 hours followed by 3 hours of tail-to-sun attitude. The door was then successfully closed and latched. Subsequent door operations were normal.

Postflight inspection of the aft port door/bulkhead interface after door opening revealed the following:

1. Environmental seal (0.75 inch diameter Teflon tube) on aft bulkhead at approximately $Y_0 -4$ was pierced through the upper and lower surfaces.
2. Edge of X_0 1306.90 bulkhead had white paint chipped off in the area of seal penetration, but no other noticeable marks were observed.
3. PLBD (Payload Bay Door) aft frame had scratches in area corresponding to damaged seal and chipped paint on bulkhead. The door structure and latching mechanism were fully inspected and there was no reportable damage.

Conclusions: Based on inflight TV camera coverage and postflight observations, the jamming resulted when the aft leg of the channel that supports the door latch gang, at latch no.4, contacted the seal and bulkhead, thus preventing aft port door latching.

Corrective action: The damaged environmental seal has been replaced. No PLBD cold case (side-to-sun attitude) operation is planned for STS-5. Changes under investigation include:

1. Redesign of environmental seal support bracket and door interface.
2. Bias door rigging forward to provide greater clearance between door and bulkhead/seal interface.
3. Additional breather panel guide control at thermal expansion joint.

APPROVED

A. Aldrich
A. Aldrich

9-20-82
Date

Effect on subsequent missions: No PLBD closure will be attempted during or immediately after an Orbiter has been exposed to a cold-case hold attitude. The PLBD should be thermally conditioned prior to any closure.

Personnel assigned: N. Jevay/EW3; R. J. Ward/WA3

N. Jevay 9-13-82 R. J. Ward 9-13-82

Resolution: CLOSED for STS-5 09/15/82

Statement of problem: Orbital DAP (Digital Autopilot) control auto select switch contact "A" failed.

Discussion: During STS-4, the contact "A" of the forward orbital DAP (digital auto pilot) control auto select pushbutton switch (switch 3 on panel C3A6) contact "A" failed when the switch was activated. Subsequent activations indicated the contact had cleared, however, the RM (redundancy management) flag remained latched as there is no preprogrammed reset capability for this switch. The problem was duplicated after the flight by slowly depressing (teasing) the switch while monitoring the output of each contact. One or two contacts could be activated while the other(s) remained open. This is normal operation for this type of switch. The crew reported that extra care was necessary to insure that firm pressure was applied to push button switches while in zero g.

A switch review showed that the orbital DAP control auto and manual select switches are the only three contact push button switches used in zero g without a backup or item reset capability. A software change is being requested to provide backup switch capability during entry phase or to clear the RM flag if it remains latched.

Conclusions: The contact failure was caused by applying gentle pressure to the switch during zero g operation.

Corrective action: The crew will insure that firm pressure is applied to all pushbutton switches for proper operation during zero g. A software change is being requested to provide either backup or reset capability for the orbital DAP control auto and manual pushbutton select switches. Fly as is for STS-5. Implement the Software Control Board decision for future flights.

APPROVED

R.M. Gorman
A. A. Drtch

8/31/82
Date

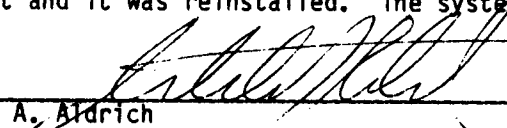
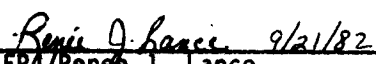

Effect on subsequent missions: None.

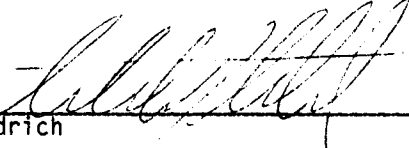
R.J. Ward 8/31/82

Personnel assigned: A. J. Farkas/EH5; R. J. Ward/WA3

A.J. Farkas 8/31/82

Resolution: CLOSED 09/01/82

Statement of problem: APU 3 Fuel Cavity Drain System Leakage	
<p>Discussion: APU 3 drain line leaked slightly on-orbit so that by entry the pressure had reached 7 psia (originally 16 psia).</p> <p>After return to KSC, every component and fitting in the drain system was leak checked. No leak was found. The drain relief valve's reseal pressure was low, however, which is sometimes an indication of contamination.</p> <p>The drain relief valve was removed from the vehicle and leak checked on the bench. No leak was found. The valve was flushed with alcohol and the alcohol subsequently filtered through a millipore pad. The constituents on the millipore pad were found to be hydrocarbon oil, an organic ester, silicone, inorganic siliceous material, and nitrate iron. The APU lubrication oil is an organic ester and there was a leak of oil into the seal cavity. There is also iron present in the APU components. The source of the other constituents is not known. All of the particles were extremely small.</p> <p>If there is still an undetected leak of the same magnitude as STS-4, there will be no adverse effect for STS-5. In fact, it is desirable to have a reduced pressure in the seal cavity drain so that the pressure in the seal cavity is lower than the gearbox pressure, thus alleviating some of the problem caused by wax in the lubrication oil. The only concern is that if the leak increases so that the drain line reaches 0 psia, the possibility exists that the fuel leakage in the drain line would freeze and plug the line. However, a frozen line would only be a problem in the event a major fuel leak occurred which is very unlikely.</p>	
Conclusions: The source of the leak was not found. It is possible that the relief valve had some contamination on the sealing surface that was washed away during an alcohol flush before the leak check was performed.	
Corrective action: The drain line was flushed with alcohol for cleaning. The drain relief valve relief pressure was reset and it was reinstalled. The system has been checked for leaks.	
APPROVED	 A. Aldrich
	9-27-82 Date
Effect on subsequent missions: None.	
Personnel assigned:	EP4/Rene J. Lance  9/21/82 MC6/Charles J. Walsh  9/21/82
Resolution: CLOSED 09/22/82	

Statement of problem: H ₂ Tank 2 Heater "B" Failed to Operate On-Orbit
<p>Discussion: The hydrogen tank 2 heater "B" failed to operate and the redundant heater "A" was used for the remainder of the mission. Failure symptoms indicated heater "B" control-circuit problems (i.e., bad RPC (remote power controller) blown fuse, etc.).</p> <p>Troubleshooting isolated the problem to a blown 5 -A fuse on the output of the two series RPC's distributing 28 Vdc to the heater. The fuse was replaced, and the heater "B" control circuit operated satisfactorily. The box wiring, vehicle wiring, and tank heaters were subjected to insulation resistance and dielectric testing to locate a possible short circuit to vehicle ground and none was found. In addition, the remaining seven 5 -A fuses from the four cryo control boxes were replaced. The removed fuses were analyzed to identify any degradation in the fusible links because of overstress conditions that might explain why the fuse had blown. The analysis was not conclusive in identifying a failure cause. The blown fuse could have been caused by an "educated" short (<6.5 -A) in the vehicle wiring or the tank heater which would only be present under the proper thermal conditions, or a degraded fuse. Any other failure would have tripped the RPC.</p>
<p>Conclusions: The 5 -A fuse distributing 28 Vdc to the heater was blown. Exhaustive attempts to identify the actual cause have been unsuccessful.</p>
<p>Corrective action: The blown fuse was replaced, and the heater control circuit has checked out satisfactorily.</p>
<p style="text-align: right;">APPROVED  9-27-82 A. Adrich Date</p>
<p>Effect on subsequent missions: None.</p>
<p style="text-align: right;"><i>Robert R. Rice</i> <i>L. Davies</i> <i>J. Blomper</i> <i>C. Walsh</i> 9/22/82</p>
<p>Personnel assigned: T. Davies/EP5; L. M66n/EH52; C. Walsh/WC6</p>
<p>Resolution: CLOSED for STS-5 09/27/82</p>

Statement of problem: High Load FES Duct Heater System "B", Zone A, Failed.

Discussion: During entry preparation on day 7 (approximately 185:10:16:00, G.m.t), the B system high-load duct heaters were activated by the crew to begin warm-up of the high-load ducts prior to payload bay door closure and FES (Flash Evaporator System) operation. Approximately 20 minutes later, the duct temperatures in duct heater zone A were not responding fast enough, and the zone B and C heaters were functioning properly. Crew activation of system "A/B" and later system "A" only resulted in proper duct temperature control.

The failed heater problem was traced to an open heater element in the system "B" heater for zone A. The FES high-load duct zone A has three heaters but only two elements are required. Heater system "C" was inoperative on STS-4 due to a failed switch in the "C" controls. The wiring to system "B" and system "C" has been exchanged for STS-5 to allow use of the existing crew-cabin heater-control procedures and to maintain the two-heater capability for zone A using systems "A" and "B."

Conclusions: The failure was due to a defective heater element, (discontinuity).

Corrective action: The wiring to heater system "B" and heater system "C" was exchanged. Heater system "C" remains inoperative as it was prior to STS-4. All high-load duct heaters in systems "A" and "B" are to be checked and monitored during launch preparation for STS-5.

APPROVED

T. L. [Signature]
A. Aldrich
8/10/82

8/10/82
Date

Effect on subsequent missions: None

Q. J. Ward 8/9/82

Personnel assigned: L. A. Trevino/EC3; A. J. Ward/WA3.

for [Signature] 8/10/82

Resolution: CLOSED for STS-5 08/09/82

Statement of problem: Payload Bay Door (PLBD) Talkback Indication Incorrect.

Discussion: During deorbit preparation, the crew saw the PLBD talkback on panel 13 change from "CLOSED" to "BARBER POLE" during the BFS initialization activities. The complete list of individual discretes which determine the PLBD status was checked via downlist and onboard, indicating the actual status of the doors was OK (closed) and the talkback indication incorrect.

A review of the BFS initialization code showed that the observed scenario is to be expected due to output reset functions coded into the BFS PLBD initialization software. Associated drawings and deorbit preparation procedures are being revised to account for this operational characteristic.

Conclusions: The observed scenario is normal.

The PLBD talkback is only meaningful when the doors are in use.

Corrective action: Associated drawings and deorbit preparation procedures are being revised to account for this operational characteristic. A documentation CR is being prepared to clarify the BFS initialization implementation.

Crews will be trained to understand that the PLBD talkback is only meaningful when the PLBD is in use.

APPROVED

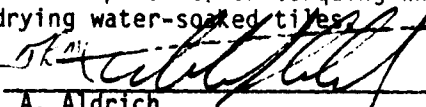
J. C. Aldrich
A. Aldrich

8/10/82
Date

Effect on subsequent missions: None.

J. D. Burke for 8/1/82 R. J. Ward 8/6/82
Personnel assigned: J. C. Boykin/EH12; R. J. Ward/WA3

Resolution: CLOSED 08/06/82

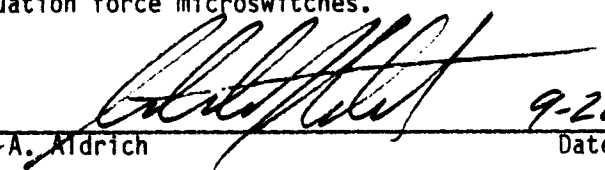


Statement of problem: Vehicle Torquing Produced Attitude Excursions.	
Discussion: During the first gravity gradient attitude control and first bottom sun attitude periods, negative-roll vehicle torquing produced attitude excursions and additional attitude control requirements.	
<p>Vehicle roll rate data taken between thruster firings during the two attitude control time periods indicate a negative roll torque of about 3 to 5 ft-lb in the sunlight and about 0.5 to 2 ft-lb in the dark portions of the orbit. No such torquing was observed during the second gravity-gradient test after the bottom sun tile dry-out periods.</p> <p>A postflight count of damaged tile has indicated about 1600 damaged tiles on the bottom surfaces of the Orbiter. About 900 of the damaged tiles show exposed LI-900. Of the 900, about 300 are to the left of the Orbiter X-axis centerline, and about 600 to the right. Of the 600, there are about 300 more at the outboard end of the right wing, compared to the left wing. The remaining 700 damages tiles are generally distributed over both sides of the centerline. Water stains in the damaged areas indicate the presence of water in the absorbant tile material prior to dry-out in space.</p> <p>Three different sets of calculations based on kinetic energy theory, effect of venting gases through restrictive openings, and water loss rates determined from chamber tests with water-soaked tiles, showed that the thrust caused by outgassing vapor from water-soaked damaged tiles would produce a negative- roll torque from the differential of 300 damaged tiles on the right wing of about 4 to 8 ft-lb. The calculated 4 to 8 ft-lb compares favorably with the 3 to 5 ft-lb derived from the slope of the roll rate data.</p> <p>Ascent trajectory reconstruction analysis for STS-4 indicates about 1200 lb of inert material at engine cut-off. The 1200 lb do not show up in the landing weight data. (continued)</p>	
Conclusions:	
<ol style="list-style-type: none"> 1. Tile damage due to hailstones allowed tiles to soak up a significant amount of water during the rainstorm. 2. Outgassing the entrapped water from the greater number of damaged tiles on the underside of the right wing provided a differential thrust which resulted in negative-roll torquing, until completion of the on-orbit bottom sun tile dry-out process. 	
Corrective action:	
<ol style="list-style-type: none"> 1. Protection against tile damage and subsequent rain soaking of tiles is desirable. See problem STS-4 - 1. 2. Should damage and rain-soaking recur: <ol style="list-style-type: none"> a. Evaluate extent for acceptability of weight for launch, and/or time required on-orbit for dry-out. b. Provide for dry-out attitude in time line. c. Provide for consumables usage to compensate for torquing which may result from unequal distribution of thrust from drying water-soaked tiles. 	
APPROVED	Date
 A. Aldrich	9-20-82
Effect on subsequent missions: See corrective action.	
Personnel assigned: K. Lindsay/EH2; R. Polifka/EP2; R. Dotto/ES3; J. Hondros/EX4; J. McNeely/FM4; J. Lobb/WA3 <i>K. Lindsay 9/1/82 R. Polifka 9/1/82 R. Dotto 9/1/82 J. Hondros 9/1/82 J. McNeely 9/1/82 J. Lobb 9/1/82</i>	
Resolution: CLOSED 09/08/82	

Discussion:

Calculations based on the results of the tile dry-out chamber tests, the damaged tile count, and inflight dry-out times data indicate a total of about 800 to 850 lb of water in the 1600 tiles at lift-off and about 720 to 750 lb at engine cutoff.

This compares favorably with the approximately 1200 lb of inert (water) which is indicated in the ascent trajectory analysis.

Orbiter systems data indicated there were no systems venting that would cause torquing during the period in which this torquing was observed.

Statement of problem: Item Entry Key on Left Keyboard Sticking
<p>Discussion: During postflight operations at DFRF (Dryden Space Flight Facility), KBU (key board unit) S/N (serial number) 19 exhibited a stuck "item" key. A keyboard routine was in progress, and after the item key on the left keyboard was entered, no other keyboard entries were recognized. The suspect key switch assembly, P/N (part number) 6091752-2, S/N 512, LDC (lot date code) 7622, was returned to IBM/Owego for failure analysis. Extensive testing failed to reproduce the anomaly. Visual examination of the disassembled assembly and X-ray of the four Otto microswitches also failed to disclose any anomalous conditions.</p> <p>Key switches of the P/N 6091752-2 level are known to exhibit an intermittent sticking condition. This is due to the Otto microswitches that have an actuation force of 2 to 4 ounces. The corrective action for this condition is to replace these switches with new switches having an actuation force of 6 to 8 ounces (P/N 6091752-3). The program has agreed to replace these switches only when they fail.</p> <p>During ground testing in the OPF (Orbiter processing facility) the no. 3 DEU (display electronics unit) bite flag tripped while loading the DEU for GPC IPL (initial program load). The data was indicative of a key stroke during IPL or an intermittent keyboard switch closure. Several problems during previous ground turnaround activities appeared to be left of number 1 keyboard common. Keyboard 1 was replaced for STS-5. Extensive testing of the keyboard at the vendor has failed to reproduce the problem or to identify any cause for the sticking item entry key or for the DEU 3 bite flag trip.</p>
Conclusions: The cause of the sticking item entry key on the left keyboard is unknown.
<p>Corrective action: The left keyboard was replaced with the spare keyboard that also contains low actuation force microswitches. The removed keyboard is being retrofitted at the vendor with all new higher actuation force microswitches.</p> <p style="text-align: right;">  APPROVED _____ Date 9-28-82 A. Aldrich </p>
Effect on subsequent missions: None.
<p> 9/27/82  9/27/82</p> <p>Personnel assigned: G. Raines/EH4; R. J. Ward/WA3</p>
Resolution: CLOSED 09/30/82

Statement of problem: Liquid Oxygen 17-inch Disconnect Flow Liner Damaged

Discussion: The flow tube which is made of 6061-T6 Aluminum alloy is 0.040 in. thick, 16.3 in. in diameter, and 2.495 in. long. The flow tube fits like a liner between the Orbiter and external tank halves of the 17-inch disconnect. This liner prevents LO₂ from being dumped overboard during the back-up mode of separation. The flow tube was bent inward one-third of the way around the circumference (toward the middle of the tube into the LO₂ flow stream). The tube is held in place by 6 screws and 3 clips. A clip is spaced every 120° around the circumference. The same flow tube had been used on STS-1, 2, and 3. Normal wear over 3 flights or possible slight damage may have caused the flow tube to be out of round prior to STS-4. An out-of-round flow tube would allow the LO₂ flow to bend the tube into the flow stream during operation of the main engines in flight.

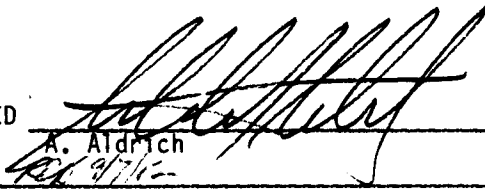
A special tool has been designed to verify the roundness of the flow tube prior to ET mating on STS-6 and subsequent flights. Possible design changes for the flow tube include using a spun tube to eliminate the welded seam, increasing the thickness to 0.080 in., and contour stiffening of the upstream end of the tube.

The flow tube was removed and replaced with a like design. Prior to mating the Orbiter and ET for STS-5, the tube will be remeasured using a calipers and reinspected.

Conclusions: Normal wear over 3 flights or possible slight damage probably caused the flow tube to be out of round prior to STS-4.

Corrective action: Calipers will be used prior to ET mating to verify that the flow tube installed for STS-5 is not out of round. Design improvements for the flow tube and a special inspection tool will be incorporated on STS-7 and subsequent flights.

APPROVED



A. Aldrich

9-8-82
Date

Effect on subsequent missions: None.

Mark C. Buchanan / EP2 / 9-1-82 Robert J. Ward 9/1/82

Personnel assigned: M. Buchanan/EP2; R. J. Ward/WA3

Resolution: Closed 09/03/82

Statement of problem: Auxiliary Power Unit (APU) 1 Fuel Tank Pressure Decay
Discussion: A small decay in fuel tank pressure of 0.05 lb/hr was observed during the flight. After the return of the Orbiter to KSC, a leak of the APU 1 GN ₂ QD (quick disconnect) was verified to occur at tank residual pressures. The QD was replaced and the new QD was leak checked by mass spectrometer. An analysis of the failed QD showed a dent (or scratch), several smaller indentations, and brownish-colored residue on the cap seats. Discoloration was seen on the metallic sealing surface (rust-colored) and whitish particles were found on the face of the poppet sealing surface. In addition, rust was noted on the interior body of the QD. The source of contamination is not known, but possibilities include the ground-half coupling, moisture from the air, or Freon cleaning of the GSE (ground support equipment). Until recently, the GSE was cleaned with Freon. Freon in the presence of hydrazine is known to attack stainless steel. The method of cleaning has been corrected at KSC.
Conclusions: The cause of the leakage was contamination that caused indentations on the sealing surface of the GN ₂ QD cap seats. The source of the contaminant is unknown, but could be caused by humidity, or from the use of Freon at KSC to clean the GSE.
Corrective action: The QD has been replaced and leak checked by mass spectrometer. The use of Freon for cleaning the GSE at KSC has been discontinued.
<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="text-align: center;"> <p>APPROVED</p> <p><i>[Signature]</i></p> <p>A. Aldrich</p> </div> <div style="text-align: center;"> <p>9-27-82</p> <p>Date</p> </div> </div>
Effect on subsequent missions: None.
Personnel assigned: <i>R. J. Lance</i> 9/24/82 <i>C. J. Walsh</i> 9/24/82
Resolution: CLOSED 09/27/82

Statement of problem: The Waste Management System (WMS) slinger speed was slow.

Discussion: The crew reported a decrease in slinger motor speed over the course of the mission. It did not completely stop or fail to operate. During postflight inspection at KSC the slinger speed was measured to be 860-1200 (< 1000 rpm is considered degraded performance). The vendor is still investigating to determine the exact cause of the slow slinger. Because of this problem and the similar STS-3 problem the slinger motor will be replaced with one that has a direct drive and has twice the torque.

The crew also reported several other problems with the WCS system as follows:

1. The urinal air flow was low but seemed to increase after the prefilter was changed. Postflights tests with a clean prefilter showed normal air flow.
2. Urine wicked out under the urinal cap.
3. The restraint system design was not adequate to provide proper positioning for use of the WMS.

A review of the WMS system design has been completed and a summary of design and procedure changes to be implemented for future missions is listed as corrective actions.

Conclusions: The cause of the slinger slow down is not known. The higher torque motor and swept back tines will provide a useable system for STS-5. System performance will be evaluated after STS-5.

Corrective action:

1. The slinger motor will be replaced with one that is direct drive and has higher torque. The lower tines will be swept back to prevent clogging.
2. The procedure will be changed to require the prefilter to be changed once a day and a change will be made to provide enough filters for flight.
3. There will be two urinal caps provided, one for male use and one for female use. The male cap will be sealed underneath to prevent leakage.
4. The restraint system has been redesigned.

APPROVED

[Signature]
A. Aldrich

9-3-82

Date

Effect on subsequent missions: None

E. Winkler 8/31/82 *C. Walsh 8/31/82*

Personnel assigned: E. Winkler/EC3; C. Walsh/WC6

Resolution: CLOSED for STS-5 09/01/82

Statement of problem: Variations in PPO₂ Sensor Response During Ascent and Entry.

Discussion: The PPO₂ sensors exhibited erratic performance during ascent and entry. Sensor A read 3.64 psia while sensors B and C read 3.44 psia early during entry. Subsequently A and B read 3.44 psia while C read 3.60 psia. Sensor readings returned to normal when the cabin heat exchanger air outlet temperature stabilized after ascent and entry. Sensors A and B are located in a common housing. The sensors are calibrated at stabilized temperature and have a specification accuracy of $\pm 3\%$.

A design change was implemented for STS-4 to provide additional airflow over the amplifiers for sensors A and B. This increased the sensor accuracy by decreasing the temperature difference between sensor and amplifier during stabilized conditions.

The variations in PPO₂ sensor response during ascent and entry are considered normal for transient temperature conditions and can be expected to occur on subsequent missions.

Conclusions: The variations in PPO₂ sensor readings were caused by transient temperature conditions during ascent and entry.

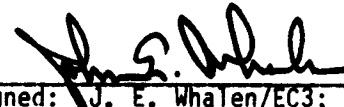
Corrective action: None.

APPROVED


A. Aldrich


Date

Effect on subsequent missions: None.

Personnel assigned:  8/24/82  8/24/82
J. E. Whalen/EC3; R. J. Ward/WA3

Resolution: CLOSED 08/24/82

Statement of problem: Mid-deck TV Camera Operation Erratic.

Discussion: The video from the mid-deck TV input location was intermittently degraded. The high frequency response was reduced and there was "smearing" of the scene content. Postmission testing revealed a problem in a spacecraft extension cable behind panel M058F. The extension cable allows for the DFI installation on OV-102 and will not be used after the DFI is removed.

The wire in the cable was probably damaged during DFI installation. The positive half of the video signal was shorted to the shield.

Conclusions: The spacecraft wiring was shorted in an extension cable used on OV-102 to allow for DFI installation.


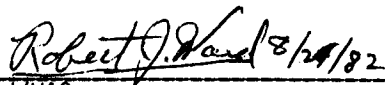
Corrective action: The extension cable was removed and two wire segments were replaced. The extension cable was reinstalled and an end-to-end functional test will be completed before STS-5.

APPROVED


Aldrich


Date

Effect on subsequent missions: None.

 ^{EE2} BE 8/24/82  RW 8/24/82
Personnel assigned: B. C. Embrey/EE2; R. J. Ward/WA3

Resolution: CLOSED 08/25/82

Statement of problem: Wireless Crew Communications Unit (WCCU) "B" Operated Intermittently.
Discussion: During a live TV pass on the fourth day the pilot reported that his audio was intermittent and that he had exchanged unit "C" for his unit "B". Prior to exchanging the units, the unit "B" batteries were checked and found to be good. The "B" leg unit and corresponding wall unit were checked postflight and found to be working perfectly. However, the wall unit's antenna was missing. The antenna was later found behind the RMS control panel. The antenna was unbroken and operational. During discussions with the pilot, it has been determined that the system "B" wall unit antenna was properly attached before it was stowed. There is no explanation of why the pilot had an intermittent problem with the "B" system. The problem was subsequently solved when the "C" system was installed. The same WCCU "B" unit had been used by the pilot without a problem on STS-2 and 3.
Conclusions: After test and analysis of the "B" system wall and leg unit, no problem can be found with the hardware.
Corrective action: The "B" system will be reused by the pilot on STS-5. Fly as is. A spare system will be onboard again for STS-5.
APPROVED <i>RMA Mached</i> 9/14/82 W.F.A. 9/14 Reginald M. Mached Date
Effect on subsequent missions: None.
<i>J.W. Armstrong</i> 9/13/82 <i>R. J. Ward</i> 9/13/82 Personnel assigned: R. Armstrong/EE3; R. J. Ward/WA3
Resolution: CLOSED 09/15/82

Statement of problem: Data missing from tracks 1 through 7 when the DFI PCM recorder was dumped after STS-4 landing.

Discussion: During normal postflight ground dumping of the DFI PCM recorder, it was noted that tracks 1 through 7 contained excessive noise while the data on tracks 8 through 14 appeared normal.

The recorder was returned to the vendor where it was found that data was recorded on tracks 1 through 7 but was subsequently erased. Data erasure resulted from tape passage across the magnetized reproduce heads on tracks 1 through 7. Head magnetization resulted from a short which occurred when two feedthrough wires on a printed circuit board contacted the top of a relay on an adjacent printed circuit board. This short caused two transistors to fail which allowed a constant DC current to flow through the reproduce heads thereby erasing the recorded data. Conditions to cause loss of data can exist only while the recorder is being operated in the reverse direction.

Dimensional analysis indicates that a 0.05 inch interference can exist if all components are within specification and workmanship standards. This condition can exist in all recorders built to date and cannot be detected by flight telemetry measurements. Conformal coating on the relay case probably prevented earlier failure of this recorder.

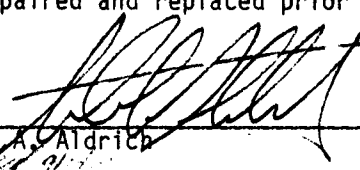
All flight units will be returned to the vendor for modification which includes opening the recorder and partial disassembly. The two leads will then be clipped "flush" with the board and an insulator bonded to the top of the relay case.

Conclusions: A short between protruding leads from a printed circuit board and the top of a relay on an adjacent board caused a constant voltage to be applied to the recorder reproduce heads which erased the recorded data on tracks 1 through 7.

Corrective action: The DFI PCM recorder will be repaired for STS-5. A spare recorder will be returned to the vendor for modification and retest. It will replace the payload recorder for STS-5 if time permits.

Risk of failure of the remaining three or four recorders of this type is acceptable since the OPS recorders are redundant and the DFI wideband ascent recorder and the payload recorder record only in parallel. Parallel recording is done in the forward direction only and recorded data will not pass across the reproduce heads until post-landing data dump. Procedures will be implemented to verify that the reproduce head has not been magnetized prior to playback of recorded data. Future corrective action includes return of all flight recorders to the vendor for modification and reacceptance. The three OV-099 recorders will be repaired and replaced prior to STS-6.

APPROVED



A. Aldrich

9-8-82
Date

Effect on subsequent missions: None

Personnel assigned: J. Melugin/EDS; C. Walsh/WC6

Resolution: CLOSED 09/08/82

Statement of problem: Upper Body Flap Tile Degradation Caused by Aft Vernier RCS Plumes.

Discussion: The orientation of the two aft vernier RCS thrusters results in direct plume impingement on the upper body flap tiles. High aft vernier usage during STS-3 and STS-4 caused degradation of the HRSI (high temperature reusable surface insulation) tiles on the upper body flap. Erosion or roughening of the tile surface was first noted after STS-3. Accumulated degradation during STS-4 resulted in severe erosion of several tiles on the upper surfaces of the body flap.

Testing indicates that RTV (room temperature vulcanizing) material will still be elastic after ascent and should provide adequate protection from the thruster plumes. Verification of RTV-coated tiles is planned at White Sands on August 20, 1982, during thruster life testing. An AFRSI (advanced flexible reusable surface insulation) blanket will also be tested as a long-range solution.

Conclusions: High usage of the two aft vernier RCS thrusters resulted in continued degradation of HRSI tiles on the upper surfaces of the body flap and tile refurbishment or replacement was required.

Corrective action: Nine tiles on the upper left body flap and three on the upper right have been coated with RTV. One tile on the upper left has been replaced. Potential long-term solutions include thruster re-orientation, scarfing or plume deflectors for the aft vernier thrusters as well as an AFRSI blanket for the upper body flap tiles. FOD will limit vernier RCS usage to under 0.2°/second rates.

APPROVED

[Signature]
A. Adrich

8-23-82
Date

Effect on subsequent missions: None. Repair and/or replacement of several upper body flap tiles may be required after each flight until a long range solution is implemented.

R. L. Dotts 8/18/82 Robert J. Ward 8/18/82

Personnel assigned: R. L. Dotts/ES3; R. J. Ward/WA3

Resolution: CLOSED for STS-5 08/25/82

Statement of problem: Fuel cell 2 water relief valve heater "B" was inoperative

Discussion: The function of the water relief valve heater is to maintain the fuel cell water relief valve temperature well above freezing throughout the mission. The heaters in both "A" and "B" circuits are thermostatically controlled to come on at 70° F. Review of the data after the flight showed that the relief valve temperatures approached 70° F between 130 and 140 hours MET. The heater "B" circuit was active at this time, and the fuel cells 1 and 3 relief valve heaters cycled repeatedly while the no. 2 heater did not. Although there was no impact to this particular mission, subsequent checkout at KSC revealed a broken heater "B" ground wire at the vehicle attach point.

The fuel cell water relief valves would only be used in the event of a failure in the potable water system. Relief valve temperatures have been well above freezing during the cold case missions flown.

Conclusions: The exact time and cause of the failure is unknown. The wire was possibly broken before liftoff but not detected because of ambient temperature above the 70° actuation point.

Corrective action: The broken wire was repaired and the circuit and heater functions verified.

APPROVED: 

A. Aldrich

9-3-82
Date

Effect on subsequent missions: None.

Personnel assigned: F. Plauche/EP5; C. Walsh/WC6
8/31/82
F. Plauche *8/31/82*

Resolution: CLOSED 09/01/82

Statement of problem: Right and Left-Hand Inboard Brake Rotors Damaged

Discussion: The numbers 3 and 4 rotors on both inboard brake assemblies were found damaged after STS-4. The inside diameter of these rotors scraped against their torque tubes which shaved off fragments of beryllium. Unlike STS-3, on this flight there were no bent drive lug notches on any rotor outside diameter, but there was a small amount of chafing on the contact face of some notches.

Braking on STS-4 averaged about 7.5 ft/sec.². Hard braking up to about 13 ft/sec² is planned for STS-5. Full brake design capability exists for STS-5, but the brake assemblies will probably require replacement again after the planned landing due to expected scraping of the rotors on the torque tubes and chafing on the contact faces of some notches. Brake modifications are being implemented for STS-6 and 7 to reduce rotor damage. If these fixes don't eliminate brake damage, consideration will be given to stiffening the axles.

The damage to the inside diameter of the rotors and to the contact face of some notches is not a safety of flight issue, but rather a lifetime and cost issue.

Conclusions: Landing loads during rollout produce relative deflections of the wheel, brake and axle resulting in damage to the brake rotors. STS-5 should have similar and more severe damage since harder braking at higher velocities is planned. The brake assemblies will probably require replacement again after STS-5.

Corrective action: The two inboard brake assemblies were replaced with new assemblies for STS-5 and full design capability exists. STS-6 will have a saddle installed between each brake assembly and axle to force the brake to move during axle deflections. Protective clips or caps for the rotor and stator drive lug notches should be installed for STS-7.

APPROVED

Aldrich
A. Aldrich

9-20-82
Date

Effect on subsequent missions: Similar brake damage may occur on STS-5. All brake rotors will be inspected for evidence of galling, bending or scraping after STS-5.

C. Campbell 9-17-82 R. J. Ward 9/17/82
Personnel assigned: C. Campbell/ET5; R. J. Ward/WA3

Resolution: CLOSED for STS-5 09/17/82

Statement of problem: Environmental Control Life Support System (ECLSS) Airlock Vent Duct Damaged

Discussion: During the EVA (extravehicular activity) preparation demonstration, the airlock vent duct was damaged while a crewmember was stowing airlock hatch "A". The vent duct was penetrated by the hatch's uplock fixture as the hatch was rotated toward the stowed position.

Postflight tests conducted in the 1g trainer at JSC verified the hatch's uplock fixture can contact the vent duct. If the hatch is pulled to a maximum position away from the airlock, then rotated to the stowed position, the hatch will not contact the vent duct.

Conclusions: The airlock vent duct was damaged by the hatch-uplock fixture when the hatch was opened.

Corrective action: KSC has repaired the vent duct damage. The duct support bracket has been removed and the duct has been reattached in a position that provides a 1.5-inch clearance when the hatch is opened. The same fix will be made for OV-099 and subsequent vehicles.

APPROVED

[Signature]
A. Aldrich

9-27-82
Date

Effect on subsequent missions: None.

R. Devas 9/24/82 *C. J. Walsh 9/24/82*
Personnel assigned: N. Devas/ET52; C. J. Walsh/WC6

Resolution: CLOSED 09/29/82

Statement of problem: Degradation of Vernier Thruster Nozzle Coating on Jets R5R and F5L.

Discussion: Post STS-4 thruster inspection revealed small coating defects in the F5L and R5R vernier thrusters. A coating defect described as a small 0.050-0.060 inch crater was found at the throat of F5L. The coating thickness was apparently zero in this area. A small chip about 0.020 x 0.020 in. was found in the coating just upstream of the throat on R5R. The depth of the chip is not exactly measurable and the shape indicates possible mechanical damage. These two problems in combination with the previous qualification problems on the vernier thrusters caused concern for all the OV-102 vernier thrusters. The thrusters apparently have much shorter life than had been previously expected. Also, the usage during the missions has been much greater than anticipated. Potential failure causes include thermal cycle fatigue of the coating, mechanical damage from throat plugs, quality problems during initial coating of the thruster, oxidation from the oxidizer rich mixture in the engine, rapid oxidation in the 1200-1500°F range or some combination of these causes.

Conclusions: The cause of the coating degradation is unknown. Because of the obvious concern for F5L and R5R and the unknown life of the other four verniers in OV-102, all six of the vernier engines were replaced with new OV-099 engines.

Corrective action: An extensive failure investigation program has been initiated. Additional testing to determine the effects of thermal cycles on nozzle life will be conducted, inspection techniques are being developed, additional engines and chambers are being ordered to meet near term replacement problems, and a program to develop an improved design is in work.

APPROVED

WTA 9/14 A. Aldrich

9-20-82

Date

Effect on subsequent missions: Frequent vernier engine changeouts are expected. Detailed vernier inspection will be performed after each mission.

Personnel assigned: *D.R. Blevins* D. R. Blevins/EP4; *C. Walsh* C. Walsh/WC6

Resolution: CLOSED for STS-5 09/15/82