NASA Technical Memorandum TM 103827

Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-44

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National Aeronautics and Space Administration

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DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-44

November 24, 1991

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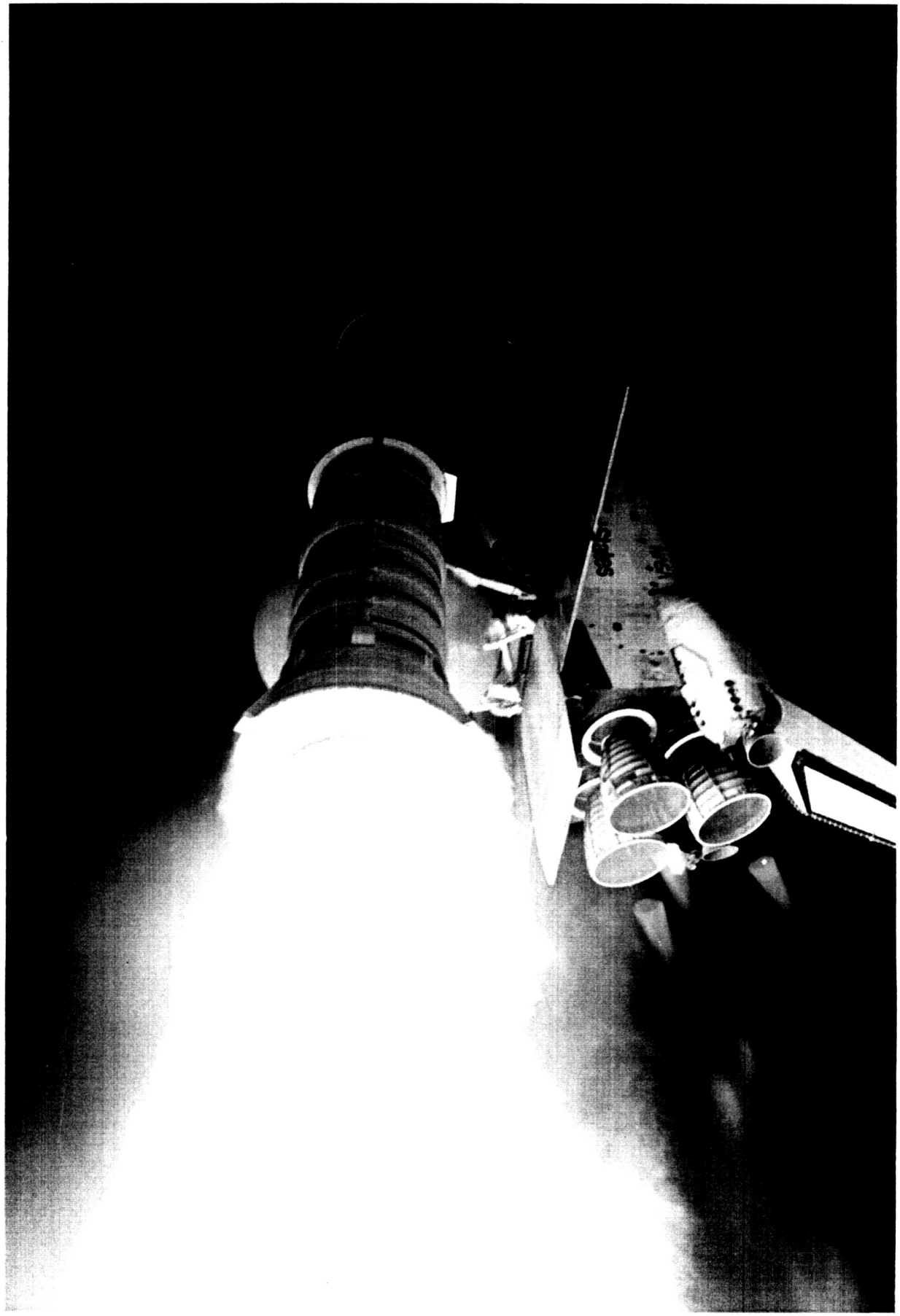
FOREWORD

The Debris Team is continuing its effort to develop and implement measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine processing and operations.



Shuttle Mission STS-44 was launched at 6:44 p.m. local 11/24/91

1.0 Summary

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 18 November 1991. The detailed walkdown of Launch Pad 39A and MLP-1 also included the primary flight elements OV-104 Atlantis (10th flight), ET-53 (LWT 46), and BI-047 SRB's. There were no vehicle anomalies. Vehicle configuration changes of interest and flown for the first time on ET-53 included the new LH2 tank pressurization line phenolic fairing at the intertank feedthrough and the modified intertank SOFI spray process.

The launch was scrubbed before the start of cryoloading due to the failure of an IMU in the payload Inertial Upper Stage (IUS).

The second pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 23 November 1991. There were no vehicle anomalies. Facility discrepancies were worked real-time or entered into OMI S0007, Appendix K, for resolution prior to vehicle tanking.

The vehicle was cryoloaded for flight on 24 November 1991. There were no Ice/Debris Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no ice/frost or TPS conditions outside of the established data base. The External Tank was dry with no condensate on any of the TPS acreage. Seven Ice/Frost Team observation/anomalies were documented and found acceptable for launch per the LCC and NSTS-08303. The LH2 umbilical leak sensor detected no significant hydrogen during the cryoload. The tubing was successfully removed from the vehicle with no TPS contact or damage.

A small amount of ice/frost had formed on the aft area of the LH2 umbilical and on the aft pyrotechnic canister inboard bondline. Thin foam exists in this area due to an incorrect mold manufacture. The amount and location of the ice/frost was acceptable for launch per the NSTS-08303 criteria. (The problem exists through end item EI-66. The mold will be changed to add more foam for EI-67 and subs. An EI spec waiver will be issued for STS-45 and subs until existing end items are expended. STS-42's umbilical will be approved for use by local PMRB.)

A debris inspection of Pad 39A was performed after launch. No flight hardware or TPS materials were found. Launch damage to the holddown posts was minimal. EPON shim material on the south holddown posts was intact, but slightly debonded at the sidewalls on HDP #1 and #5. There was no visual indication of a stud hang-up on any of the south holddown posts. No frangible nut/ordnance fragments were found. The GH2 vent line had latched properly. Damage to the facility overall was minimal.

A total of 132 film and video items were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. An orange streak occurred along the -Y side of the SSME #2 plume starting at SSME ignition. The streak disappeared as the vehicle lifted off. Film item E-16 was reviewed to investigate orange vapors and a reported burning of insulation on SSME #2 between the #9 hatband and the coolant manifold at the -Z axis. Engineering consensus concluded a very small hydrogen leak occurred at the aft manifold or behind the steer horn resulting in a stream of vapor to the #9 hatband and around the -Z drain line. Determination of the small leak was based upon similar events/data observed during SSME testing at the Stennis Space Center. Engineering consensus further concluded that no material, such as insulation, was burning. No frangible nut/ordnance fragments fell from any of the holddown post DCS/stud holes. This was the fourth flight utilizing the new optimized frangible links. There was no evidence of stud hang-ups on any of the holddown posts. ET aft dome charring, plume recirculation, and SRB separation were nominal. OV-104 was not equipped to carry umbilical cameras. Insufficient light due to the late time of launch prevented the crew from photographing the External Tank after separation from the Orbiter. Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were normal. The Orbiter was allowed to roll the length of the runway without braking per a DTO, though light braking was applied near the end of the runway.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums exhibited a total of 19 debonds over fasteners. The field joint protection system closeouts were in generally good condition. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing prior to water impact. All HDP Debris Containment System (DCS) plungers were seated and post flight disassembly of the DCS housings revealed virtually no loss of frangible nut/ordnance fragments. The overall system debris retention averaged 99 percent. None of the EPON shim material was lost during flight.

The LH forward skirt, LH forward segment, and LH forward center segment sustained structural damage from either water impact "slap down" loads or parachute deployment side loads. The LH forward assembly was fractured 180 degrees of the circumference. Eight buckles, dents, and flat spots were found in the forward and forward center segments. The forward, forward center, and aft center segments also exhibit out-of-round conditions. Initial assessment indicates the damage was not a source of debris nor was caused by a debris problem.

A detailed post landing inspection of OV-104 (Atlantis) was conducted on December 1-3, 1991, at Ames-Dryden (EAFB) in the Mate-Demate Device. The Orbiter TPS sustained a total of 101 hits, of which 9 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 74 hits, of which 6 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, both the total number of Orbiter TPS debris hits and the number of hits with a major dimension of 1 inch or larger were much less than average. Damage sites were noted on the perimeter tiles of Orbiter windows #1 through #6. Most of the impact sites were only surface coating losses. This damage may have been caused by the RTV used to bond paper covers to the FRCS nozzles. A cluster of hits was present on the leading edge of the vertical stabilizer near the root and the leading edges of the OMS pods. The largest tile damage site on the vehicle was located on the RH OMS pod and measured approximately 5"x2"x1" in size (involved two tiles). The cause of this damage was not apparent and no adjacent tile gap fillers were missing. Damage in this area is uncommon and may possibly be related to the damage around the forward facing windows.

The ET/ORB (EO-2 and 3) separation ordnance device plungers were seated and appeared to have functioned properly. An assembly consisting of an ordnance connector, detonator, and lockwire fell from the ET/Orbiter LH2 umbilical aft separation device fell to the runway when the ET door was opened.

A variety of residuals were present in the Orbiter window samples and indicated sources such as Orbiter TPS, SRB BSM exhaust residue, Orbiter window polishing compound, natural landing site products, organics, and paint. A deposit was present on the LOX ET umbilical plate that is currently being analyzed for source determination. The data does not indicate a single source of damaging debris as all of the materials have been previously documented in post-landing samples.

A total of three Post Launch Anomalies, but no IFA candidates, were observed during this mission assessment. From a debris damage standpoint, this flight can be considered one of the best in program history.

2.0 KSC ICE/FROST/DEBRIS TEAM ACTIVITIES

Team Composition: NASA KSC, NASA MSFC, NASA JSC, LSOC SPC, RI - DOWNEY, MMMSS - MAF, USBI - BPC, MTI - UTAH

Team Activities:

1) Prelaunch Pad Debris Inspection

Objective:	Identify and evaluate potential debris material/sources. Baseline debris and debris sources existing from previous launches.
Areas:	MLP deck, ORB and SRB flame exhaust holes, FSS, Shuttle external surfaces
Time:	L - 1 day
Requirements:	OMRSD S00U00.030 - An engineering debris inspection team shall inspect the Shuttle and launch pad to identify and resolve potential debris sources. The prelaunch vehicle and pad configuration shall be documented and photographed.
Documents:	OMI S6444
Report:	Generate PR's and recommend corrective actions to pad managers.

2) Launch Countdown Firing Room 2

Objective:	Evaluate ice/frost accumulation on the Shuttle and/or any observed debris utilizing OTV cameras.
Areas:	MLP deck, FSS, Shuttle external surfaces
Time:	T - 6 hours to Launch + 1 hour or propellant drain
Requirements:	OMRSD S00FB0.005 - Monitor and video tape record ET TPS surfaces during loading through prepressurization.
Documents:	OMI S0007, OMI S6444
Report:	OIS call to NTD, Launch Director, and Shuttle managers. Generate IPR's.

3) Ice/Frost TPS and Debris Inspection

Objective:	Evaluate any ice formation as potential debris material. Identify and evaluate any ORB, ET, or SRB TPS anomaly which may be a debris source or safety of flight concern. Identify and evaluate any other possible facility or vehicle anomaly.
Areas:	MLP deck, FSS, Shuttle external surfaces
Time:	T - 3 hours (during 2 hour BIH)
Requirements:	OMRSD S00U00.020 - An engineering debris inspection team shall inspect the Shuttle for ice/frost, TPS, and debris anomalies after cryo propellant loading. Evaluate, document, and photograph all anomalies. During the walkdown, inspect Orbiter aft engine compartment (externally) for water condensation and/or ice formation in or between aft compartment tiles. An IR scan is required during the Shuttle inspection to verify ET surface temperatures. During the walkdown inspect ET TPS areas which cannot be observed by the OTV system.
Documents:	OMI S0007, OMI S6444
Report:	Briefing to NTD, Launch Director, Shuttle management; generate IPR's.

4) Post Launch Pad Debris Inspection

Objectives:	Locate and identify debris that could have damaged the Shuttle during launch
Areas:	MLP zero level, flame exhaust holes and trenches, FSS, pad surfaces and slopes, extension of trenches to the perimeter fence, walkdown of the beach from Playalinda to Complex 40, aerial overview of inaccessible areas.
Time:	Launch + 1 hours (after pad safing, before washdown)
Requirements:	OMRSD S00U00.010 - An engineering debris inspection team shall perform a post launch pad/area inspection to identify any lost flight or ground systems hardware and resultant debris sources. The post launch pad and area configuration shall be documented and photographed.
Documents:	OMI S0007, OMI S6444

Report:	Initial report to NTD and verbal briefing to Level II at L+8 hours; generate PR's.

5) Launch Data Review

Objective:	Detailed review of high speed films video tapes, and photographs from pad cameras, range trackers, aircraft and vehicle onboard cameras to determine possible launch damage to the flight vehicle. Identify debris and debris sources.
Time:	Launch + 1 day to Launch + 6 days
Requirements:	OMRSD S00U00.011 - An engineering film review and analysis shall be performed on all engineering launch film as soon as possible to identify any debris damage to the Shuttle. Identify flight flight vehicle or ground system damage that could affect orbiter flight operations or future SSV launches.
Documents:	OMI S6444
Report:	Daily reports to Level II Mission Management Team starting on L+1 day through landing; generate PR's.

6) SRB Post Flight/Retrieval Inspection

Objective:	Evaluate potential SRB debris sources. Data will be correlated with observed Orbiter post landing TPS damage.
Areas:	SRB external surfaces (Hangar AF, CCAFS)
Time:	Launch + 24 hours (after on-dock, before hydrolasing)
Requirements:	OMRSD S00U00.013 - An engineering debris damage inspection team shall perform a post retrieval inspection of the SRB's to identify any damage caused by launch debris. Anomalies must be documented/photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.
Documents:	OMI B8001
Report:	Daily reports to Level II Mission Management Team. Preliminary report to SRB Disassembly Evaluation Team. Generate PR's.

7) Orbiter Post Landing Debris Damage Assessment

Objective:	Identify and evaluate areas of Orbiter TPS damage due to debris and correlate if possible, source and time of occurrence. Additionally, runways are inspected for debris/sources of debris
Areas:	Orbiter TPS surfaces, runways
Time:	After vehicle safing on runway, before towing
Requirements:	OMRSD S00U00.040 - An engineering debris inspection team shall perform a prelanding runway inspection to identify, document, and collect debris that could result in orbiter damage. Runway debris and any facility anomalies which cannot be removed/corrected by the Team shall be documented and photographed; the proper management authority shall be notified and corrective actions taken.
Requirements:	OMRSD S00U00.050 - An engineering debris inspection team shall perform a post landing runway inspection to identify and resolve potential debris sources that may have caused vehicle damage but was not present or was not identified during pre-launch runway inspection. Obtain photographic documentation of any debris, debris sources, or flight hardware that may have been lost on landing.
Requirements:	OMRSD S00U00.060 - An engineering debris inspection team shall map, document, and photograph debris-related Orbiter TPS damage and debris sources.
Requirements:	OMRSD S00U00.012 - An engineering debris damage inspection team shall perform a post landing inspection of the orbiter vehicle to identify any damage caused by launch debris. Any anomalies must be documented/ photographed and coordinated with the results of the post launch shuttle/ pad area debris inspection.
Requirements:	OMRSD V09AJ0.095 - An engineering debris inspection team shall perform temperature measurements of RCC nose cap and RCC RH wing leading edge panels 9 and 17.
Documents:	OMI S0026, OMI S0027, OMI S0028

Report: Briefing to NASA Convoy Commander and generate PR's. Preliminary report to Level II on the day of landing followed by a more detailed update the next day.

8) Level II report

Objective: Compile and correlate data from all inspections and analyses. Results of the debris assessment, along with recommendations for corrective actions, are presented directly to Level II via SIR and PRCB. Paper copy of complete report follows in 3 to 4 weeks. (Ref NASA Technical Memorandum series).

3.0 PRE-LAUNCH BRIEFING

The Ice/Frost/Debris Team briefing for launch activities was conducted on 23 November 1991 at 1400 hours with the following key personnel present:

B. Bowen	NASA - KSC	ET Processing, Ice/Debris
K. Tenbusch	NASA - KSC	ET Processing, Ice/Debris
P. Rosado	NASA - KSC	Chief, ET Mechanical Systems
S. Higginbotham	NASA - KSC	STI, Ice/Debris Assessment
B. Davis	NASA - KSC	STI, Ice/Debris Assessment
G. Katnik	NASA - KSC	Lead, Ice/Debris/Photo Team
B. Speece	NASA - KSC	Lead, ET Thermal Protection
J. Rivera	NASA - KSC	Lead, ET Structures
M. Bassignani	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	ET Processing, Ice/Debris
A. Biamonte	NASA - KSC	ET Processing, Ice/Debris
J. Cawby	LSOC - SPC	Supervisor, ET Mech Systems
J. Hoffman	LSOC - SPC	Supervisor, ET Mech Systems
W. Richards	LSOC - SPC	ET Processing, Ice Assess
M. Young	LSOC - SPC	ET Processing, Ice Assess
M. Dean	LSOC - SPC	ET Processing, Ice Assess
Z. Byrns	NASA - JSC	Level II Integration
C. Gray	MMC - MAF	ET TPS & Materials Design
S. Copsey	MMC - MAF	ET TPS Testing/Certif
J. McClymonds	RI - DNY	Debris Assess, LVL II Integ
T. Brees	RI - LSS	Vehicle Integration
S. Otto	MMC - LSS	ET Processing
W. Simpson	USBI - LSS	SRB Processing
K. Parsons	MTI - LSS	SRM Processing
M. Nowling	MTI - LSS	SRM Processing

These personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 18 November 1991 from 1500 - 1615 hours. The detailed walkdown of Launch Pad 39A and MLP-1 also included the primary flight elements OV-104 Atlantis (10th flight), ET-53 (LWT 46), and BI-047 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes. Two such changes consisted of a new LH2 pressurization line phenolic fairing at the intertank feedthrough. In addition, ET-53 was the first External Tank with the modified intertank SOFI spray process. One facility addition was the first use of the Holddown Post Bushing Bearing Rotation Measurement System, which contained components specially designed to minimize debris during liftoff

Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload/ launch, temporary hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical until a permanent sensor could be designed and installed. The tygon tubes are intended to remain in place during cryogenic loading and be removed by the Ice Inspection Team during the T-3 hour hold.

There were no vehicle anomalies. Four bolts in the raised deck north of the SSME exhaust hole, one bolt with insufficient grip length east of the LO2 TSM, and two bolts on a platform actuation access cover on the LH2 TSM were loose. A round cover for an electrical conduit box adjacent to the Portable Purge Unit electrical connector was removed and tethered. These discrepancies were corrected real-time by Pad Operations and no items were entered in S0007, Appendix K.

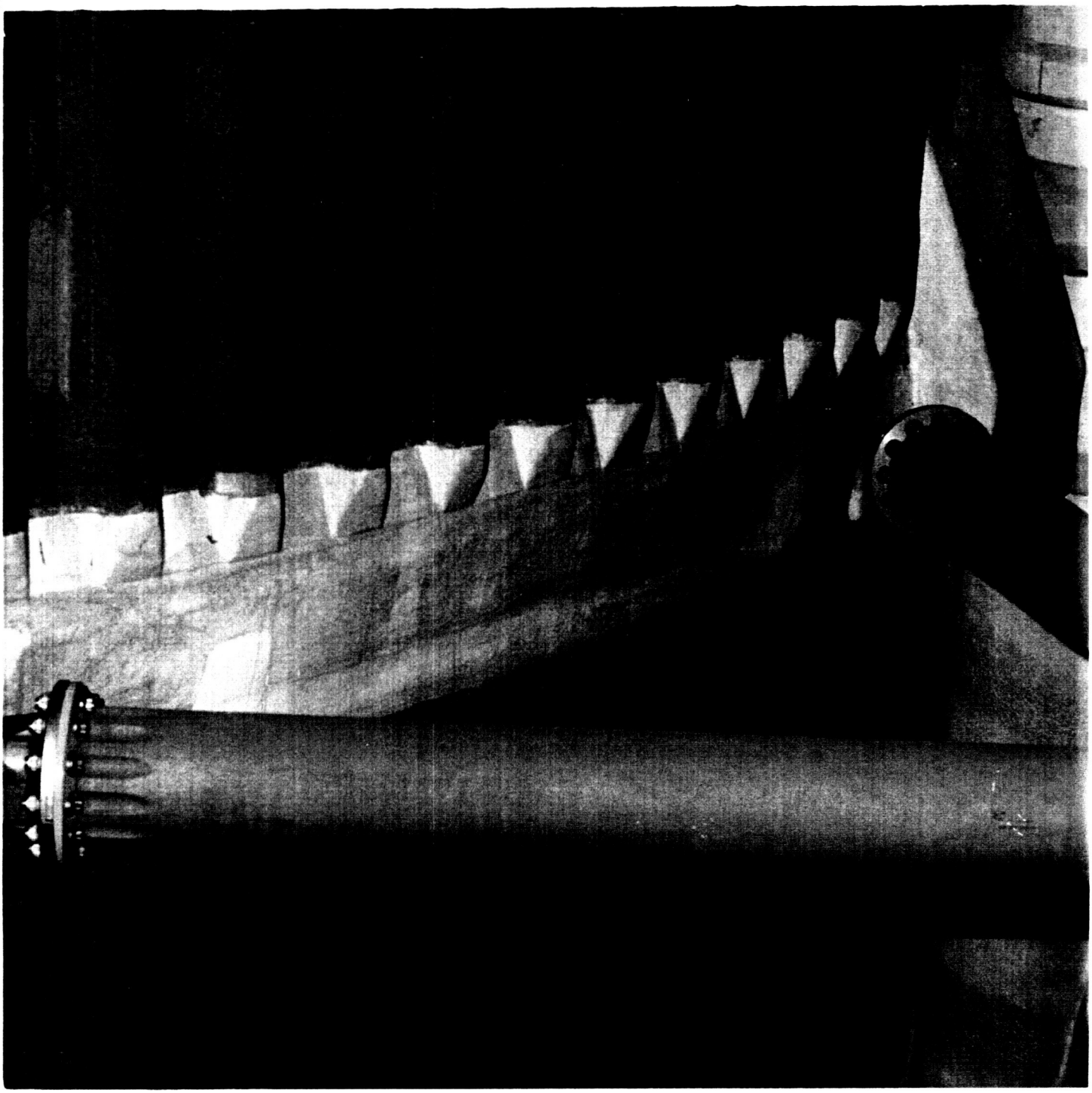
The launch was scrubbed before the start of cryoloading due to the failure of an IMU in the payload Inertial Upper Stage (IUS).

The second pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 23 November 1991 from 1425 - 1530 hours. There were no vehicle anomalies.

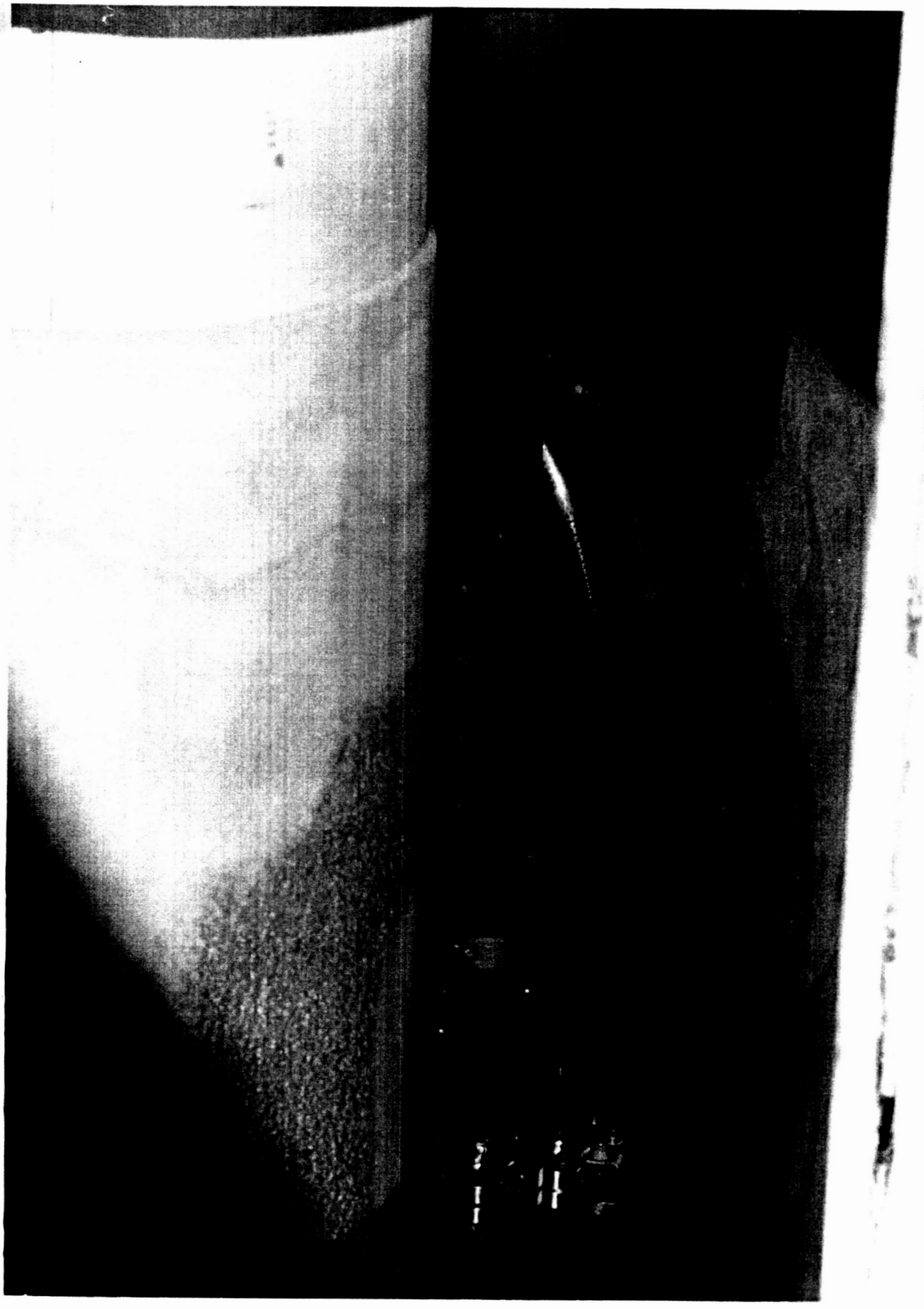
The tygon tubes for LD54 and LD55 had not been removed during the scrub turn-around and were still in proper configuration to support cryogenic loading.

Set screws on the Portable Purge Unit (PPU) electrical connector covers on the MLP zero level (northwest corner) were loose. Five protective domes on bolt threads of the sound suppression rainbirds had rusted and were removed. Several other domes were loose.

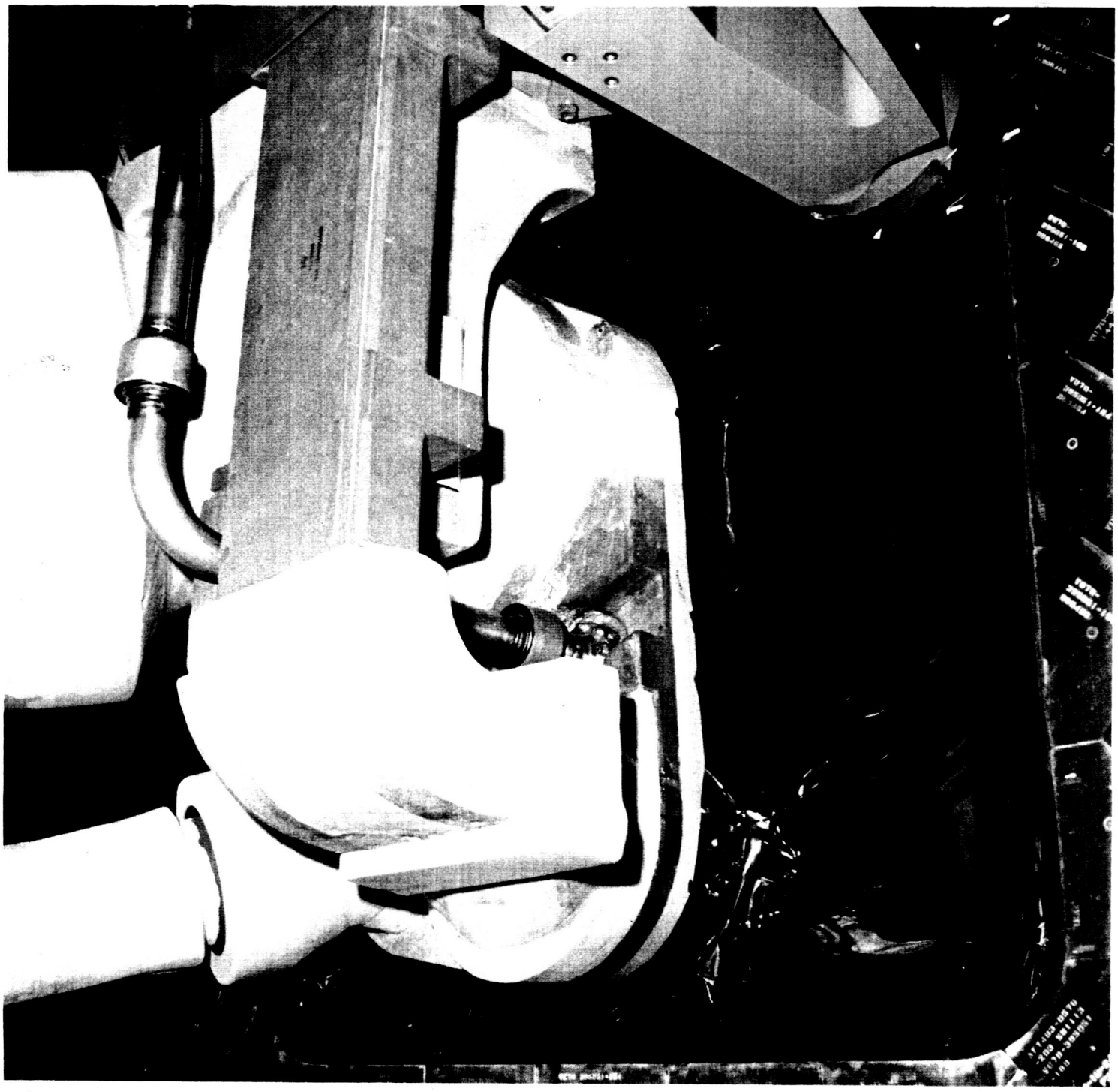
The facility discrepancies were worked real-time or entered into OMI S0007, Appendix K, for resolution prior to vehicle tanking.



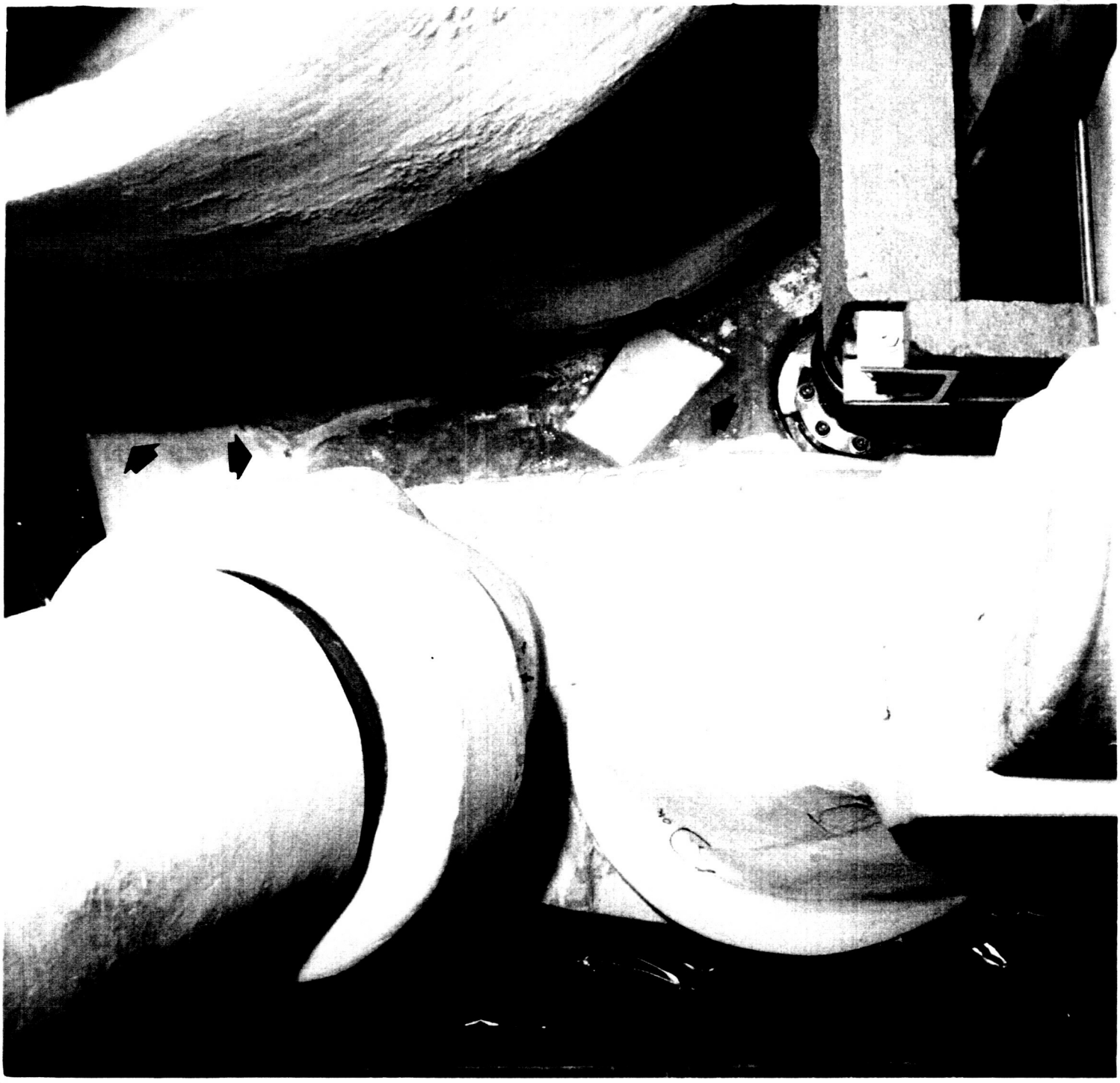
Pre-launch configuration of bipod jack pad closeouts. After cryogenic loading, a frost ball formed on the bondline of the +Y bipod jack pad closeout at the 4 o'clock position. Presence of the frost ball at this location was not a constraint to launch per NSTS-08303.



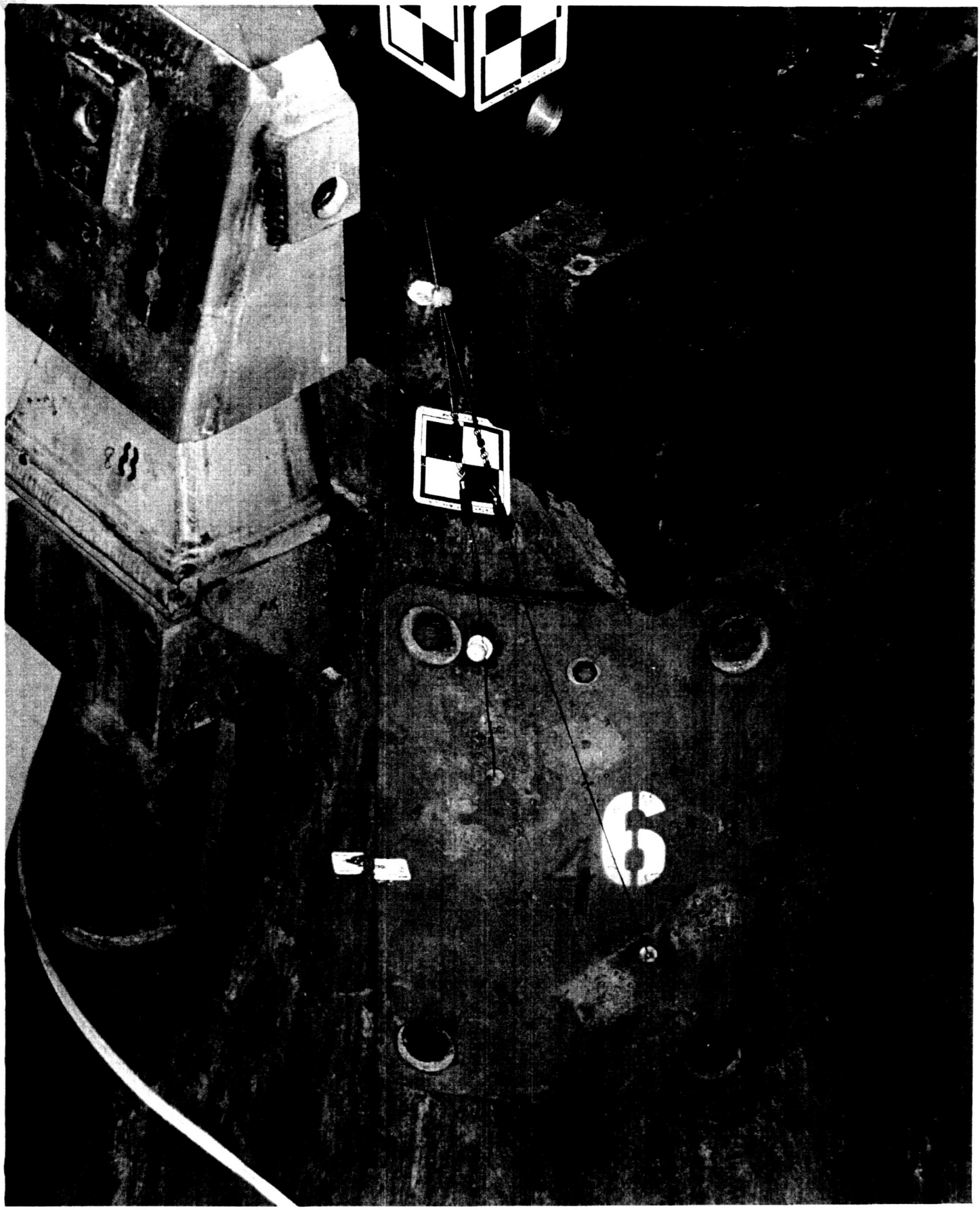
Pre-launch configuration of new LH2 pressurization line phenolic fairing at the intertank feedthrough



Overall view of the LH2 ET/ORB umbilical



Pre-launch view of LH2 feedline 17-inch flapper valve actuator tool access port closeout and thin foam area around LH2 umbilical aft pyrotechnic canister closeout.



Components of the Holddown Post Bushing Bearing Rotation Measurement System had been designed to minimize debris during ignition and liftoff.

4.0 LAUNCH

STS-44 was launched at 24:23:44:00 GMT (18:44:00 p.m. local) on 24 November 1991.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 24 November 1991 from 1300 to 1500 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no conditions outside of the established data base. Ambient weather conditions at the time of the inspection were:

Temperature:	67.9 F
Relative Humidity:	43.1 %
Wind Speed:	10.0 Knots
Wind Direction:	308 Degrees

The portable STI infrared scanner was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figure 1 and 2.

4.2 ORBITER

No Orbiter tile anomalies were observed. All RCS paper covers were intact and bonded to the RCS thrusters. Several thruster paper covers were wet (L4U, L1U, L2L, L3L, L1L, R4R, R3R), but there was no evidence of a leak or a liquid level line on any of the covers. The water spray boiler plugs were intact. The average Orbiter surface temperature was 68 degrees F. The average surface temperatures of the engine mounted heat shields were 63 degrees F for SSME #1, 63 degrees F for SSME #2, and 62 degrees F for SSME #3. Light frost coated the SSME #1 heat shield-to-nozzle interface along the full circumference and the SSME #2 heat shield-to-nozzle interface at the 7-12 o'clock positions. The SSME #3 heat shield was dry. No GOX vapors originated from inside the SSME nozzles. No condensate was present on base heat shield tiles.

4.3 SOLID ROCKET BOOSTERS

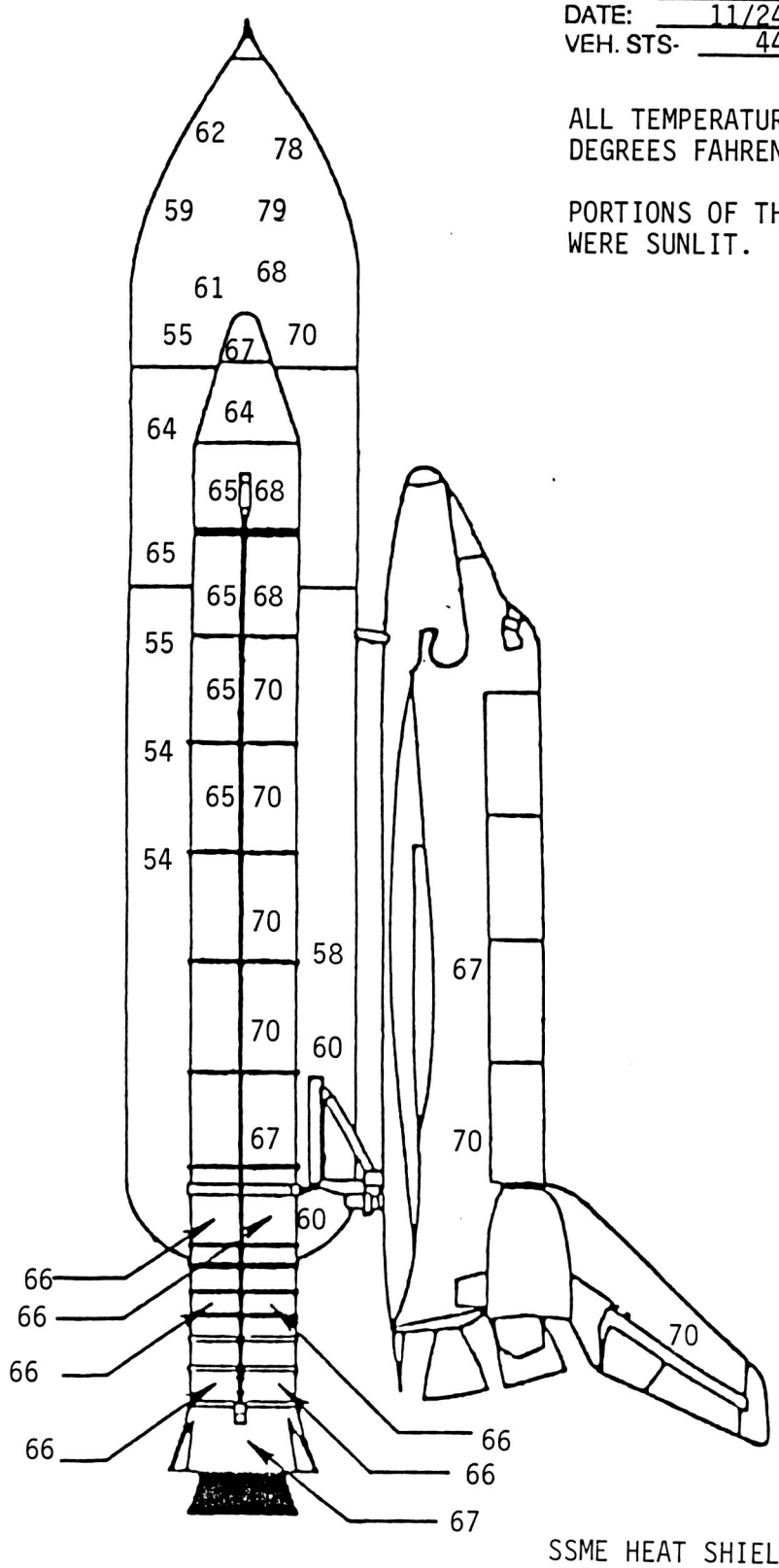
No SRB anomalies or loose ablator/cork were observed. The K5NA closeouts of the aft booster stiffener ring splice plates were intact. Both the STI portable infrared scanner and the Cyclops radiometer recorded RH and LH SRB case surface temperatures that averaged 63 degrees F in the shade and 70 degrees F in the sunlit areas. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 72 degrees F, which was within the required range of 44-86 degrees F.

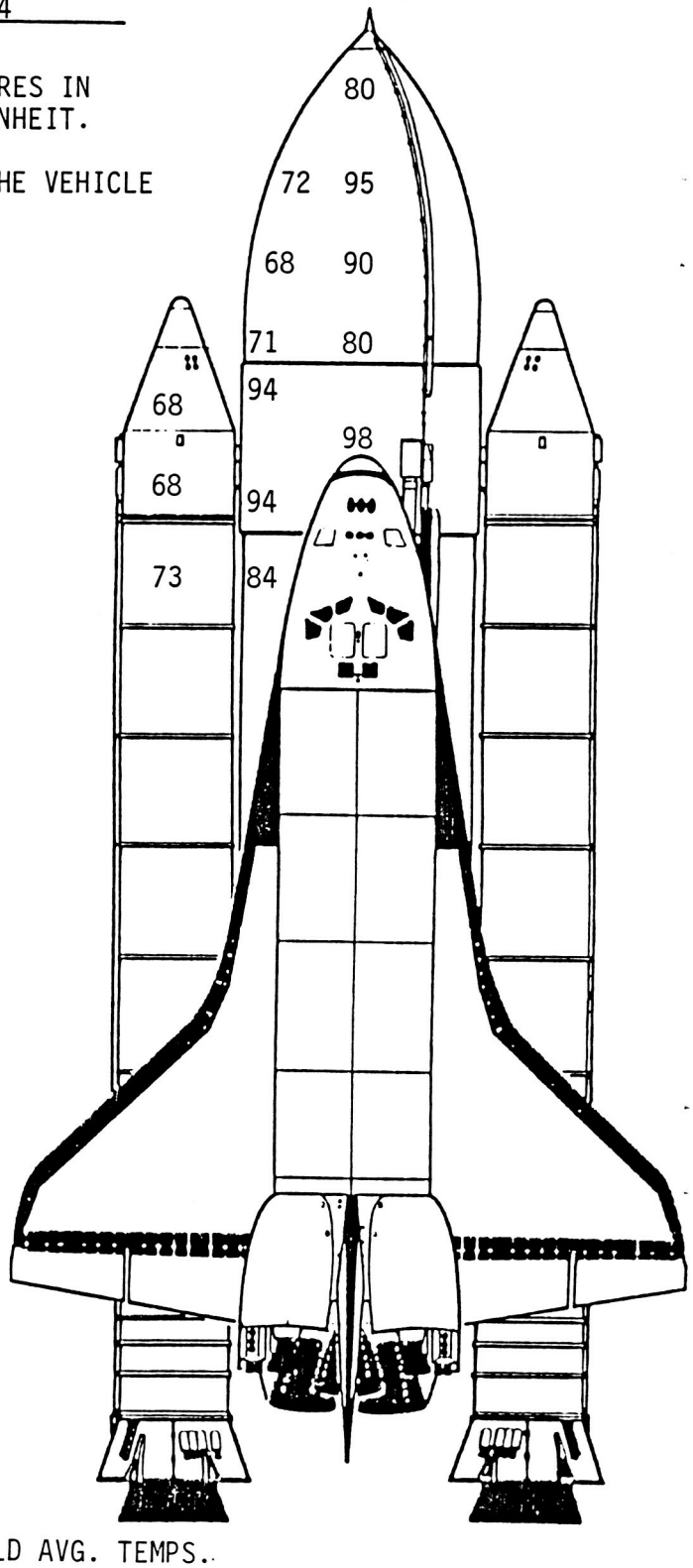
FIGURE 1. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 1300 - 1500
DATE: 11/24/91
VEH. STS- 44

ALL TEMPERATURES IN DEGREES FAHRENHEIT.

PORTIONS OF THE VEHICLE WERE SUNLIT.





SSME HEAT SHIELD AVG. TEMPS.
#1: 63
#2: 63
#3: 62

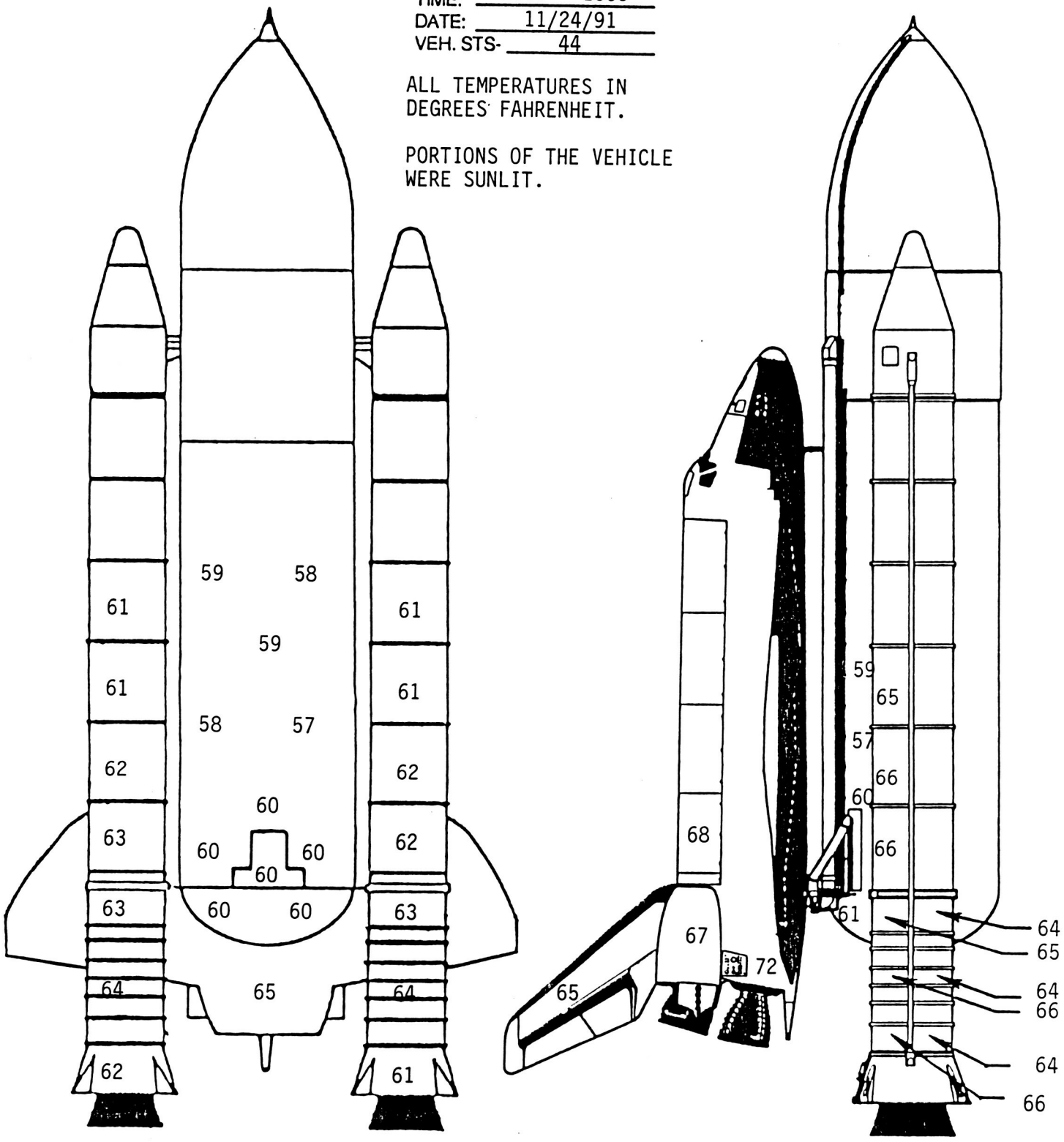
EGG/V--343D

FIGURE 2. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 1300 - 1500
DATE: 11/24/91
VEH. STS- 44

ALL TEMPERATURES IN DEGREES FAHRENHEIT.

PORTIONS OF THE VEHICLE WERE SUNLIT.



EGG/V-343C

4.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 1030 to 1845 hours and the results tabulated in Figures 3 and 4. The program predicted condensate with no ice accumulation on the TPS acreage surfaces during cryoload. As the ambient temperature dropped in late afternoon and early evening, SURFICE predicted below-freezing temperatures with ice/frost formation and/or freezing run-off condensate on the LO2 tank barrel section and the upper LH2 tank. Ice Team inspection and OTV surveillance revealed the acreage areas were dry (no condensate) with no ice/frost accumulations. SURFICE was not programmed to incorporate the effects of solar radiation and the predictions were therefore conservative.

There was no ice/frost accumulation or condensate on the LO2 tank ogive and barrel sections. There were no TPS anomalies. The tumble valve cover was intact. There were no anomalies on the pressurization line and support ramps. Both the portable STI and the Cyclops radiometer measured surface temperatures averaging 60 (shade) and 81 (sunlit) degrees F on the ogive and 58 (shade) and 79 (sunlit) degrees F on the barrel section. In comparison, SURFICE predicted 55 degrees F on the ogive and 48 degrees F on the barrel.

The intertank TPS acreage was dry. There were no anomalies with the new intertank TPS configuration or the LH2 pressurization line phenolic fairing. No frost spots were present in the stringer valleys. No unusual vapors or ice formations were present on the ET umbilical carrier plate. Both the portable STI and the Cyclops radiometer measured surface temperatures that averaged 64 degrees F in the shade and 95 degrees F in the sunlit areas.

The LH2 tank acreage and aft dome were dry. There were no ice/frost accumulations on the acreage. Both the portable STI and the cyclops radiometer measured surface temperatures averaging 56 (shade) and 84 (sunlit) degrees F on the upper LH2 tank and 60 degrees F (all areas in shade) on the lower LH2 tank. In comparison, SURFICE predicted 45 degrees F on the upper LH2 tank and 54 degrees F on the lower LH2 tank.

There were no anomalies on the bipods, PAL ramp, cable tray/press line ice/frost ramps, longerons, thrust struts, manhole covers, or aft dome apex. A small frost spot appeared on the +Y bipod jack pad closeout bondline. Small ice/frost spots had formed along the aft perimeter of the LH2 PAL ramp and three ice/frost ramps. Some ice/frost was present in the ET/SRB cable tray-to-upper strut fairing expansion joints. Ice/frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry.

STS- 44	TEST S0007 LAUNCH																	DATE: 24 Nov. 1991			T-0 TIME: 17:44:00 DATE: 11/24/91				NASA
ORBITER 104	ET 53	SRB BI-047	MLP 1	PAD A	LO2 CHILLDOWN TIME: 09:54 SLOW FILL TIME: 10:14					FAST FILL TIME: 10:28 REPLENISH TIME: 12:33					LH2 CHILLDOWN TIME: 09:38 SLOW FILL TIME: 09:51					FAST FILL TIME: 10:14 REPLENISH TIME: 12:19					KSC Ice/Frost/Debris Team
TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EST)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
1030	64.60	64.4	52.43	13	319	II	7.67	52.14	0.0002	-0.1473	II	7.67	48.73	0.0018	-0.1187	II	5.98	46.14	0.0023	-0.0828	II	15.99	52.23	0.0002	-0.2617
1045	65.40	63.4	52.79	15	324	I	8.85	53.67	0.0000	-0.1742	II	8.85	50.22	0.0014	-0.1452	II	6.90	47.89	0.0021	-0.1040	I	18.45	54.00	0.0000	-0.3140
1100	63.80	62.6	50.88	13	323	I	7.67	50.97	0.0000	-0.1372	II	7.67	47.49	0.0015	-0.1090	II	5.98	44.87	0.0021	-0.0747	I	15.99	51.18	0.0000	-0.2438
1115	65.80	61.8	52.48	12	319	II	7.08	52.41	0.0000	-0.1411	II	7.08	48.80	0.0016	-0.1126	II	5.52	46.13	0.0022	-0.0783	II	14.76	52.44	0.0000	-0.2478
1130	65.20	61.4	51.72	13	318	I	7.67	52.34	0.0000	-0.1464	II	7.67	48.64	0.0014	-0.1179	II	5.98	46.07	0.0020	-0.0823	I	15.99	52.53	0.0000	-0.2596
1145	66.60	60.2	52.54	11	321	II	6.49	52.48	0.0000	-0.1329	II	6.49	48.63	0.0016	-0.1046	II	5.06	45.85	0.0021	-0.0722	II	13.53	52.43	0.0001	-0.2306
1200	67.00	58.6	52.19	11	309	I	6.49	52.74	0.0000	-0.1330	II	6.49	48.65	0.0014	-0.1047	II	5.06	45.89	0.0020	-0.0724	I	13.53	52.64	0.0000	-0.2304
1215	65.20	59.0	50.63	12	288	I	7.08	51.64	0.0000	-0.1311	II	7.08	47.52	0.0013	-0.1030	II	5.16	44.25	0.0019	-0.0640	I	14.52	51.60	0.0000	-0.2260
1230	65.40	57.4	50.08	8	301	II	4.72	49.18	0.0003	-0.0875	II	4.72	44.22	0.0016	-0.0602	II	3.68	40.81	0.0019	-0.0366	II	9.84	48.87	0.0007	-0.1441
1245	67.40	55.8	51.25	14	294	I	8.26	54.94	0.0000	-0.1639	II	8.26	49.93	0.0007	-0.1353	II	6.44	47.57	0.0014	-0.0966	I	17.22	55.26	0.0000	-0.2919
1300	67.40	54.2	50.45	10	307	I	5.90	52.22	0.0000	-0.1167	II	5.90	47.28	0.0011	-0.0889	II	4.60	44.35	0.0016	-0.0599	I	12.30	52.01	0.0000	-0.1988
1315	67.00	53.4	49.66	9	318	I	5.31	50.91	0.0000	-0.1019	II	5.31	45.86	0.0012	-0.0744	II	4.14	42.74	0.0016	-0.0483	I	11.07	50.48	0.0000	-0.1706
1330	68.20	50.6	49.36	11	295	I	6.49	53.67	0.0000	-0.1265	II	6.49	47.83	0.0006	-0.0986	II	5.06	45.10	0.0012	-0.0678	I	13.53	53.70	0.0000	-0.2178
1345	67.20	45.4	45.46	9	294	I	5.31	50.77	0.0000	-0.0903	II	5.31	43.97	0.0004	-0.0634	II	4.14	40.89	0.0010	-0.0395	I	11.07	50.54	0.0000	-0.1501
1400	67.80	44.0	45.19	6	311	I	3.54	47.79	0.0000	-0.0616	II	3.54	40.72	0.0008	-0.0353	II	2.76	37.02	0.0011	-0.0174	I	7.38	46.43	0.0000	-0.0933
1415	68.80	42.6	45.28	12	284	I	7.08	54.66	0.0000	-0.1246	I	7.08	47.98	0.0000	-0.0971	II	5.16	43.72	0.0004	-0.0608	I	14.52	54.85	0.0000	-0.2122
1430	68.40	34.4	39.17	12	322	I	7.08	53.89	0.0000	-0.1042	I	7.08	47.28	0.0000	-0.0776	II	5.52	42.95	0.0000	-0.0511	I	14.76	54.48	0.0000	-0.1797
1445	68.00	31.0	36.03	12	321	I	7.08	53.29	0.0000	-0.0944	I	7.08	46.74	0.0000	-0.0681	II	5.52	42.42	0.0000	-0.0434	I	14.76	54.03	0.0000	-0.1625
1500	68.00	32.0	36.88	9	324	I	5.31	50.83	0.0000	-0.0724	I	5.31	43.17	0.0000	-0.0464	I	4.14	38.54	0.0000	-0.0262	I	11.07	51.03	0.0000	-0.1185
1515	68.40	29.8	35.37	8	301	I	4.72	50.00	0.0000	-0.0626	I	4.72	41.91	0.0000	-0.0369	I	3.68	37.18	0.0000	-0.0188	I	9.84	50.01	0.0000	-0.0995
1530	67.40	25.8	31.26	8	291	I	4.72	48.74	0.0000	-0.0530	I	4.72	40.72	0.0000	-0.0278	I	3.44	35.06	0.0000	-0.0083	I	9.68	48.74	0.0000	-0.0821
1545	67.60	25.4	31.08	8	318	I	4.72	48.91	0.0000	-0.0536	I	4.72	40.89	0.0000	-0.0284	I	3.68	36.19	0.0000	-0.0117	I	9.84	49.12	0.0000	-0.0849
1600	65.80	24.0	28.55	11	320	I	6.49	49.98	0.0000	-0.0681	I	6.49	43.24	0.0000	-0.0427	I	5.06	38.84	0.0000	-0.0226	I	13.53	50.87	0.0000	-0.1166
1615	65.80	29.6	32.95	9	321	I	5.31	48.49	0.0000	-0.0575	I	5.31	40.93	0.0000	-0.0320	I	4.14	36.28	0.0000	-0.0141	I	11.07	48.86	0.0000	-0.0938
1630	64.00	33.4	34.24	8	297	I	4.72	45.84	0.0000	-0.0476	I	4.72	37.84	0.0000	-0.0222	II	3.68	33.40	0.0001	-0.0058	I	9.84	45.88	0.0000	-0.0759
1645	65.00	34.6	36.11	8	306	I	4.72	46.93	0.0000	-0.0539	I	4.72	38.86	0.0000	-0.0283	II	3.68	34.68	0.0002	-0.0109	I	9.84	46.87	0.0000	-0.0862
1700	64.00	37.2	37.09	6	308	I	3.54	43.51	0.0000	-0.0377	II	3.54	35.09	0.0003	-0.0123	III	2.76	31.65	0.0007	0.0020	I	7.38	42.57	0.0000	-0.0552
1715	63.80	36.6	36.47	7	311	I	4.13	44.61	0.0000	-0.0437	II	4.13	36.17	0.0000	-0.0182	II	3.22	32.69	0.0005	-0.0026	I	8.61	44.19	0.0000	-0.0674

FIGURE 3. "SURFICE" Computer Predictions

STS- 44	TEST S0007 LAUNCH																					DATE: 24 Nov. 1991		T-0 TIME: 17:44:00 DATE: 11/24/91	NASA KSC Ice/Frost/Debris Team
ORBITER 104	ET 53	SRB BI-047	MLP 1	PAD A	LO2 CHILLDOWN TIME: 09:54 SLOW FILL TIME: 10:14					FAST FILL TIME: 10:28 REPLENISH TIME: 12:33					LH2 CHILLDOWN TIME: 09:38 SLOW FILL TIME: 09:51					FAST FILL TIME: 10:14 REPLENISH TIME: 12:19					
TIME (EST)	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
1730	61.60	40.6	37.12	5	291	I	2.95	39.60	0.0000	-0.0245	III	2.95	31.99	0.0006	0.0004	III	2.15	27.38	0.0009	0.0149	I	6.05	37.78	0.0000	-0.0310
1745	60.20	44.6	38.28	7	289	I	4.13	41.45	0.0000	-0.0370	II	4.13	34.60	0.0006	-0.0114	III	3.01	30.59	0.0010	0.0063	I	8.47	40.70	0.0000	-0.0560
1800	59.80	47.0	39.29	3	301	I	1.77	35.05	0.0004	-0.0084	III	1.77	27.44	0.0010	0.0157	III	1.38	26.01	0.0012	0.0203	II	3.69	32.55	0.0011	-0.0022
1815	61.20	46.8	40.52	3	312	I	1.77	36.48	0.0004	-0.0124	III	1.77	28.87	0.0011	0.0113	III	1.38	27.46	0.0012	0.0159	II	3.69	33.88	0.0010	-0.0078
1830	60.20	47.6	40.01	6	311	I	3.54	40.21	0.0000	-0.0328	II	3.54	33.77	0.0009	-0.0072	III	2.76	30.34	0.0012	0.0071	II	7.38	39.48	0.0002	-0.0485
1845	59.60	48.0	39.66	5	312	II	2.95	38.53	0.0002	-0.0234	III	2.95	31.78	0.0010	0.0020	III	2.30	27.75	0.0012	0.0146	II	6.15	37.49	0.0006	-0.0311
AVG	65.34	45.39	42.72	9.24	WSW		5.45	48.50				5.45	42.29				4.21	38.79				11.33	48.23		

Period of Ice Team Inspection

FIGURE 4. "SURFICE" Computer Predictions

Typical amounts of ice/frost were present in all LO2 feedline bellows and support brackets.

There were no anomalies on the LO2 ET/ORB umbilical. The purge barrier (baggie) was configured properly and was holding positive purge pressure. There were no accumulations of ice/frost on the acreage areas of the umbilical, though some isolated frost spots were present on the forward side of the purge barrier (baggie). Ice/frost fingers 4-6 inches in length had formed on the separation bolt pyrotechnic canister purge vents. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

Light ice/frost had formed in both LH2 feedline bellows, in the LH2 recirculation line bellows and on both burst disks. Isolated ice/frost formations were present on the inboard and top sides of the LH2 ET/ORB umbilical purge barrier. Ice/frost fingers 4-6 inches in length had formed on the pyro canister and plate gap purge vents. A small amount of ice/frost had formed on the aft pyrotechnic canister inboard bondline. Thin foam exists in this area due to an incorrect mold manufacture. The amount and location of the ice/frost was acceptable for launch per the NSTS-08303 criteria. (The problem exists through end item EI-66. The mold will be changed to add more foam for EI-67 and subs. An EI spec waiver will be issued for STS-45 and subs until existing end items are expended. STS-42's umbilical will be approved for use by local PMRB.) Normal venting of helium purge gas had occurred during tanking, stable replenish, and launch. There were no unusual vapors emanating from the umbilicals nor any evidence of cryogenic drips. No ice or frost was present on the cable tray vent hole. The 17-inch flapper valve actuator access port foam plug was properly closed out with no ice/frost on the bondline.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was successfully removed from the vehicle with no flight hardware contact or TPS damage.

The summary of Ice/Frost Team observations/anomalies consisted of 7 OTV recorded items:

Anomaly 001 documented ice/frost formations along the bondline at the LH2 PAL ramp aft perimeter. The ice/frost was diminishing due to direct sunlight. The frost line extended from approximately station XT1360-1464. The condition was acceptable per NSTS-08303.

Anomaly 002 recorded ice/frost formations on the cable tray/ pressurization line ramp bondlines at stations XT 1722, 1787, and 1851. These formations were acceptable per NSTS-08303.

Anomaly 003 documented a small frost formation on the +Y bipod jack pad closeout bondline. This formation was acceptable per NSTS-08303.

Anomaly 004 (documentation only) recorded ice/frost accumulations in the LO2 feedline bellows and support brackets. The ice/frost was acceptable per NSTS-08303.

Anomaly 005 (documentation only) noted ice/frost formations on the LO2 ET/ORB umbilical pyro canister purge vents and on the purge barrier baggie material. These formations were acceptable per NSTS-08303.

Anomaly 006 (documentation only) recorded ice/frost formations on the LH2 ET/ORB umbilical pyro canister purge vents, aft pyro canister closeout, purge barrier baggie material, LH2 feedline/ recirculation line bellows, and LH2 recirculation line burst disk areas. These formations were acceptable per NSTS-08303.

Anomaly 007 documented ice/frost accumulations at the +Y and -Y thrust strut-to-longeron attach points. The accumulations were acceptable per NSTS-08303.

4.5 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch. There was no debris on the MLP deck or in the SRB holddown post areas.

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, though typical accumulations of ice/frost were present on the cryogenic lines. There was also no apparent leakage anywhere on the GH2 vent line or GUCP. The modification to the GH2 vent line prevented ice from forming, but some ice/frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

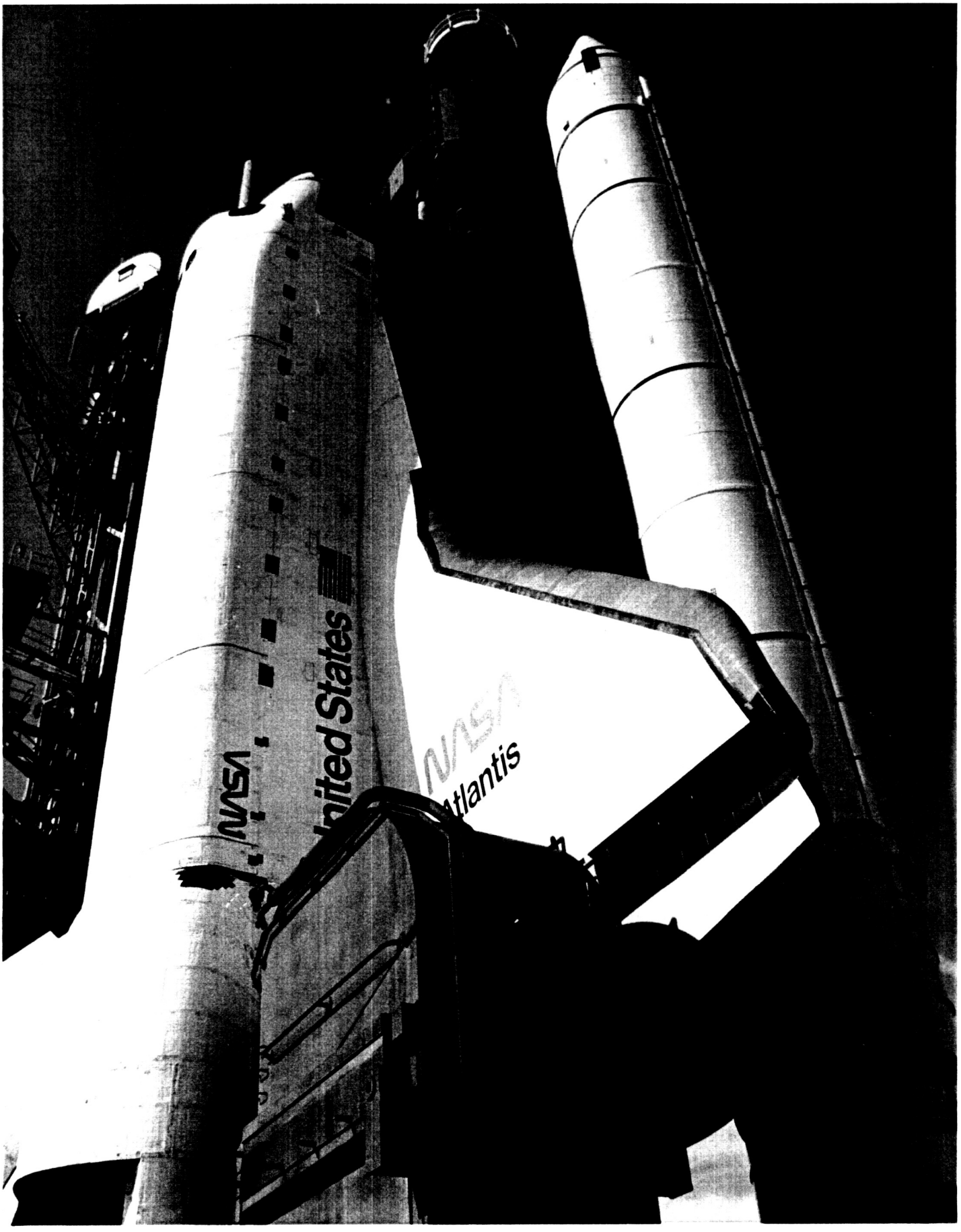
Shortly after the start of topping, LD23 and LD25 indicated high hydrogen concentrations in the GH2 vent quick disconnect (7-inch QD) purge cavity (IPR 44V-0141). These concentrations remained high for approximately 45 minutes, reaching a maximum value of about 32,000 ppm (3.2%), but then fell below 0.2% during replenish. This was not an OMRS violation since the maximum GH2 limit is 44,000 ppm. The S0007 IPR was deferred to IPR 42V-0087 by the Prime Board. Post launch evaluation of the 7-inch QD revealed two anti-rotation pins between the QD body and the purge shroud that prevent the QD body from rotating during loading nut adjustment were broken. It is not known when the two anti-rotation pins sheared, but the failure was not related to the sealing surface. The QD was leak checked at 6 and 37 psi in this configuration prior to disassembly and no leak was apparent. The QD probe sealing surface was nominal by inspection. All soft goods were installed properly and showed no signs of damage.

The dimensions between the load ring and the QD housing (purge shroud) measured 9/64" during disassembly. A properly loaded QD should measures 5/64" +/- 1/64". Metal on metal contact between the purge shroud and the QD body was preventing the QD from being loaded to the 5/64" dimension.

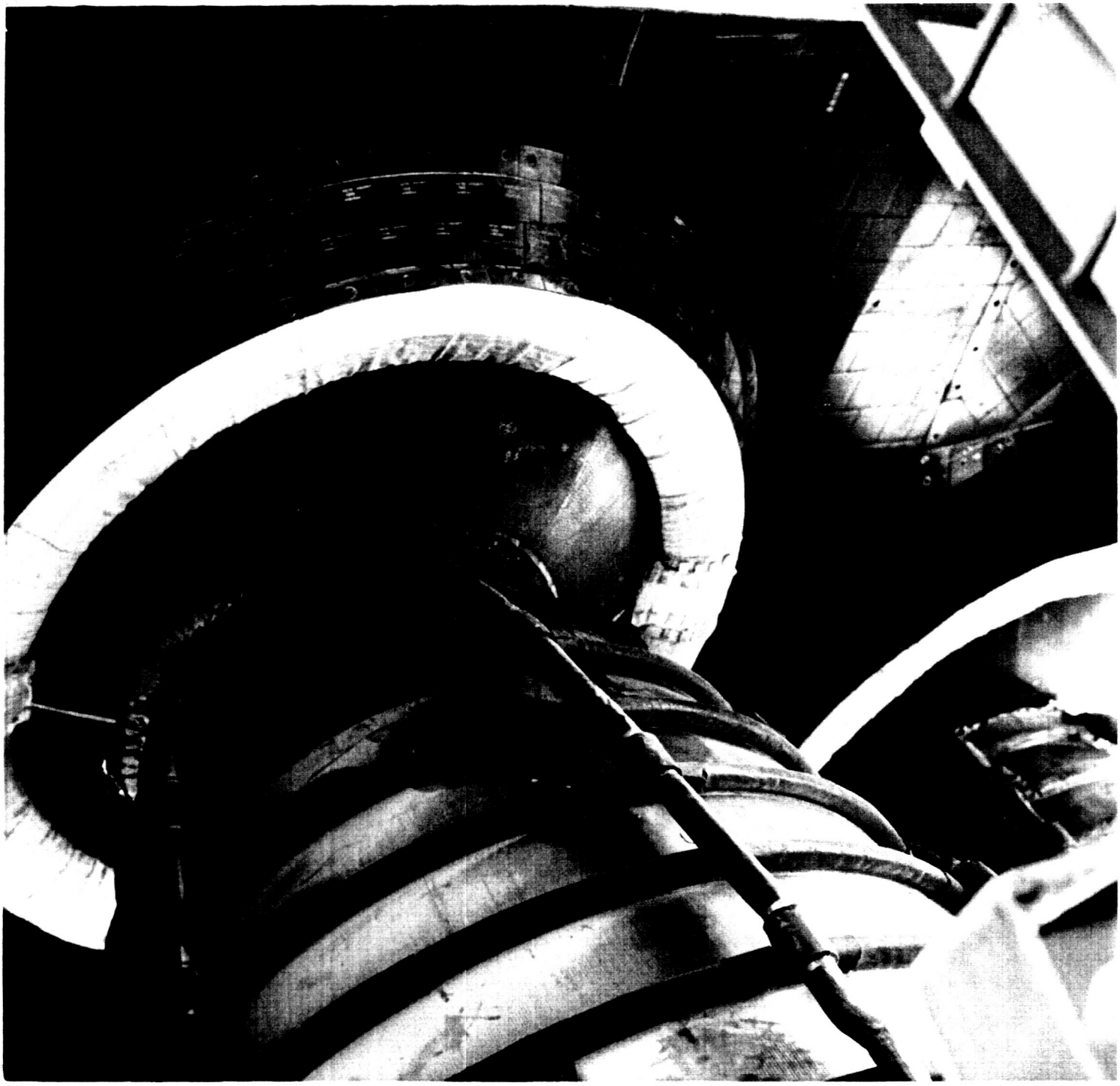
The probable cause of the hydrogen leak was the thermal contraction of the QD bellows combined with the pressure wave associated with opening the H2 vent valve, which reduced the QD loading force sufficiently to create a leak path. Insufficient loading of the QD probe could contribute to the leak rate.

Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted. Five icicles less then 3/4-inch in length had formed on the north GOX vent duct during cryoload, but had melted before launch.

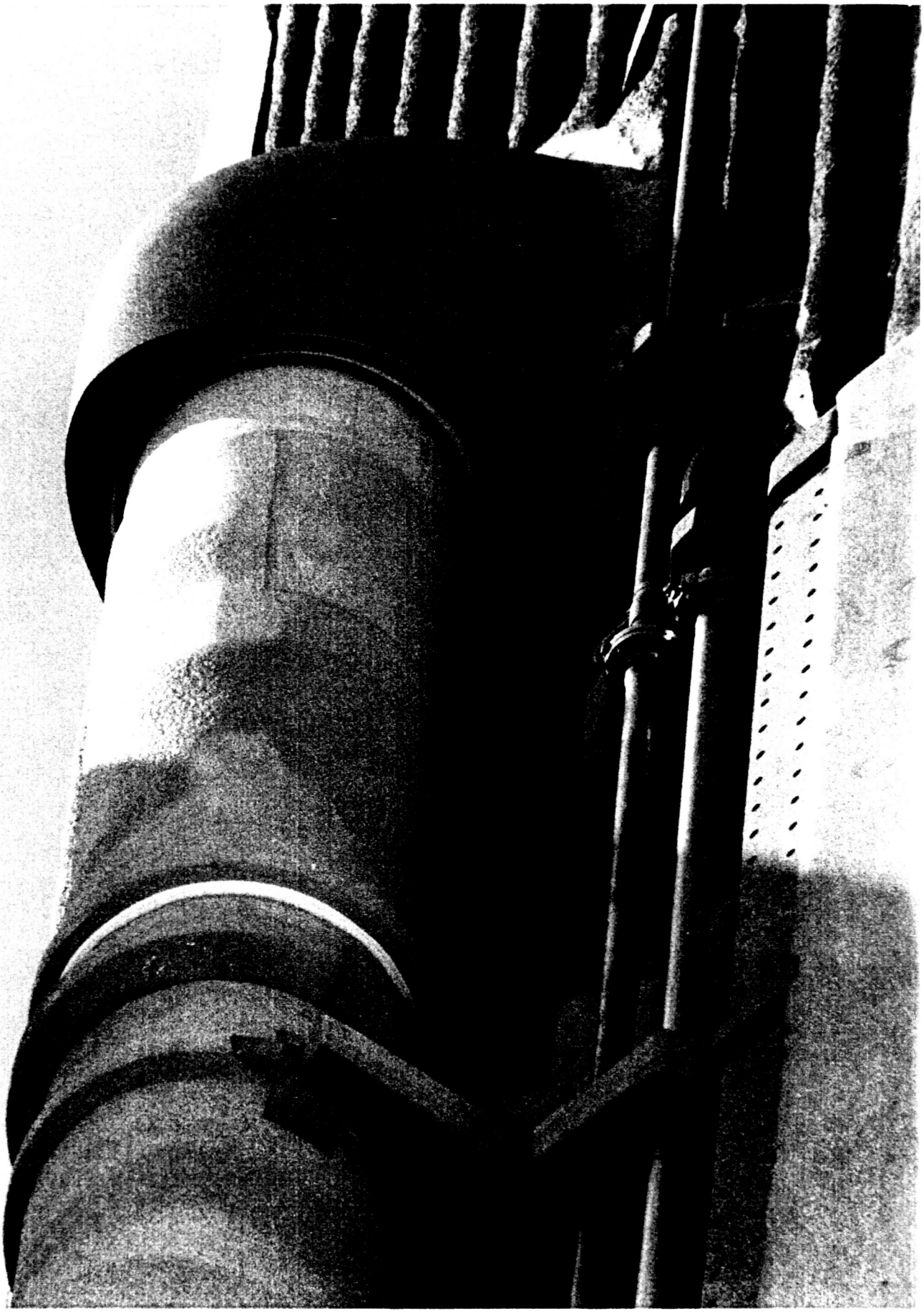
Overall view of OV-104, ET-53 (LWT 46), and BI-047 SRB's



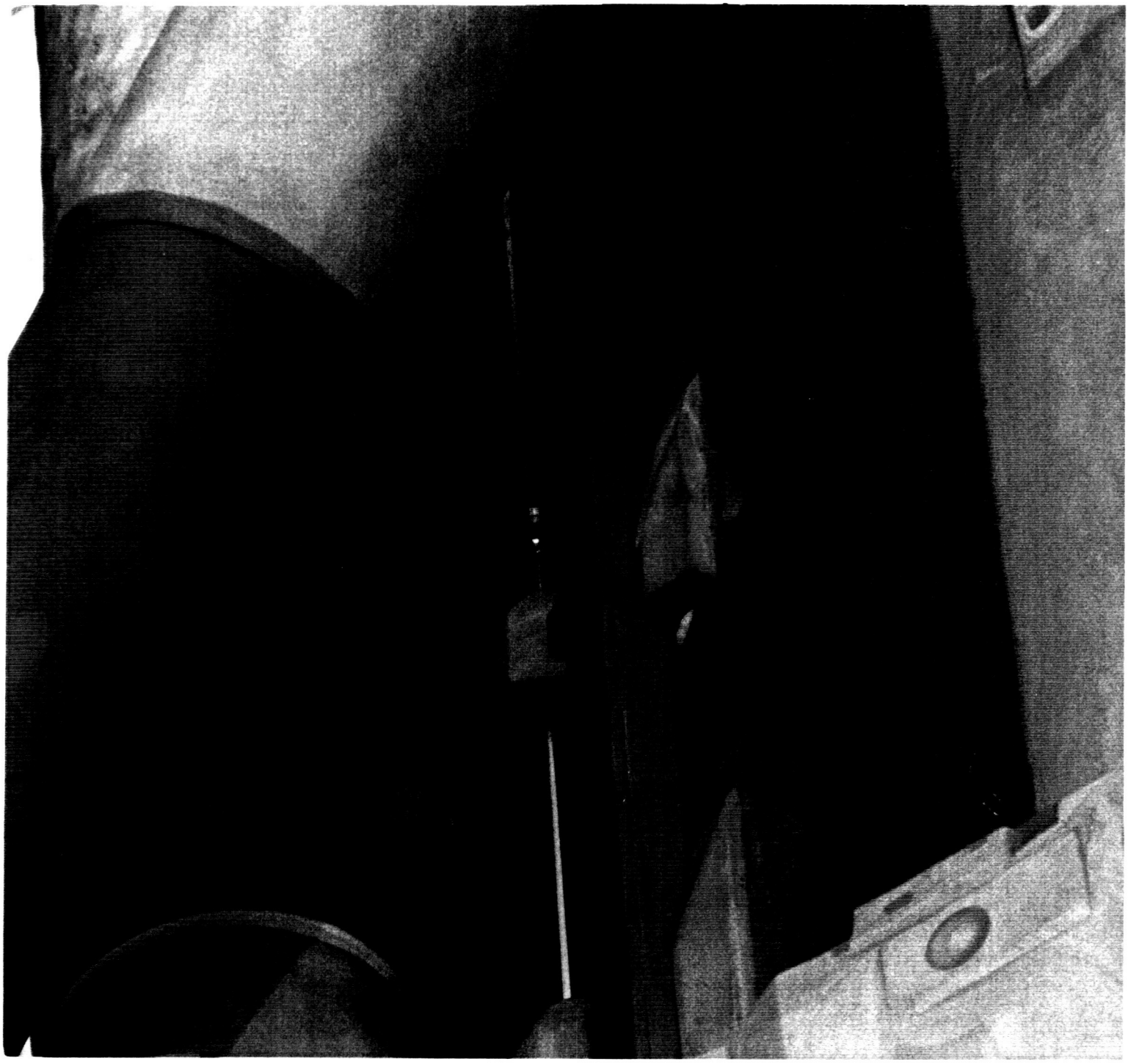
There were no TPS anomalies, ice/frost accumulations, or condensate on the External Tank acreage



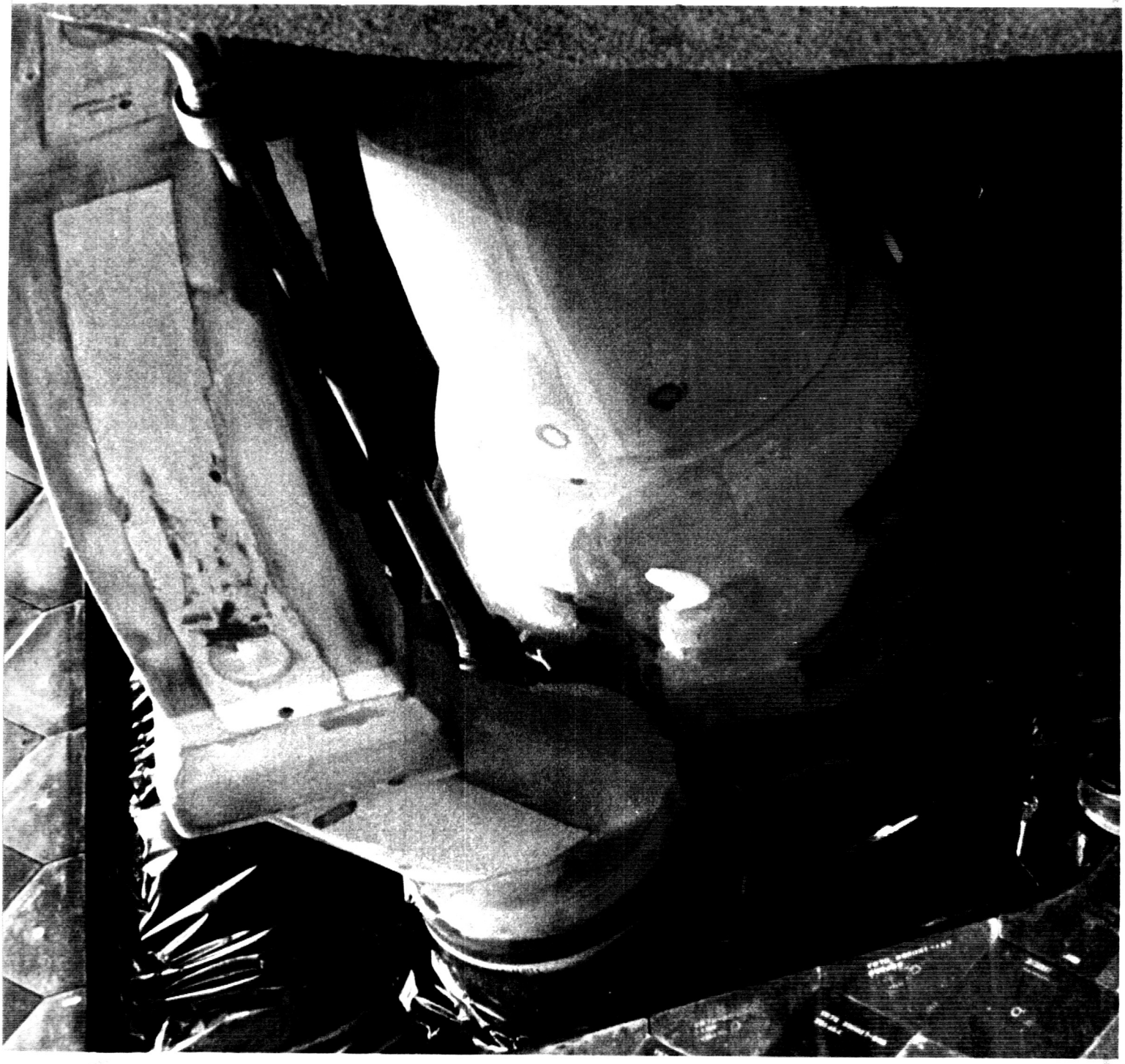
Overall view of SSME's. Some ice/frost had formed at the SSME heat shield-to-nozzle interfaces.



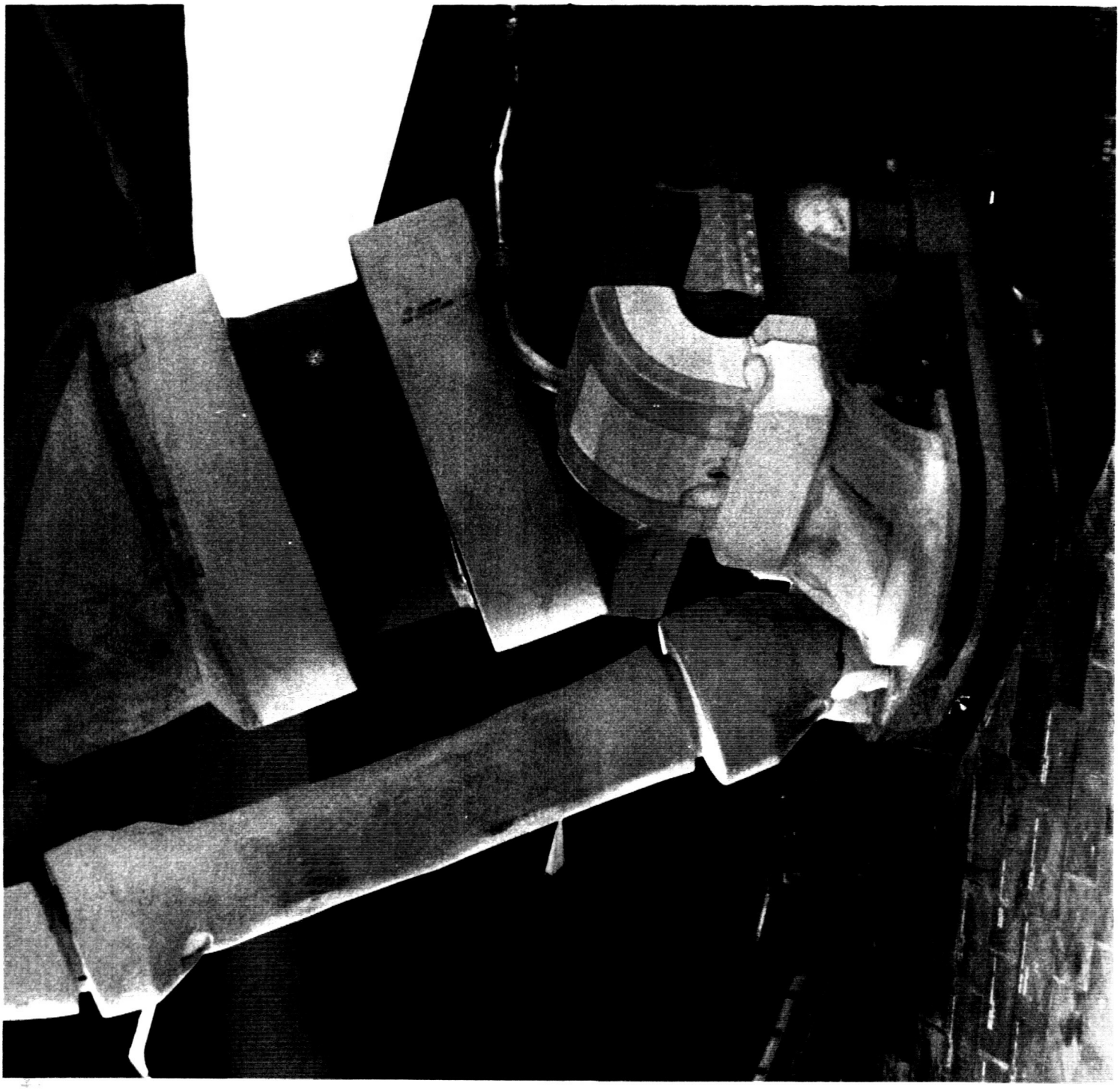
Ice/frost accumulations in the LO2 feedline upper bellows and support brackets were typical



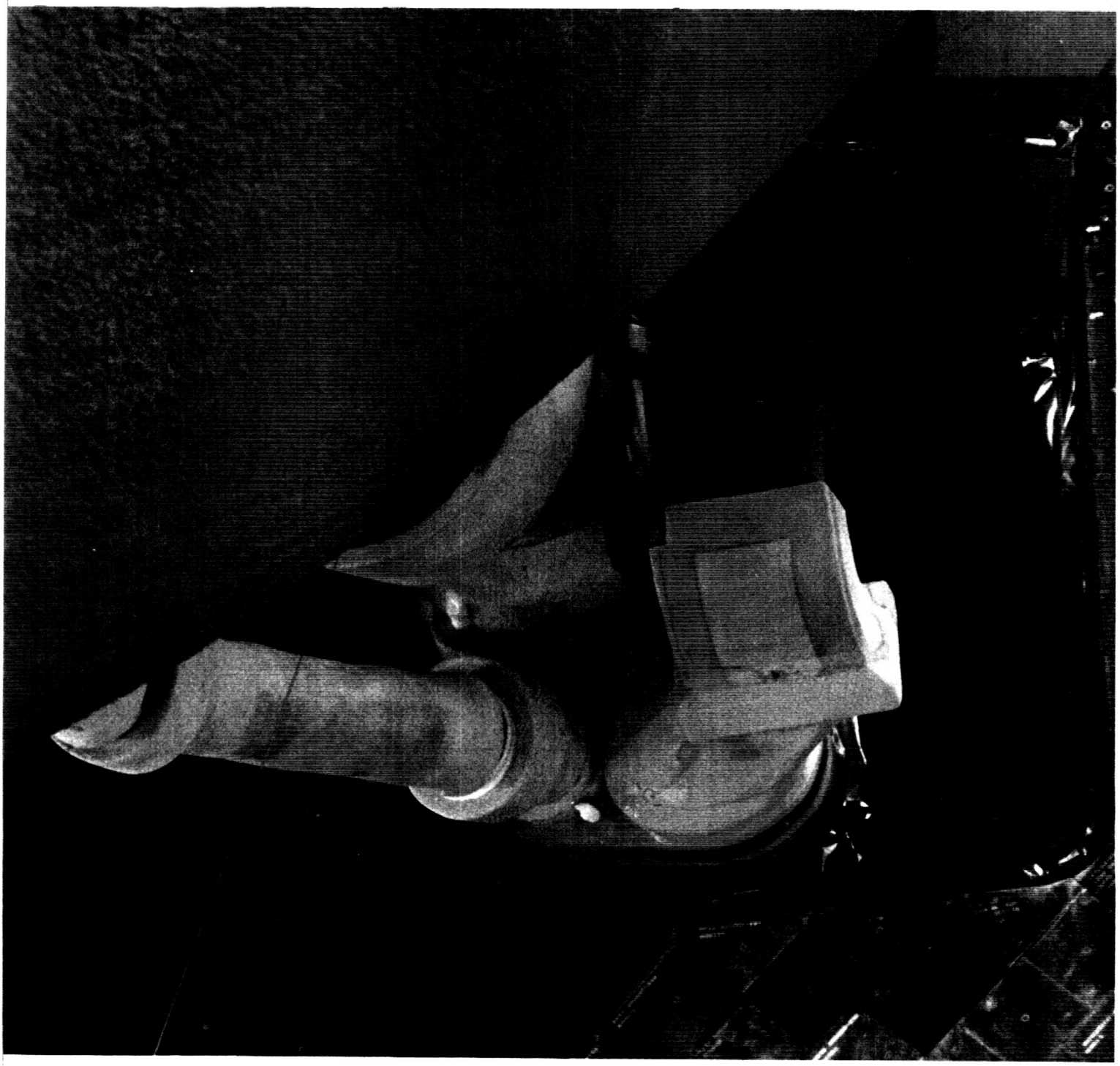
Ice/frost formations in the LO2 feedline lower bellows and support brackets were typical. Ice/frost also formed on the cable tray/pressurization line ramp bondlines, a condition that was acceptable per NSTS-08303.



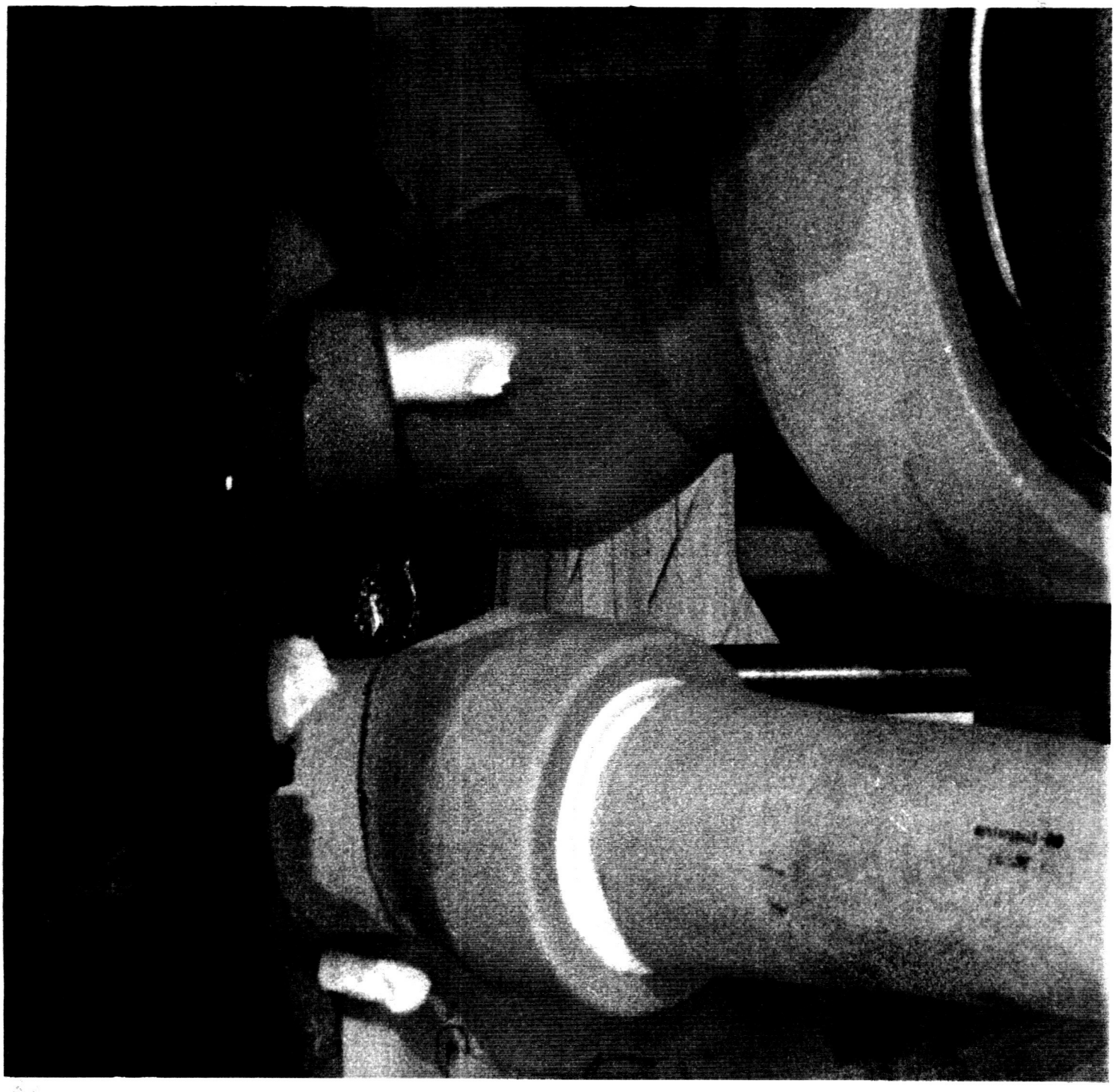
Overall view of the LO2 ET/ORB umbilical. Ice/frost fingers on the pyro canister purge vents were typical. There were no acreage TPS anomalies or ice/frost accumulations.



Overall view of the LH2 ET/ORB umbilical. There were no unusual vapors emanating from the umbilical nor any evidence of cryogenic drips. Ice/frost accumulations in the recirculation line bellows, on the burst disks, on the umbilical purge vents, and on the top side of the umbilical were typical. Although typically present for most cryogenic loadings, no ice/frost had formed on the outboard and aft sides of the umbilical/purge barrier (baggie).



Less than usual ice/frost had accumulated on the inboard and aft sides of the LH2 ET/ORB umbilical. Ice/frost formations on the lower plate gap purge vent and in the LH2 recirculation line bellows were typical. The cable tray vent hole and 17-inch flapper valve actuator tool access port closeout exhibited no ice or frost accumulations.



A small amount of ice/frost had formed around the LH2 umbilical aft pyrotechnic canister closeout. Thin foam exists in this area due to an incorrect mold manufacture. The amount and location of the ice/frost was acceptable for launch per NSTS-08303. The mold will be changed to add more foam to this area.

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP and the FSS was conducted on 24 November 1991 from Launch + 1-1/2 to 3 hours. No flight hardware or TPS materials were found.

Plume erosion of the south SRB holddown posts was typical. All south HDP EPON shim material was intact, but slightly debonded at the sidewalls on HDP #1 and #5. There was no visual indication of a stud hang-up on any of the south holddown posts. North holddown post doghouse blast covers were in the closed position and exhibited typical erosion. The SRB aft skirt purge lines were in place but slightly damaged. The SRB T-0 umbilicals and connector saver sacrificial pieces showed normal plume impingement effects.

The GOX vent arm, OAA, and TSM's showed the usual minor amount of damage. The GH2 vent arm was latched on the eighth tooth of the latching mechanism and had no loose cables (static retract lanyard). The GH2 vent line appeared to have retracted normally, though the north latch contacted and rode against the saddle stabilizer. The damage from this contact was minimal and has occurred on previous launches. The GH2 vent line showed typical signs of SRB plume impingement. The External Tank intertank access structure also sustained typical plume heating effects.

Damage to the facility appeared to be less than usual and included:

1. A metal "175 FT Level" sign was detached from the north side of the FSS and found on the east side of the 175 foot level.
2. Two cable tray cover fasteners were detached and found on the west side of the 195 and 215 foot levels.

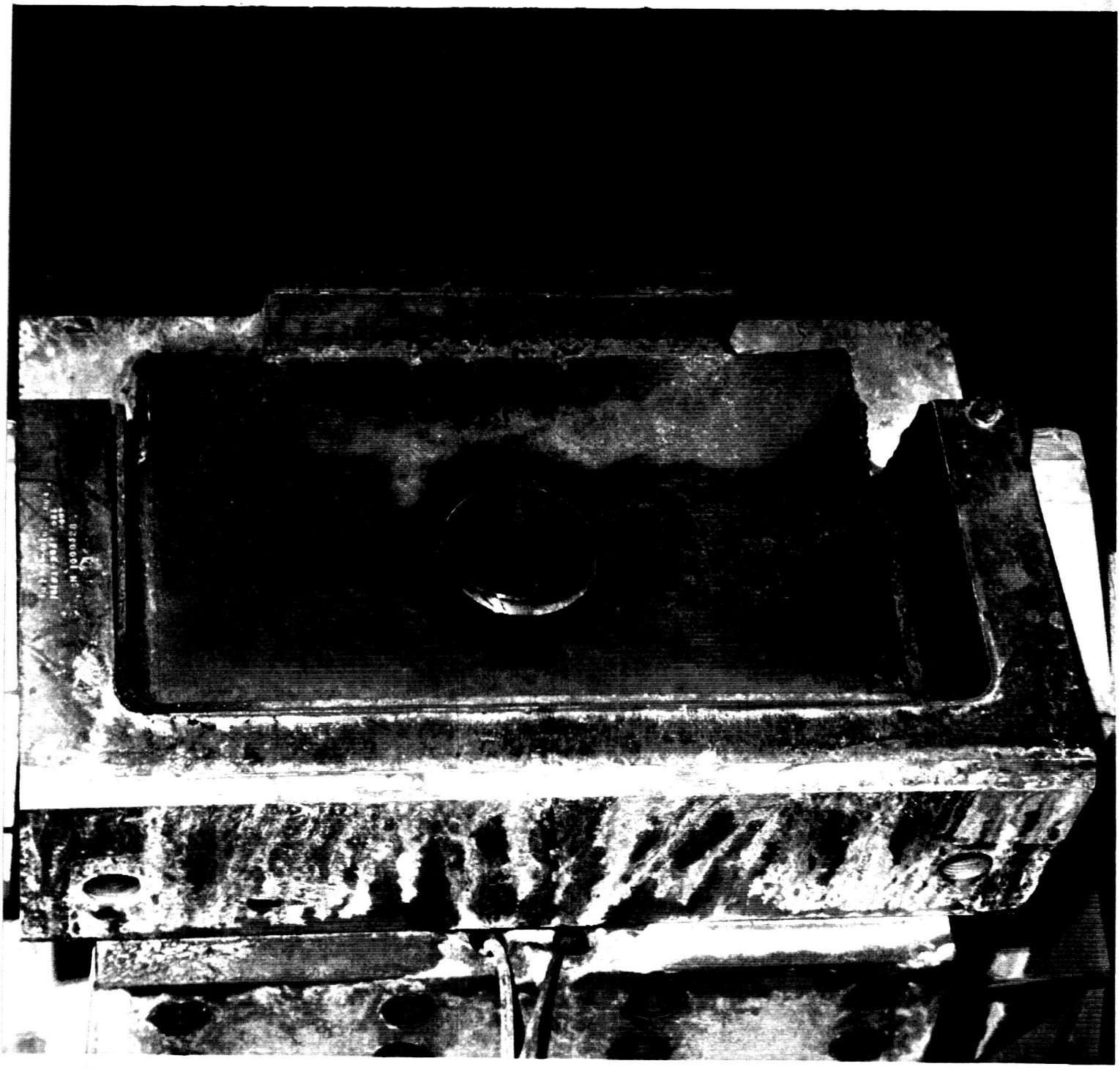
All seven emergency egress slidewire baskets were secured on the FSS 195 foot level and sustained no launch damage.

MLP-1 was configured with overpressure sensors at the top of both TSM's, at the bottom of both SRB exhaust holes, and at the bottom of the SSME exhaust hole. With the exception of the sensor in the LH SRB exhaust hole, which failed during liftoff, the readings were consistent with previous launches and were within nominal limits.

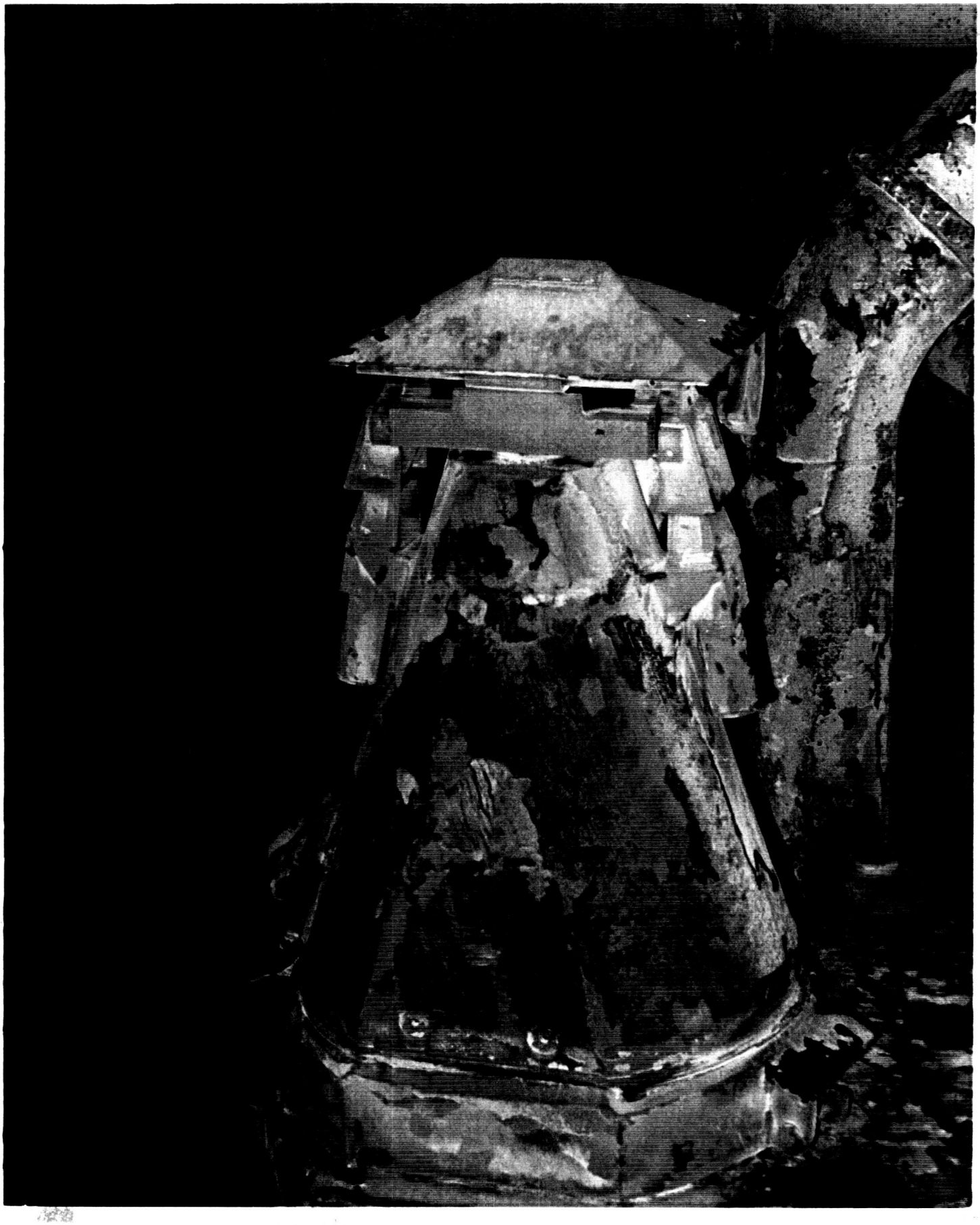
Inspection of the pad acreage was completed on 25 November 1991 along with the areas outside the pad perimeter, railroad tracks, the beach from UCS-10 to the Titan complex, the beach access road, and the ocean areas under the vehicle flight path. No flight hardware or TPS materials were found.

Patrick AFB and MILA radars were configured in a mode for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent but after SRB separation (due to the masking effect of the SRB exhaust plume). Most of the signal registrations were very weak and often barely detectable, which generally compares with the types of particles detected on previous Shuttle flights. A total of 61 particles were imaged in the T+140 to 336 second time period. 31 of the particles were imaged by only one radar, 25 particles were imaged by two radars, and 5 particles were imaged by all three radars.

Post launch pad inspection anomalies are listed in Section 10.



Plume erosion of the south SRB holddown posts was typical. All EPON shim material was intact, but slightly debonded from the holddown post shoe sidewalls on HDP #1 and #5. There was no visual indication of a stud hang-up on any of the south holddown posts.



North HDP blast covers were in the closed position and exhibited typical SRB plume erosion effects

Typical post launch debris included SRB throat plug material and facility nuts, bolts, line caps, and covers

6.0 FILM REVIEW AND PROBLEM REPORTS

A total of 132 film and video data items, which included forty-nine videos, fifty 16mm films, twenty-seven 35mm films, and six 70mm films were reviewed starting on launch day.

No IFA's were generated as a result of the film and video data review. Post Launch Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. These anomalies are listed in Section 10.

6.1 LAUNCH FILM AND VIDEO SUMMARY

No major vehicle damage or lost flight hardware was observed that would have affected the mission.

Helium purge vapors and ice build-up on the LH2 ET/ORB umbilical had been typical during tanking, stable replenish, flight pressurization, and launch. There were no unusual vapors or cryogenic drips (OTV 009, 054, 063).

SSME ignition and Mach diamond formation appeared normal. Free burning hydrogen drifted upward to the OMS pods and under the body flap. An orange streak occurred along the -Y side of the SSME #2 plume starting at SSME ignition. The streak disappeared as the vehicle lifted off. (RSS STI, C/S-2 STI, OTV 051, 063, 070, 071, E-2, 3, 19, 20).

Film item E-16 was reviewed with NASA KSC MPS and Rocketdyne engineers to investigate orange vapors and a reported burning of insulation on SSME #2 between the #9 hatband and the coolant manifold at the -Z axis. The engineering consensus concluded a very small hydrogen leak occurred at the aft manifold or behind the steer horn resulting in a stream of vapor to the #9 hatband and around the -Z drain line. Determination of the small leak was based upon similar events/data observed during SSME testing at the Stennis Space Center. The engineering consensus further concluded that no material, such as insulation, was burning.

SSME ignition caused numerous pieces of ice/frost to fall from the ET/Orbiter umbilicals. No damage to Orbiter tiles or ET TPS was visible (OTV 009, 054, 056, 063, 064, E-4). Pieces of ice continued to fall from the umbilical area after liftoff. Two pieces of ice from the LO2 feedline upper bellows fell aft, but no contact with Orbiter tiles was apparent (OTV 061, E-25, 40). Several small pieces of ice, most likely from the EB-3 and EB-5 fittings, fell past the LH inboard elevon as viewed from camera E-18.

SSME ignition vibration/acoustics caused the loss of small pieces of tile surface coating material from six locations on the base heat shield, one location on the aft face of the RH RCS stinger, and three locations on the LH RCS stinger (E-19, 20, 23, 24).

One RCS paper cover from the RH aft RCS stinger fell aft and lodged between the SSME #3 nozzle and +Z drain line (E-23).

Light frost was present in the southwest (-Y) louver. There was no TPS damage to the ET nose cone acreage, footprint, or fairing (OTV 061, 062).

There were no major facility anomalies. No swing arms or other pad structures contacted the vehicle during liftoff. The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 049, 063). GUCP disconnect from the External Tank was nominal (OTV 004). Some pieces of ice from the GUCP impacted the LH SRB factory joint, but no damage was visible. The GH2 vent line appeared to latch normally with no rebound (OTV 060). There was no excessive slack in the static retract lanyard (E-31, 33, 41, 42, 50).

Film item E-60 confirmed that water flowed properly from all MLP rainbirds.

There was no evidence of stud hang-ups on any of the holddown posts. No debris fell from the DCS/stud holes. Two dark particles appeared from behind the HDP #7 shoe and may have been pieces of shim putty or shim material (E-11). Closure of north holddown post doghouse blast covers was nominal.

Numerous pieces of SRB throat plug material, some with vapor trails, were ejected out of the SRB flame trench north of the vehicle. More SRB throat plug material was ejected upward out of the SRB exhaust holes. This is a common occurrence and none of the material was a threat to the vehicle (E-213, OTV 033).

A facility line bracket, approximately 4 inches in length, passed close to the camera lens after the vehicle had cleared the tower (E-40, frame 5054).

Clusters of particles falling aft of the Orbiter after completion of the roll maneuver were traced to the forward RCS thrusters and were pieces of RCS paper covers. Other pieces of RCS paper covers were visible passing over the Orbiter wings. Pieces of ET/ORB purge barrier baggie material were also visible falling aft of the vehicle (E-207, 222, 223).

Numerous white, blurred objects fell from top to bottom in the field of view outboard of the SRB's (E-54, 213, 222). The apparent sizes and trajectories of the objects did not indicate any relation to the vehicle and were probably blurred images of birds.

Orange streaks occurred in the SSME plume during ascent (E-207, 208, 212, 213, 223).

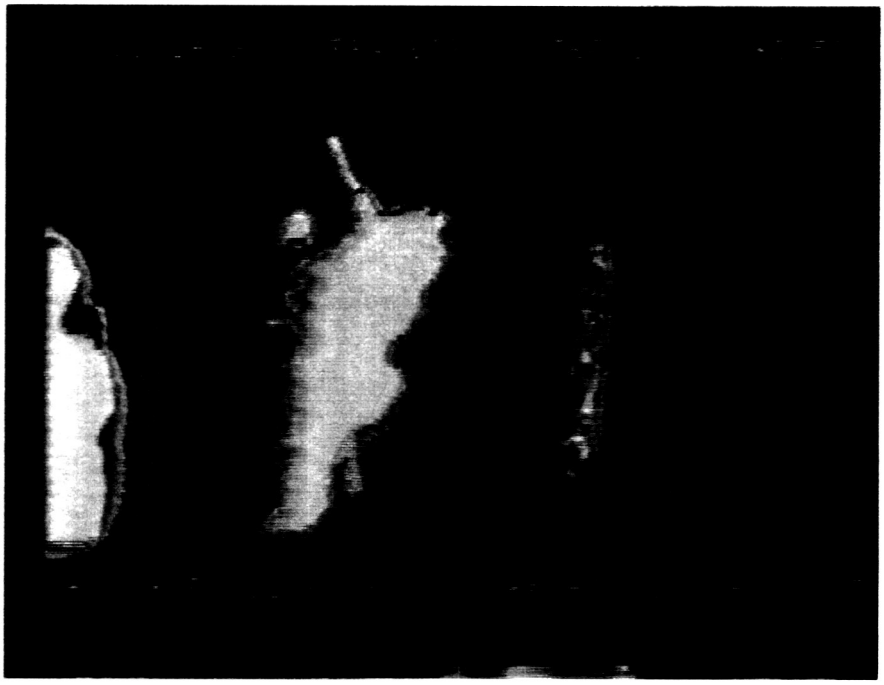
Just after the roll maneuver and during ascent, over 100 light colored particles dropped out of the SRB plume. These particles are believed to be pieces of SRB aft skirt instafoam or SRB propellant (E-207, 208, 212, 218, 222, 223). Four light-colored particles, most likely small pieces of SRB propellant, fell out of the SRB plumes in the 70-77 second time frame (ET-213).

SSME closeout blankets appeared intact while in view (E-207). Thermal curtain tape was loose on the LH SRB aft skirt (E-212).

Movement of the body flap appeared similar in amplitude and frequency to that observed on previous flights (E-207, 212).

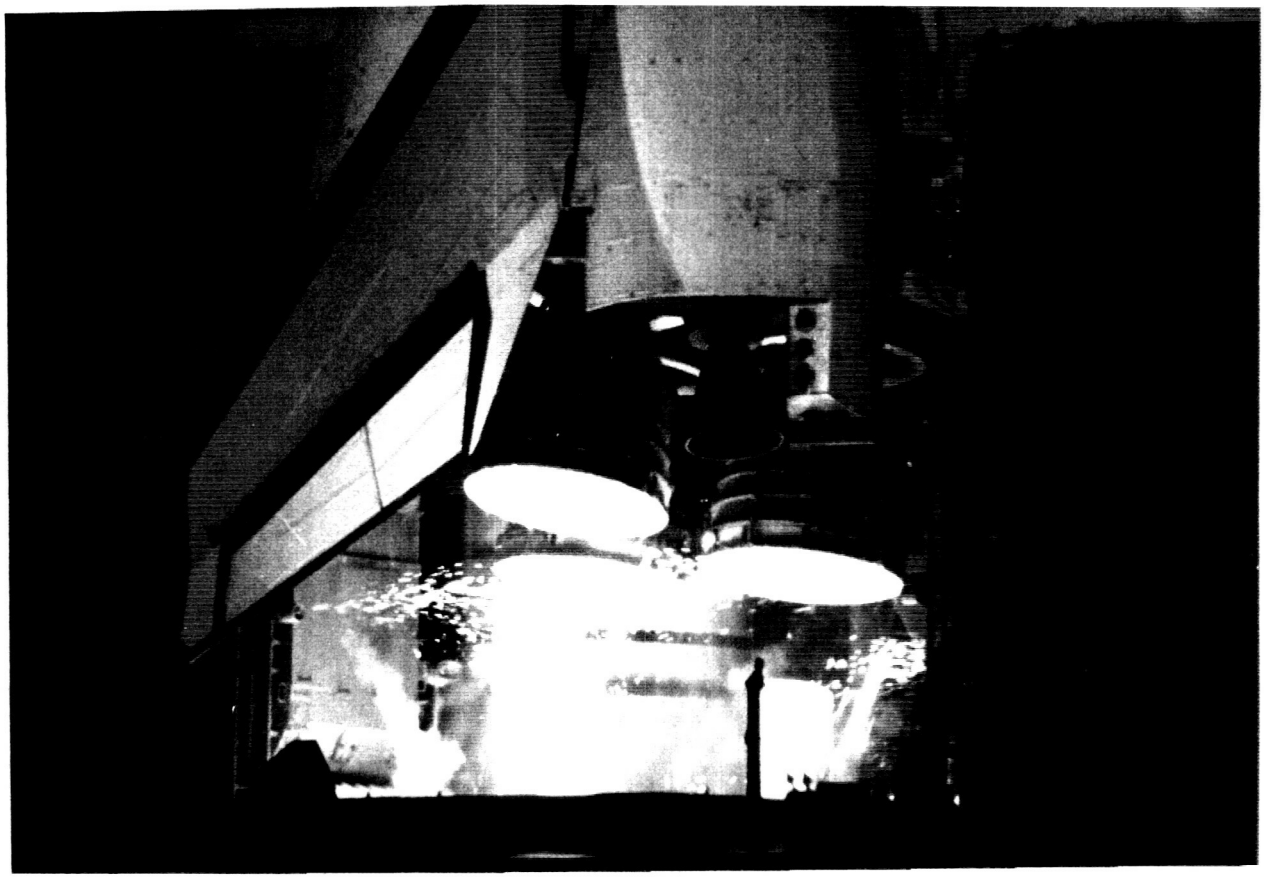
An optical linear distortion appeared eight times in film item E-212. This phenomenon has been observed on previous flights.

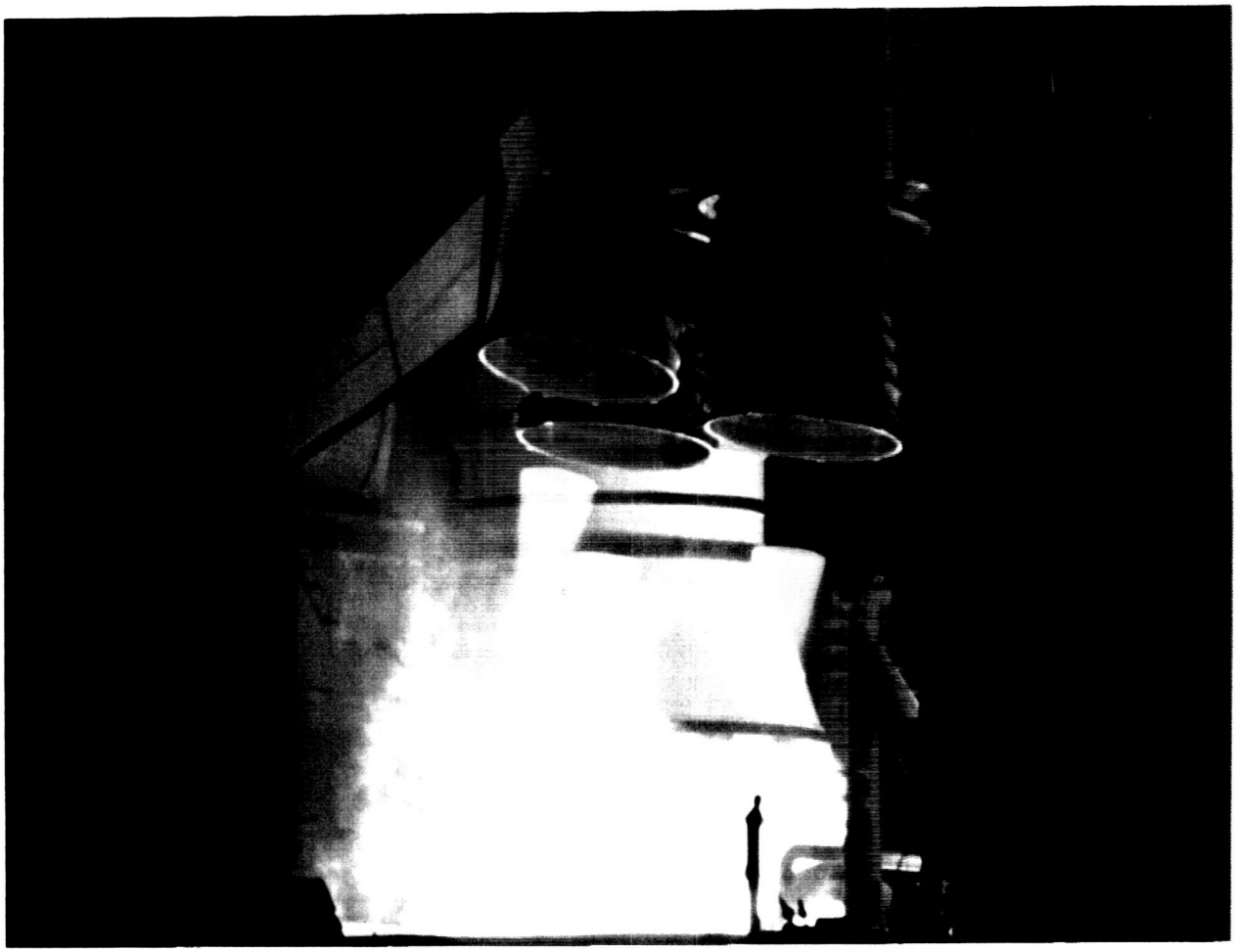
Localized flow condensation appeared on the vehicle during ascent. ET aft dome charring, plume recirculation, and SRB separation appeared normal. No unusual plume brightening was observed. Numerous, large pieces of slag fell out of the SRB exhaust plumes before and after separation, a typical occurrence. (ET-204, 206, 208, 212, E-204, 205, 206, 207, 208, 212, 213, TV-4A, TV-13, TV-21). Large pieces of slag were visible falling out of the SRB exhaust plumes before and after separation.



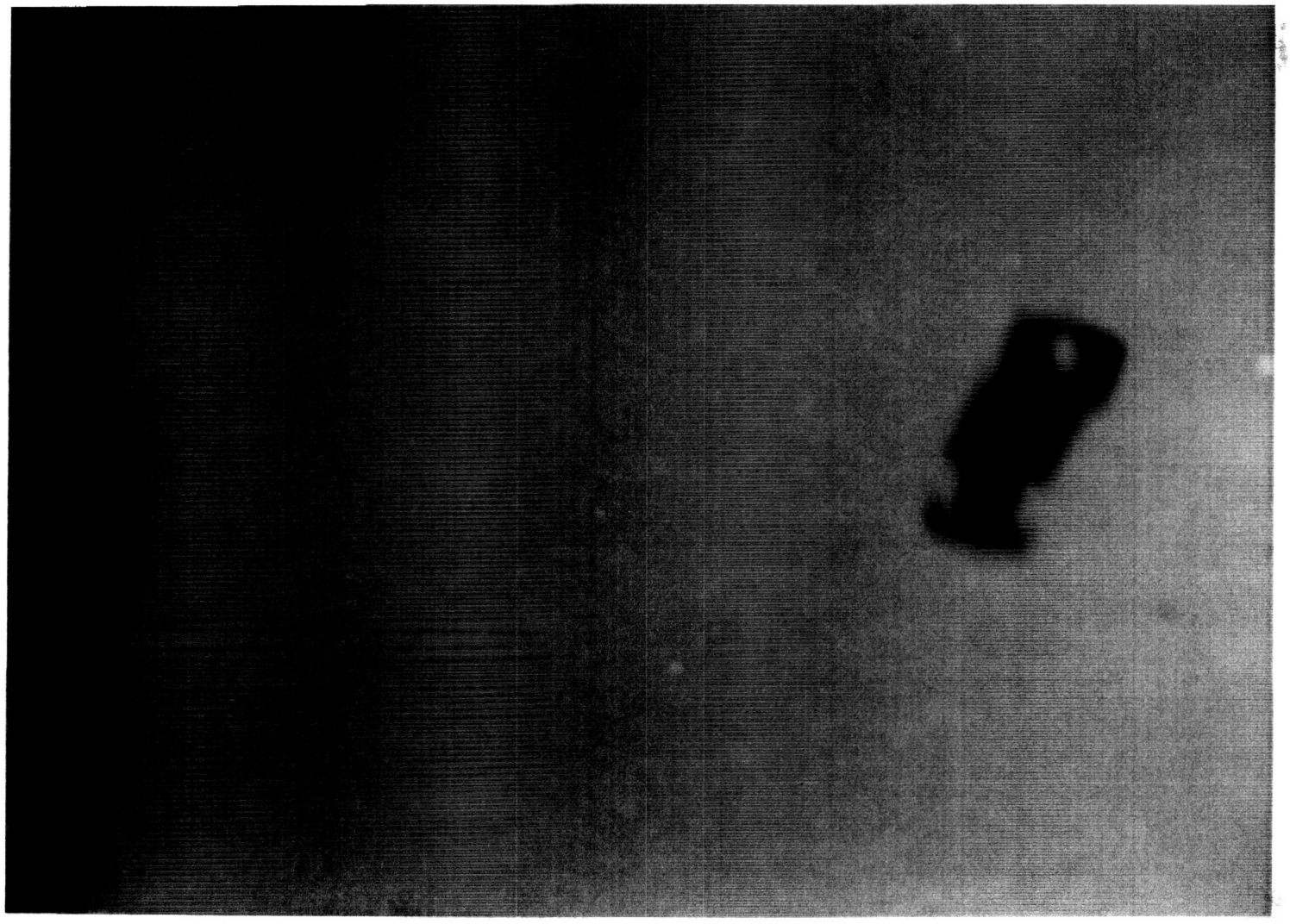
Shuttle Thermal Imager (STI) at camera site #2 showed free burning hydrogen from SSME ignition passing underneath Orbiter body flap and rising to body flap hinge area. Bright spot in left field of view is SSME #1 plume. Bright spots in right field of view are infrared reflections on SRB aft booster case.

Orange vapor visible against SSME #2 nozzle indicated the presence of a very small hydrogen leak between the #9 hatband and the steer horn or the coolant manifold at the -Z axis. Determination of the small leak was based on similar events and data observed during previous SSME tests.





View from Camera E-76 shows orange streaks along edges of SSME plumes during ignition. The streaks had disappeared by liftoff.



A facility line bracket, approximately four inches in length, passed close to the Camera E-40 lens well after the vehicle had cleared the tower.

6.2 ON-ORBIT FILM AND VIDEO SUMMARY

OV-104 was not equipped to carry ET/ORB umbilical cameras. Insufficient light due to the late time of launch prevented the crew from photographing the External Tank after separation from the Orbiter (DTO-0312).

6.3 LANDING FILM AND VIDEO SUMMARY

Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were nominal. The Orbiter was allowed to roll the length of the runway without braking per a DTO, though light braking was applied near the end of the runway.

7.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 27 November 1991 from 0800 to 1130 hours. From a debris standpoint, both SRB's were in excellent condition.

7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum had one area of missing TPS and 8 MSA-2 debonds over fasteners. The missing TPS was located between the -Y and -Z axis near the 275 ring frame. The remaining material in the divot was not sooted and the TPS was most likely lost after re-entry. There was minor localized blistering of the Hypalon paint (Figure 5). All BSM covers were locked in the fully opened position.

The RH forward skirt exhibited no debonds or missing TPS. The phenolic plates on both RSS antennae were intact. The forward separation bolt and electrical cables appeared to have separated cleanly. No pins were missing from the frustum severance ring. Minor blistering of the Hypalon paint occurred forward of the ET/SRB attach point (Figure 6).

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and all three aft booster stiffener rings appeared undamaged. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing prior to water impact.

The phenolic material on the kick ring was delaminated between the -Z and +Z axes. Thirteen K5NA protective domes between HDP #1 and #3 were lost from bolt heads on the aft side of the phenolic kick ring after water impact (clean substrate). The aft skirt acreage TPS was generally in good condition. K5NA was missing from all aft BSM nozzles (Figure 7). The TVC "rock" actuator strut/nozzle attach clevis was broken at water impact and was not a debris issue.

All four HDP Debris Containment System (DCS) plungers were seated. This was the fourth flight utilizing the optimized link. There was no sign of broaching in any of the stud holes. None of the EPON shim material was lost during flight.

FIGURE 5. RIGHT SRB FRUSTUM

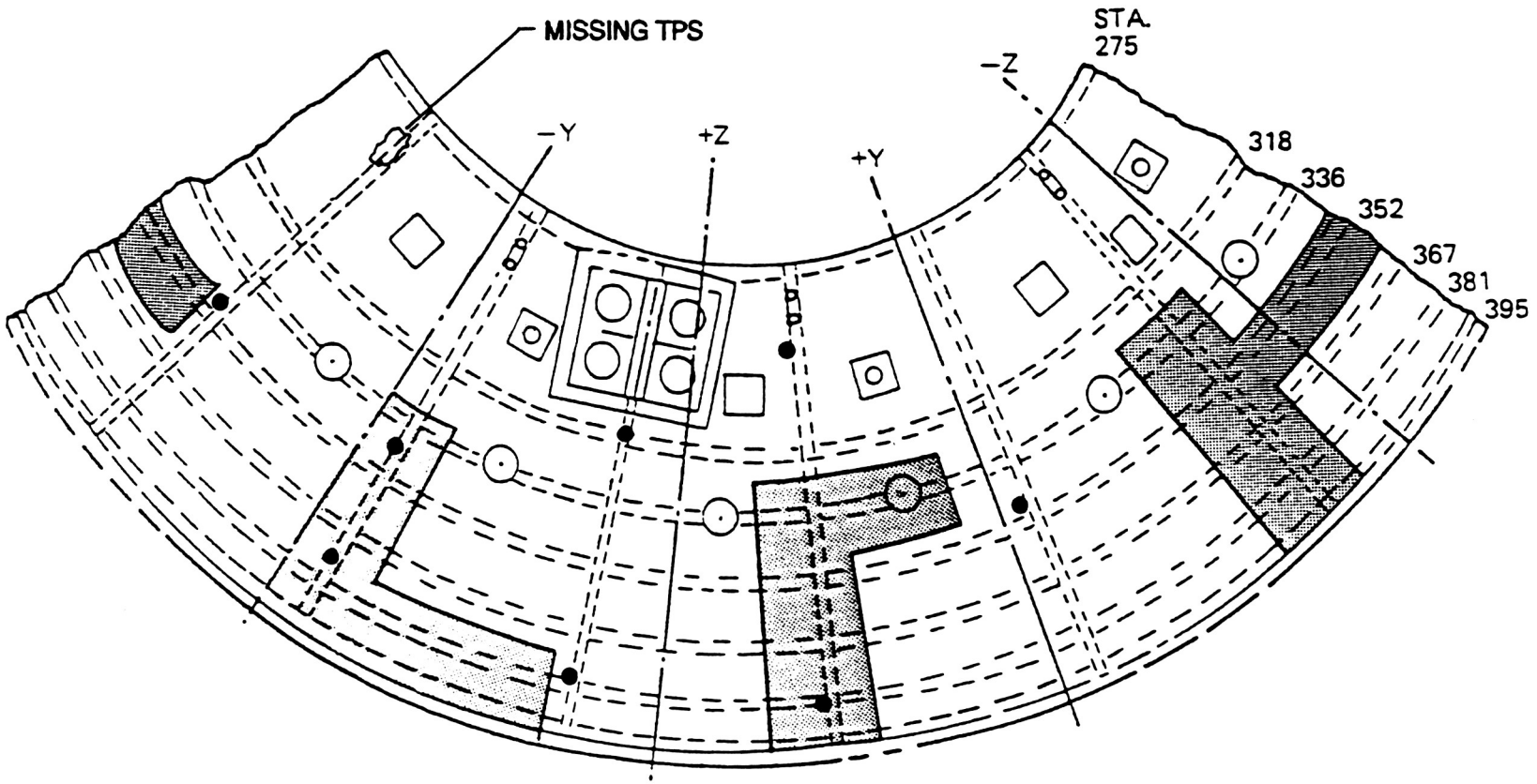
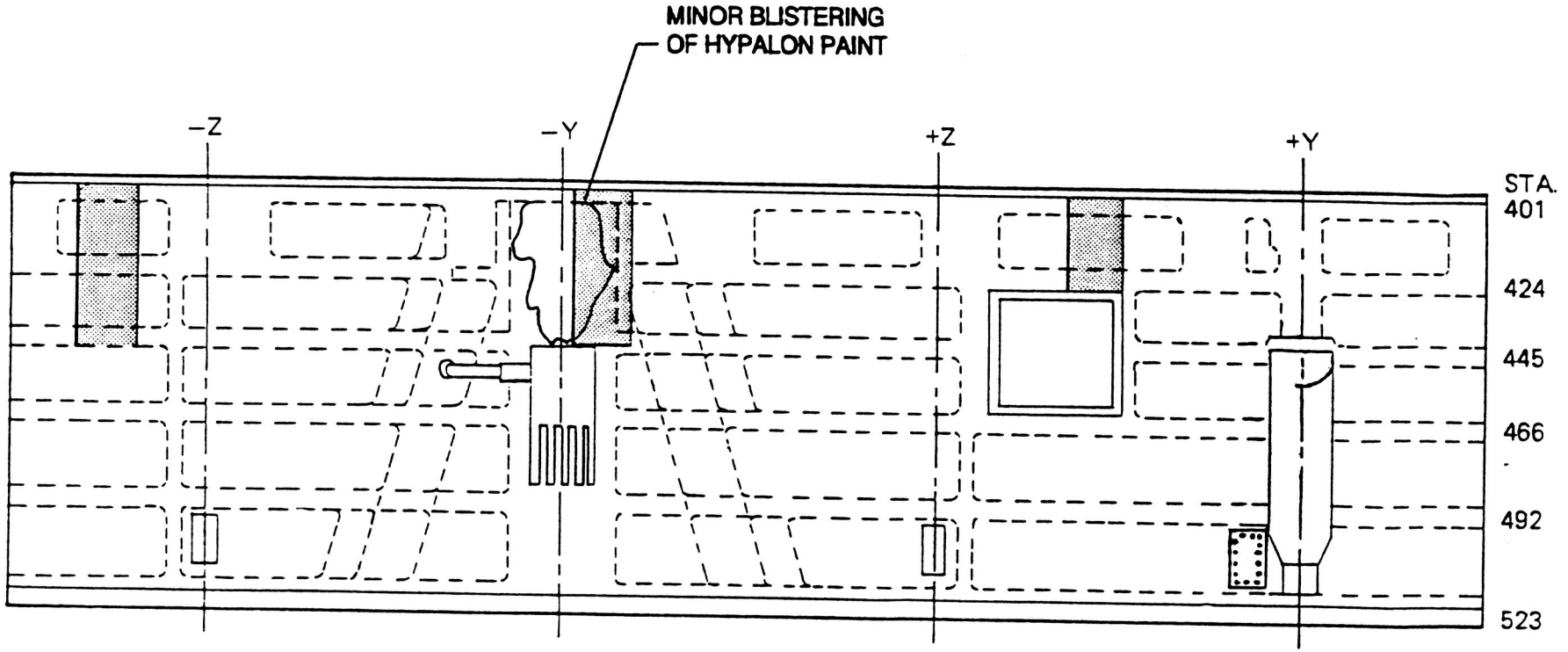


FIGURE 6. RIGHT SRB FWD SKIRT



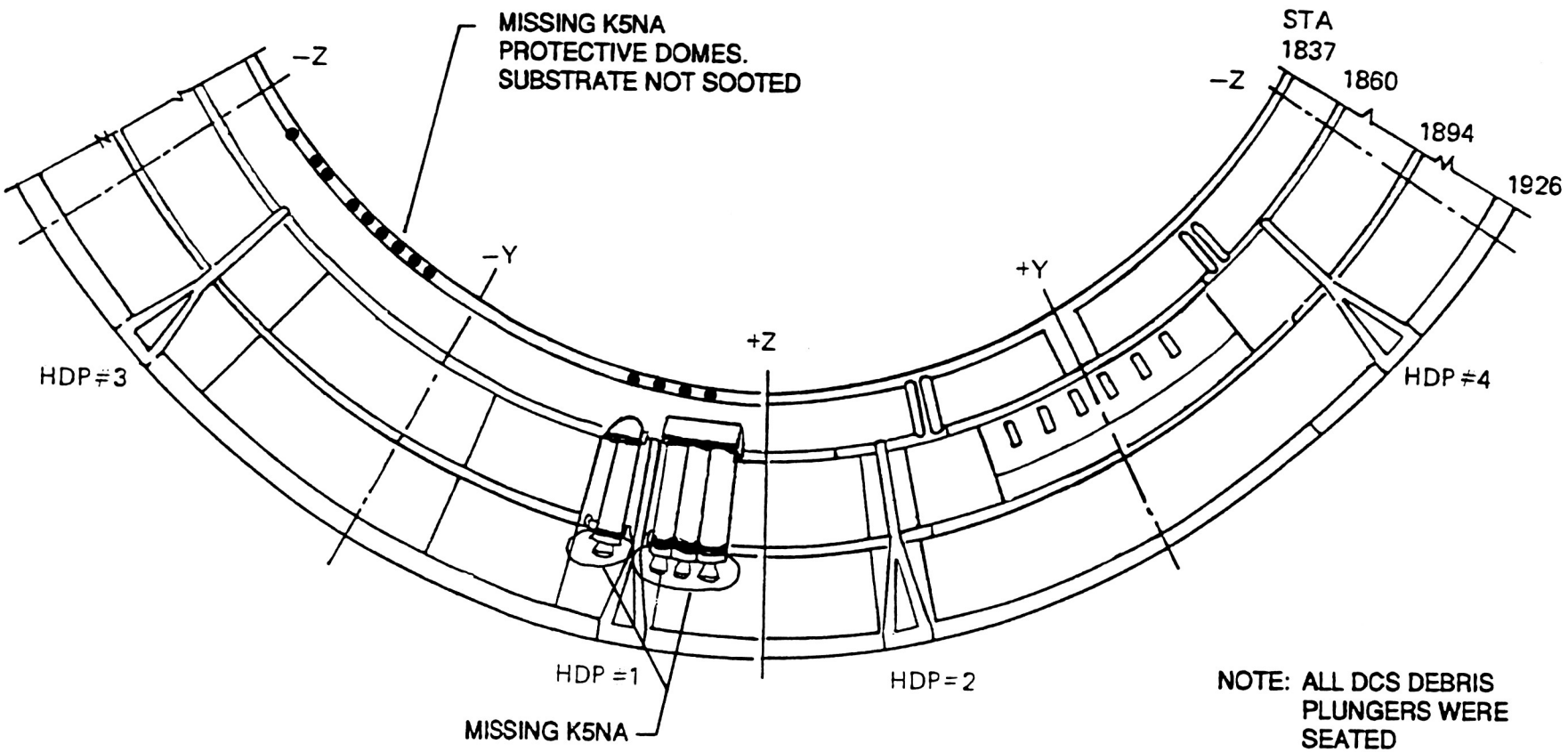
TPS MISSING

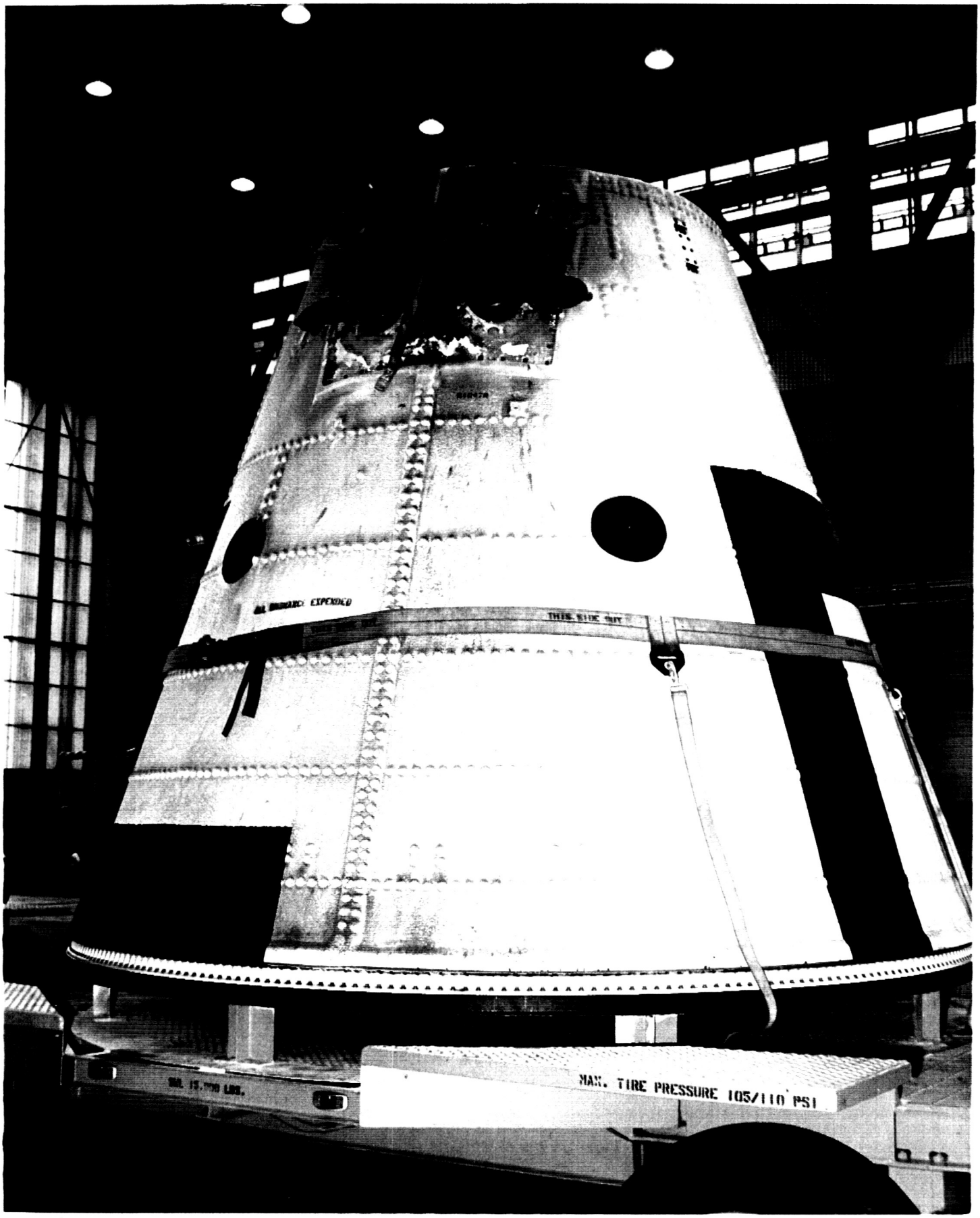
NONE

DEBONDS

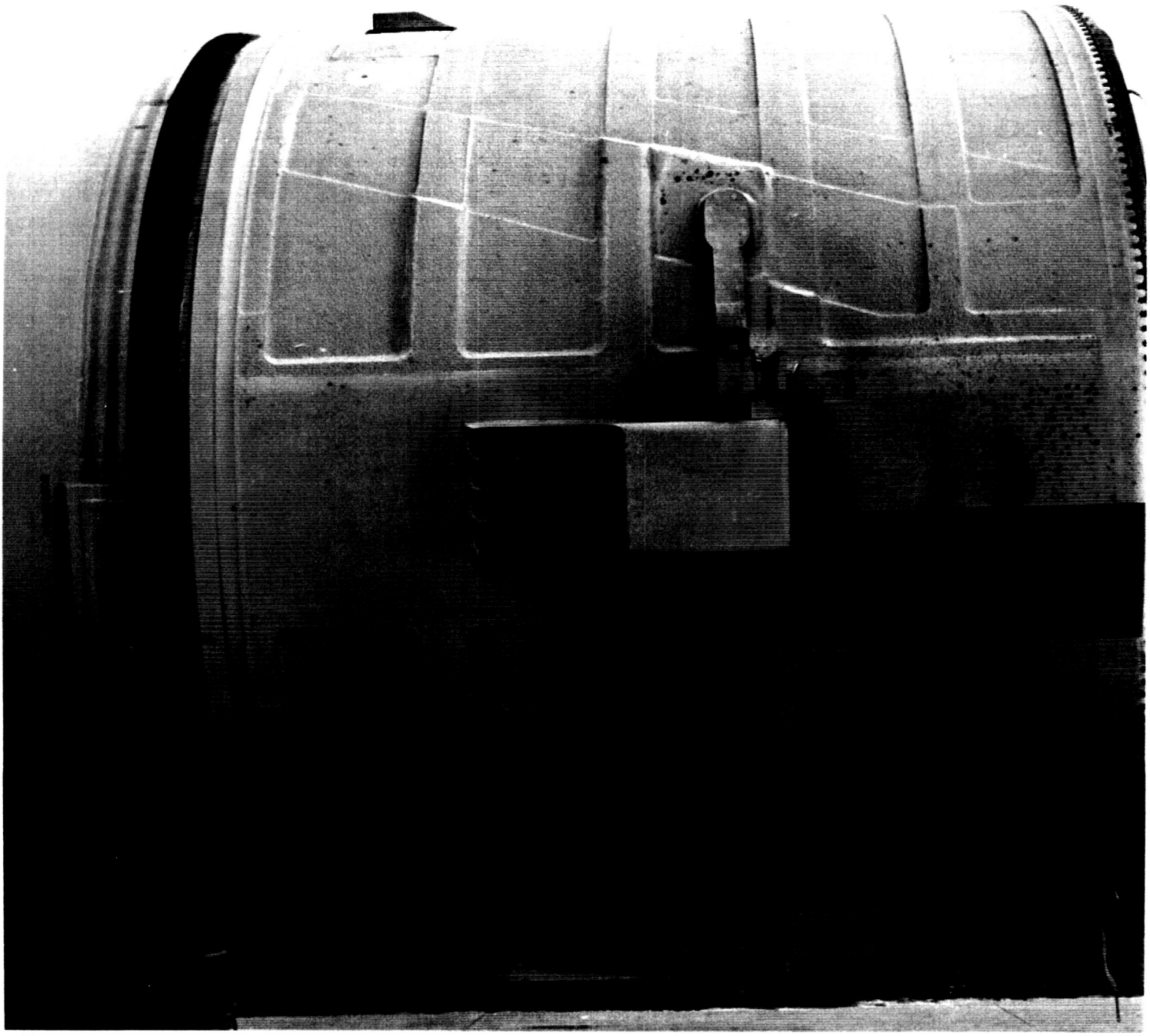
NONE

FIGURE 7. RIGHT SRB AFT SKIRT EXTERIOR TPS

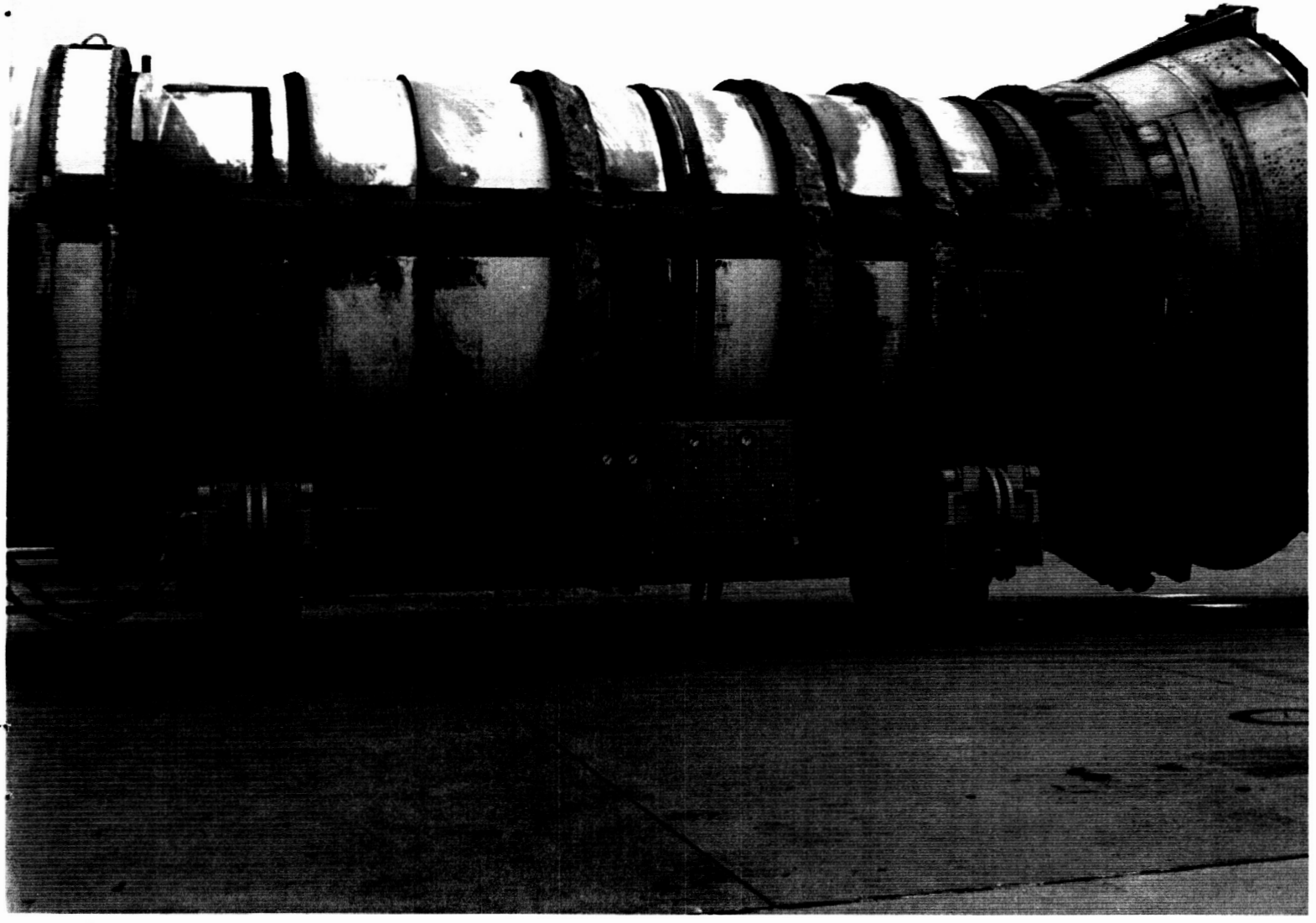




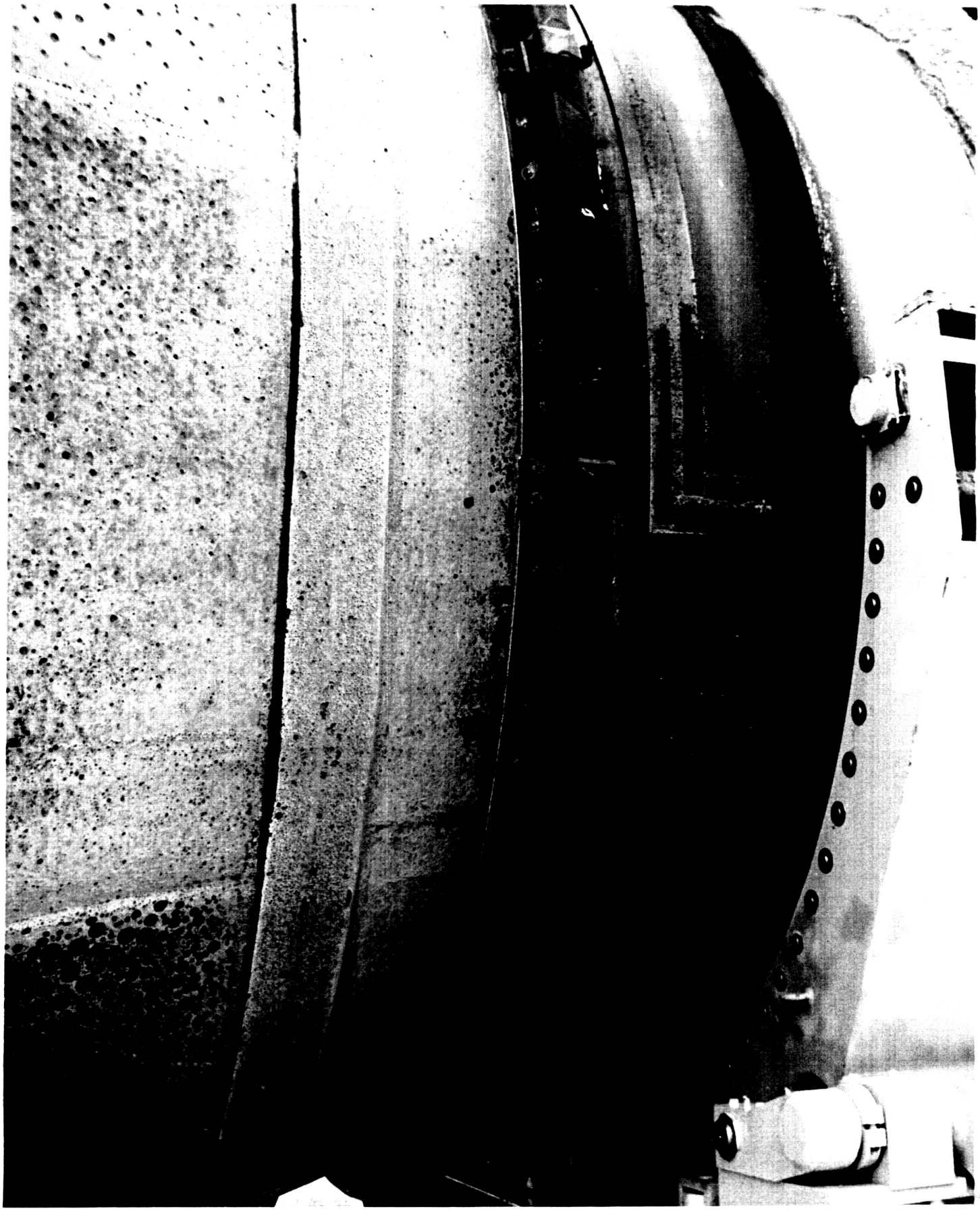
The RH frustum had 8 MSA-2 debonds over fasteners. Although one small piece of MSA-2 was missing near the 275 ring frame, the remaining material in the divot was not sooted and the missing material was most likely lost after re-entry.



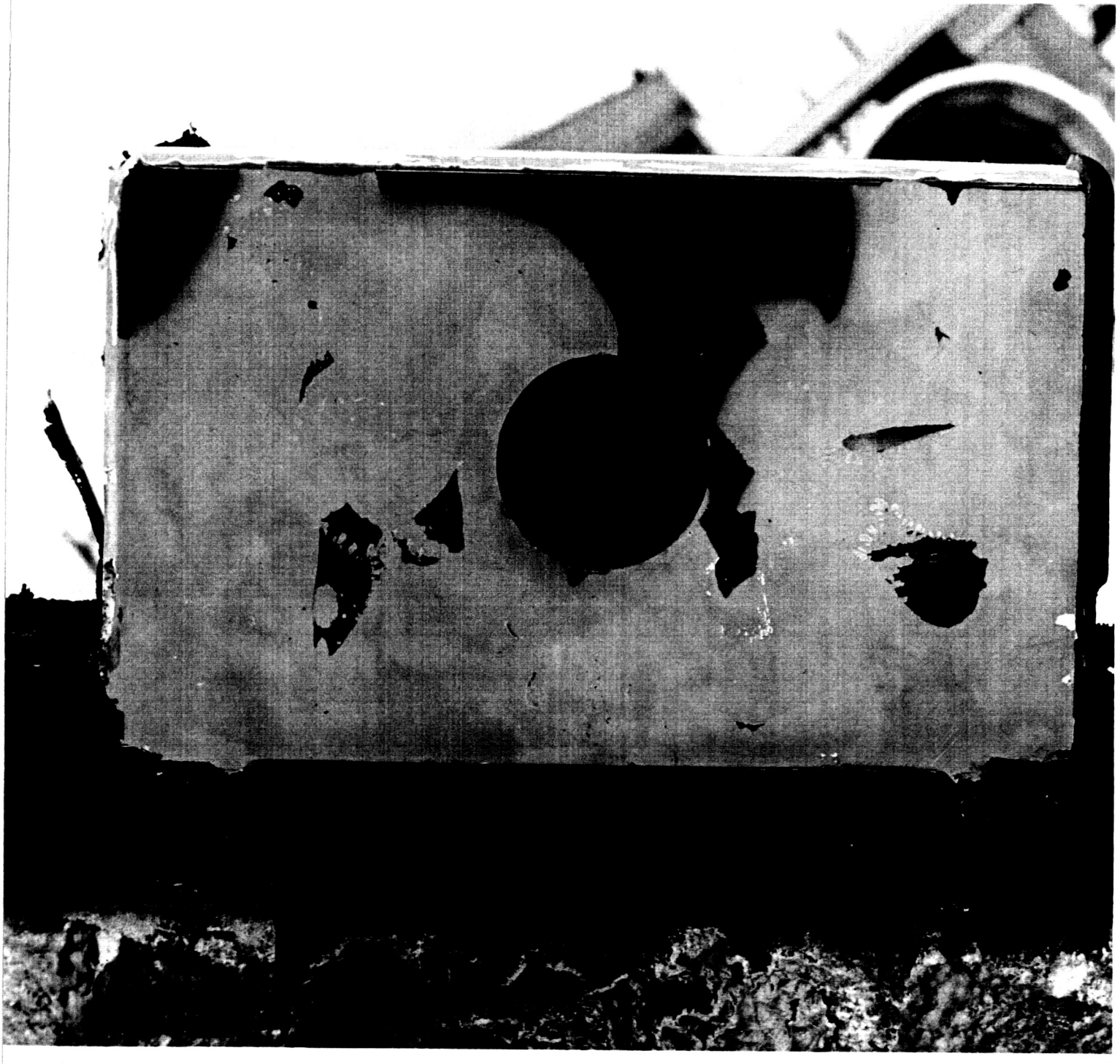
The RH forward skirt exhibited no debonds or missing TPS. Both RSS antenna phenolic plates were intact. Minor blistering of the Hypalon paint occurred forward of the ET/SRB attach point.



Post flight condition of the RH aft booster. The aft skirt acreage TPS was sooted but in good condition. The ET/SRB aft struts, ETA ring, IEA, and all three aft booster stiffener rings appeared undamaged.



The phenolic material on the kick ring was delaminated between the -Z and +Z axes. Thirteen K5NA protective domes were lost from bolt heads on the aft side of the phenolic kick ring after re-entry.



All four HDP Debris Containment System plungers were seated. There was no sign of broaching in any of the stud holes. None of the EPON shim material was lost prior to re-entry.

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum had one area of missing TPS and 11 MSA-2 debonds over fasteners. The missing TPS was located between the -Y and +Z axis near the 275 ring frame. The remaining material in the 1 inch diameter divot was not sooted and the TPS was most likely lost after re-entry. There was minor localized blistering of the Hypalon paint (Figure 8). The BSM covers were locked in the fully opened position though the upper and lower right cover attach rings were deformed and the covers bent back to the 135 degree position.

The LH forward skirt exhibited no debonds or missing TPS. The phenolic plate on one RSS antenna was intact. The forward separation bolt and electrical cables appeared to have separated cleanly. No pins were missing from the frustum severance ring. Minor blistering of the Hypalon paint occurred forward of the ET/SRB attach point (Figure 9).

The LH forward skirt, LH forward segment, and LH forward center segment sustained structural damage from either water impact "slap down" loads or parachute deployment side loads. The LH forward assembly was fractured 180 degrees of the circumference. Eight buckles, dents, and flat spots were found in the forward and forward center segments. The forward, forward center, and aft center segments also exhibited out-of-round conditions. Initial assessment indicated the damage was not a source of debris nor was caused by a debris problem.

The Field Joint Protection System (FJPS) closeouts were in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts and all three aft booster stiffener rings appeared undamaged. All four of the External Tank attach (ETA) ring segments were damaged. The ETA ring stubs on the segment case were buckled and cracked in several areas. Numerous bolt heads from the ETA ring covers were sheared off. All of this damage may be related to the cause of the forward assembly damage. The forward and aft stiffener ring splice plate closeouts at the 330 degree location were missing K5NA similar to previous flights. The substrates were not sooted. All other splice plate closeouts were intact and no K5NA material was missing prior to water impact.

Four K5NA protective domes were missing from bolt heads on the phenolic kick ring. Two of these domes were lost prior to water impact (charred substrate). The aft skirt acreage TPS was in generally good condition (Figure 10). K5NA was missing from all aft BSM nozzles.

FIGURE 8. LEFT SRB FRUSTUM

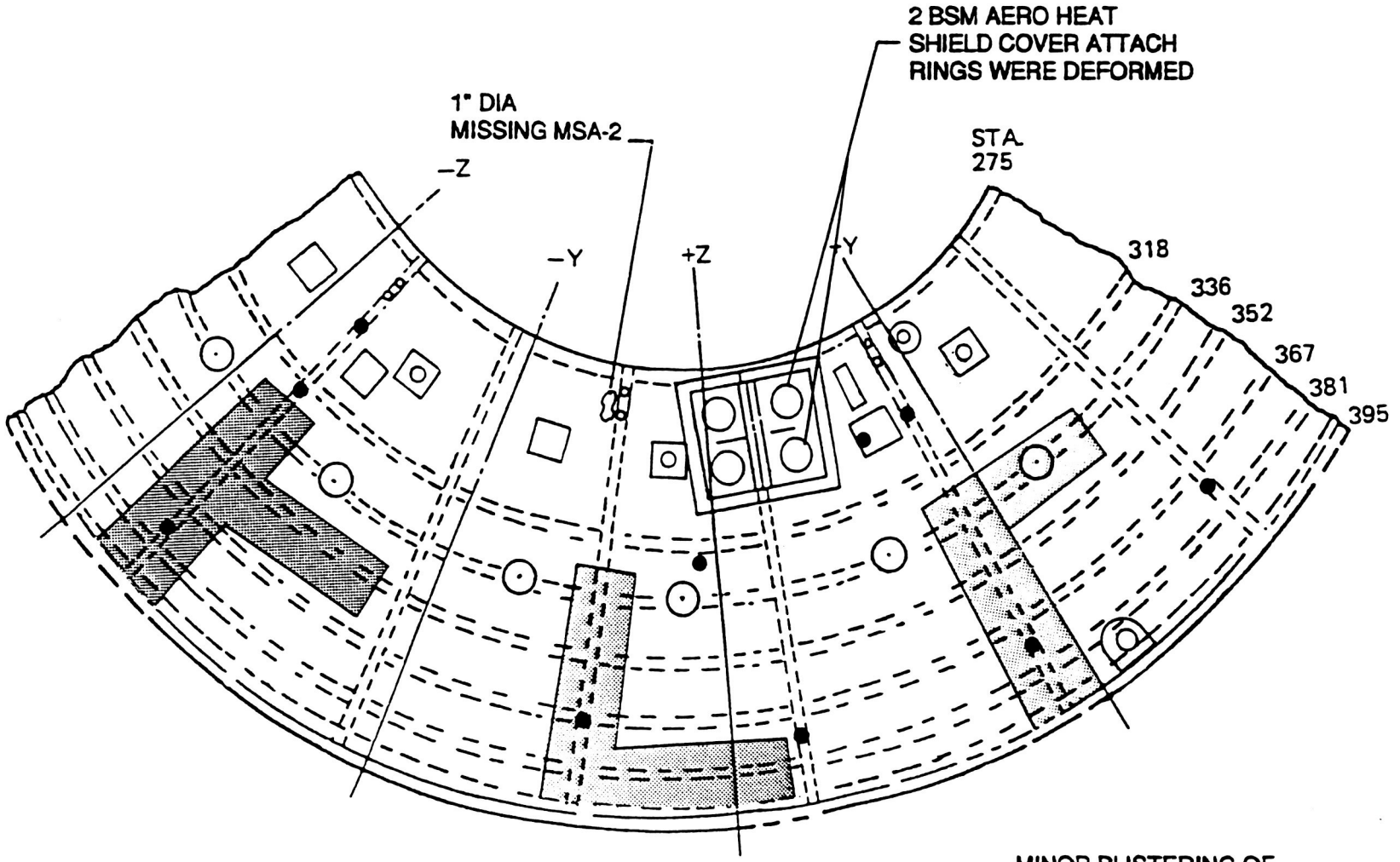
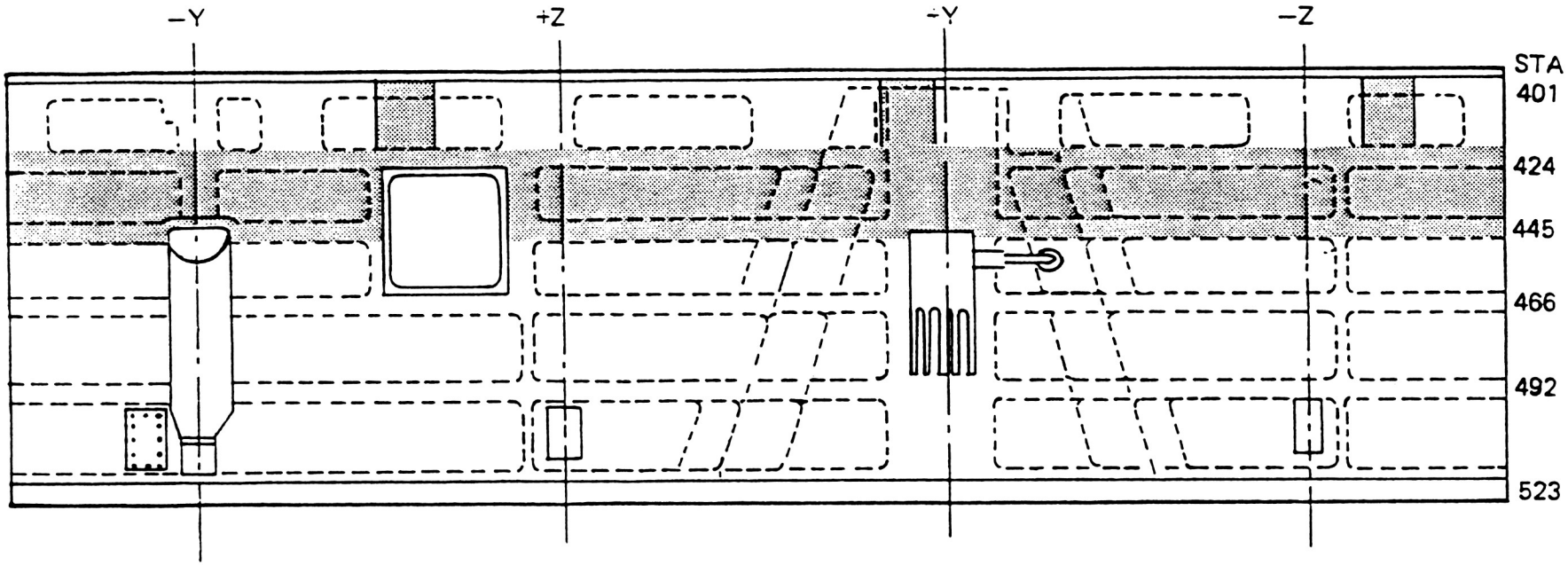
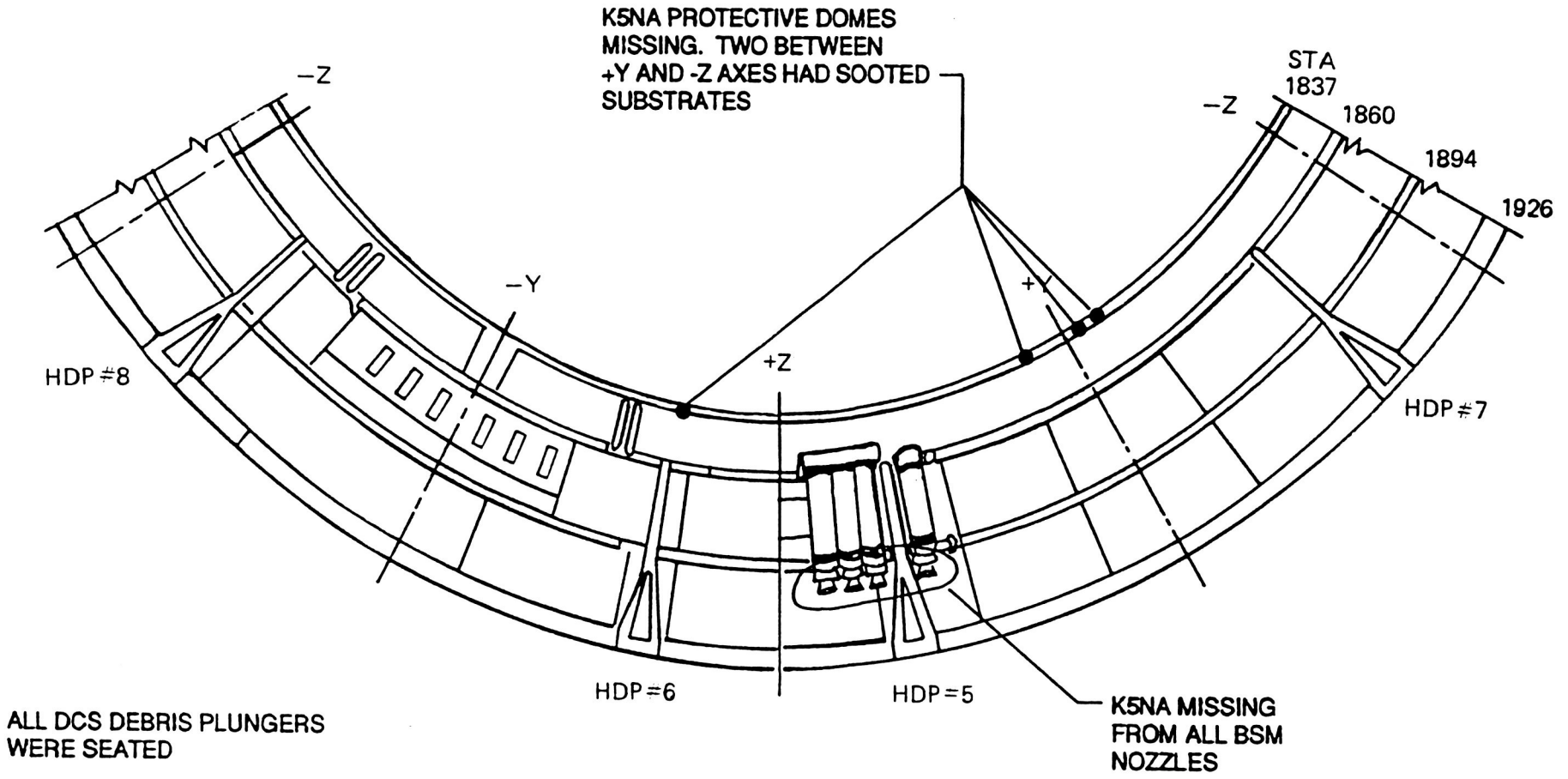


FIGURE 9. **LEFT SRB FWD SKIRT**

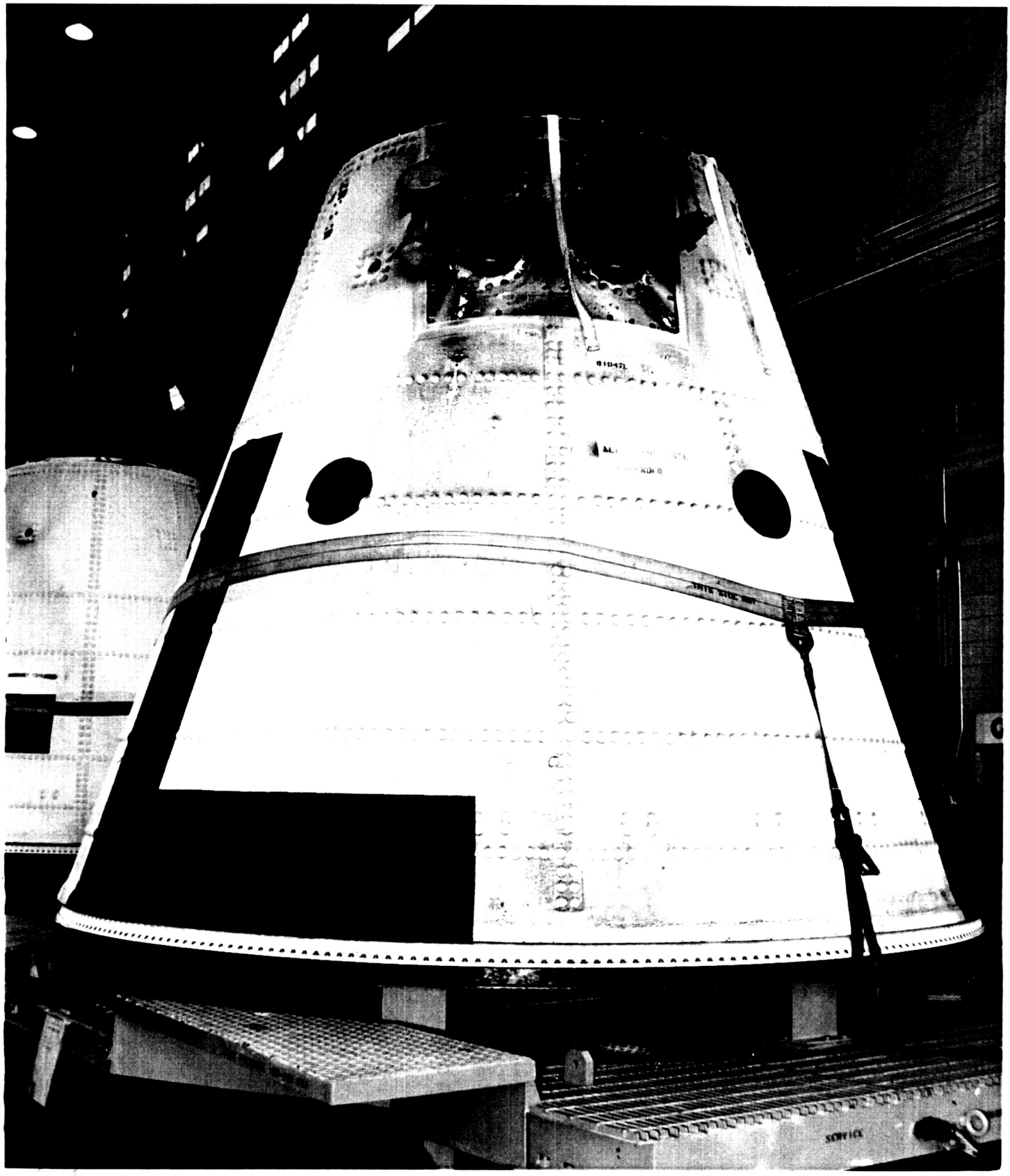


TPS MISSING	DEBONDS	NOTE: See photographs for structural damage views.	**MINOR BLISTERING OF HYPALON PAINT ON SYSTEMS TUNNEL COVER AND AROUND ET/SRB ATTACH FITTING**
NONE	NONE		

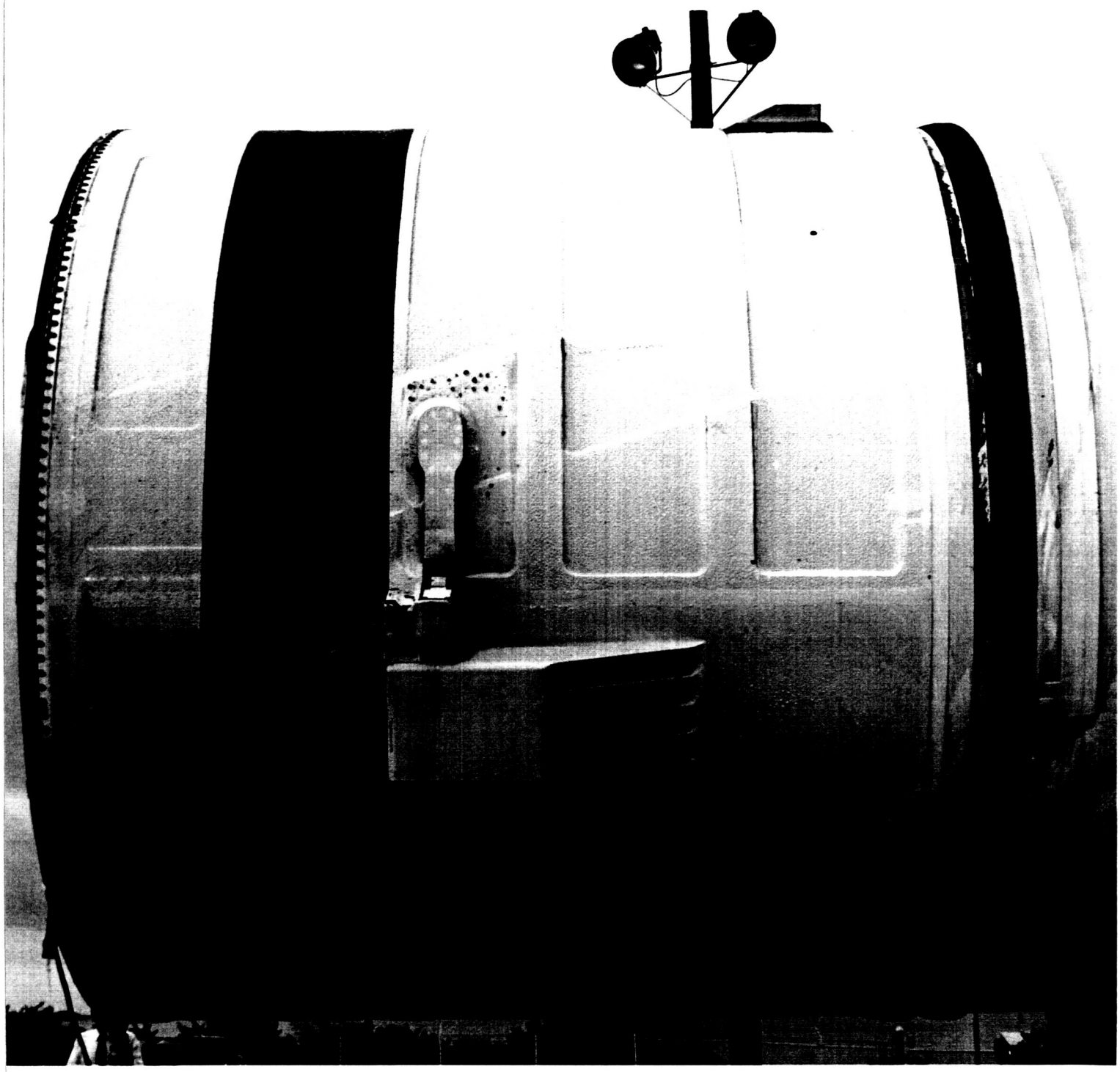
FIGURE 10. **LEFT SRB AFT SKIRT EXTERIOR TPS**



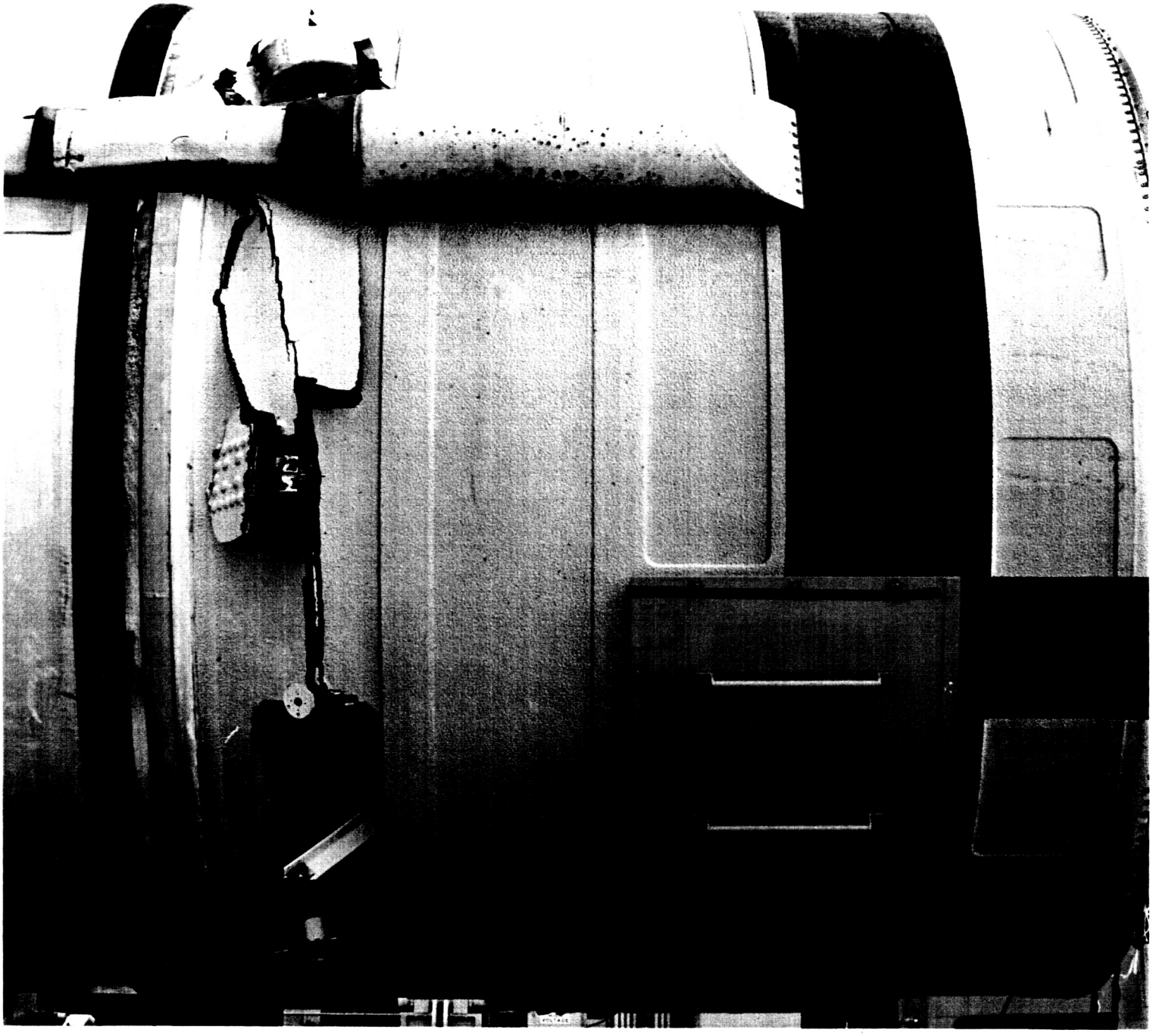
All four HDP Debris Containment System (DCS) plungers were seated. This was the fourth flight utilizing the optimized link. There was no sign of broaching in any of the stud holes. None of the EPON shim material was lost during flight.



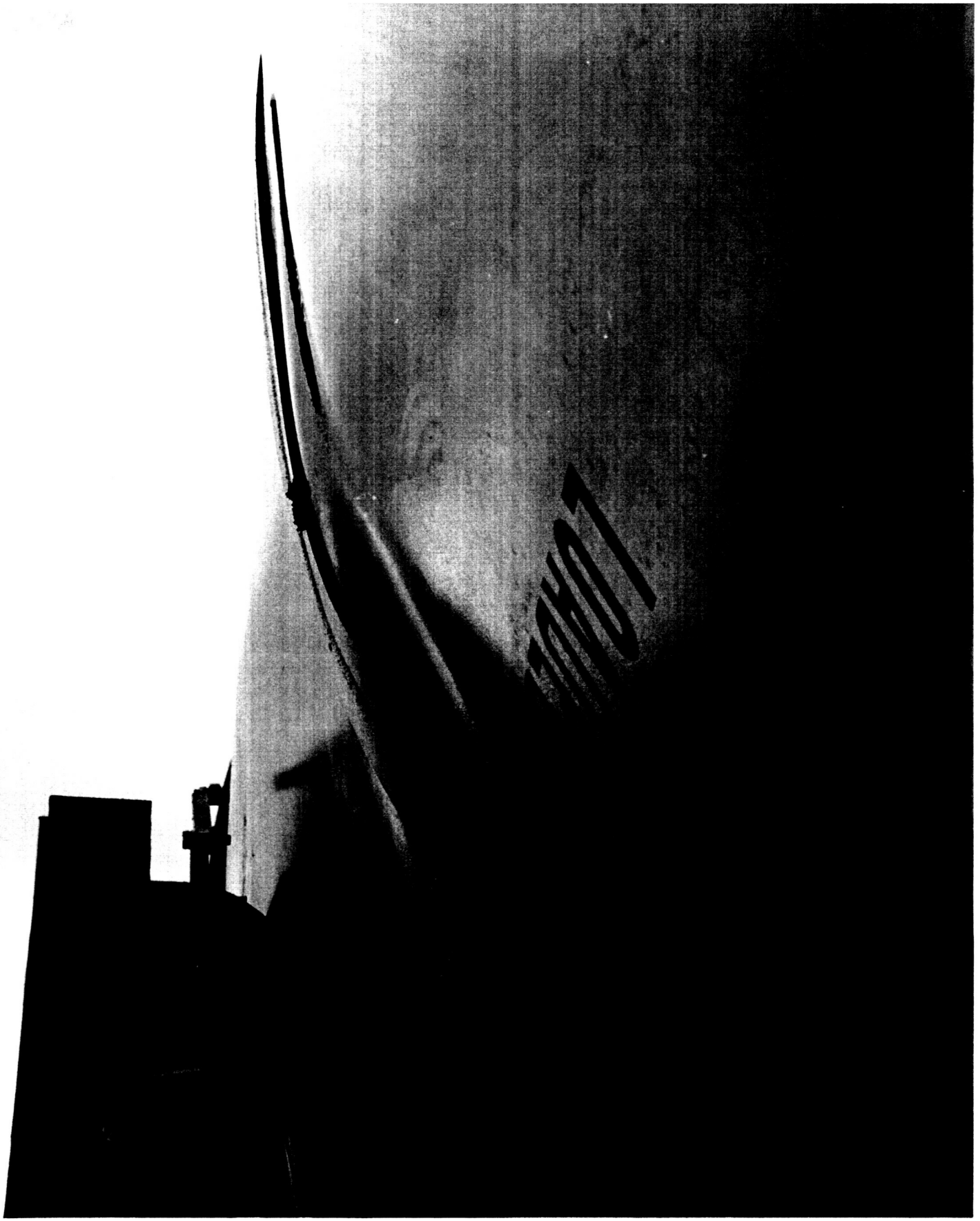
The LH frustum had 11 MSA-2 debonds over fasteners. Although one small piece of MSA-2 was missing near the 275 ring frame, the remaining material in the divot was not sooted and the missing material was most likely lost after re-entry. The BSM covers had locked in the fully opened position, though the upper and lower right cover attach rings were deformed and the covers bent back to the 135 degree position.



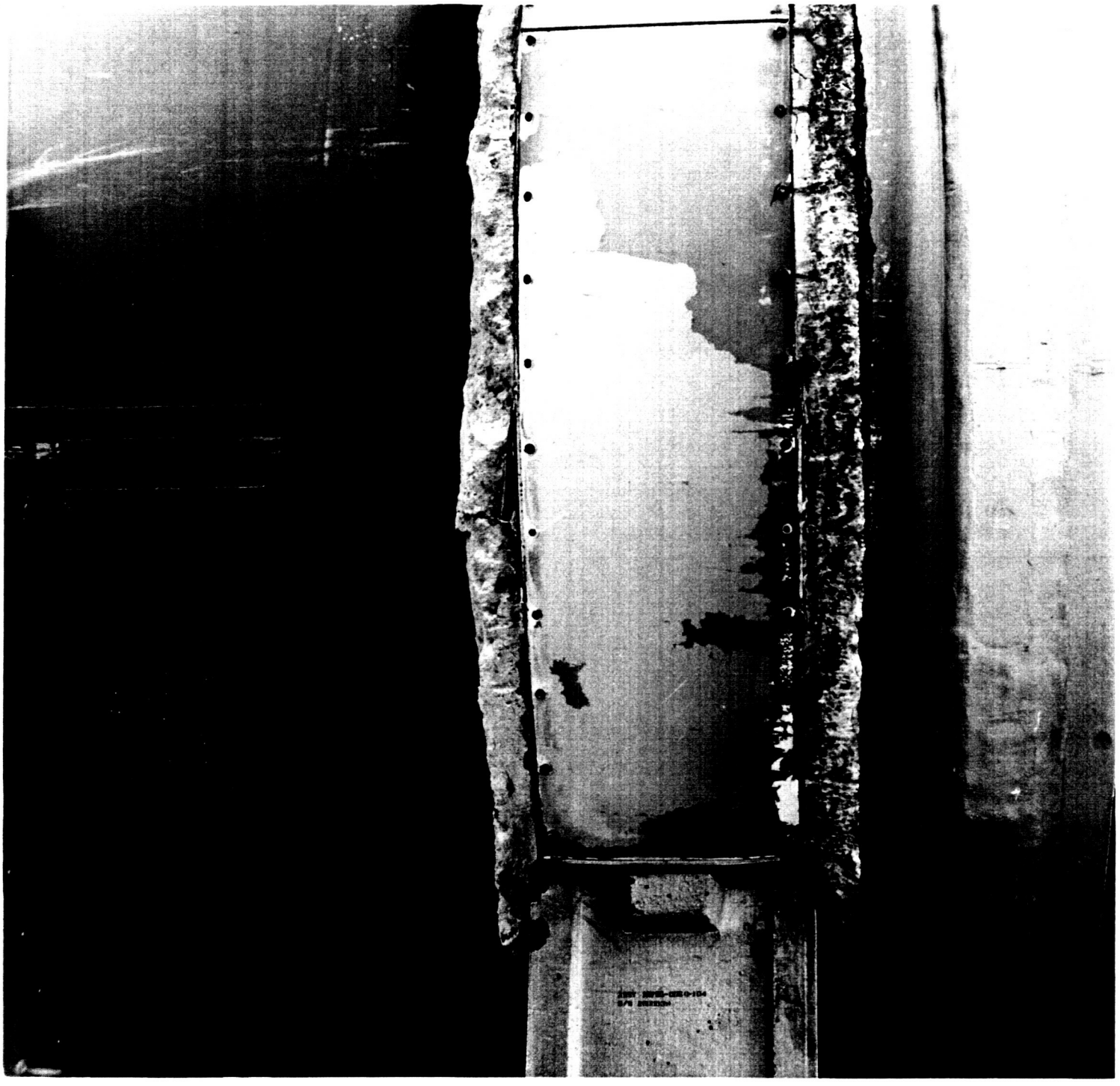
The left forward skirt exhibited no MSA-2 debonds or missing TPS. Minor blistering of Hypalon paint occurred forward of the ET/SRB attach point.



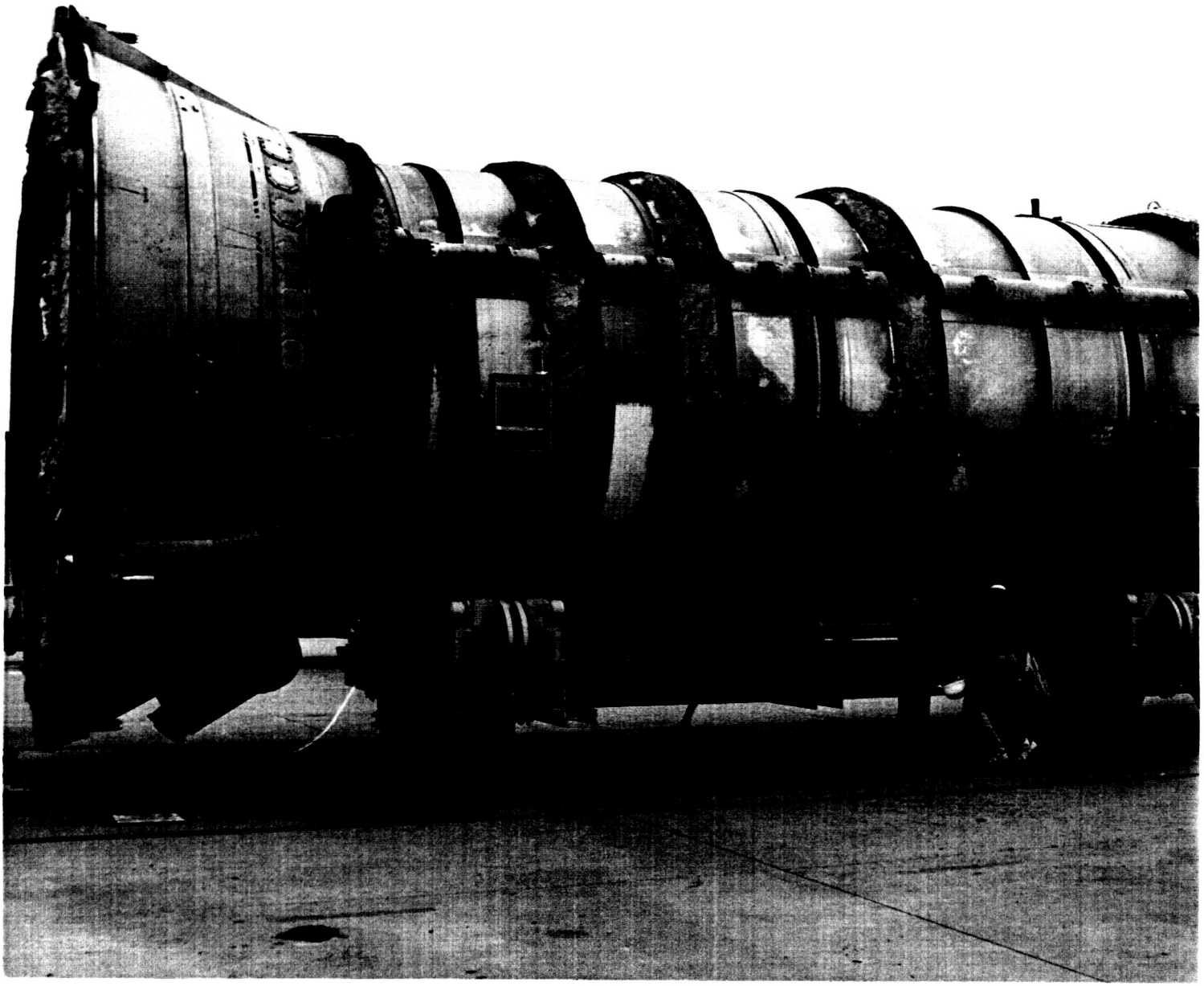
The LH forward skirt, LH forward segment, and LH forward center segment sustained structural damage from either water impact "slap down" loads or parachute deployment side loads. The LH forward assembly was fractured 180 degrees of the circumference



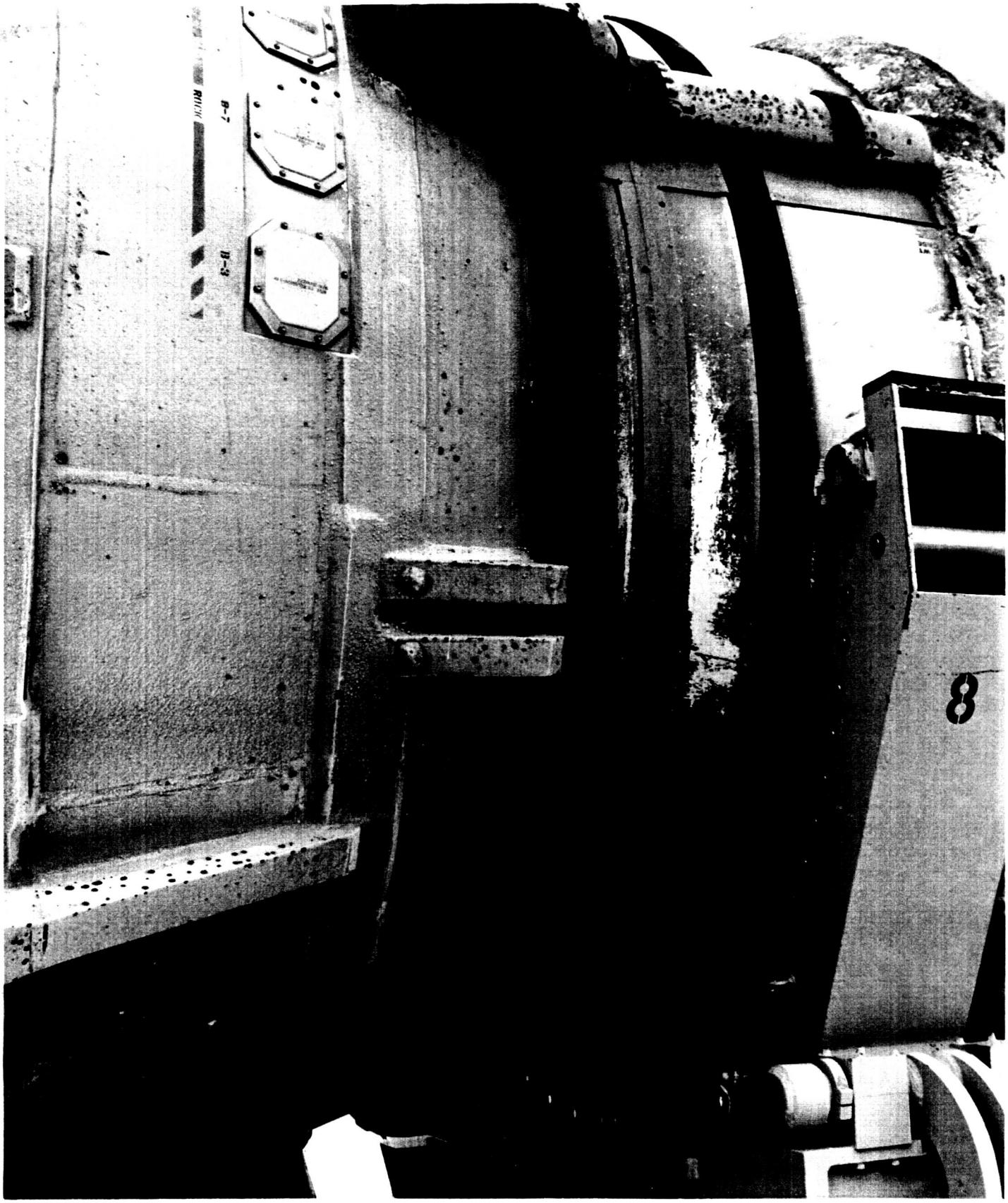
Buckles, dents, flat spots, and out-of-round conditions were found on the forward, forward center, and aft center segments. Initial assessment indicated the damage was not a source of debris nor was caused by a debris problem.



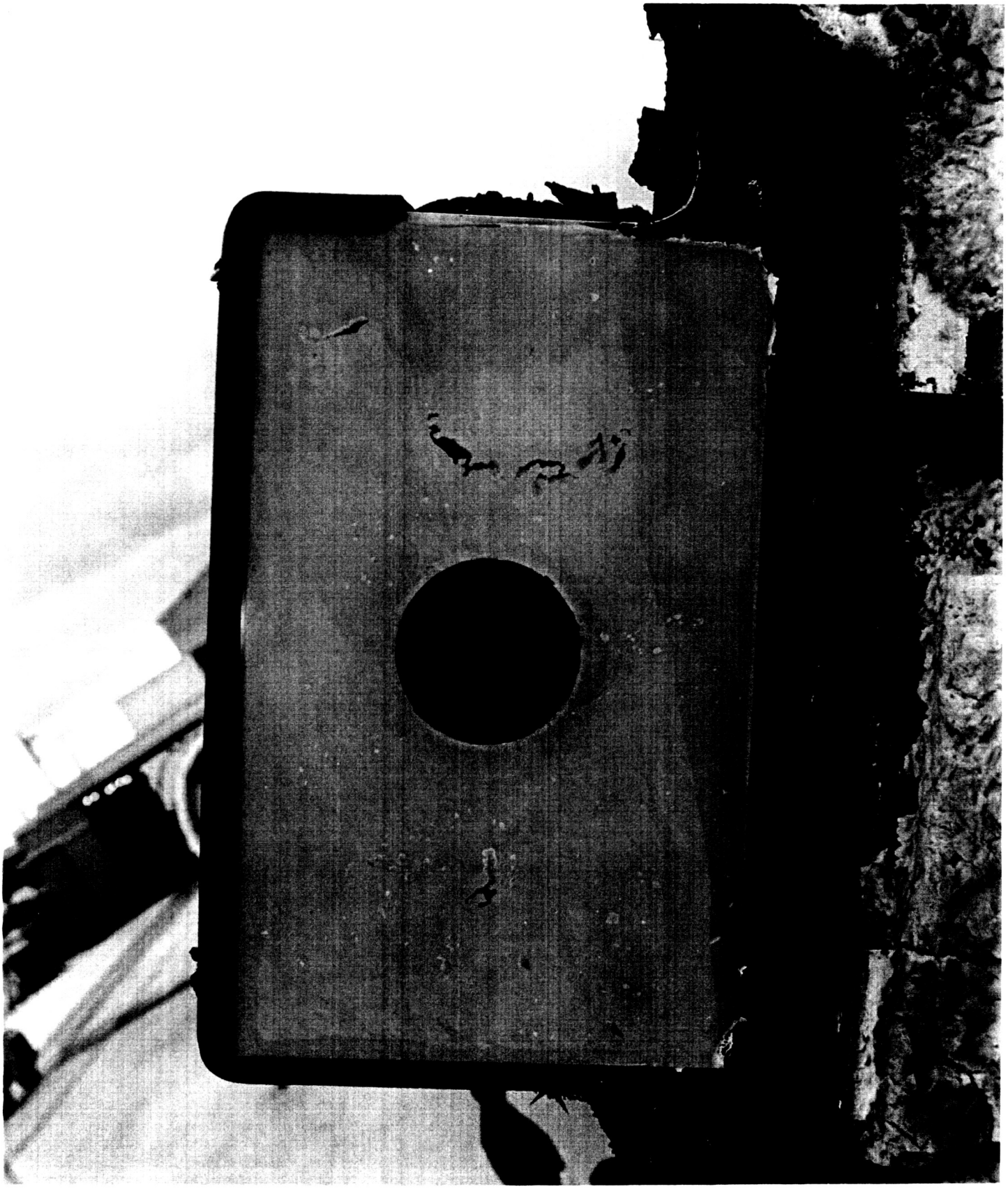
All four of the ETA ring segments and ring stubs on the segment case were damaged. Numerous bolt heads from the ETA ring covers were sheared off. All of this damage may be related to the cause of the forward assembly damage.



Post flight condition of the LH aft booster/aft skirt. The aft skirt acreage TPS was sooted but generally in good condition



The phenolic material on the kick ring was intact and had not delaminated. K5NA protective domes were missing from bolt heads on the phenolic kick ring prior to water impact. The substrate under the missing domes was sooted.



All four HDP Debris Containment System plungers were seated. There was no sign of broaching in any of the stud holes. None of the EPON shim material was lost prior to re-entry.

7.3 RECOVERED SRB DISASSEMBLY FINDINGS

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 99 percent and individual holddown post retention percentages as listed:

HDP #	% of Nut without 2 large halves	% of Ordnance fragments	% Overall
1	99	93	99
2	99	91	99
3	99	93	99
4	99	93	99
5	99	94	99
6	99	93	99
7	99	91	99
8	99	94	99

STS-44 was the fourth flight to utilize the new "optimized" frangible links in the holddown post DCS's. The link was designed to increase the DCS plunger velocity and improve the seating alignment while leaving the stud ejection velocity the same. The design was intended to prevent ordnance debris from falling out of the DCS yet not increase the likelihood of a stud hang-up. According to NSTS-07700, the Debris Containment System should retain a minimum of 90 percent of the ordnance debris. Overall percentages of retention for the four flights utilizing the "optimized" link are:

HDP #	BI-044 STS-40	BI-045 STS-43	BI-046 STS-48	BI-047 STS-44
1	99%	98%	99%	99%
2	99%	**31%**	**88%**	99%
3	**38%**	99%	99%	99%
4	99%	99%	99%	99%
5	**23%**	99%	**58%**	99%
6	99%	99%	99%	99%
7	**62%**	99%	99%	99%
8	99%	99%	99%	99%
TOTAL	78%	90%	92%	99%
Debris Loss	58 oz	25 oz	19 oz	negl

SRB Post Launch Anomalies are listed in Section 10.

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-104 (Atlantis) was conducted on December 1-3, 1991, at Ames-Dryden (EAFB) on runway 05 and in the Mate/Demate Device (MDD). This inspection was performed to identify debris impact damage, and if possible, debris sources. The Orbiter TPS sustained a total of 101 hits, of which 9 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield attributed to engine vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 30 previous missions of similar configuration (excluding missions STS-24, 25, 26, 26R, 27R, and 30R which had damage from known debris sources), indicates that both the total number of hits and the number of hits one inch or larger were much less than average. Figures 11-14 show the TPS debris damage assessment for STS-44. The following table breaks down the STS-44 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	6	74
Upper surface	1	9
Right side	0	10
Left side	1	4
Right OMS POD	1	2
Left OMS POD	0	2
TOTALS	9	101

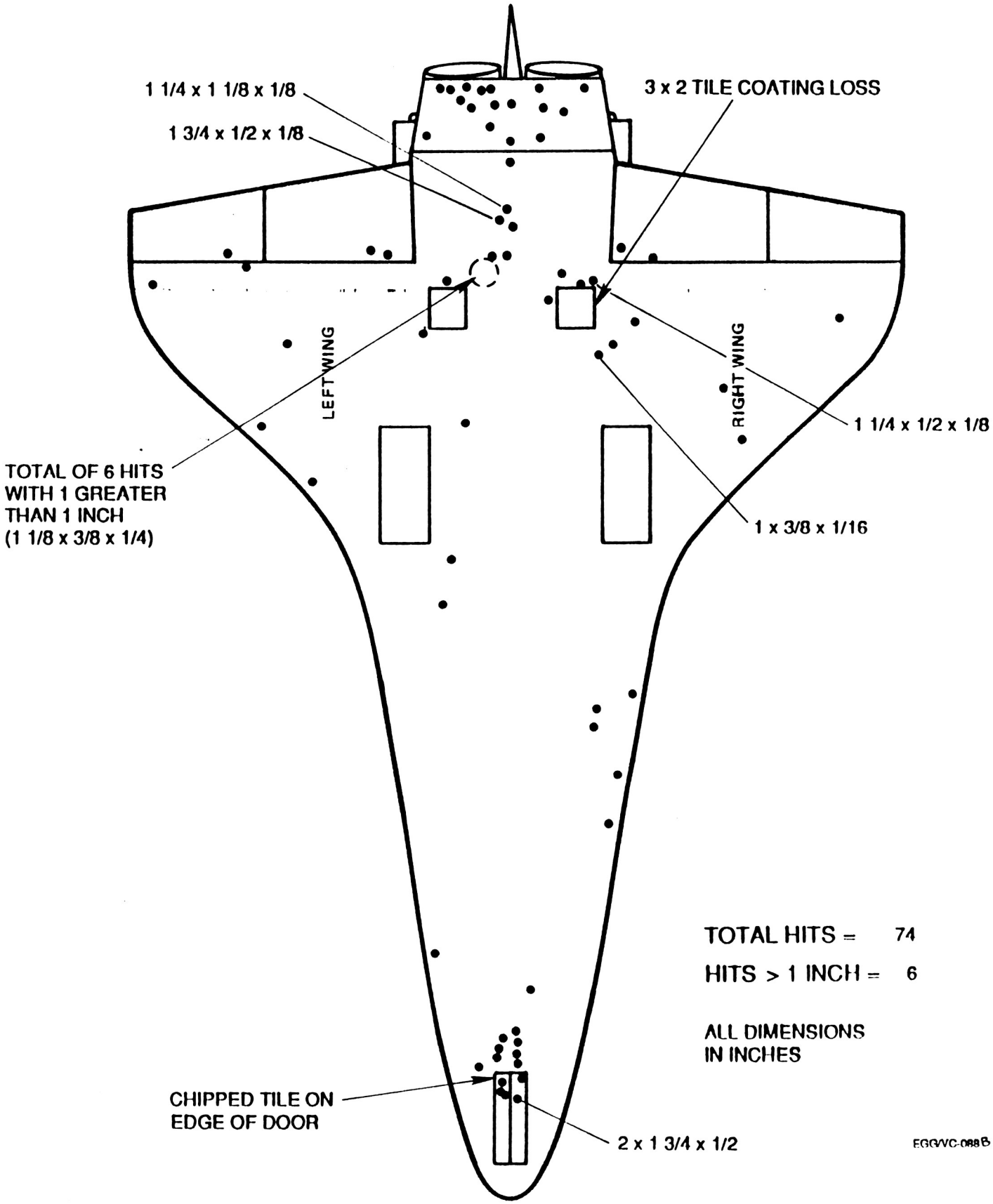
No TPS damage was attributed to material from the wheels, tires, or brakes. The main landing gear tires were considered to be in excellent condition.

All ET/Orbiter separation ordnance device plungers appeared to have functioned properly. The stop-bolts on the EO-1 separation assembly did not sustain any damage or deformation. A piece of beta tape adhered to the LO2 ET/ORB umbilical aft door hinge. The tape was charred and showed signs of heating. An assembly consisting of an ordnance connector, detonator, and lockwire fell from the ET/Orbiter LH2 umbilical upon door opening. Part numbers on the assembly identify it as originating from the LH2 ET/ORB umbilical aft separation device. This event was documented on PR PYR-4-11-0142.

Damage to the base heat shield tiles was less than average. The main engine closeout blankets were in good condition with the only observed damage being minor fraying from 5 to 6 o'clock on SSME #1 and a 6 inch long detached outboard blanket edge on SSME #2 at the 5 o'clock position.

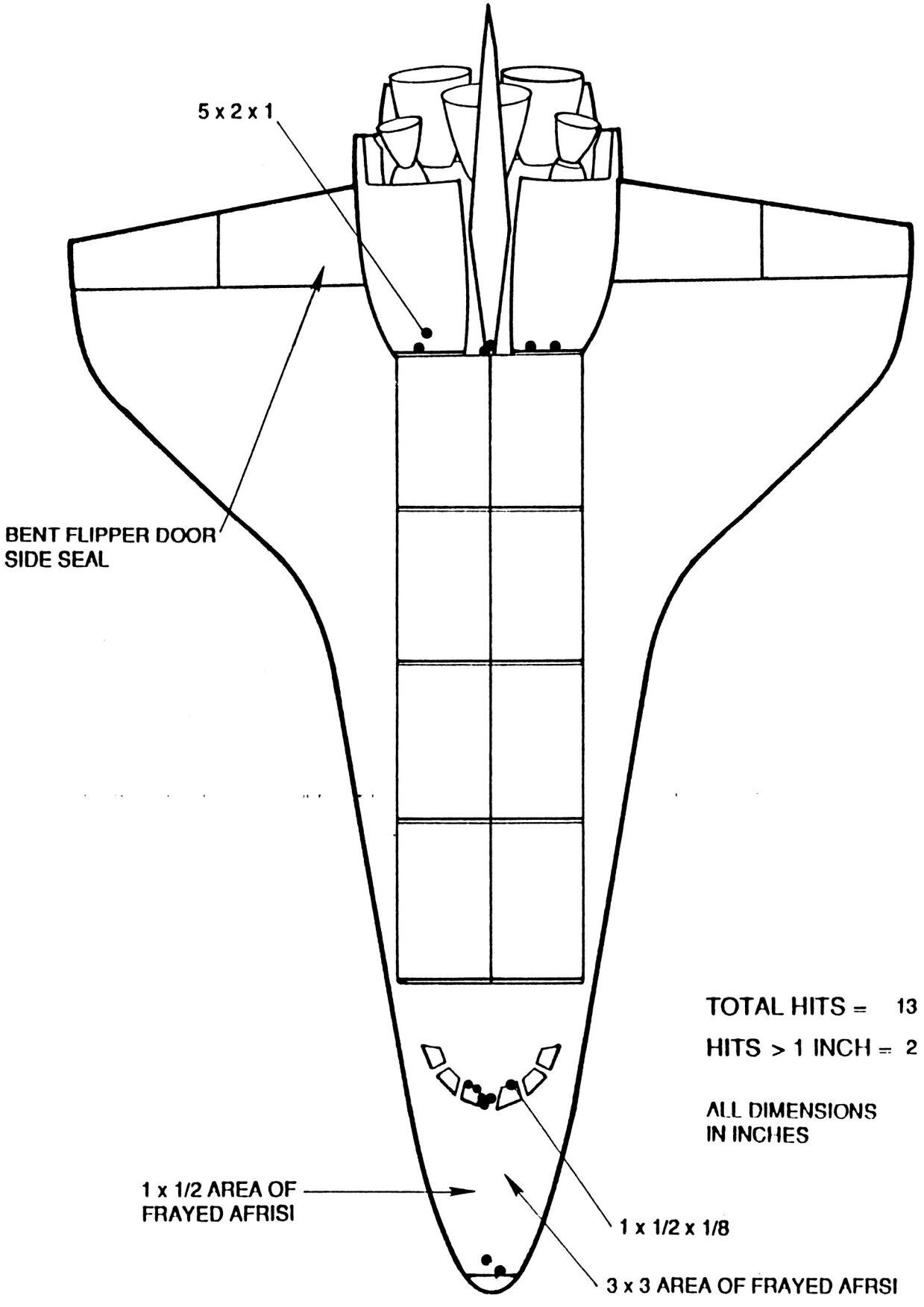
STS-44

FIGURE 11. DEBRIS DAMAGE LOCATIONS



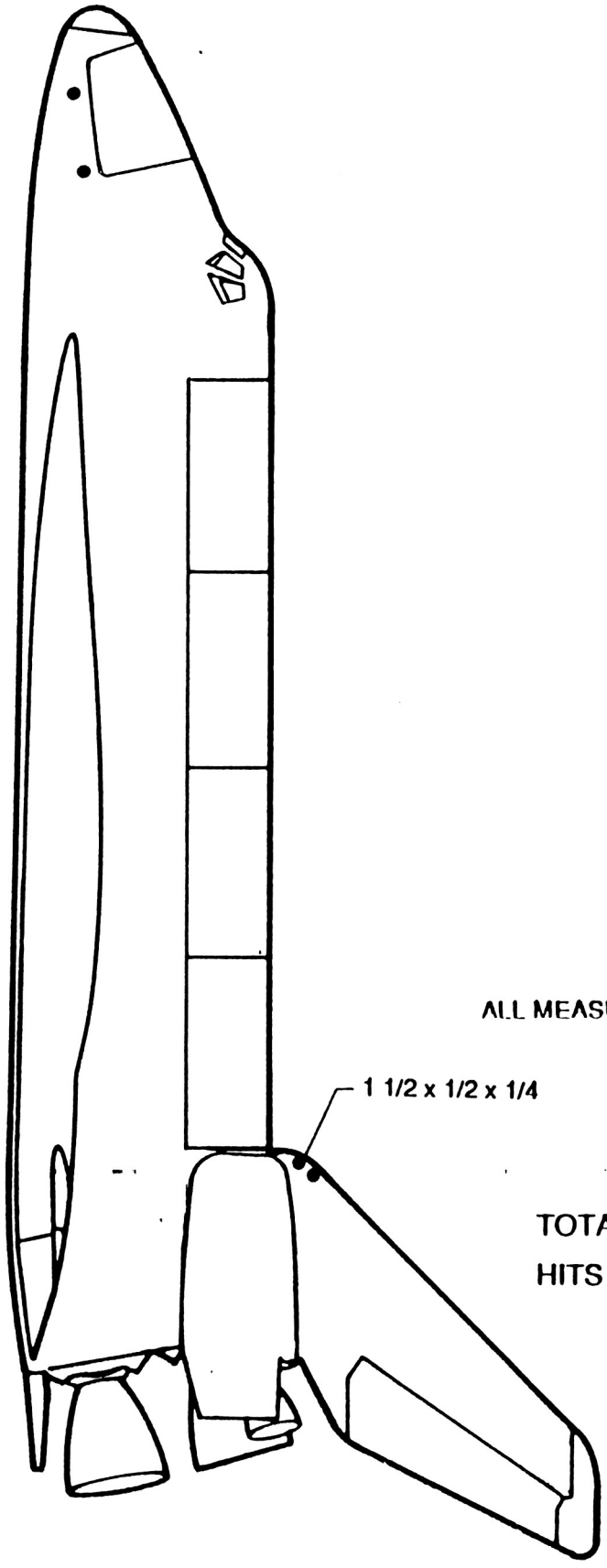
STS-44

FIGURE 12. **DEBRIS DAMAGE LOCATIONS**



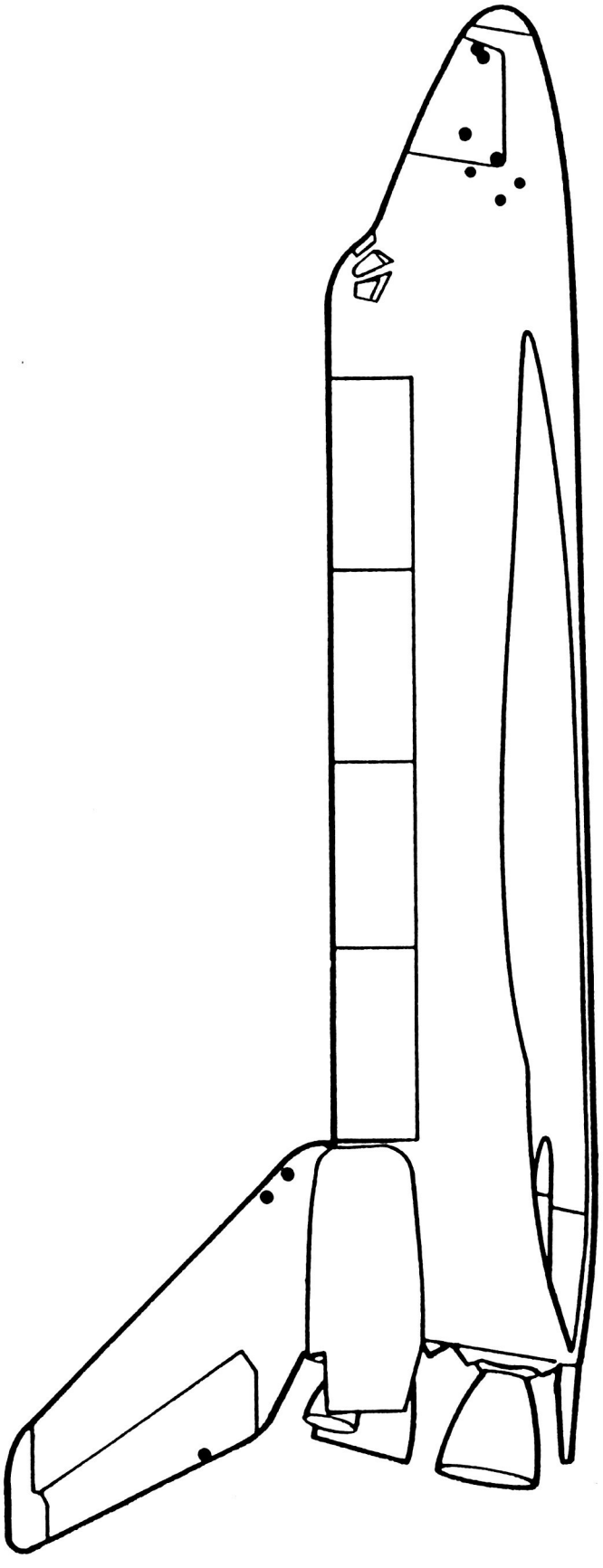
STS-44

FIGURE 13. **DEBRIS DAMAGE LOCATIONS**



STS-44

FIGURE 14. **DEBRIS DAMAGE LOCATIONS**



TOTAL HITS = 10

HITS > 1 INCH = 0

EGG/VC 088A

Although liftoff films recorded what is believed to have been a small hydrogen leak on the SSME #2 nozzle cold wall near the aft manifold/steer horn, no external damage was observed.

Orbiter windows #1, #2, #5, and #6 were lightly hazed. Windows #3 and #4 exhibited moderate to heavy hazing and had numerous streaks. Laboratory analysis will be performed on samples taken from all windows.

The largest tile damage site on the vehicle was located on the RH OMS pod, measured approximately 5"x 2"x 1" in size, and involved two tiles. The cause of this damage was not apparent and no adjacent tile gap fillers were protruding or missing. The remainder of the OMS pod tiles appeared to be in good condition.

The forward edge of the side seal between flipper doors #1 and #2 on the RH inboard elevon was peeled aft approximately three inches. This damage was documented on PR-STR-4-11-2413.

Samples were taken from selected sites on the Orbiter for laboratory analysis (Figure 15).

A portable infrared thermometer was used to measure the surface temperatures of three areas on the Orbiter TPS after landing (OMRSD V09AJ0.095). Seventeen minutes after wheel stop the Orbiter nosecap RCC was 183 degrees F. Twenty-four minutes after landing, the RH wing leading edge RCC panel #9 was 87 degrees F and the RH wing leading edge RCC panel #17 was 73 degrees F (Figure 16).

A pre-landing inspection of Runway 05 was performed by LSOC personnel on November 30, 1991, and all potentially damaging debris was removed. Runway 04 was inspected and swept by Air Force personnel. Both runways were found to be in good condition.

A post-landing inspection of runway 05 was performed immediately after landing. No flight hardware was found with the exception of the ordnance device below the Orbiter umbilical.

In summary, both the total number of Orbiter TPS debris hits and the number of hits with a major dimension one inch or greater were much less than average when compared to previous flights (Figures 17-19). From a debris damage standpoint this flight can be considered one of the best in program history. The distribution of hits on the Orbiter does not point to a single source for ascent debris, but indicates a shedding of ice and TPS debris from random sources.

Orbiter Post Landing Anomalies are listed in Section 10.

STS-44

FIGURE 15. **CHEMICAL SAMPLE LOCATIONS**

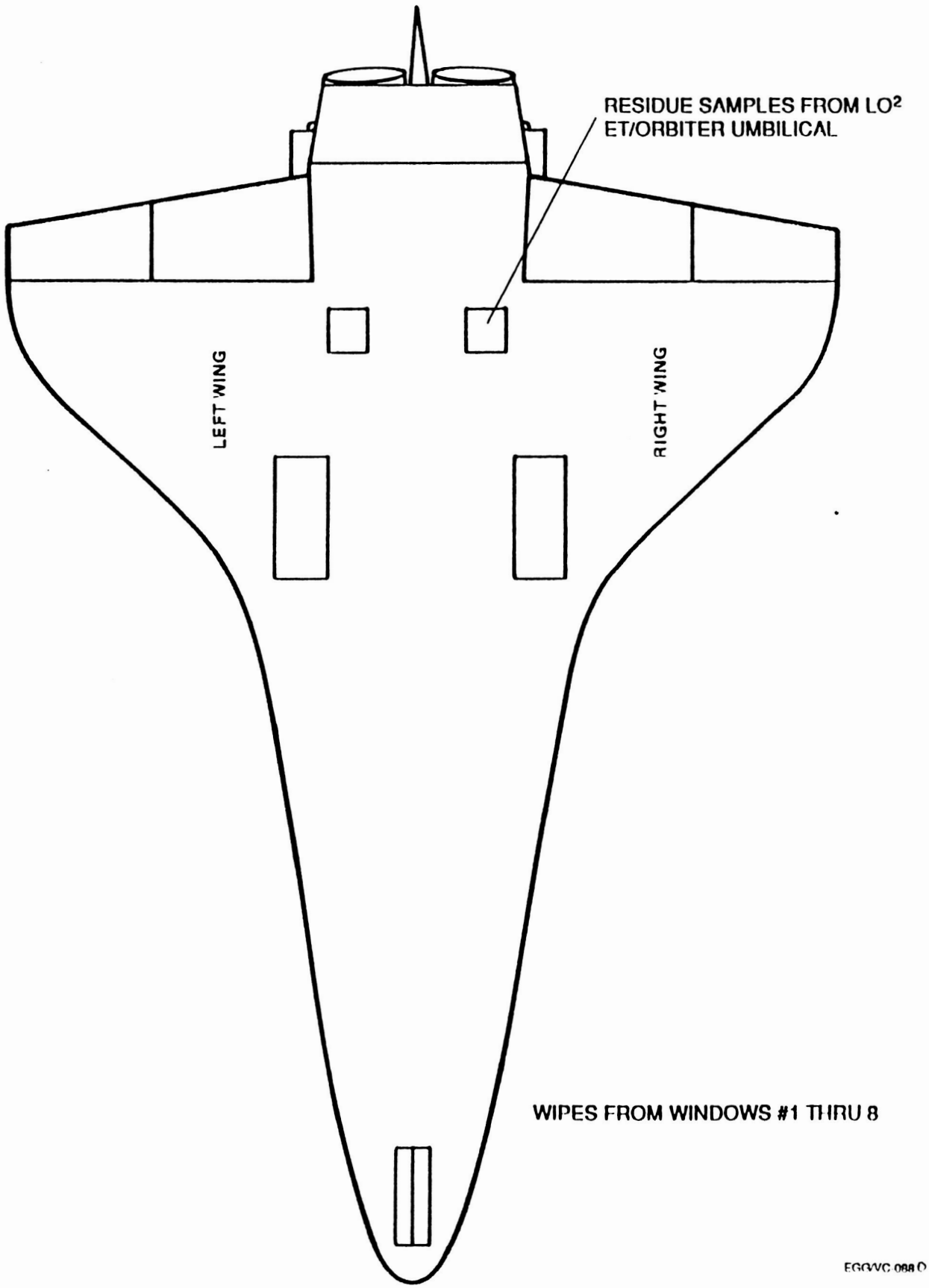


FIGURE 16. **STS-44 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**

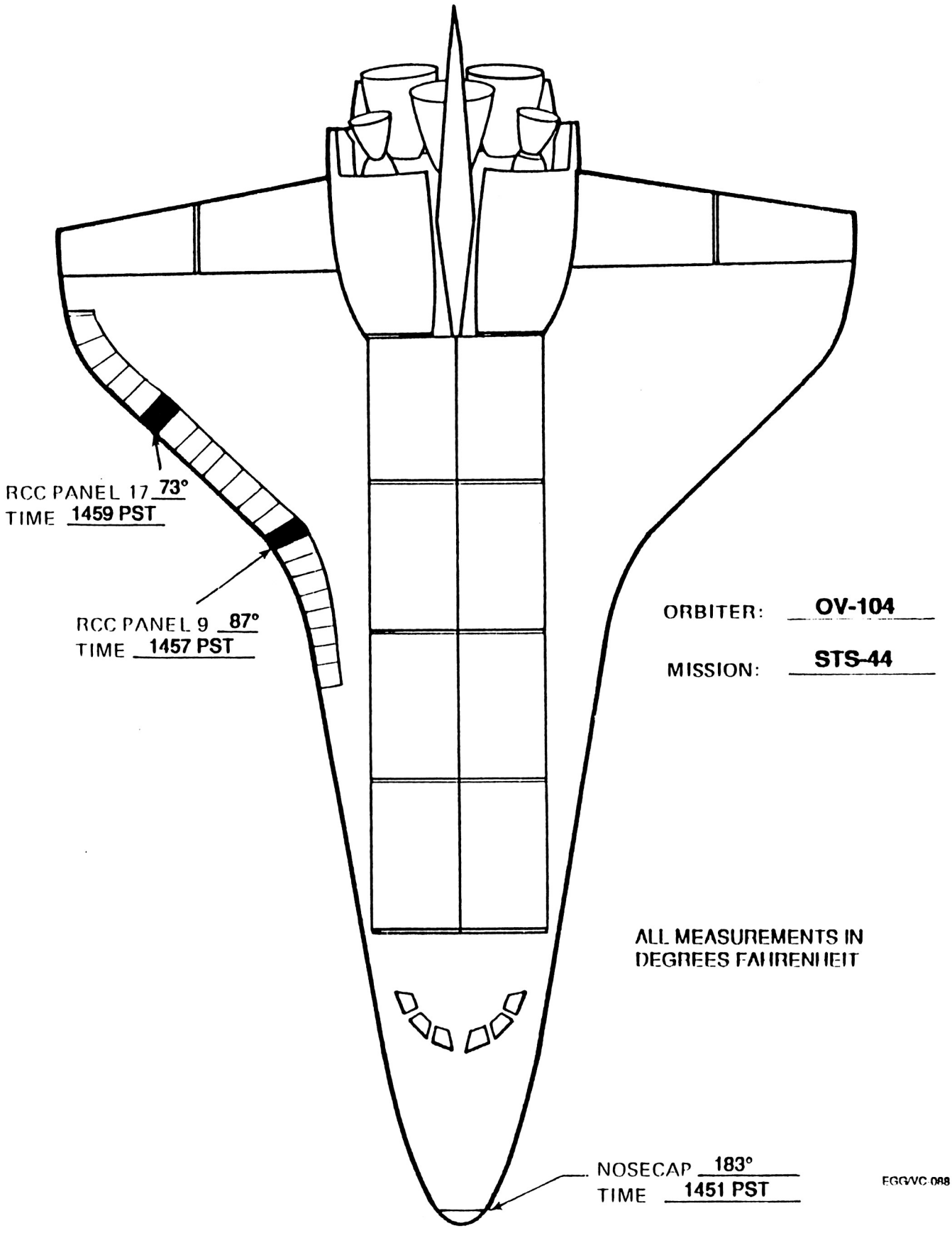


FIGURE 17: POST FLIGHT DEBRIS DAMAGE SUMMARY

	> 1 INCH	TOTAL	SINCE RETURN TO FLIGHT	
			> 1 INCH	TOTAL
STS-6	36	120		
STS-8	7	56		
STS-9	14	58		
STS-11	34	63		
STS-13	8	36		
STS-14	30	111		
STS-17	36	154		
STS-19	20	87		
STS-20	28	81		
STS-23	46	152		
STS-27	33	141		
STS-28	17	111		
STS-30	34	183		
STS-31	55	257		
STS-32	39	193		
STS-29	23	132	23	132
STS-28R	20	76	20	76
STS-34	18	53	18	53
STS-33R	21	118	21	118
STS-32R	15	120	15	120
STS-36	19	81	19	81
STS-31R	14	63	14	63
STS-41	16	76	16	76
STS-38	8	81	8	81
STS-35	17	147	17	147
STS-37	10	113	10	113
STS-39	16	238	16	238
STS-40	25	197	25	197
STS-43	25	131	25	131
STS-48	25	182	25	182
STS-44	9	101	9	101
SUM	718	3712	281	1909
AVERAGE	23.2	119.7	17.6	119.3
SIGMA	11.7	55.2	5.5	51.5

FIGURE 18. # COMPARISON TABLE

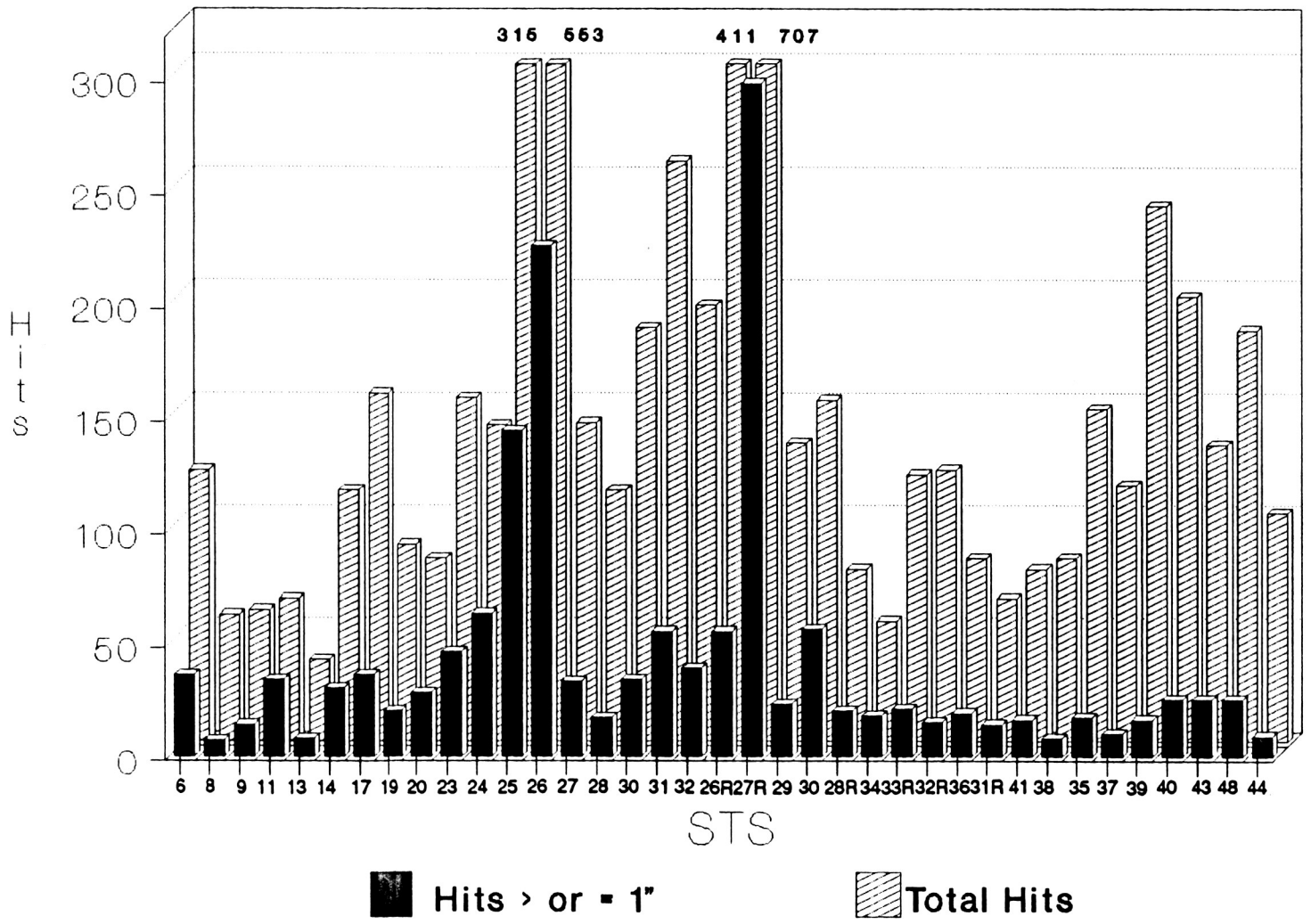
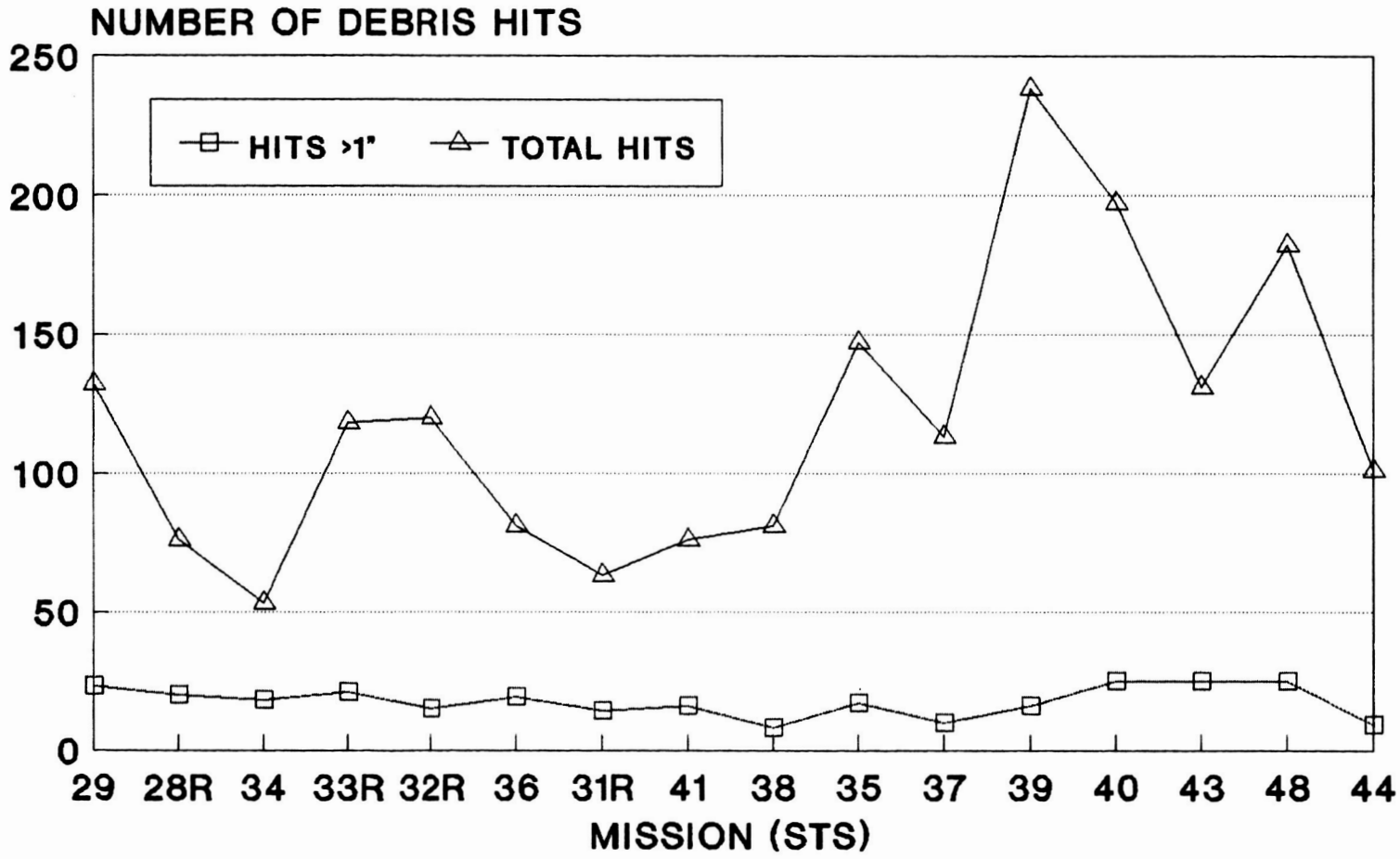
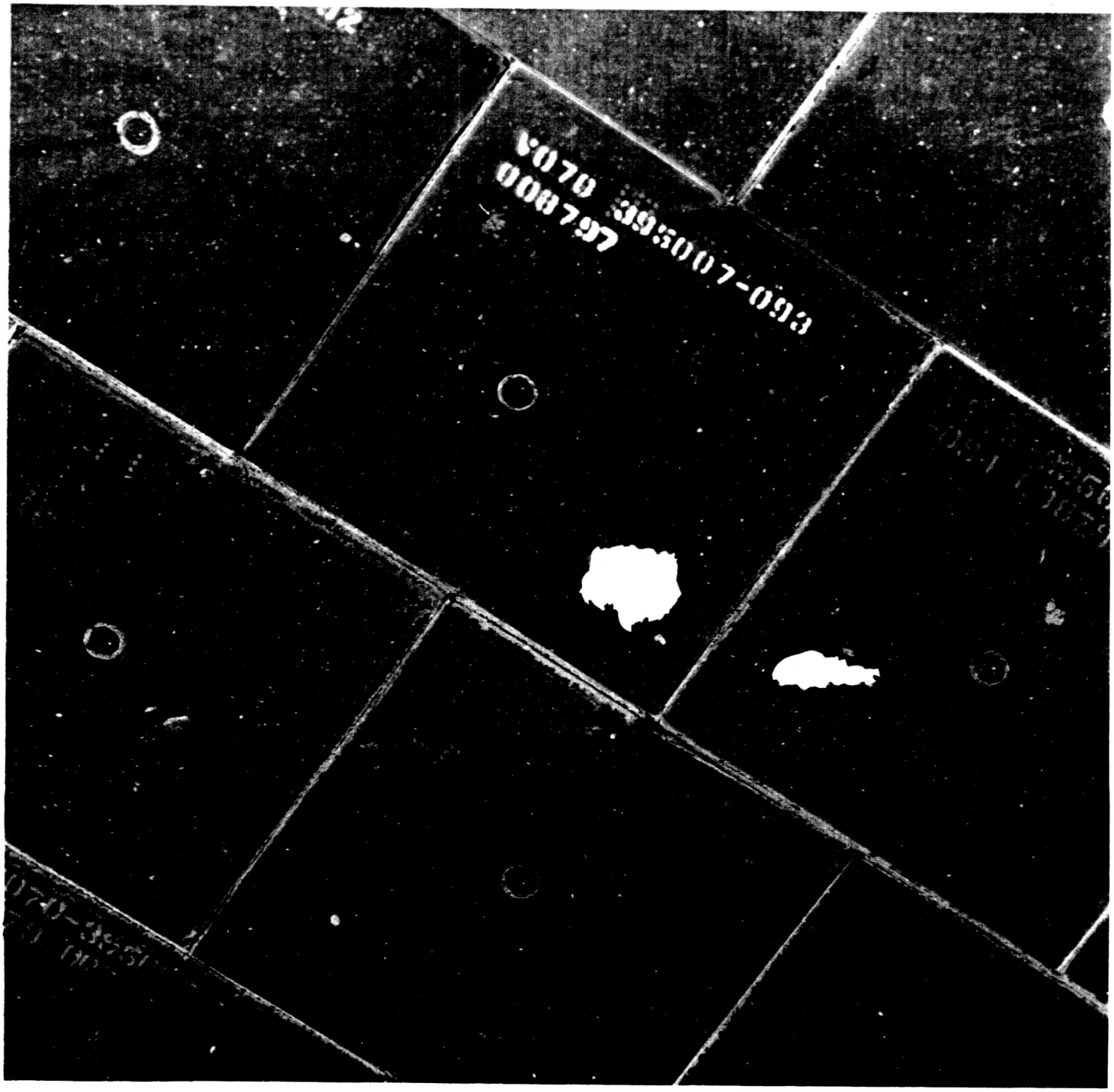


FIGURE 19.

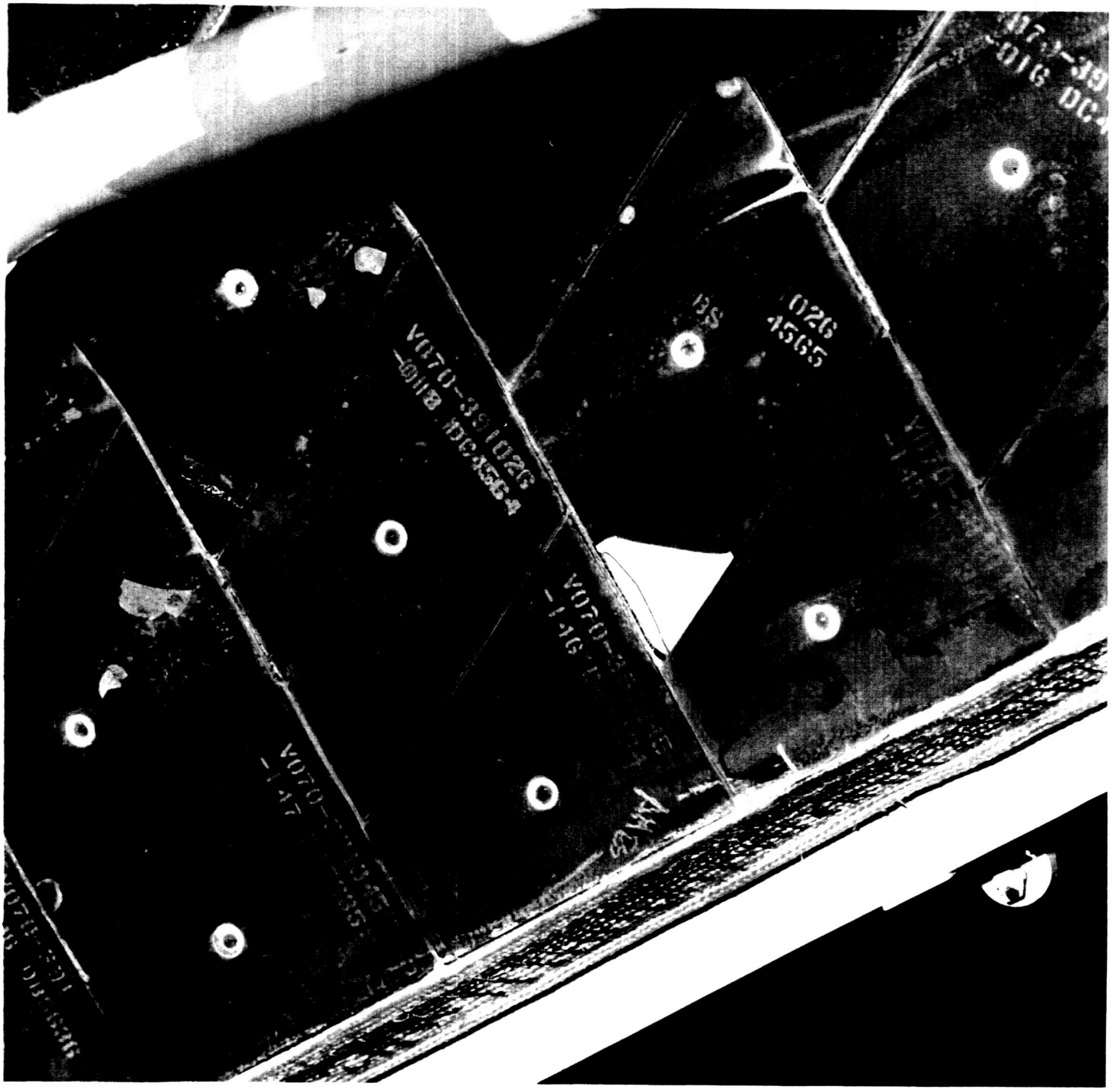
ORBITER TPS DEBRIS DAMAGE
STS-29 THROUGH STS-44



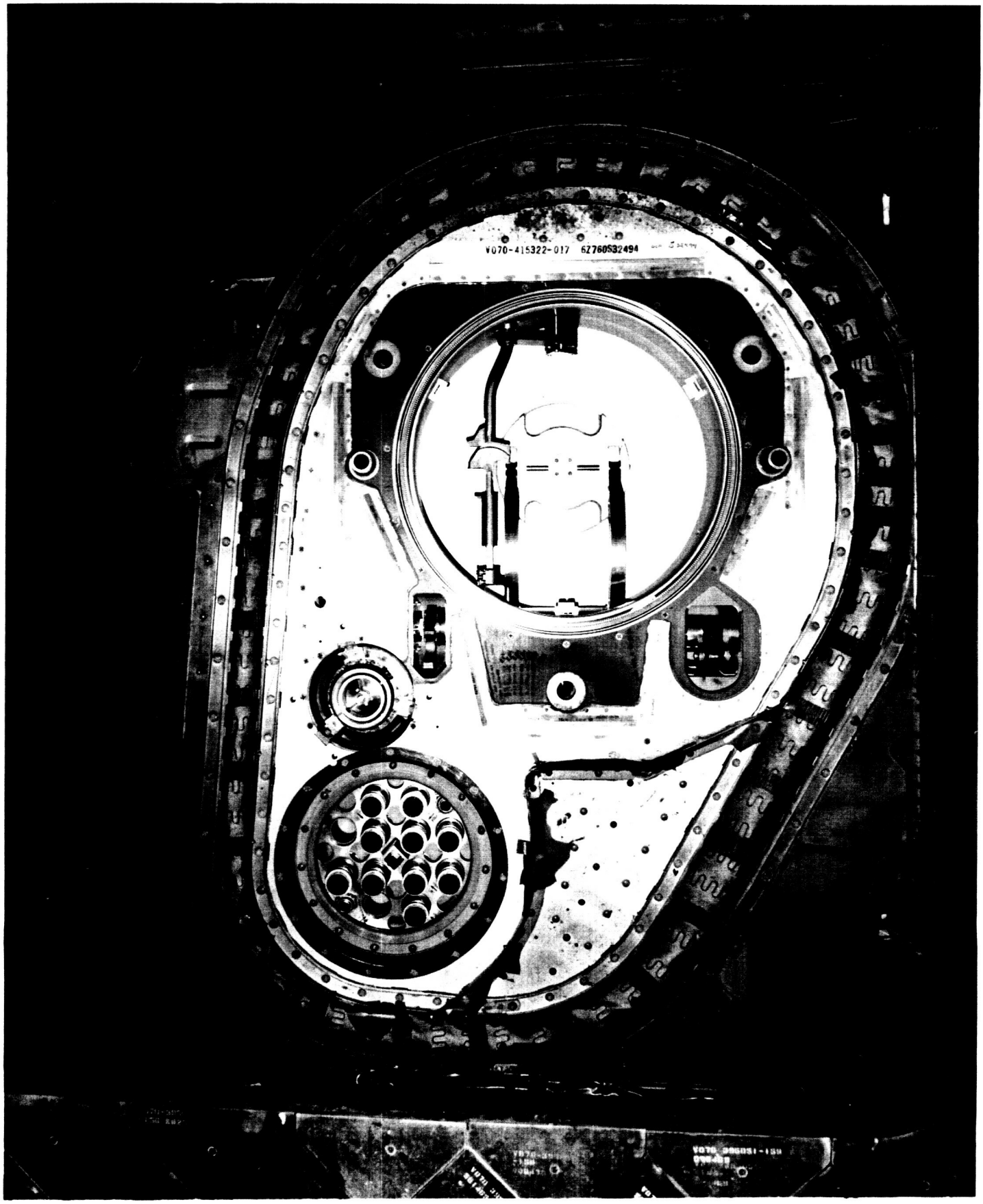
AVERAGES: > 1" = 23.2, TOTAL = 119.7



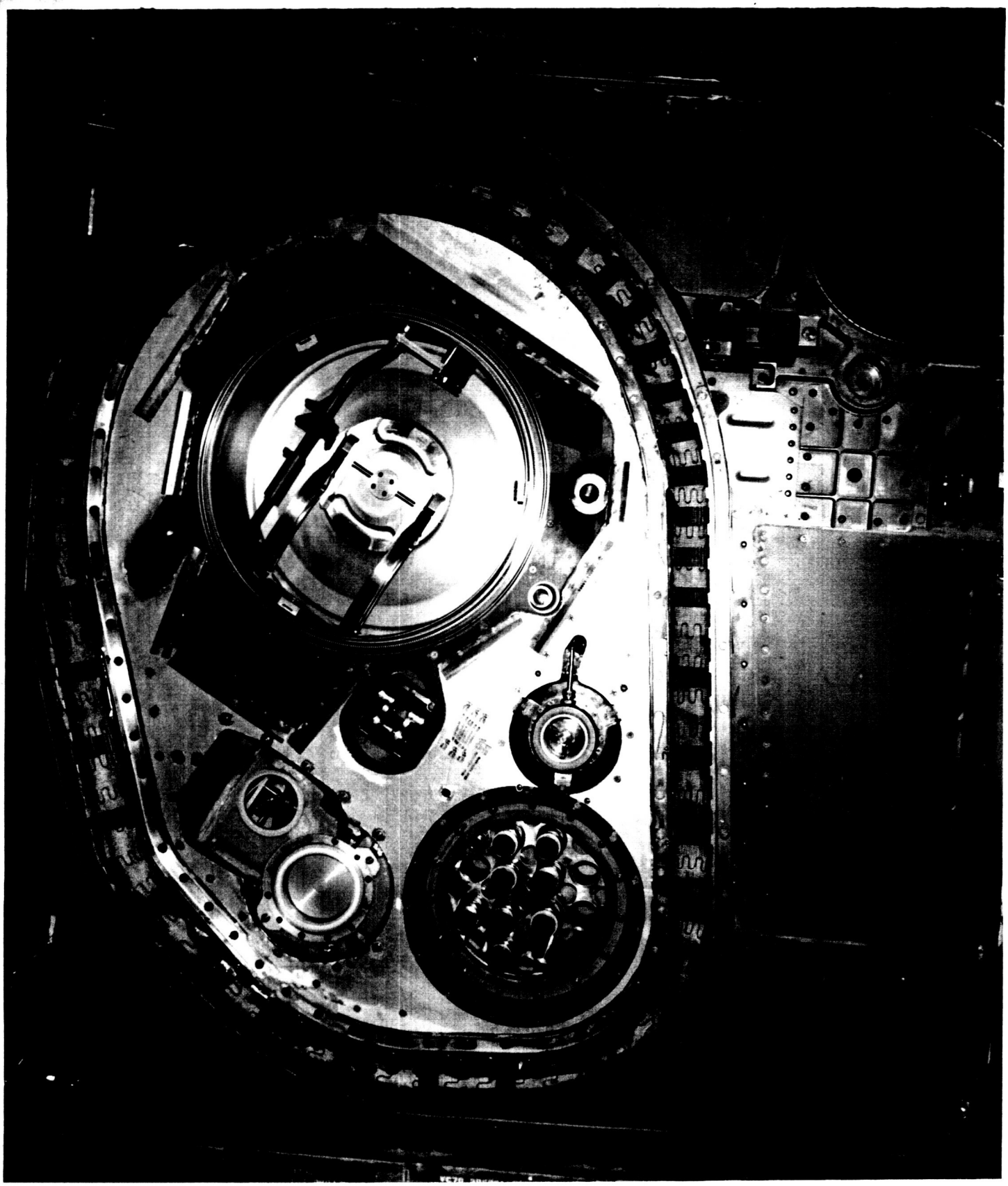
Typical tile damage on the Orbiter lower surface



Tile damage on the nose gear door

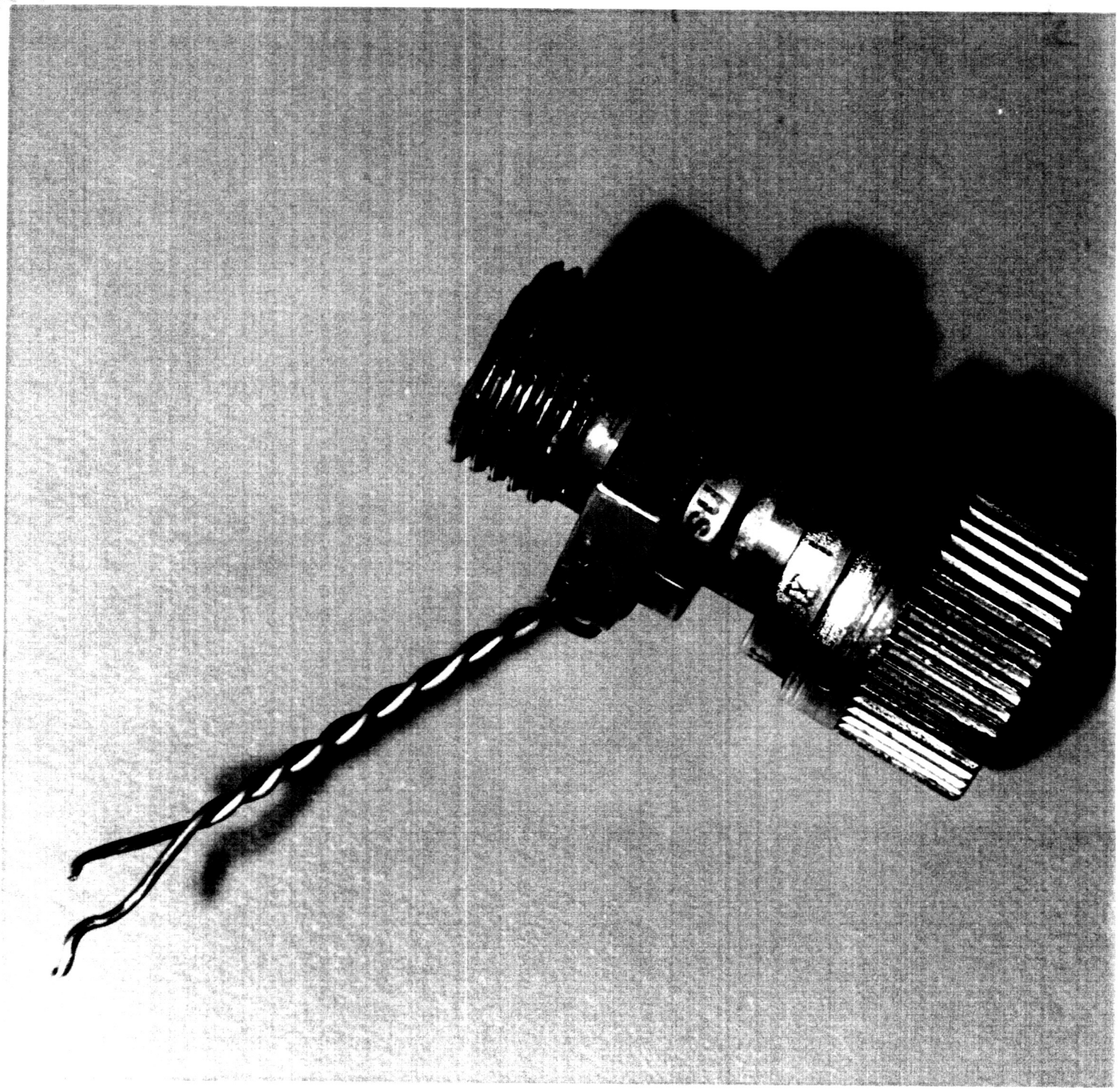


Overall view of the LO2 ET/ORB umbilical. The separation ordnance device debris plunger in EO-3 was seated and appeared to have functioned properly. There was no significant heat intrusion past the ET door thermal barrier.

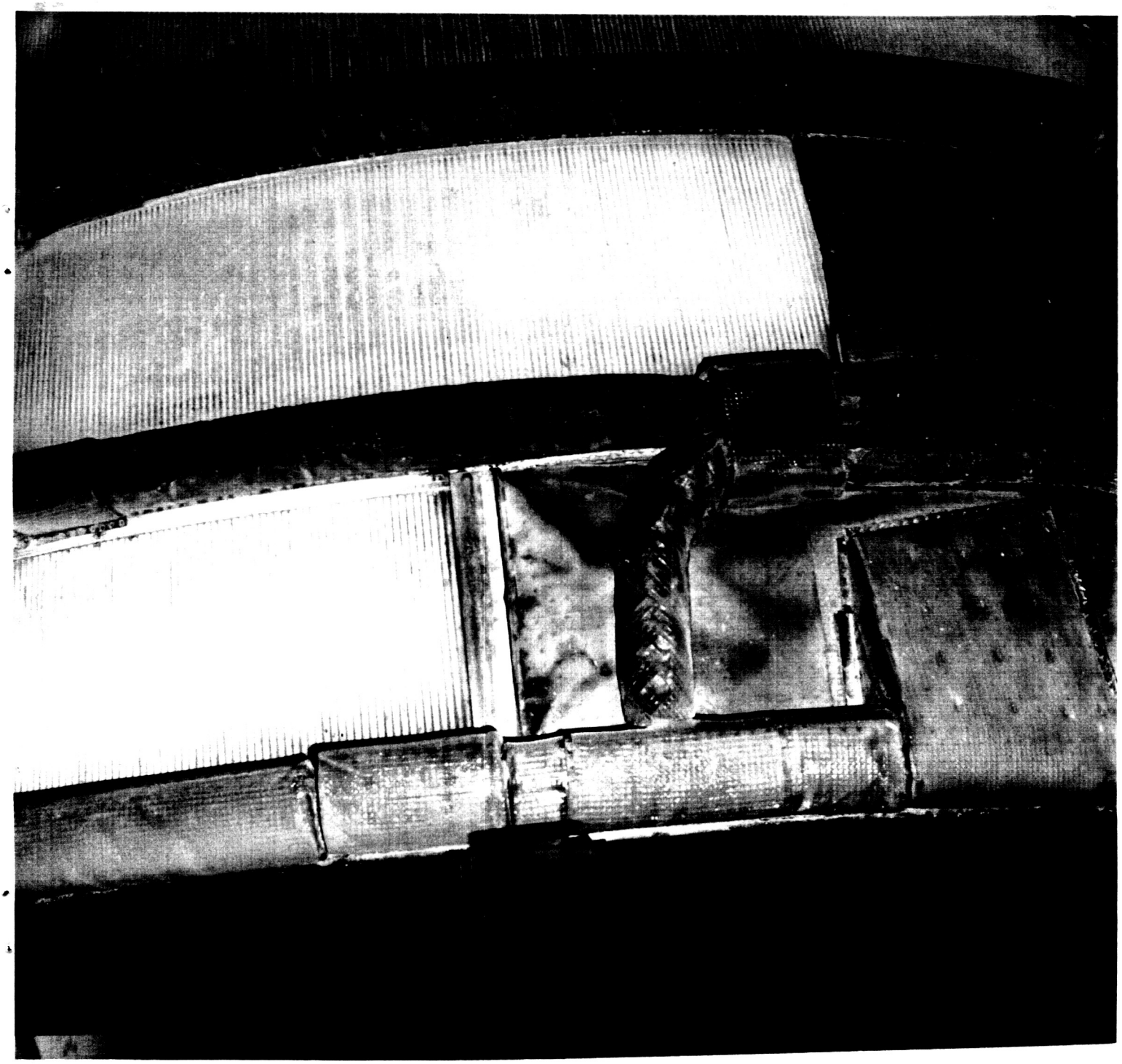


Overall view of the LH2 ET/ORB umbilical. The separation ordnance device debris plunger in EO-2 was seated and appeared to have functioned properly. There was no significant heat intrusion past the ET door thermal barrier.

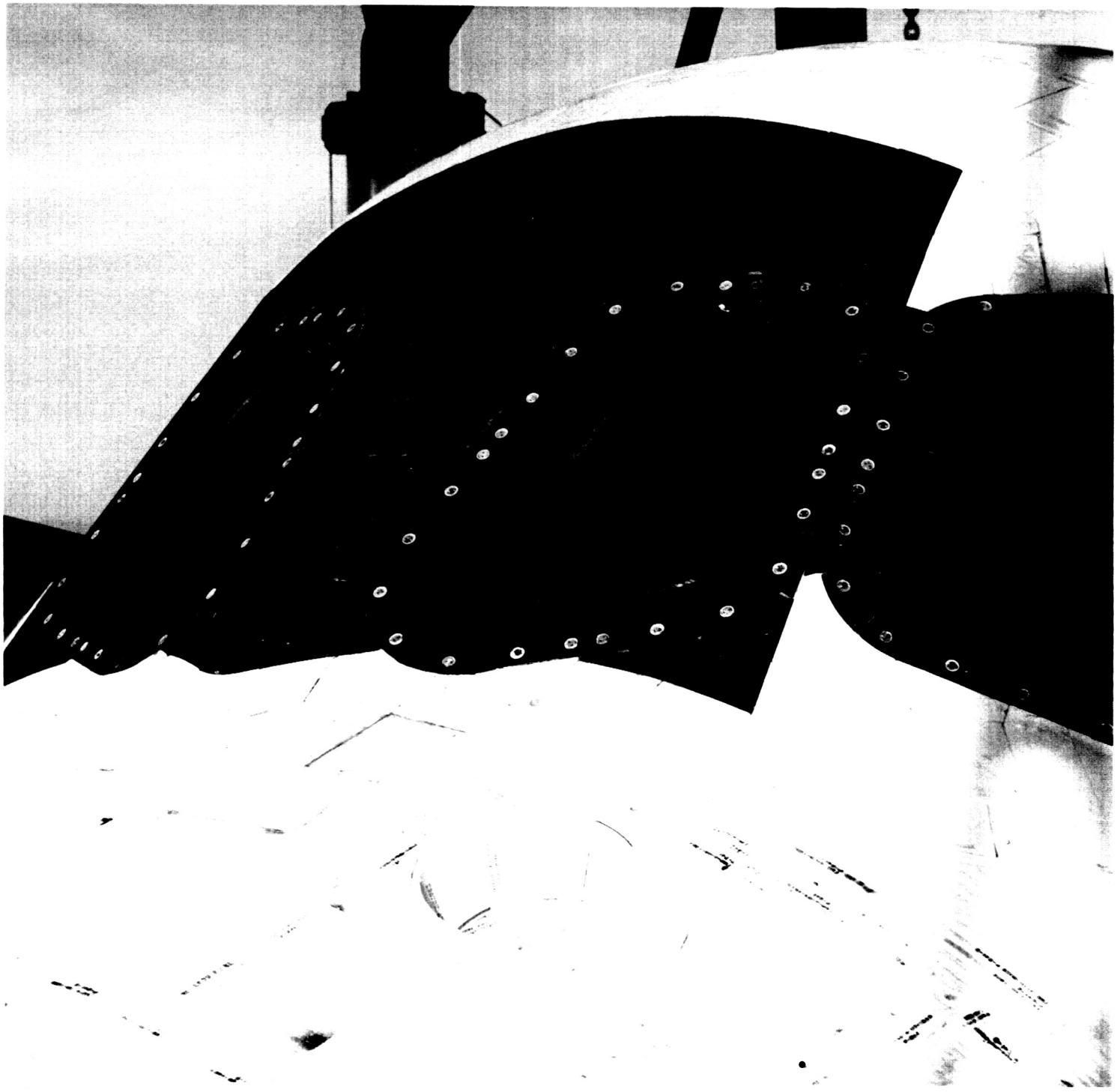
Beta tape adhered to the LO2 ET/ORB umbilical aft door hinge



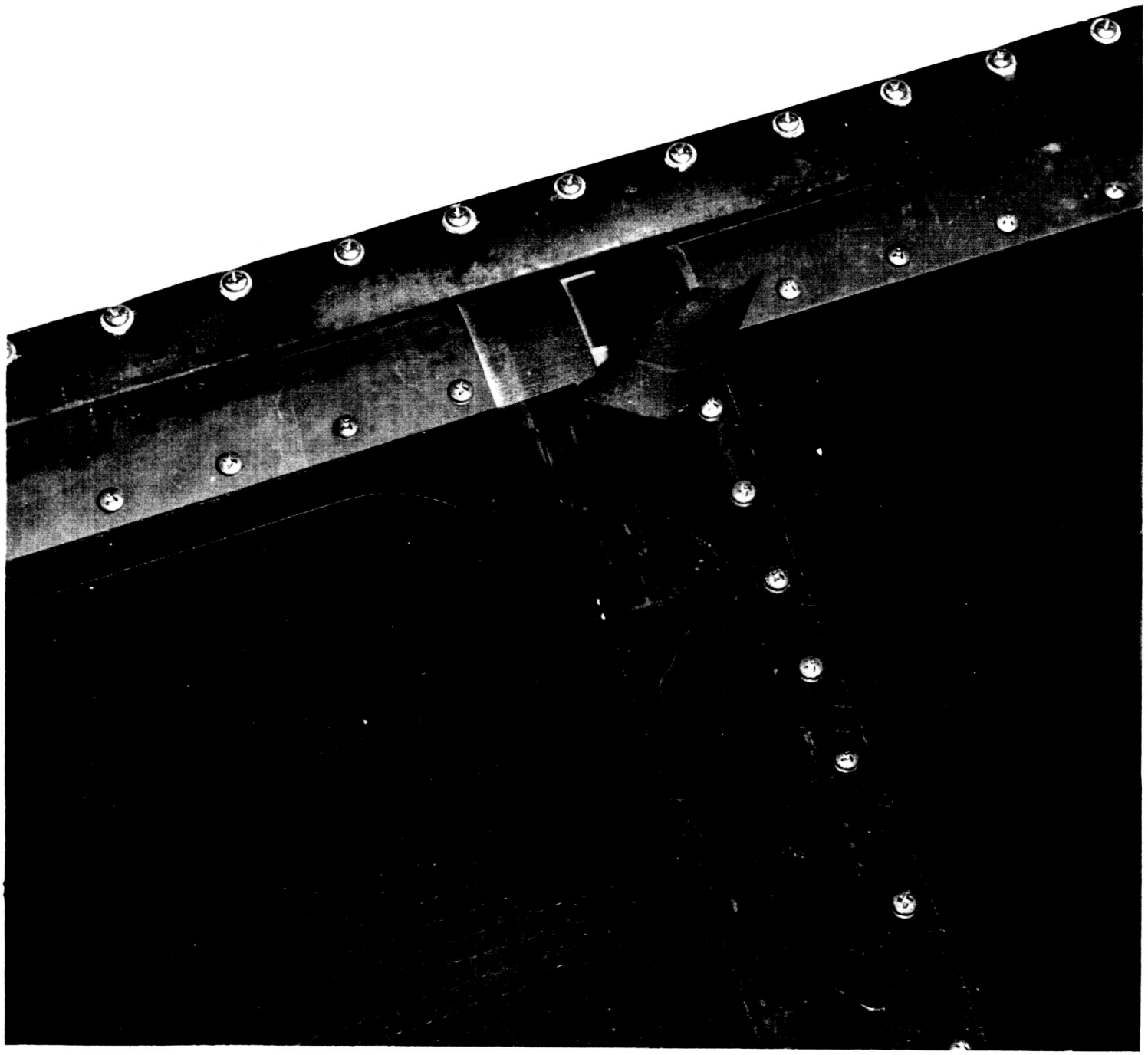
An assembly consisting of an ordnance connector, detonator, and lockwire fell from the ET/ORB LH2 umbilical after the ET doors were opened. Part numbers on the assembly identified it as originating from the LH2 umbilical aft separation device.



Although liftoff films recorded a small hydrogen leak on the SSME #2 nozzle cold wall near the aft manifold/steer horn, no external damage or burnt insulation was visible.



Orbiter windows #1, #2, #5, and #6 were lightly hazed. Windows #3 and #4 exhibited moderate to heavy hazing and had numerous streaks. A greater than previously observed number of damage sites occurred on the perimeter tiles of windows #3 and #4. This damage may have been caused by the RTV used to bond paper covers to the FRCS nozzles.



The forward edge of the side seal between flipper doors #1 and #2 on the RH inboard elevon was peeled aft approximately three inches.

9.0 DEBRIS SAMPLE LAB REPORTS

A total of 9 samples were obtained from Orbiter OV-103 during the STS-44 post landing debris assessment at Ames-Dryden Flight Research Facility (ADFRF), California (Figure 19). The nine submitted samples consisted of 8 window wipes and 1 residual sample from the LO2 ET/ORB umbilical plate. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves the identification and correlation of particles with respect to composition, thermal (mission) effects, and availability. Debris sample results and analyses are listed by Orbiter location in the following summaries.
Note: Chemical fingerprinting of the organic samples is a continuing effort. Specific results will be published when available.

Orbiter Windows

Results of the window sample analysis revealed the presence of the following materials:

1. Metallics
2. Silica tile, glass fibers, insulation
3. Cerium-rich materials
4. Paints, dust, rust, salt
5. Organics
6. Earth compounds

Debris analysis provides the following correlations:

1. Metallic particles (brass, aluminum, and carbon steel alloys) are common to SRB/BSM exhaust residue but are not considered a debris concern in this quantity (micrometer) and have not generated a known debris effect.

2. Silica tile, glass fibers, and insulation originate from Orbiter TPS (thermal protection system).

3. Cerium-rich materials originate from Orbiter window polishing compounds.

4. Paint is of flight hardware/facility/GSE origin. Dust and salt are naturally-occurring landing site products.
   Rust is an SRB/BSM exhaust residue.

5. Organics are being analyzed by chemical fingerprint (Infrared spectroscopy) method; results are pending. This detailed process is more difficult due to small sample quantity (less than 350 um).

6. Earth compounds (muscovite, calcite, and alpha-quartz) are of landing site origin.

LO2 ET/ORB UMBILICAL

Results of the umbilical sample revealed the presence of the following materials:

1. Silica-Magnesium material
2. Organics

Debris analysis provides the following correlations:

1. Silica-Magnesium material is seen as a possible filler material in the unidentified organics. Chemical fingerprint (infrared spectroscopy) results will be published when available.

2. Organics are being analyzed by chemical fingerprint (Infrared spectroscopy) method; results are pending. This detailed process is especially difficult in small sample quantities.

Conclusions

The Orbiter tile TPS sustained damage to a less than average degree on the STS-44 mission. The chemical analysis results from post flight samples were consistent in that no data pointed to a single source of damaging debris.

Orbiter window samples provided evidence of SRB/BSM exhaust, Orbiter TPS, Orbiter window polishing compound, landing site products, organics, and paint.

The Orbiter/ET umbilical sample contained organic materials with possible inorganic fillers present. Detailed results of the organic material analysis are pending.

STS-43 "White Film" Material Analysis

Final test results of the STS-43 "white film" found on the runway, postlanding, indicate the recovered sample to be similar to the FRSI blanket coating (DC-92-007). This result is based on the chemical analyses of the recovered sample, the FRSI blanket repair coating (cab-o-sil), and the FRSI blanket coating materials. Analyses indicate the quantity of titanium dioxide in the recovered sample is most like the FRSI blanket coating (DC-92-007).

10.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 3 Post Launch Anomalies, but no IFA candidates, were observed on the STS-44 mission.

10.1 LAUNCH PAD/FACILITY

1. No major items.

10.2 EXTERNAL TANK

1. No items.

10.3 SOLID ROCKET BOOSTERS

1. The LH forward skirt, LH forward segment, and LH forward center segment sustained structural damage from either water impact "slap down" loads or parachute deployment side loads. Assessment indicated the damage was not a source of debris nor was caused by a debris problem.

10.4 ORBITER

1. Film item E-16 was reviewed to investigate orange vapors and a reported burning of insulation on SSME #2 between the #9 hatband and the coolant manifold at the -Z axis. The engineering consensus concluded a very small hydrogen leak occurred at the aft manifold or behind the steer horn cover resulting in a stream of vapor to the #9 hatband and around the -Z bracket. The engineering consensus further concluded that no material, such as insulation, was burning.

2. SSME ignition vibration/acoustics caused the loss of tile surface coating material from six locations on the base heat shield, three locations on the LH RCS stinger, and one location on the aft face of the RH RCS stinger.

3. An ordnance assembly from the LH2 ET/ORB umbilical aft pyro debris container lay on the runway after ET door opening.

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15. Supplementary Notes

16. Abstract

A Debris/Ice/TPS assessment and photographic analysis was conducted for Space Shuttle Mission STS-44. Debris inspections of the flight elements and launch pad were performed before and after launch. Ice/frost conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography was analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and photographic analysis of Mission STS-44, and their overall effect on the Space Shuttle Program.

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