NASA Technical Memorandum TM 103826

508980

Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-48

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National Aeronautics and
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Gregory N. Katnik
NASA/Kennedy Space Center

Scott A. Higginbotham
NASA/Kennedy Space Center

J. Bradley Davis
NASA/Kennedy Space Center

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KSC FORM 16-12 (REV. 6/76)

DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-48

September 12, 1991

Prepared By:

Scott A. Higginbotham
NASA/Kennedy Space Center
TV-MSD-22

J. Bradley Davis
NASA/Kennedy Space Center
TV-MSD-22

Approved:

Gregory N. Katnik
Lead, Ice/Debris/Photo Analysis
NASA/Kennedy Space Center
TV-MSD-22

Pedro J. Rosado
Chief, ET Mechanical Sys
NASA/Kennedy Space Center
TV-MSD-22

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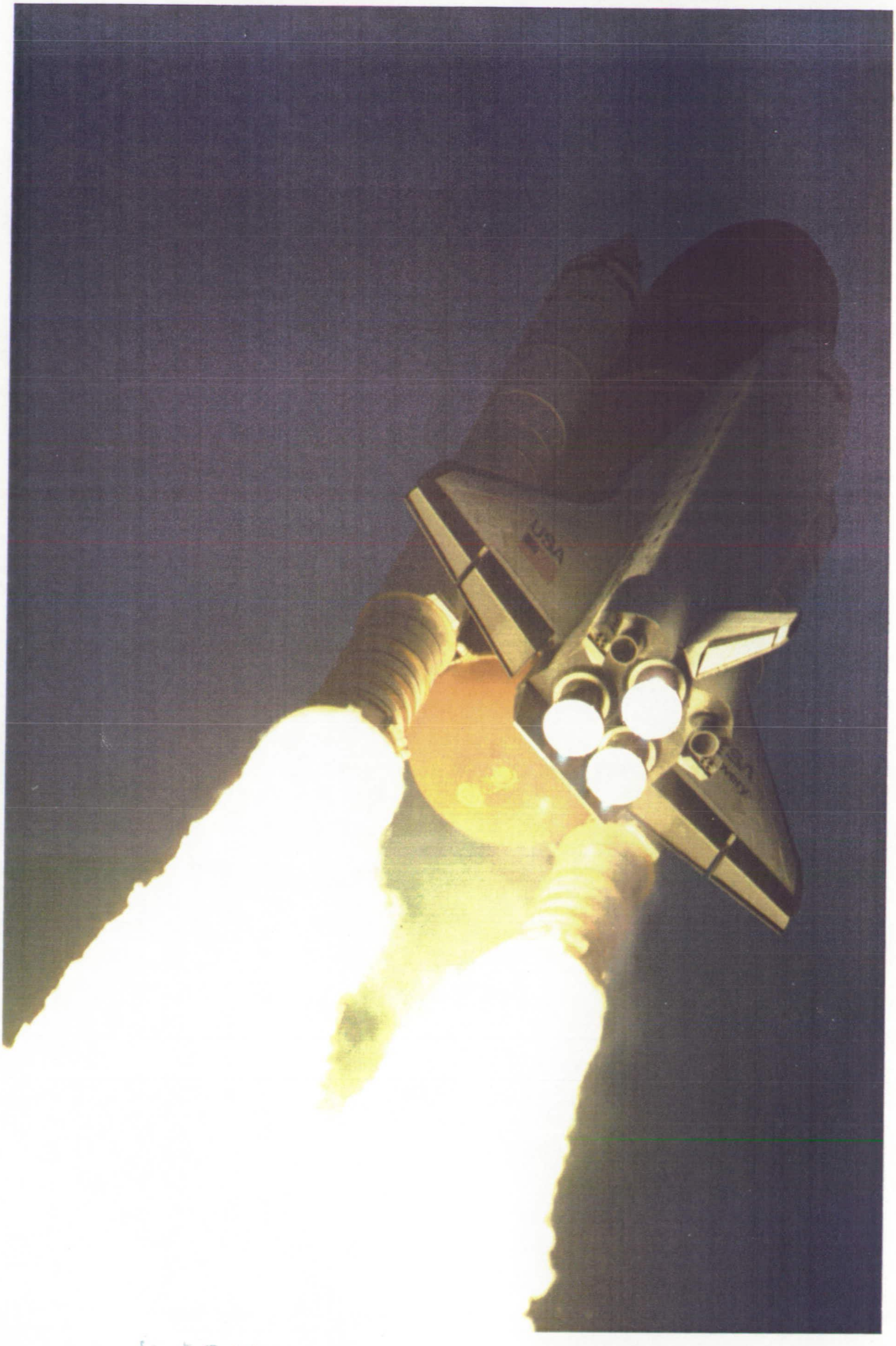
FOREWORD

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-48 was launched at 7:11 p.m. local 9/12/91

1.0 Summary

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 11 September 1991. The detailed walkdown of Launch Pad 39A and MLP-3 also included the primary flight elements OV-103 Discovery (13th flight), ET-42 (LWT-35), and BI-046 SRB's. There were no vehicle anomalies. Facility discrepancies were entered into OMI S0007, Appendix K, for resolution prior to cryoload.

The vehicle was cryoloaded for flight on 12 September 1991. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no ice or TPS conditions outside of the established data base. There were no ET anomalies. Light condensate, but no ice or frost, was present on the acreage areas of the External Tank. Three 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. Ice Team inspection of the south holddown posts revealed debris in the haunch areas. The debris included a metal universal clamp, safety wire with lead seal, tie wrap fragments, and cork closeout trimmings. The debris was removed by the Ice Team prior to launch.

A debris inspection of Pad 39A was performed after launch. No flight hardware or TPS materials were found with the exception of two Orbiter base heat shield Q-felt plugs. Launch damage to the holddown posts was minimal. EPON shim material on the south holddown posts was intact and bonded to the shoes. Frangible nut/ordnance fragments were visible resting on the stud in holddown post #5. The GH2 vent line had latched properly. Damage to the facility overall was minimal.

A total of 117 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. After liftoff, 5 ordnance fragments including two NSI booster pieces or frangible nut webs (3 inches in length), fell from the HDP #5 DCS/stud hole. Two dark particles were visible between the aft skirt foot and the HDP #7 shoe, but could not be identified as ordnance fragments. These particles may have been pieces of shim putty or shim material. This was the third flight utilizing the new optimized frangible links. There was no evidence of stud hang-ups on any of the holddown posts. Two large orange flashes occurred in the SSME plume during ascent at T+29 seconds MET from SSME #2 and at T+31 seconds MET from SSME #1. At T+58 seconds MET, the vehicle passed through a layer of moisture or high cirrus ice particles and a bright cloud of condensation/reflection surrounded the vehicle. The event was caused by atmospheric effects and was not a vehicle

problem. SRB separation was nominal. Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were normal.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums exhibited a total of 77 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. Although all HDP Debris Containment System (DCS) plungers were seated, post flight disassembly of the DCS housings revealed loss of ordnance debris from HDP #2 and #5. The overall system debris retention averaged 92 percent.

A 2.9" x 2.75" area of MSA-2 was missing from the LH frustum on the stiffener below the BSM's near the 381 ring. A laboratory analysis was performed at MSFC on the MSA-2 divot area. Examination of the surrounding material showed that the exposed surfaces were clean and free of sooting/charring/ heat effects in an aero-thermal environment. Hypalon peelback occurred laterally and was not in the direction of the nosecone (forward flight). The report concluded the MSA-2 was lost either during the late stages of descent, at water impact, or during retrieval operations.

The upper left and lower right BSM covers on the LH frustum had locked in the fully opened position and then had been subsequently deformed. The lower right attach ring was fractured at one location. The upper right BSM cover was missing. The substrate at the fracture planes, including the threads of the exposed screws, were sooted. Curved TPS cuts/substrate indentations near the location of the missing cover matched the size of a BSM cover lip. A laboratory analysis was performed on the remaining attach hardware of the missing aero heatshield cover. It should be noted that covers have been lost on seven previous flights (STS-2, 3, 4, 9, 11, 17, 28) and were attributed to re-entry, water impact, or retrieval operations. The analysis of the STS-48 damage showed that the cover did not fail prior to BSM firing. (Radar data at the time of BSM firing and SRB separation could not conclusively prove the forward BSM cover came off in the vicinity of the Orbiter). There were no unusual aero loads during the ascent and separation phases which could cause the loss of the cover. (Max Q for the SRB's occurs during re-entry). A gouge in the cork, which was attributed to an impact from the lost cover, just forward and between the two upper cover positions negated the possibility of losing the cover during ascent or separation. The MSFC study concluded the cover came off during re-entry and was not a debris threat to the Orbiter. However, the report did not explain why normal aerodynamic loading during re-entry caused this kind of damage. The IFA was closed based on the results of the study.

A detailed post landing inspection of OV-103 (Discovery) was conducted on September 18-19, 1991, at Ames-Dryden (EAFB) in the Mate-Demate Device. The Orbiter TPS sustained a total of 182 hits, of which 25 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 100 hits, of which 14 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of hits was slightly greater than average and the number of hits with a major dimension of 1 inch or larger was slightly less than average. A greater than previously observed number of damage sites were noted on the perimeter tiles of Orbiter windows #1 through #6. Most of the impact sites were only surface coating losses or were no more than 1/16th inch deep. This damage may have been caused by the RTV used to bond paper covers to the FRCS nozzles. A cluster of 7 hits with one larger than one inch (3" x 2" x 1") was present on the leading edge of the vertical stabilizer near the root. Damage in this area is uncommon and may possibly be related to the damage around the forward facing windows. The ET/ORB separation ordnance device plungers were seated and appeared to have functioned properly.

A variety of residuals were present in the Orbiter window samples and indicated sources such as Orbiter TPS, SRB BSM exhaust residue, natural landing site products, organics, and paint. The lower surface tile sample indicated localized heating from re-entry. The residual sample recovered from the damage site indicated tile repair material and a material variety similar to that observed in the window sample area. The ET/Orbiter samples provided indications of Shuttle Program processing and earthen environment residuals. This data does not indicate a single source of damaging debris and all of the materials are similar to those documented in previous post-landing sample reports.

A total of eight Post Launch Anomalies, including one IFA candidate, were observed during this mission assessment.

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 11 September 1991 at 1500 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. Hoffman	LSOC - SPC	Supervisor, ET Mech Systems
R. Seale	LSOC - SPC	ET Processing, Ice Assess
J. Blue	LSOC - SPC	ET Processing, Ice Assess
W. Richards	LSOC - SPC	ET Processing, Ice Assess
D. Thorpe	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
K. Mayer	RI - LSS	Vehicle Integration
S. Otto	MMC - LSS	ET Processing
G. Witters	USBI - LSS	SRB Processing
J. Cook	MTI - LSS	SRM Processing
M. Barber	LSOC - SPC	Safety Engineering

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

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 11 September 1991 from 1600 - 1720 hours. The detailed walkdown of Launch Pad 39A and MLP-3 also included the primary flight elements OV-103 Discovery (13th flight), ET-42 (LWT-35), and BI-046 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

There were no vehicle anomalies.

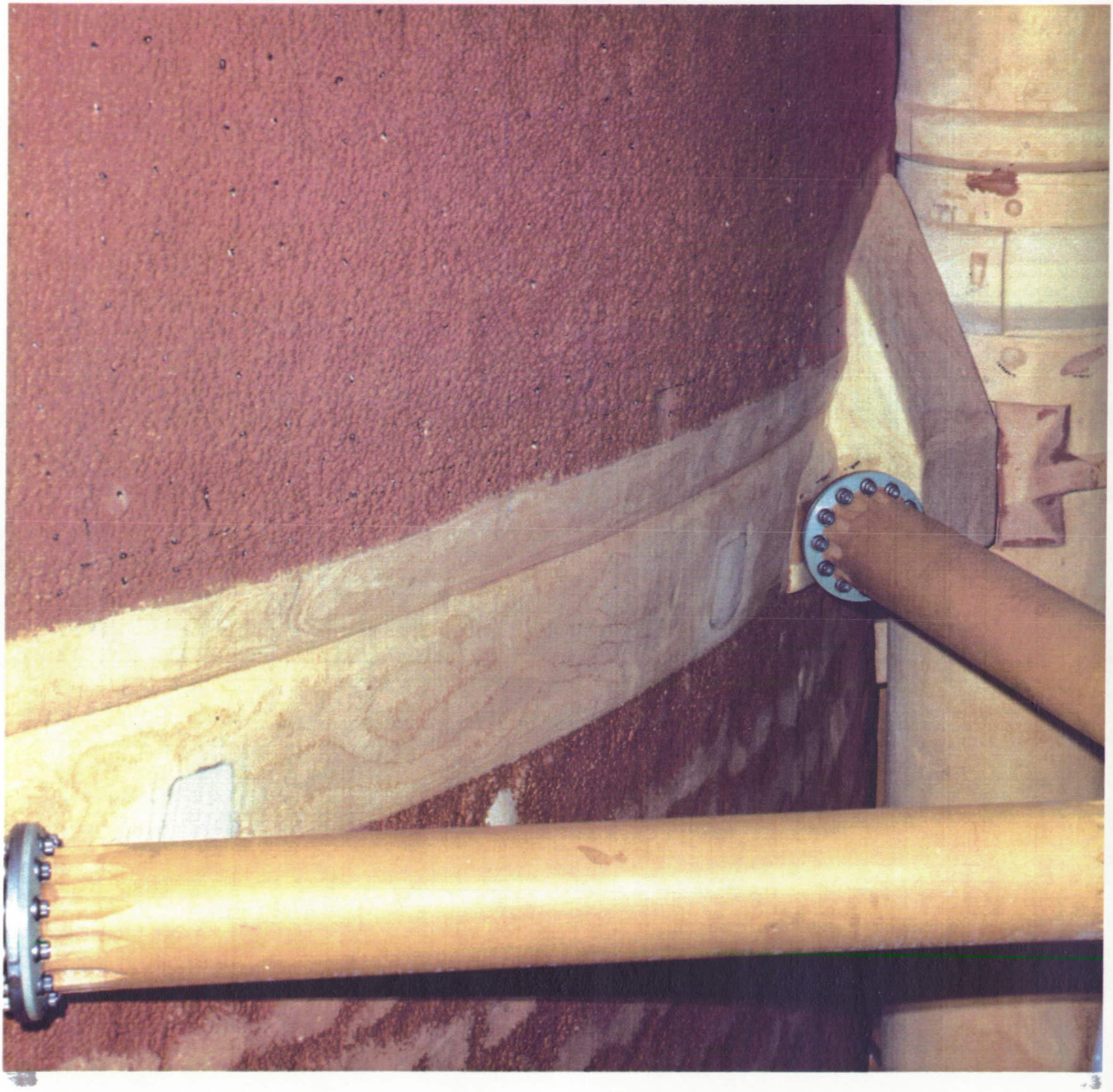
Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload/launch, temporary hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical until a permanent sensor could be designed and installed. The tygon tubes are intended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

An electrical conduit box cover adjacent to the Portable Purge Unit (PPU) outlets on the MLP zero level (northwest corner) was loose.

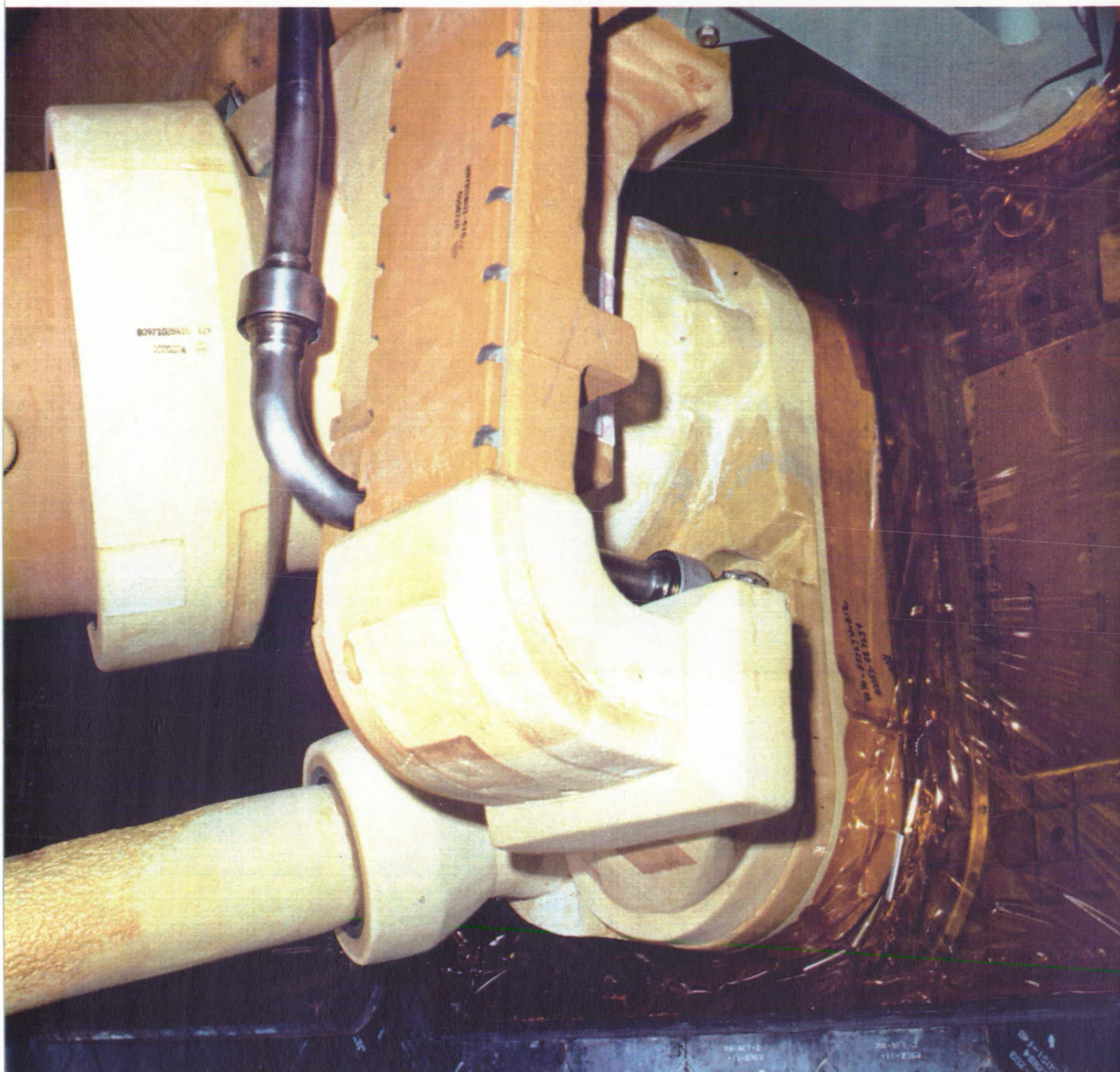
Holddown post hardware lay on the MLP deck near the northeast corner of the RH SRB exhaust hole.

Cleanup of the MLP deck and pad surface was almost complete at the time of the inspection. A universal hose clamp lay near the base of HDP #5. Tape and a plastic bag lay on the HDP #1 haunch. Debris, such as safety wire, tie wraps, K5NA pieces, and instafoam trimmings were present on all the south holddown post haunch areas.

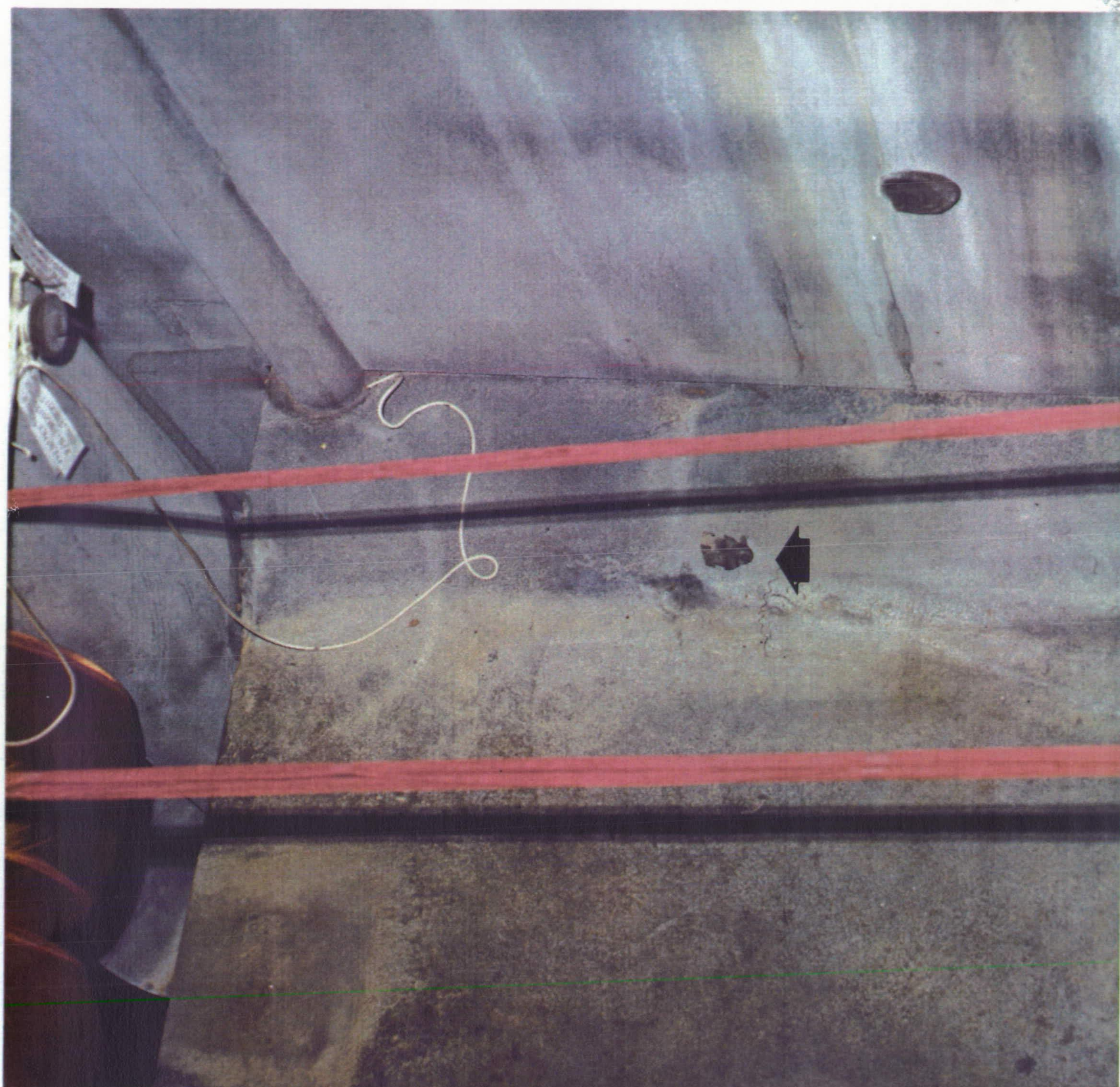
The facility discrepancies were worked real-time or entered into OMI S0007, Appendix K, for resolution prior to vehicle tanking.



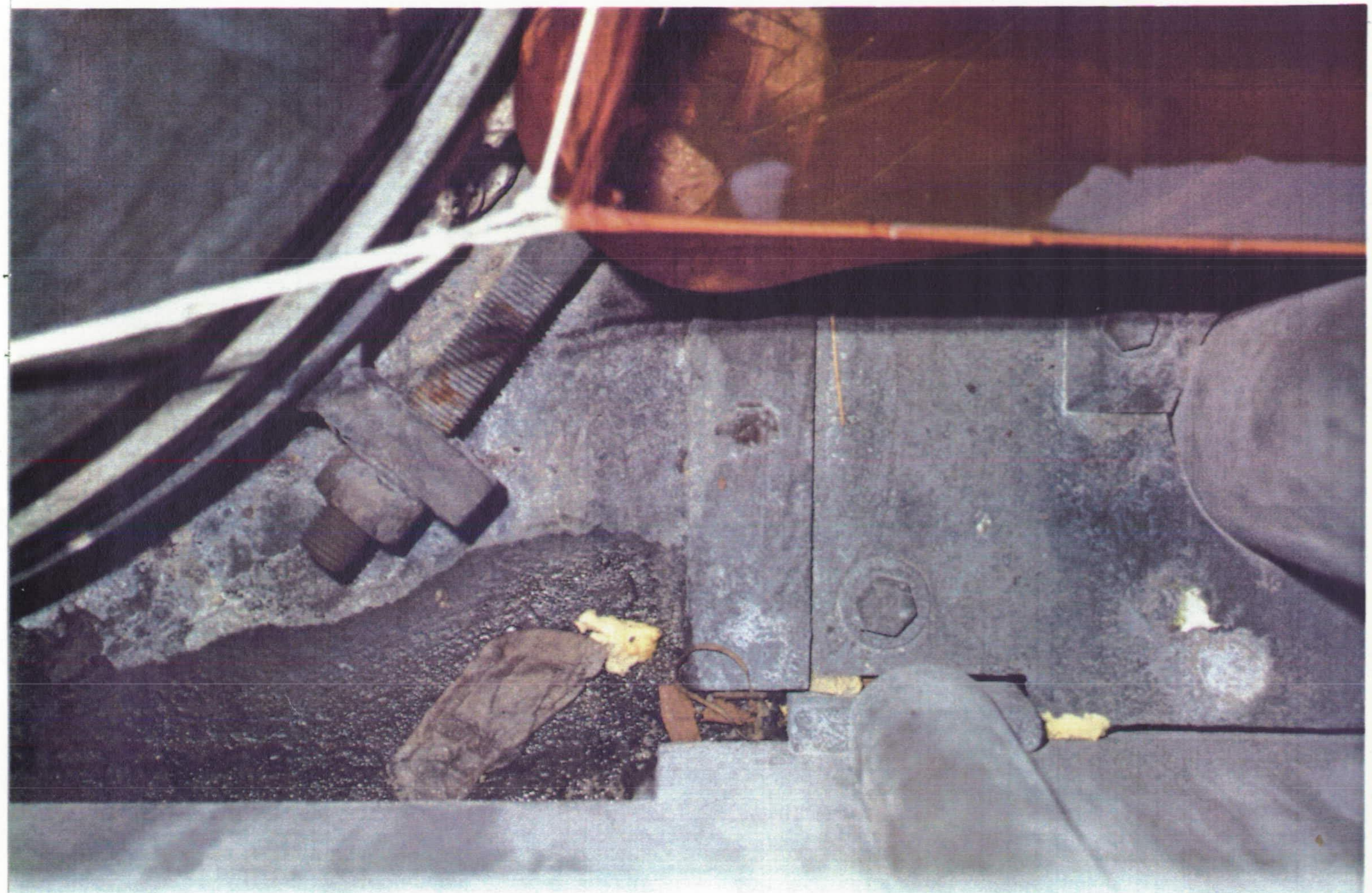
Bipod jack pad closeouts prior to cryogenic loading



Overall view of the LH2 ET/ORB umbilical



Universal metal clamp lay on the holddown post haunch near the base of HDP #5



K5NA and instafoam trimmings, tie wrap pieces, and other debris were present around the bases of the south holddown posts and in the haunch areas

4.0 LAUNCH

STS-48 was launched at 12:23:11:04 GMT (7:11:04 p.m. local) on 12 September 1991.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 12 September 1991 from 1320 to 1530 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:	84.0 F
Relative Humidity:	63.9 %
Wind Speed:	7.8 Knots
Wind Direction:	029 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.

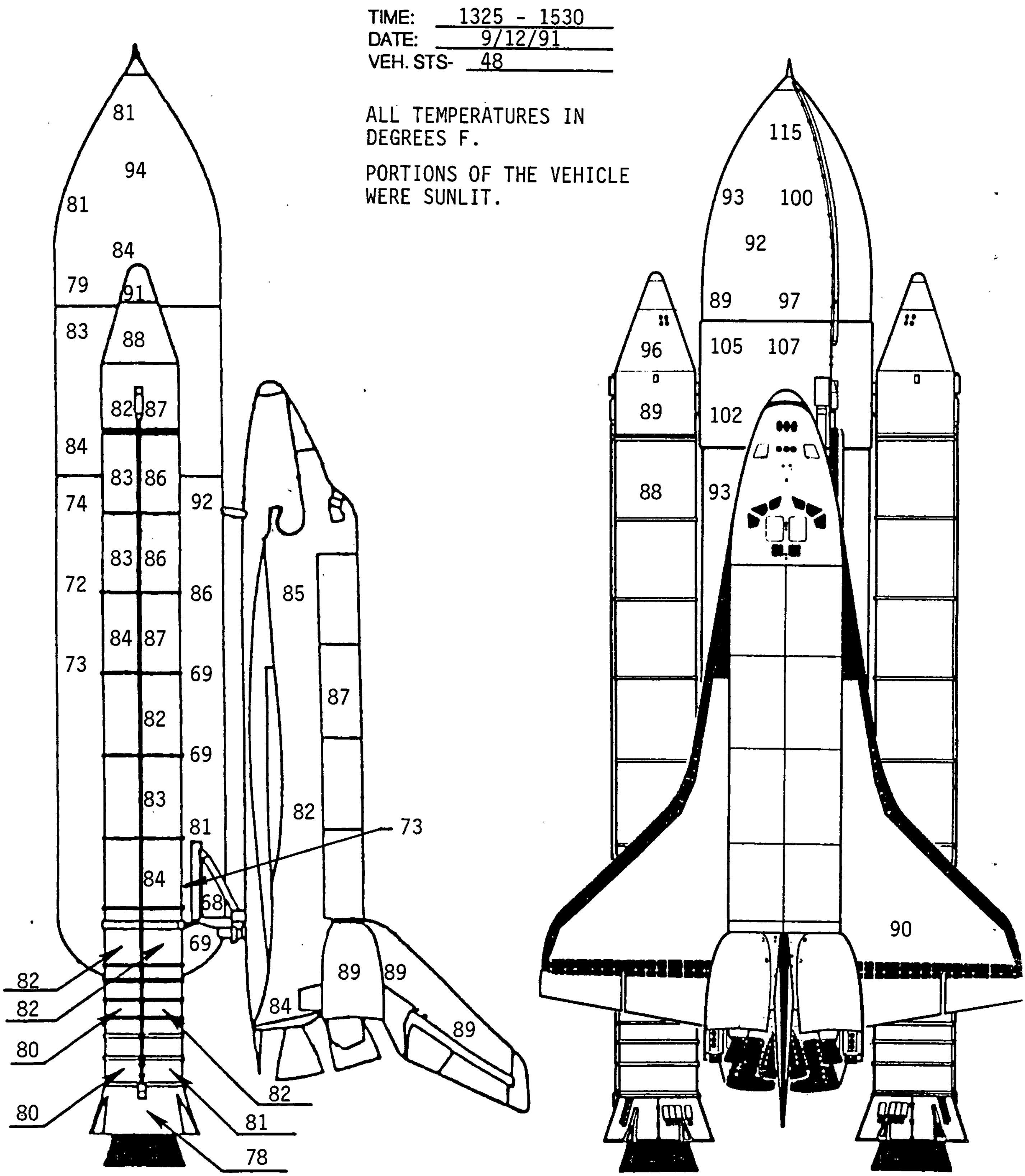
4.2 ORBITER

No Orbiter tile anomalies were observed. All RCS paper covers were intact. There was no evidence of a leak or a liquid level line on any of the RCS paper covers. The water spray boiler plugs were intact. The average Orbiter surface temperature was 85 degrees F. The average surface temperatures of the engine mounted heat shields were 75 degrees F for SSME #1, 73 degrees F for SSME #2, and 77 degrees F for SSME #3. All of the SSME heat shields were wet with some condensate. Light frost coated the SSME #1 heat shield-to-nozzle interface at the 3-10 o'clock position and the SSME #2 heat shield-to-nozzle interface at the 3-4, 5-10, and 12 o'clock positions. No GOX vapors originated from inside the SSME nozzles. Some condensate was present on base heat shield tiles between SSME #2 and #3 and outboard of SSME #2.

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. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 81 and 88 degrees F. In comparison, the Cyclops radiometer gave measurements between 77 and 90 degrees F and the SRB GEI showed temperatures between 86 and 99 degrees F. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 81 degrees F, which was within the required range of 44-86 degrees F.

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



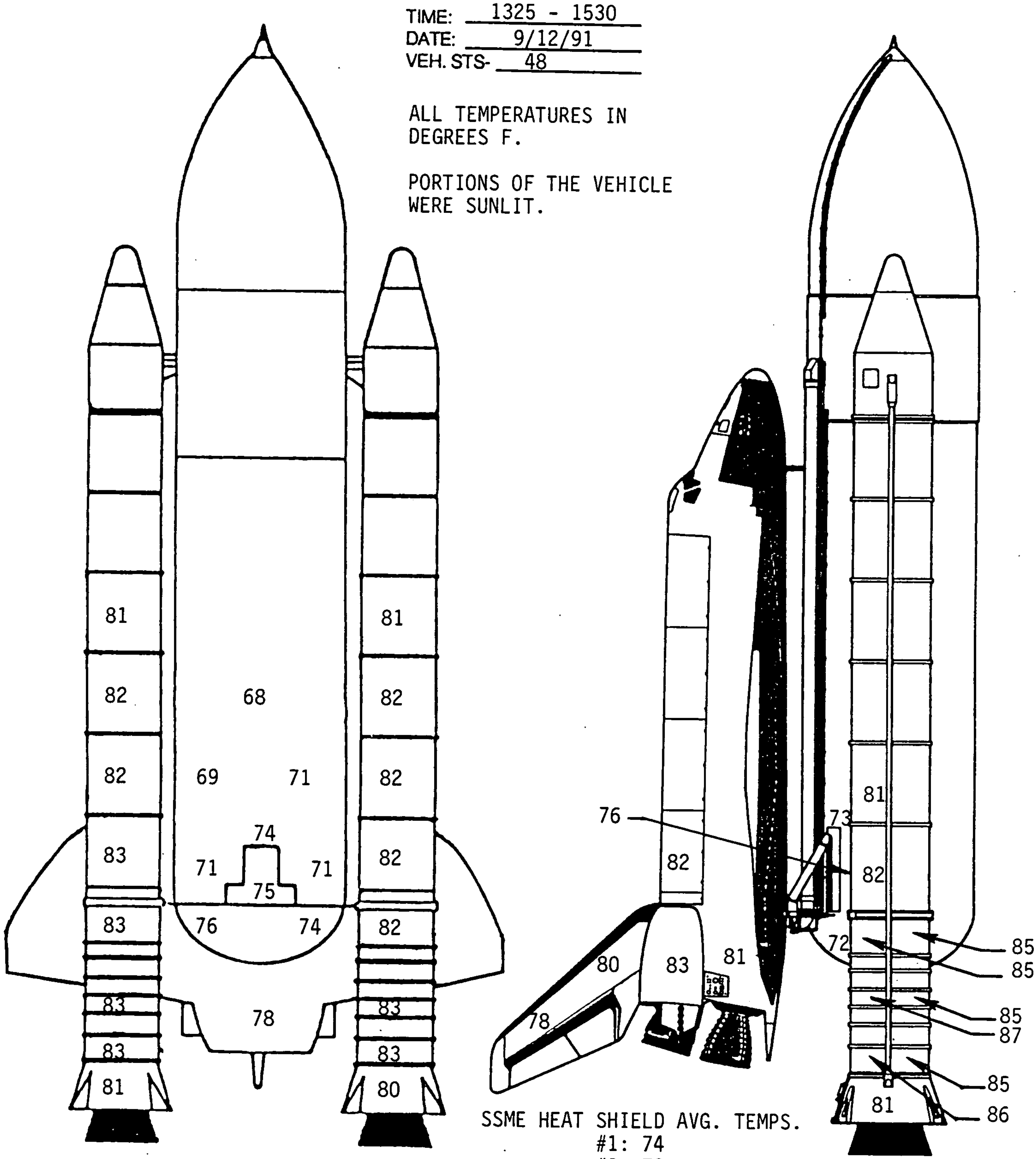
EGG/V-343D

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

TIME: 1325 - 1530
DATE: 9/12/91
VEH. STS- 48

ALL TEMPERATURES IN DEGREES F.

PORTIONS OF THE VEHICLE WERE SUNLIT.



SSME HEAT SHIELD AVG. TEMPS.
#1: 74
#2: 72
#3: 77

4.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 1100 to 1900 hours and the results tabulated in Figures 3 and 4. The program predicted condensate with no ice accumulation on all TPS acreage surfaces.

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. The STI measured surface temperatures from 115 (sun) to 81 (shade) degrees F on the ogive and from 97 (sun) to 79 (shade) degrees F on the barrel section. In comparison, SURFICE predicted 71 degrees F on the ogive and 67 degrees F on the barrel and the Cyclops IR radiometer measured temperatures from 122 (sun) to 77 (shade) on the ogive and from 103 (sun) to 74 (shade) degrees F on the barrel.

The intertank TPS acreage was dry. There were no TPS anomalies. One small frost spot appeared in a stringer valley at the LH2 tank-to-intertank +Y-Z flange. No unusual vapors or ice formations were present on the ET umbilical carrier plate. Both the STI and the Cyclops IR radiometer measured surface temperatures that averaged 107 in the sun and 83 in the shade.

The upper LH2 tank acreage was dry. The lower LH2 tank acreage and aft dome TPS acreage were covered with a light amount of condensate. There were no ice/frost accumulations on the acreage. The STI measured surface temperatures from 92 (sun) to 72 (shade) degrees F on the upper LH2 tank and from 81 (sun) to 68 (shade) degrees F on the lower LH2 tank. In comparison, SURFICE predicted 64 degrees F on the upper LH2 tank and 69 degrees F on the lower LH2 tank. The Cyclops IR radiometer measured temperatures from 96 (sun) to 72 (shade) degrees F on the upper LH2 tank and from 83 (sun) to 70 (shade) 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. 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.

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 baggie or on the acreage areas of the umbilical. Ice/frost fingers 3-6 inches in length had formed on the

STS- 48	TEST S0007 LAUNCH															DATE: 12 Sept. 1991				T-0 TIME: 19:11:04 DATE: 9/12/91				NASA KSC Ice/Frost/Debris Team	
ORBITER 103	ET 42	SRB BI-046	MLP 3	PAD A	LO2 CHILLDOWN TIME: 10:09 SLOW FILL TIME: 10:47 FAST FILL TIME: 11:00 REPLENISH TIME: 13:00											LH2 CHILLDOWN TIME: 10:09 SLOW FILL TIME: 10:19 FAST FILL TIME: 10:42 REPLENISH TIME: 13:00									
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				
(EDT)	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
1100	84.80	64.0	71.99	2	287	II	1.18	65.52	0.0014	-0.1350	II	1.18	58.89	0.0029	-0.1104	II	0.86	57.60	0.0032	-0.1049	II	2.42	60.43	0.0034	-0.1065
1115	83.30	64.2	70.61	3	349	II	1.77	64.81	0.0014	-0.1263	II	1.77	57.18	0.0028	-0.1018	II	1.32	55.87	0.0031	-0.0962	II	2.97	60.68	0.0034	-0.1203
1130	84.00	62.6	70.58	8	357	II	4.72	69.42	0.0007	-0.2257	II	4.72	65.47	0.0028	-0.1941	II	3.52	62.47	0.0033	-0.1431	II	7.92	67.88	0.0024	-0.3067
1145	84.00	64.0	71.21	8	10	II	4.72	69.83	0.0008	-0.2292	II	4.72	65.90	0.0029	-0.1974	II	3.52	62.90	0.0034	-0.1457	II	7.92	68.30	0.0027	-0.3119
1200	83.60	63.2	70.46	7	6	II	4.13	68.71	0.0009	-0.2013	II	4.13	64.32	0.0029	-0.1702	II	3.08	61.05	0.0033	-0.1247	II	6.93	66.93	0.0028	-0.2682
1215	83.80	63.6	70.83	8	22	II	4.72	69.51	0.0008	-0.2265	II	4.72	65.57	0.0029	-0.1949	II	3.52	62.56	0.0034	-0.1436	II	7.92	67.98	0.0026	-0.3080
1230	84.00	61.6	70.13	8	20	II	4.72	69.13	0.0006	-0.2233	II	4.72	65.16	0.0027	-0.1918	II	3.52	62.17	0.0032	-0.1413	II	7.92	67.57	0.0023	-0.3030
1245	83.80	62.4	70.30	7	15	II	4.13	68.68	0.0009	-0.2011	II	4.13	64.28	0.0028	-0.1700	II	3.08	61.04	0.0032	-0.1246	II	6.93	66.89	0.0027	-0.2677
1300	84.40	62.2	70.79	8	10	II	4.72	69.71	0.0007	-0.2281	II	4.72	65.77	0.0028	-0.1964	II	3.52	62.80	0.0032	-0.1450	II	7.92	68.16	0.0024	-0.3100
1315	84.00	62.2	70.40	8	15	II	4.72	69.30	0.0007	-0.2248	II	4.72	65.34	0.0027	-0.1932	II	3.52	62.35	0.0032	-0.1424	II	7.92	67.75	0.0024	-0.3052
1330	84.20	63.0	70.96	9	14	II	5.31	70.13	0.0006	-0.2512	II	5.31	66.55	0.0027	-0.2190	II	3.96	63.77	0.0033	-0.1621	II	8.91	68.79	0.0022	-0.3469
1345	83.20	64.2	70.51	7	18	II	4.13	68.58	0.0010	-0.2004	II	4.13	64.18	0.0030	-0.1693	II	3.08	60.89	0.0034	-0.1239	II	6.93	66.81	0.0029	-0.2671
1400	83.80	64.0	71.01	8	17	II	4.72	69.62	0.0008	-0.2275	II	4.72	65.69	0.0029	-0.1958	II	3.52	62.68	0.0034	-0.1443	II	7.92	68.10	0.0026	-0.3094
1415	83.40	65.4	71.23	8	15	II	4.72	69.62	0.0010	-0.2275	II	4.72	65.67	0.0031	-0.1958	II	3.52	62.64	0.0035	-0.1442	II	7.92	68.12	0.0028	-0.3097
1430	84.20	64.4	71.58	9	9	II	5.31	70.54	0.0007	-0.2550	II	5.31	66.98	0.0029	-0.2227	II	3.96	64.19	0.0034	-0.1650	II	8.91	69.22	0.0025	-0.3527
1445	84.00	65.2	71.73	7	10	II	4.13	69.70	0.0011	-0.2088	II	4.13	65.35	0.0032	-0.1774	II	3.08	62.11	0.0035	-0.1304	II	6.93	67.96	0.0031	-0.2790
1500	84.20	63.6	71.22	7	114	II	4.13	69.44	0.0010	-0.2068	II	4.13	65.09	0.0030	-0.1755	II	2.24	58.85	0.0032	-0.1007	II	9.73	69.37	0.0021	-0.3795
1515	84.60	62.6	71.17	8	32	II	4.72	70.03	0.0007	-0.2308	II	4.72	66.12	0.0028	-0.1990	II	5.60	66.53	0.0030	-0.2270	II	9.68	69.44	0.0019	-0.3789
1530	84.20	62.4	70.69	7	30	II	4.13	69.09	0.0009	-0.2041	II	4.13	64.72	0.0029	-0.1729	II	4.90	65.14	0.0031	-0.1965	II	8.47	68.35	0.0023	-0.3284
1545	84.40	62.4	70.88	7	27	II	4.13	69.30	0.0009	-0.2056	II	4.13	64.94	0.0029	-0.1744	II	4.90	65.36	0.0031	-0.1982	II	8.47	68.56	0.0023	-0.3310
1600	84.60	60.8	70.34	7	24	II	4.13	69.03	0.0007	-0.2036	II	4.13	64.66	0.0027	-0.1724	II	4.90	65.07	0.0029	-0.1959	II	8.47	68.26	0.0020	-0.3271
1615	84.60	59.6	69.78	8	47	II	4.72	69.14	0.0004	-0.2232	II	4.72	65.17	0.0025	-0.1918	II	5.60	65.58	0.0026	-0.2187	II	9.68	68.49	0.0014	-0.3655
1630	83.20	62.0	69.53	6	37	II	3.54	67.34	0.0010	-0.1735	II	3.54	62.39	0.0028	-0.1430	II	4.20	62.82	0.0031	-0.1619	II	7.26	66.40	0.0025	-0.2718
1645	83.20	60.8	68.98	6	39	II	3.54	67.00	0.0009	-0.1712	II	3.54	62.03	0.0027	-0.1408	II	4.20	62.45	0.0030	-0.1594	II	7.26	66.03	0.0023	-0.2678
1700	83.00	62.0	69.33	7	33	II	4.13	67.74	0.0008	-0.1942	II	4.13	63.30	0.0028	-0.1633	II	4.90	63.72	0.0030	-0.1857	II	8.47	67.00	0.0022	-0.3120
1715	84.60	61.2	70.53	6	37	II	3.54	68.57	0.0009	-0.1814	II	3.54	63.70	0.0028	-0.1507	II	4.20	64.11	0.0031	-0.1705	II	7.26	67.60	0.0024	-0.2845
1730	83.40	61.6	69.54	8	44	II	4.72	68.52	0.0006	-0.2183	II	4.72	64.52	0.0027	-0.1870	II	5.60	64.93	0.0029	-0.2134	II	9.68	67.92	0.0017	-0.3579
1745	83.00	62.0	69.33	7	49	II	4.13	67.74	0.0008	-0.1942	II	4.13	63.30	0.0028	-0.1633	II	4.90	63.72	0.0030	-0.1857	II	8.47	67.00	0.0022	-0.3120

FIGURE 3. "SURFICE" Computer Predictions

STS- 48	TEST S0007 LAUNCH	DATE: 12 Sept. 1991	T-0 TIME: 19:11:04 DATE: 9/12/91	NASA KSC Ice/Frost/Debris Team

ORBITER	ET	SRB	MLP	PAD	LO2	LH2
103	42	BI-046	3	A	CHILLDOWN TIME: 10:09 FAST FILL TIME: 11:00 SLOW FILL TIME: 10:47 REPLENISH TIME: 13:00	CHILLDOWN TIME: 10:09 FAST FILL TIME: 10:42 SLOW FILL TIME: 10:19 REPLENISH TIME: 13:00

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				
(EDT)	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
1800	83.00	61.4	69.06	7	55	II	4.13	67.57	0.0008	-0.1929	II	4.13	63.11	0.0027	-0.1621	II	4.90	63.53	0.0029	-0.1843	II	8.47	66.82	0.0021	-0.3098
1815	82.40	63.8	69.56	8	50	II	4.72	68.13	0.0008	-0.2154	II	4.72	64.11	0.0029	-0.1841	II	5.60	64.54	0.0031	-0.2102	II	9.68	67.58	0.0021	-0.3535
1830	82.40	66.2	70.60	6	58	II	3.54	67.69	0.0013	-0.1759	II	3.54	62.73	0.0032	-0.1453	II	4.20	63.17	0.0035	-0.1645	II	7.26	66.84	0.0031	-0.2767
1845	82.20	67.2	70.83	7	59	II	4.13	68.38	0.0013	-0.1991	II	4.13	63.96	0.0033	-0.1680	II	4.90	64.41	0.0036	-0.1912	II	8.47	67.75	0.0030	-0.3214
1900	81.60	69.2	71.07	7	72	II	4.13	68.30	0.0015	-0.1987	II	4.13	63.87	0.0034	-0.1675	II	3.85	62.43	0.0038	-0.1513	II	8.54	67.74	0.0032	-0.3236
T-0	81.20	71.0	71.41	6	78	II	3.54	67.72	0.0017	-0.1763	II	3.54	62.74	0.0036	-0.1455	II	3.30	61.16	0.0039	-0.1307	II	7.32	67.01	0.0037	-0.2805
AVG.	83.60	63.41	70.53	7.06	NE		4.16	68.63				4.16	64.20				3.93	62.78				7.85	67.35		

Period of Ice Team Inspection

FIGURE 4. "SURFICE" Computer Predictions

separation bolt pyrotechnic canister purge vents. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

Ice/frost had formed in the LH2 recirculation line bellows and on both burst disks. The LH2 feedline bellows were wet with condensate. The outboard side of the LH2 ET/ORB umbilical and purge barrier were covered by light ice/frost formations. Ice/frost accumulation on the inboard and aft areas of the baggie was nonexistent. Ice/frost fingers 3-6 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 outboard bondline. 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 3 OTV recorded items:

Anomaly 001 (documentation only) noted ice/frost accumulations on the LH2 ET/ORB umbilical purge vents, purge barrier (baggie), aft pyrotechnic canister closeout bondline, and the LH2 recirculation line bellows and burst disks. All of these accumulations were acceptable per NSTS-08303.

Anomaly 002 (documentation only) recorded ice/frost formations in the LO2 feedline bellows and support brackets. These formations were acceptable per NSTS-08303.

Anomaly 003 (documentation only) noted ice/frost formations on the LO2 ET/ORB umbilical pyrotechnic canister purge vents with typical ice/frost fingers. These formations were acceptable per NSTS-08303.

4.5 FACILITY

Ice Team inspection of the south holddown posts revealed debris in the haunch areas. The largest piece, a universal metal clamp, had been entered in S0007, Appendix K, during the Pre-Launch SSV/Pad Debris Inspection the previous day. In addition, a piece of safety wire with lead seal, tie wrap fragments, and cork closeout trimmings were present. The debris was removed using the ice net. Post launch assessment of the event revealed lack of coordination between pad operations work and quality verification. A change to Appendix K will provide more detailed information on a debris anomaly, location, point of contact, responsible organization, and method of verification.

One potential debris concern was identified during the ice/frost inspection of the vehicle. The handrails on the FSS 115 foot level RBUS platform near the Orbiter LH wingtip were bolted in place rather than welded. Facility Engineering reported the configuration had been approved for launch. Welding of the handrails is planned/scheduled after launch.

All SRB sound suppression water troughs were filled and properly configured for launch.

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.

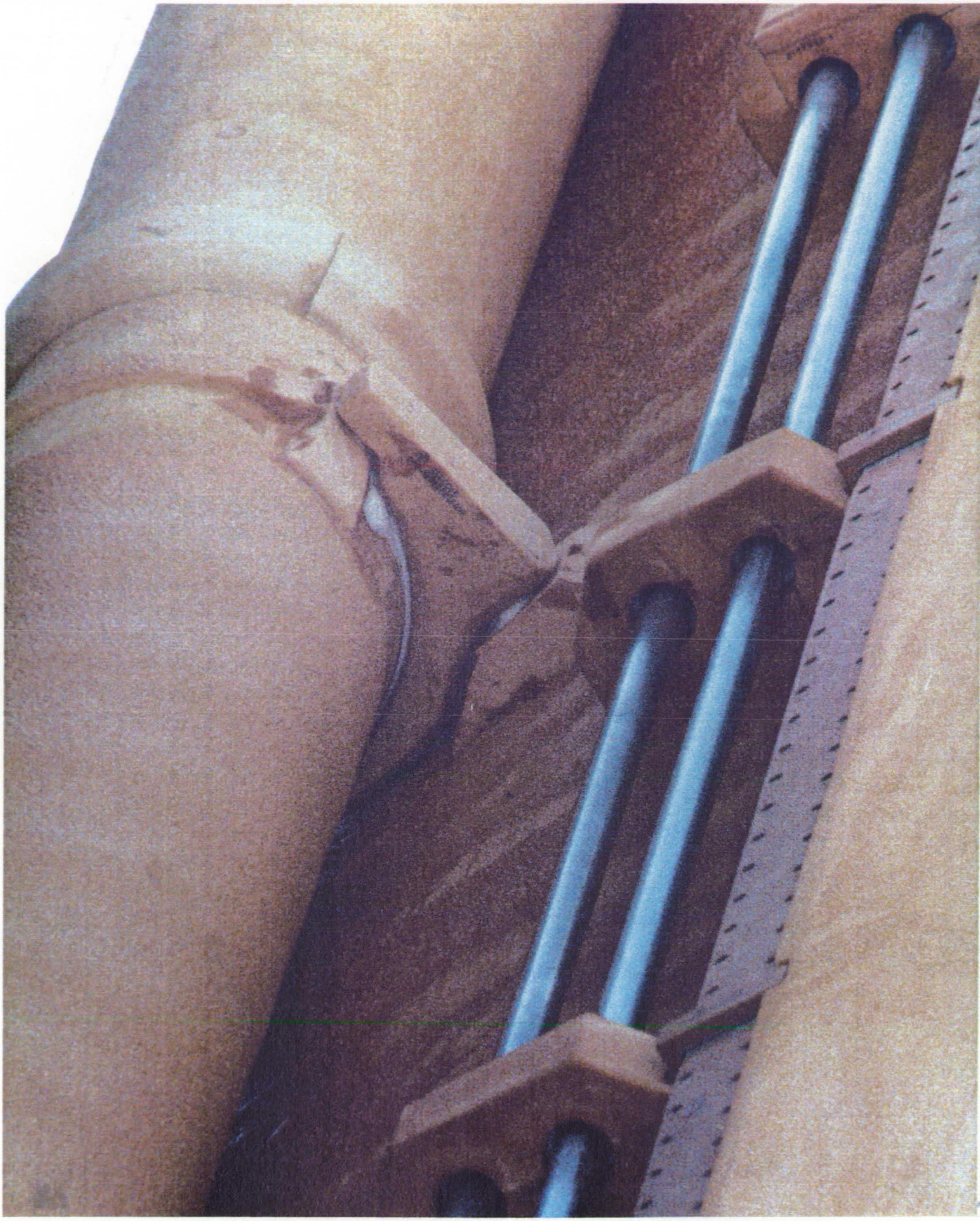
Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted. There were no icicles on the GOX vent ducts.

Overall view of OV-103, ET-42 (LWT 35), and BI-046 SRB's

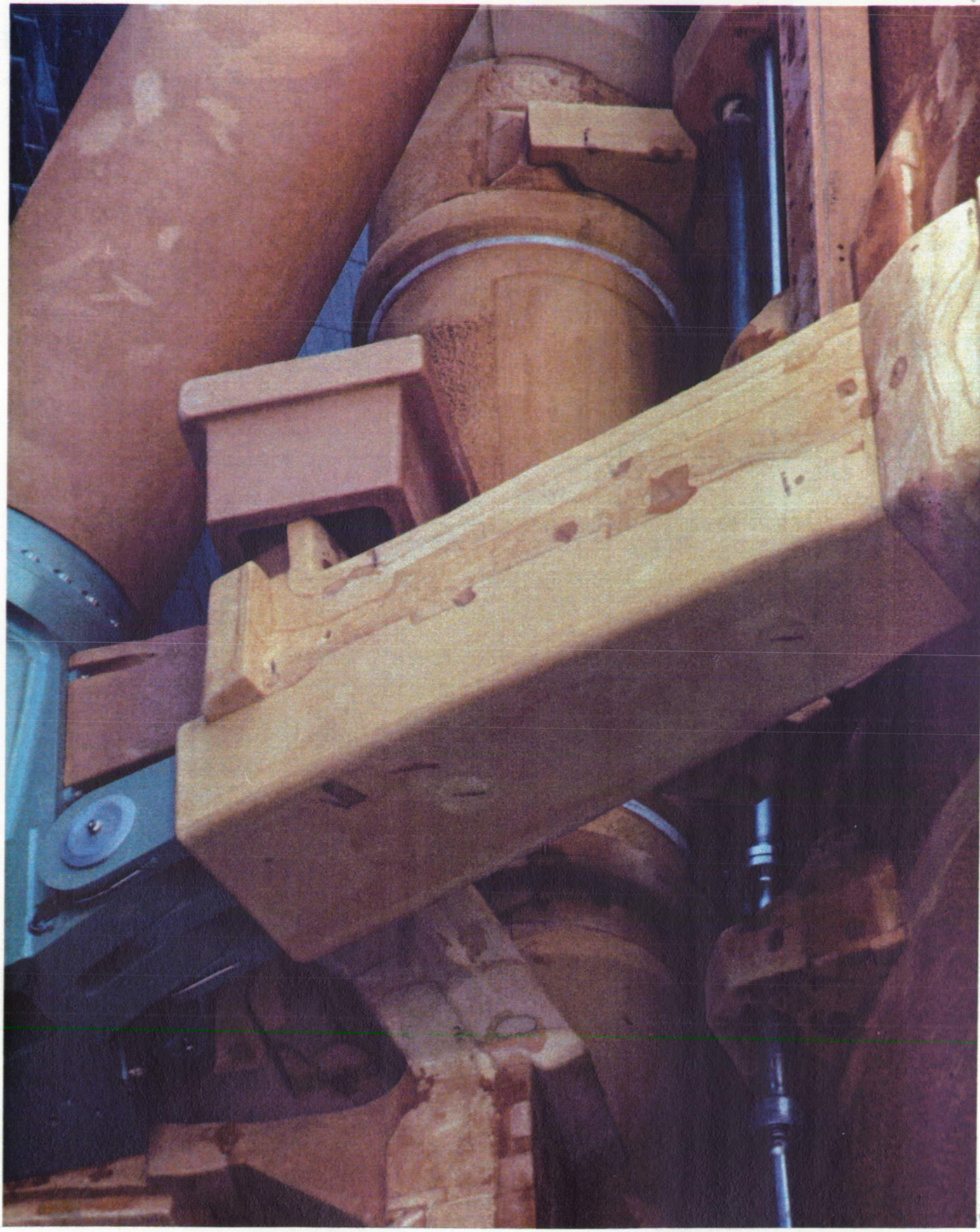
There were no TPS anomalies or ice/frost accumulations on the External Tank acreage

Overall view of SSME cluster. Some ice/frost had formed at the SSME #2 heat shield-to-nozzle interface.

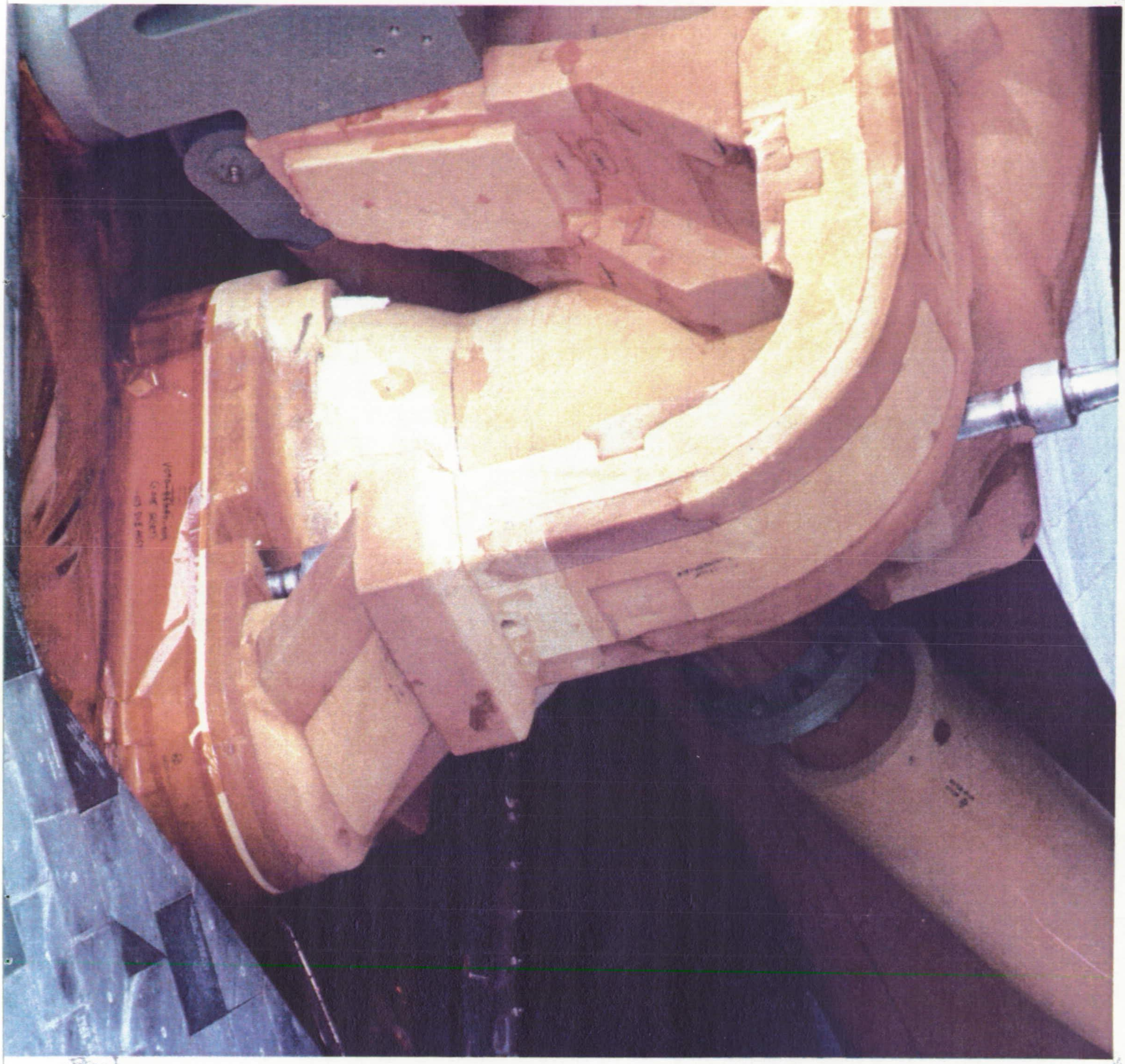
Ice/frost accumulations in the LO2 feedline upper bellows and support brackets were typical



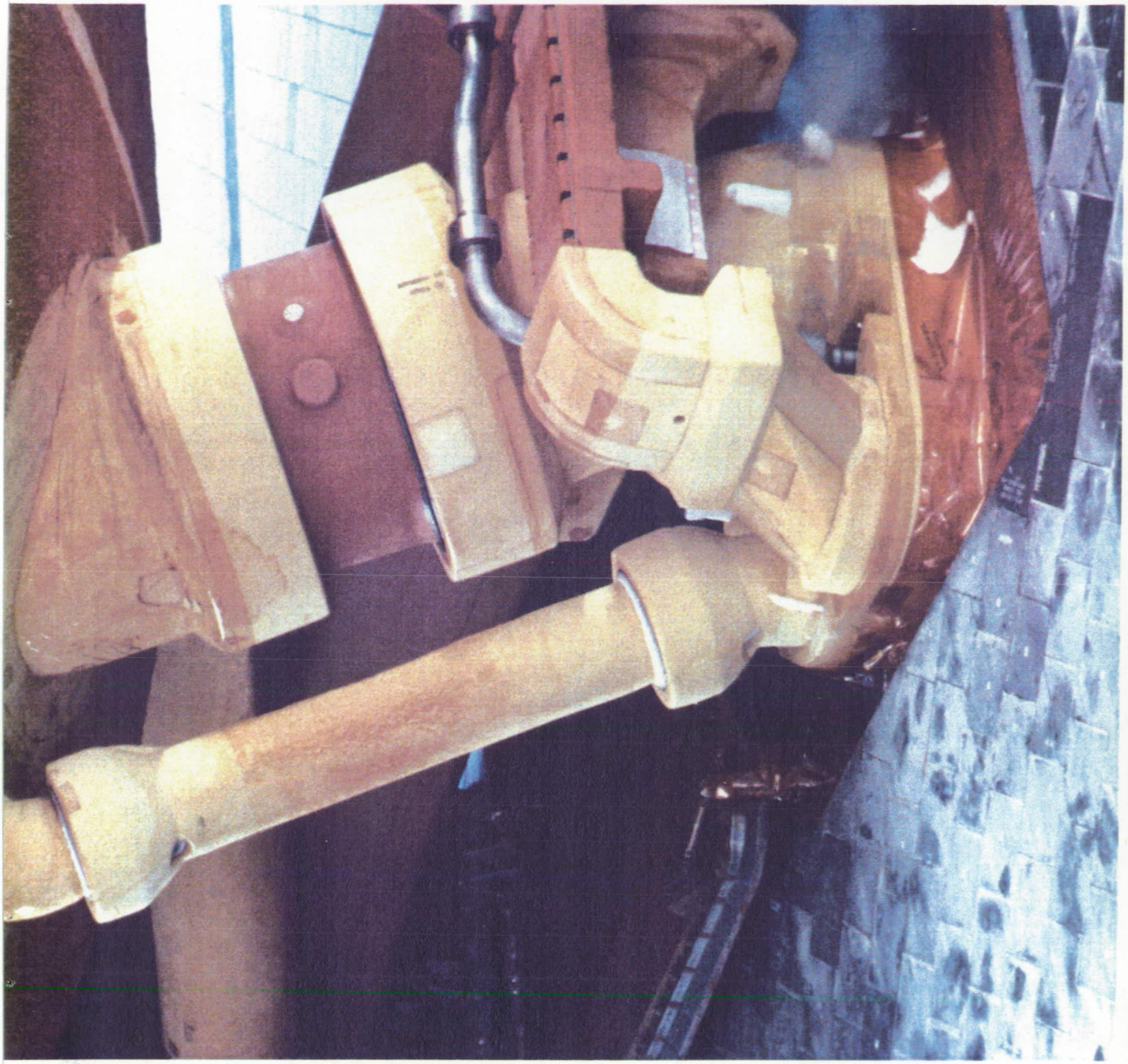
Ice/frost formations in the LO2 feedline support brackets were typical



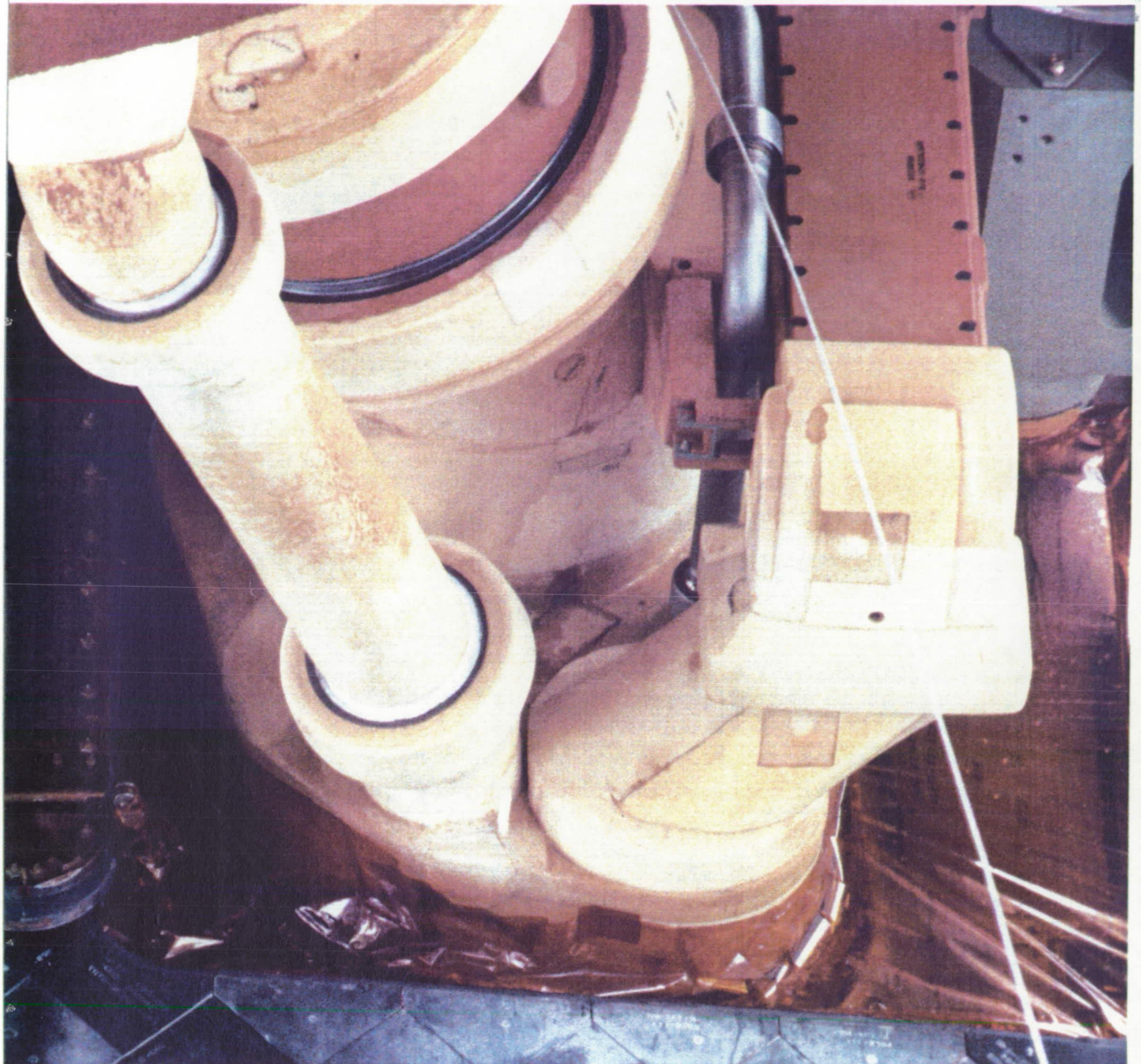
Ice/frost formations in the LO2 feedline lower bellows
and support brackets were typical



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 on the umbilical out board side and on the purge vents were typical. Ice/frost in the recirculation line bellows and burst disks was typical.



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 LH2 feedline bellows, cable tray vent hole, and 17-inch flapper valve actuator tool access port closeout exhibited no ice or frost accumulations.

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The MLP deck and FSS were inspected approximately two hours after launch on 12 September 1991. No flight hardware or TPS materials were found. However, frangible nut fragments were visible resting on top of the stud in holddown post #5. The inspection of the MLP deck, pad apron, and pad acreage areas resumed on 13 September 1991 from 1500-1730 hours. The only flight hardware recovered consisted of two Orbiter base heat shield Q-felt plugs near the Engine Service Platform park site on the crawlerway slope.

Plume erosion of the south SRB holddown posts was typical. All EPON shim sidewall material and bottom plate material was intact and bonded to the shoes. 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 plume erosion. The SRB aft skirt purge lines were in place but slightly damaged. The SRB T-0 umbilical and connector saver sacrificial pieces showed normal plume impingement effects.

The OAA and TSM's showed the usual minor post launch damage. The Hydrogen Dispersal System structure was undamaged. The GOX vent arm was locked in the retracted position and exhibited minor launch damage. The GH2 vent arm appeared to have retracted nominally, was latched on the eighth tooth of the latching mechanism, and had no loose cables. The ET intertank access structure sustained typical plume heating effects.

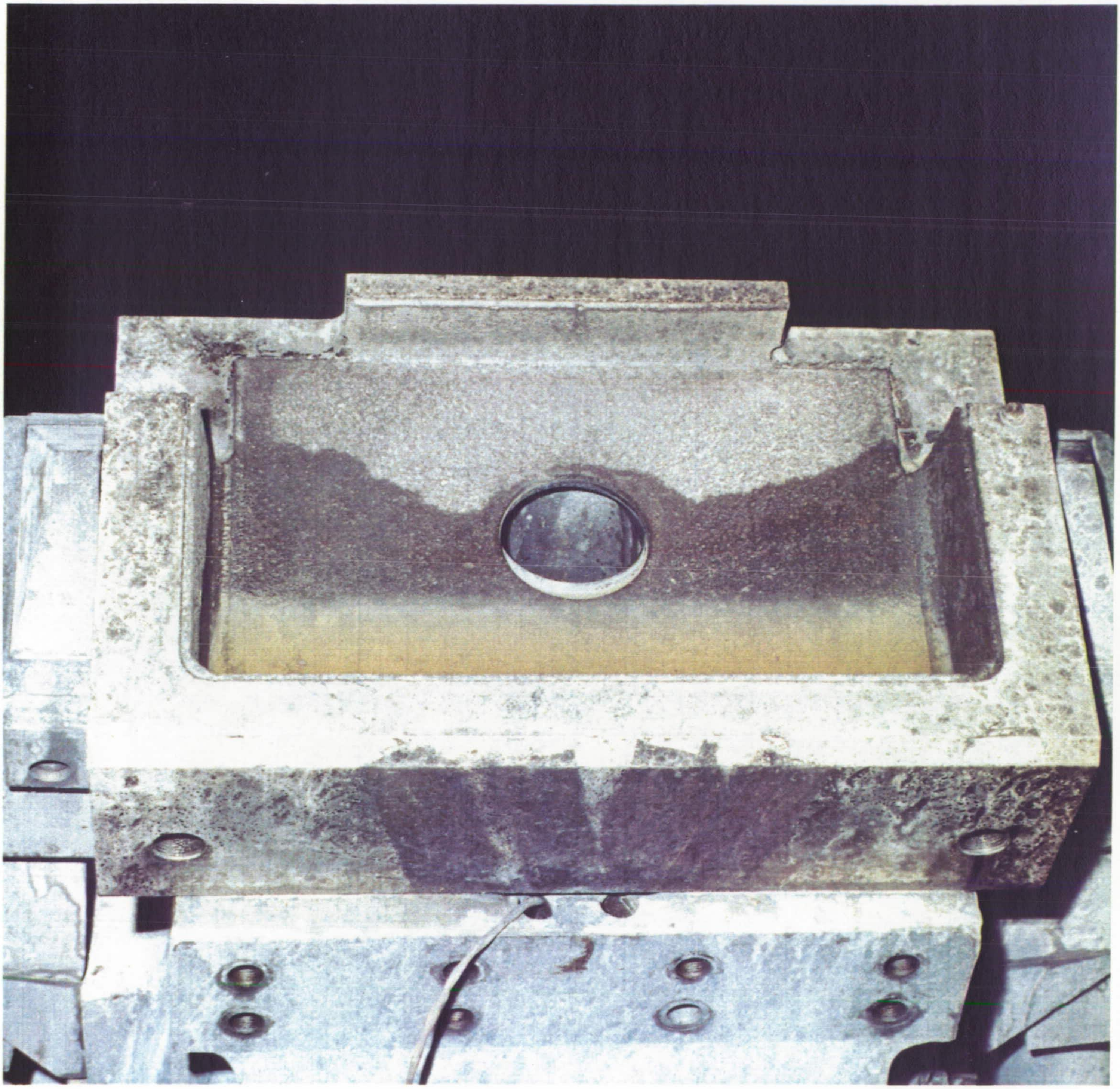
Damage to the facility appeared to be minimal. Facility debris was typical and included fasteners, identification plates, clamps, and an alarm bell. The handrails on the FSS 115 foot level RBUS platform remained in place with no apparent damage. No emergency egress slidewire baskets had released during launch.

Expanded inspection of the launch area included 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 was 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 56 particles were imaged in the T+137 to 329 second time period. Seventeen of the particles were imaged by only one radar, 27 particles were imaged by two radars, and 12 particles was imaged by all three radars.

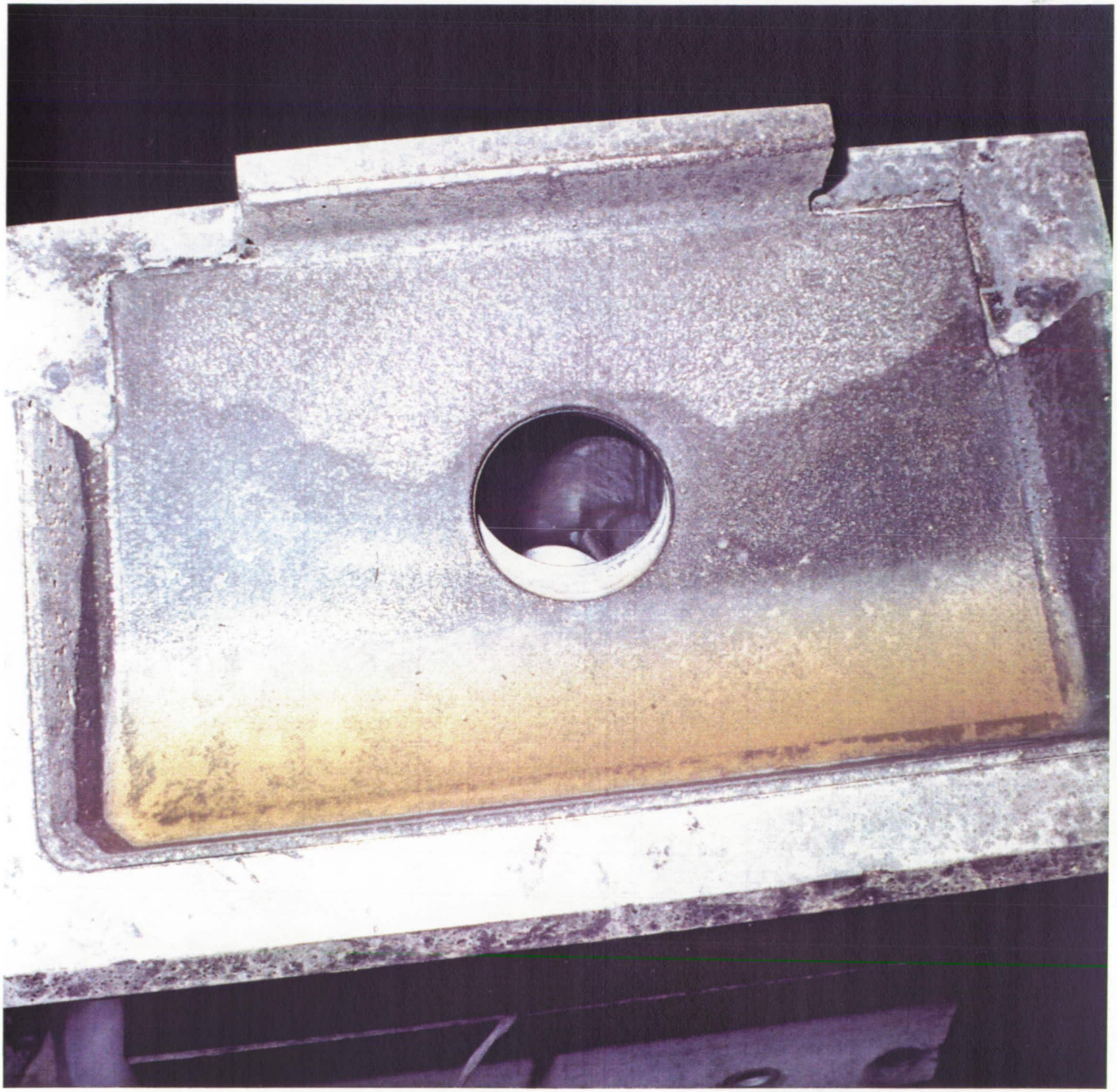
Post flight inspection of the LH SRB frustum revealed a missing forward BSM aero heatshield cover. Radar data was analyzed with the intent of identifying the cover falling away from the vehicle if the failure occurred at the time of SRB separation while in proximity to the Orbiter. Pieces of slag, which are propelled out of the SRB's and have a velocity of 900-1200 m/sec, were readily discernible. Slag particles exhibit a continuous signal return since there is always a broad reflective surface. Aft BSM covers also have high velocity but exhibit an on-off-on again signal as the flat plates tumble. The search focused on a flat plate type of return with low velocity, which might be characteristic of an object falling off the vehicle. Two radars imaged an object that appeared to separate from the vehicle in the T+124 second time frame, had a velocity of 200-300 m/sec, and exhibited a tumbling flat plate type of signal return. However, the object appeared before BSM firing and the signal return was not strong, as would be expected from a metallic object such as an aero heatshield cover. The object was most likely a flat piece of SRB slag.

Post launch pad inspection anomalies are listed in Section 10.



Plume erosion of the south SRB holddown posts was typical. All EPON shim sidewall material and shim bottom plate material was intact and bonded to the shoes. 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



Frangible nut/ordnance fragments lay on the stud in HDP #5. These fragments had not been retained by the Debris Containment System (DCS) and fell from the aft skirt stud hole shortly after liftoff.

6.0 FILM REVIEW AND PROBLEM REPORTS

A total of 117 film and video data items, which included forty-four videos, forty-two 16mm films, twenty-six 35mm films, and five 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 during liftoff.

SSME ignition and Mach diamond formation appeared normal. Free burning hydrogen was blown upward to the OMS pods and under the body flap by prevailing winds (OTV 051, 060, 063, 070, TV-4, E-1, 3, 19, 20).

SSME ignition vibration/acoustics caused numerous pieces of ice/frost to fall from the LO2 and LH2 ET/Orbiter umbilicals. No damage to Orbiter tiles or ET TPS was visible (OTV 009, 054, 063). Pieces of ice continued to fall from the umbilical area during early ascent. One piece of ice fell aft from the LO2 feedline upper bellows and may have made two "glancing" contacts with tiles on the Orbiter lower surface (OTV 061, E-40). No tile damage was visible. East winds caused the ice particle to traverse the Orbiter underside and pass outboard of the EO-2 fitting.

SSME ignition vibration/acoustics caused the loss of tile surface coating material from seven locations between the RH OMS and SSME's #1/#3, one location on the aft face of the RH RCS stinger, and one location at the base of the RH OMS nozzle (E-23). A 2"x1" piece of tile surface coating material fell from the aft surface of the LH RCS stinger (E-24). In addition, a 4-inch flexible strip of material, most likely a gap filler, appeared to originate from tiles on the aft face of the LH OMS pod near the OMS nozzle.

One FRSI plug fell from a carrier panel on the base heat shield shortly after liftoff (E-18).

There were no major facility anomalies. No swing arms or other pad structures contacted the vehicle during liftoff. Disconnect and retraction of all T-0 umbilicals was nominal. Separation of the GUCP from the External Tank was nominal. The GH2 vent arm retracted and latched with no rebound. There was no excessive slack in the static retract lanyard.

All rainbirds on the MLP deck activated properly at T-0 (OTV 060).

After liftoff, 5 ordnance fragments including two NSI booster pieces or frangible nut webs (3 inches in length), fell from the HDP #5 DCS/stud hole (E-12). Two dark particles were visible between the aft skirt foot and the HDP #7 shoe, but could not be identified as ordnance fragments. These particles may have been pieces of shim putty or shim material (E-11). This was the third flight utilizing the new optimized frangible links. There was no evidence of stud hang-ups on any of the holddown posts. Closure of doghouse blast covers was nominal. One piece of aft skirt instafoam broke off near the RH SRB HPU exhaust horn/HDP #3 after liftoff (E-10, 15).

Numerous pieces of SRB throat plug material were ejected out of the SRB flame trench north of the vehicle (E-62, 64). More SRB throat plug material was ejected upward out of the SRB exhaust holes (E-64). This is a common occurrence and none of the material was a threat to the vehicle.

Two 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 (E-54, 59, 207). Other pieces of RCS paper covers were visible passing over the Orbiter wings. Pieces of ET/ORB purge barrier baggie material were also visible caught in the aerodynamic recirculation and falling aft of the vehicle (E-207, 213, 222, 223, 224).

Numerous white flashes occurred in the SSME plume during and shortly after the roll maneuver (E-54, 222). These flashes have been observed on previous launches. A total of fifteen orange streaks occurred in the SSME plume during ascent (E-207, 212, 223). These streaks are typically caused by debris particles, such as RCS paper covers.

Two large orange flashes occurred in the SSME plume during ascent at T+29 seconds MET from SSME #2 and at T+31 seconds MET from SSME #1 (TV-4, E-54). At T+58 seconds MET, the vehicle passed through a layer of moisture or high cirrus ice particles and a bright cloud of condensation/reflection surrounded the vehicle. The event was caused by atmospheric effects and was not a vehicle problem.

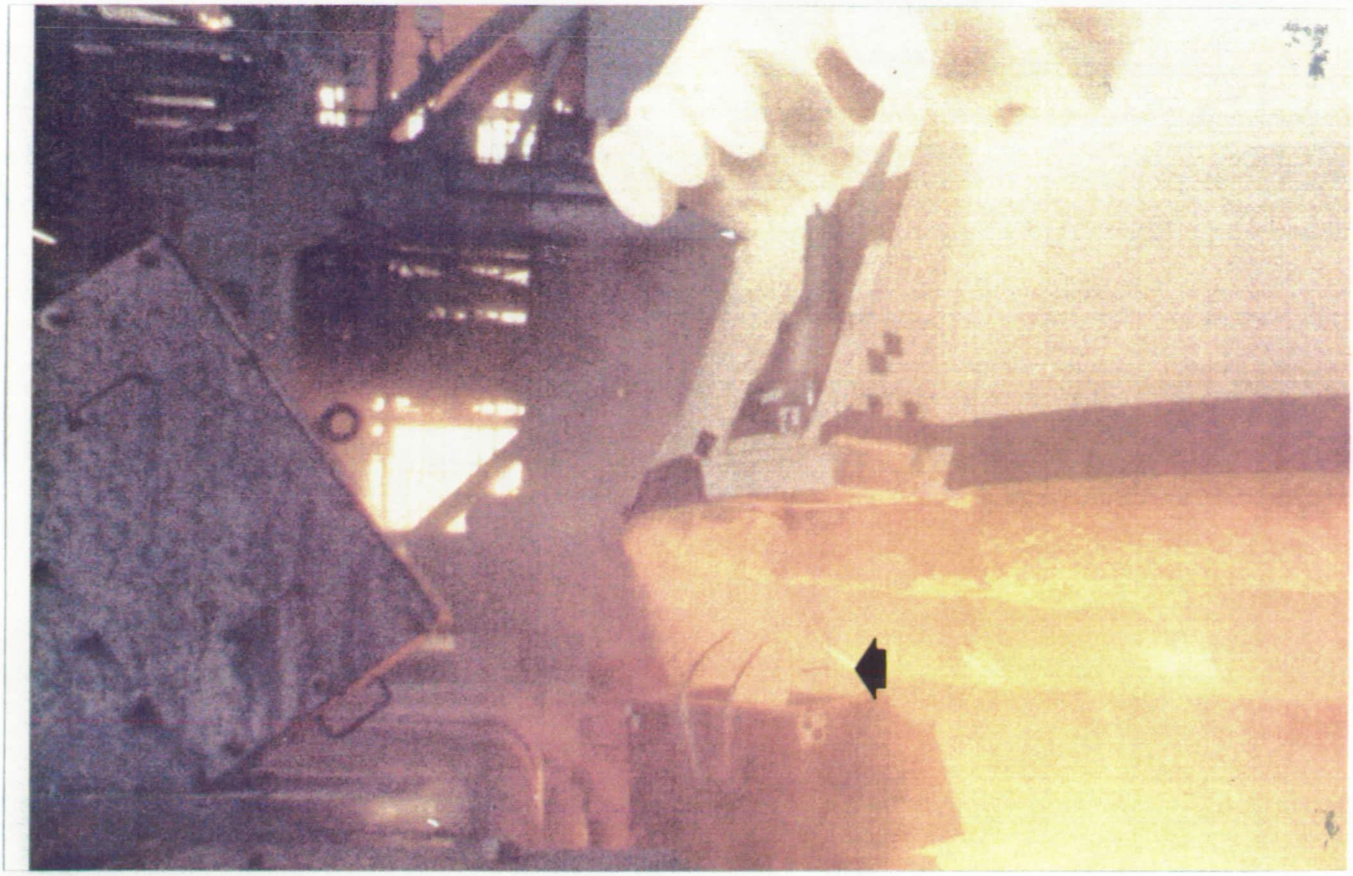
Just after the roll maneuver and during ascent, over 100 light colored particles dropped out of the LH SRB plume. These particles are believed to be pieces of SRB aft skirt instafoam or SRB propellant (E-54, 59, 207, 213, 221, 222, 223, 224).

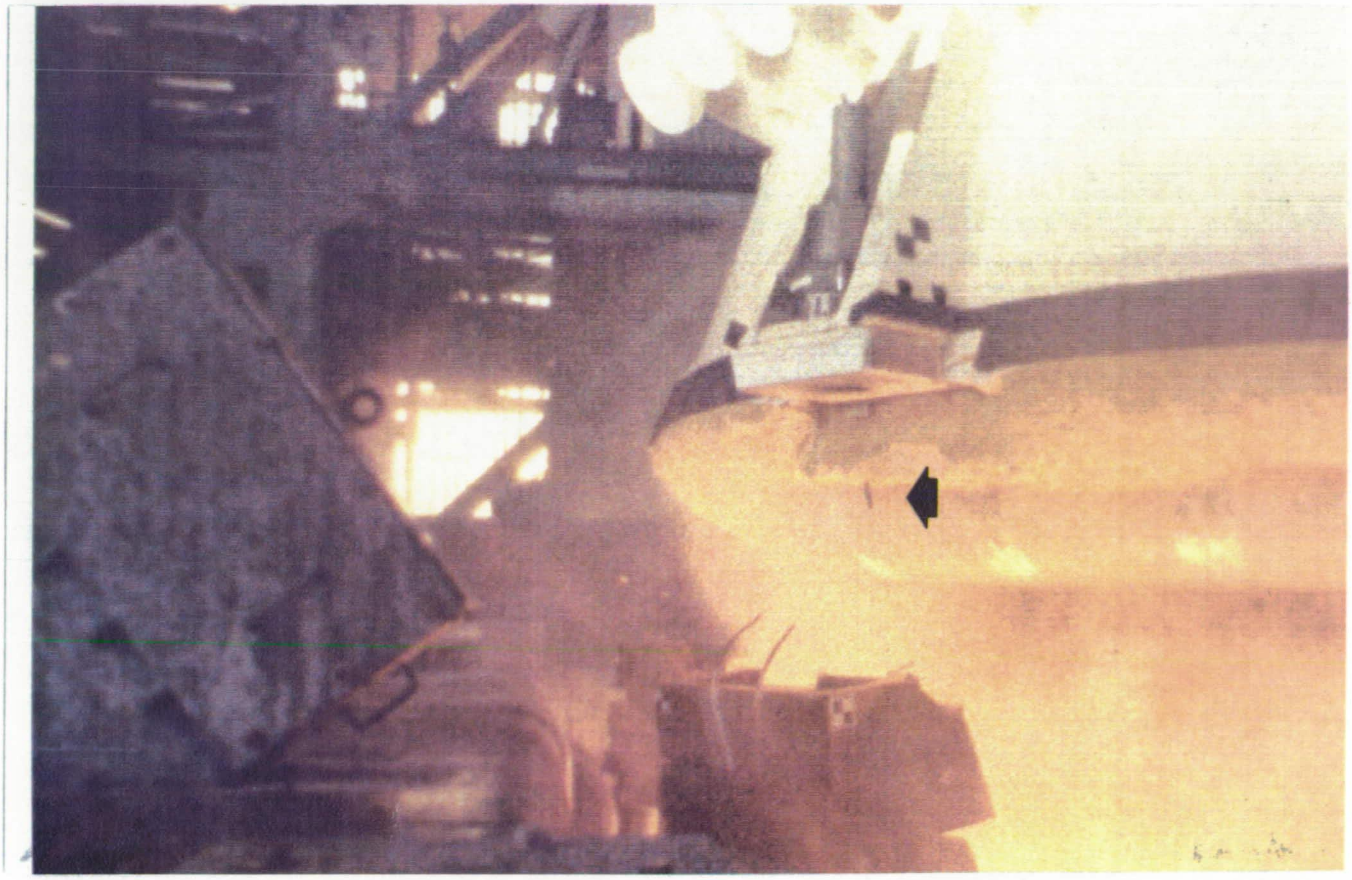
Four pieces of SRB thermal curtain tape came loose during ascent. SSME closeout blankets were intact while in the field of view. (E-207, 212).

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

Late in flight during the period of plume recirculation, four bright flashes occurred on the SSME #1 nozzle and were most likely sunlight reflections (E-207). ET aft dome charring and plume recirculation appeared normal.

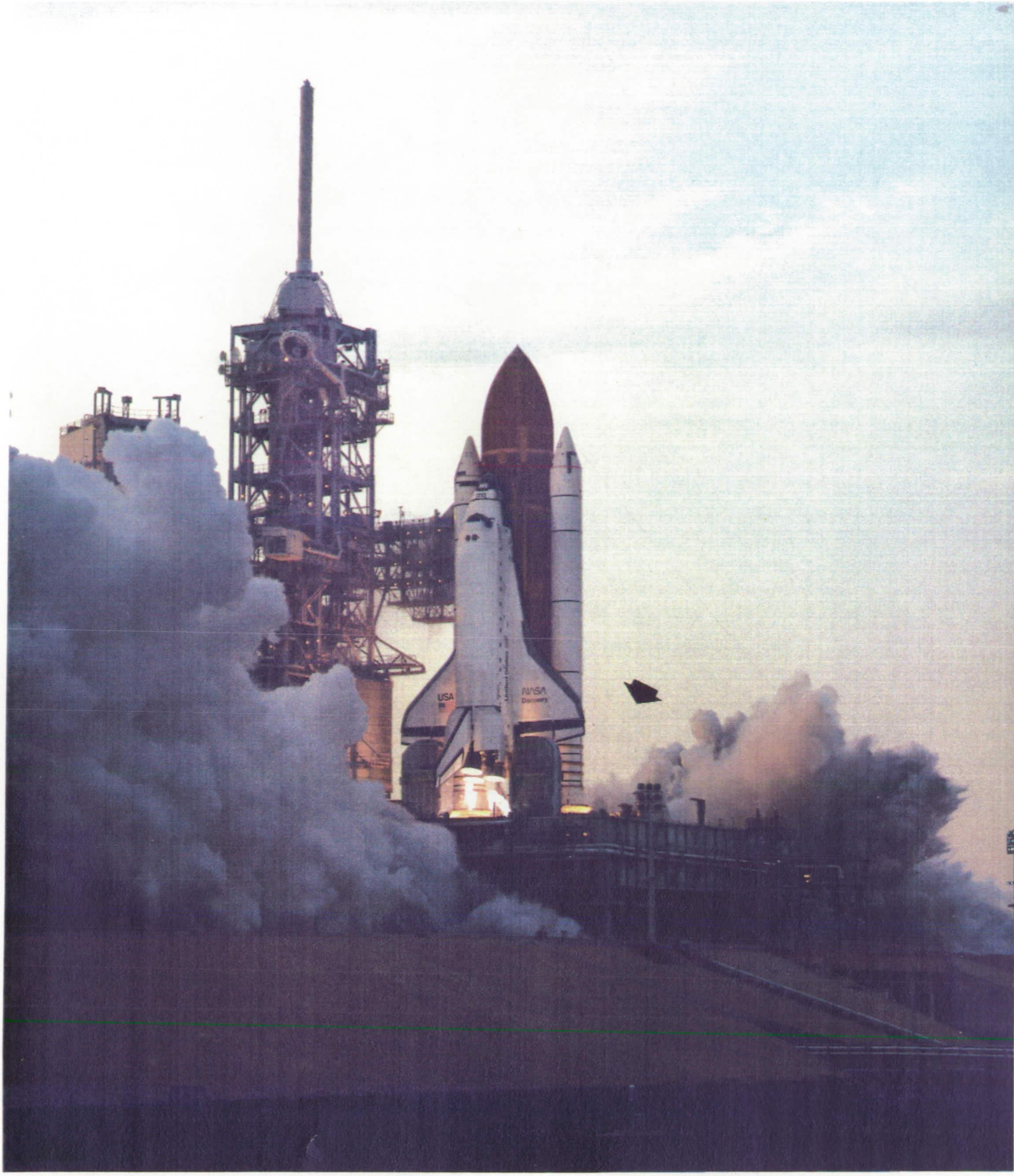
SRB separation appeared nominal (E-207, 223). No unusual SRB plume events, such as localized brightening, occurred (TV-4, TV-13). However, two puffs of black smoke associated with tailoff were visible.



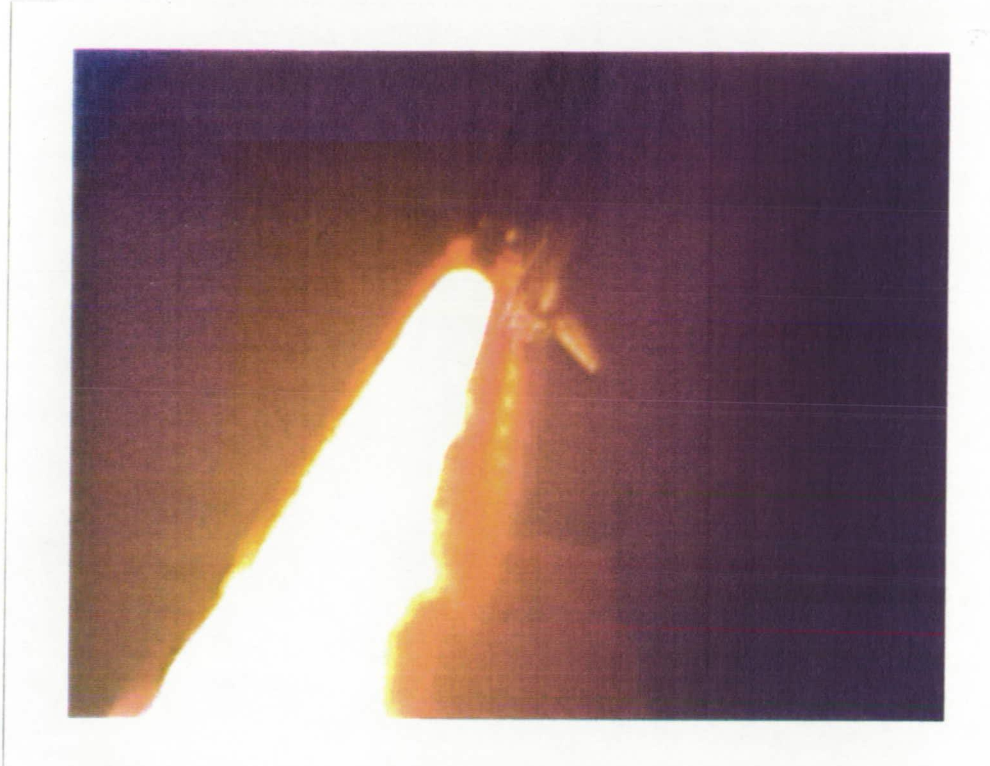


Shortly after liftoff, five ordnance fragments including two NSI booster pieces or frangible nut webs (3 inches in length), fell from the HDP #5 DCS/stud hole.

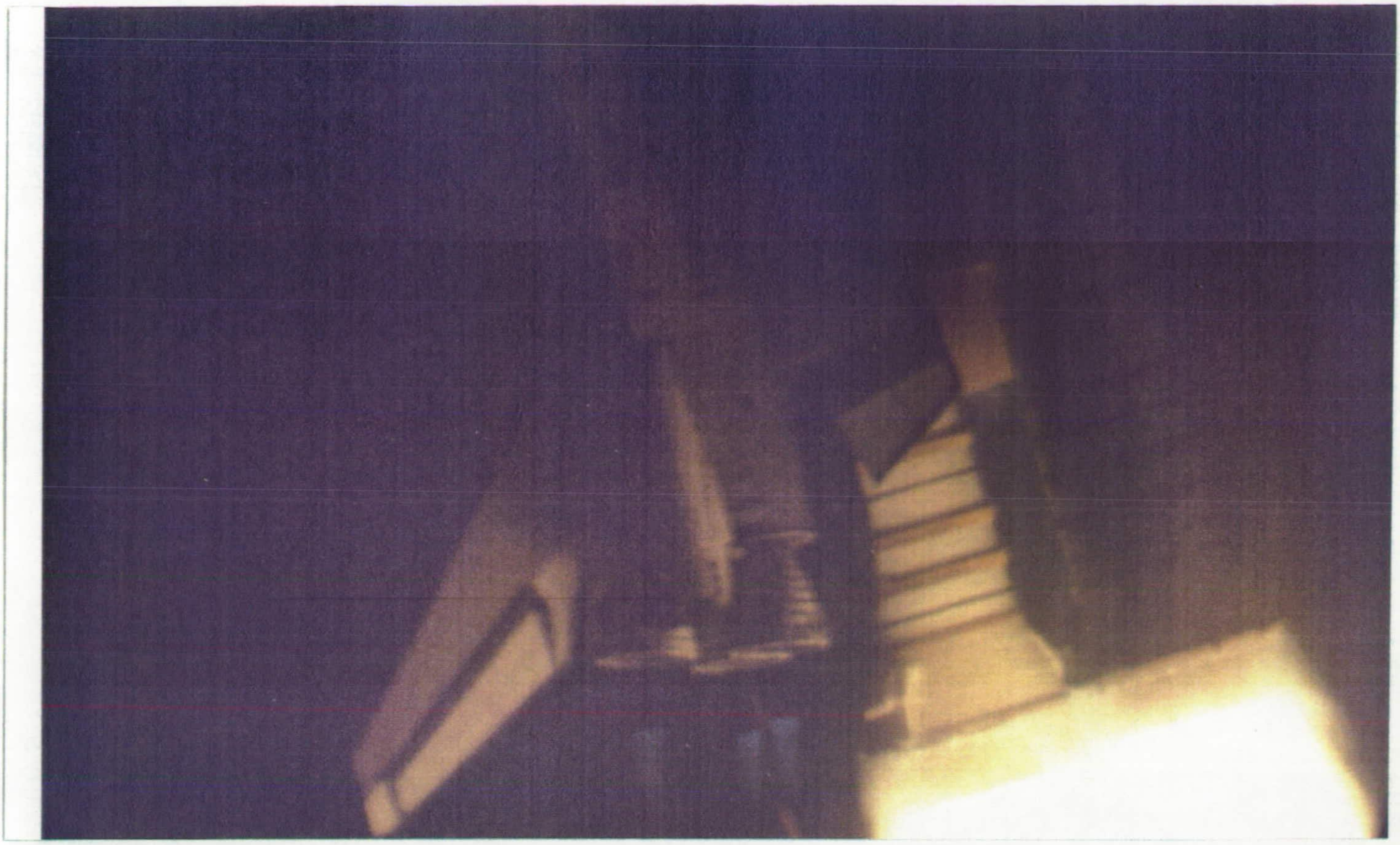
ORIGINAL PAGE
COLOR PHOTOGRAPH

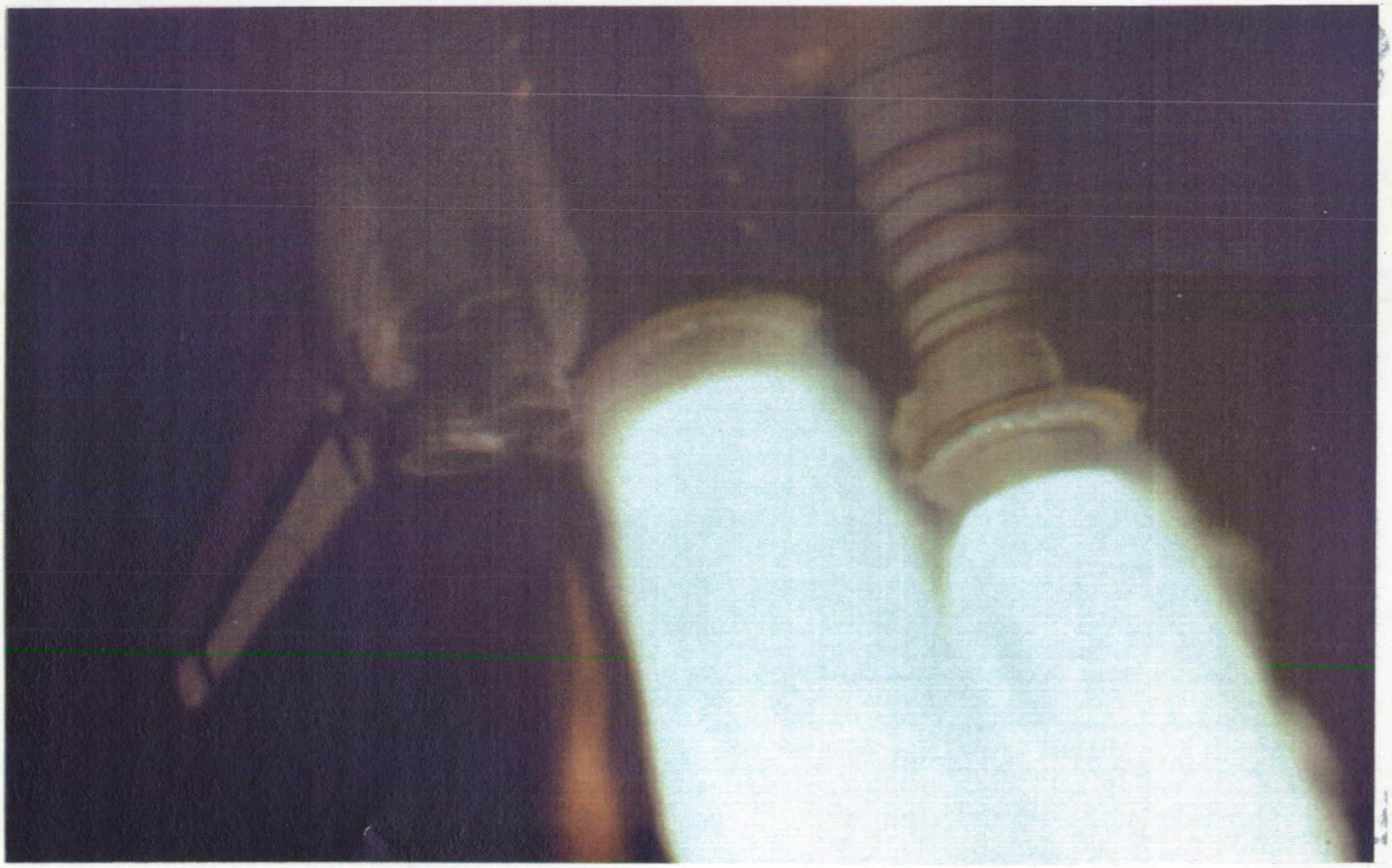


Numerous pieces of SRB throat plug material were ejected out of the SRB flame trench north of the vehicle. More SRB throat plug material was ejected upward out of the SRB exhaust holes. This is a common occurrence and none of the material was a threat to the vehicle.

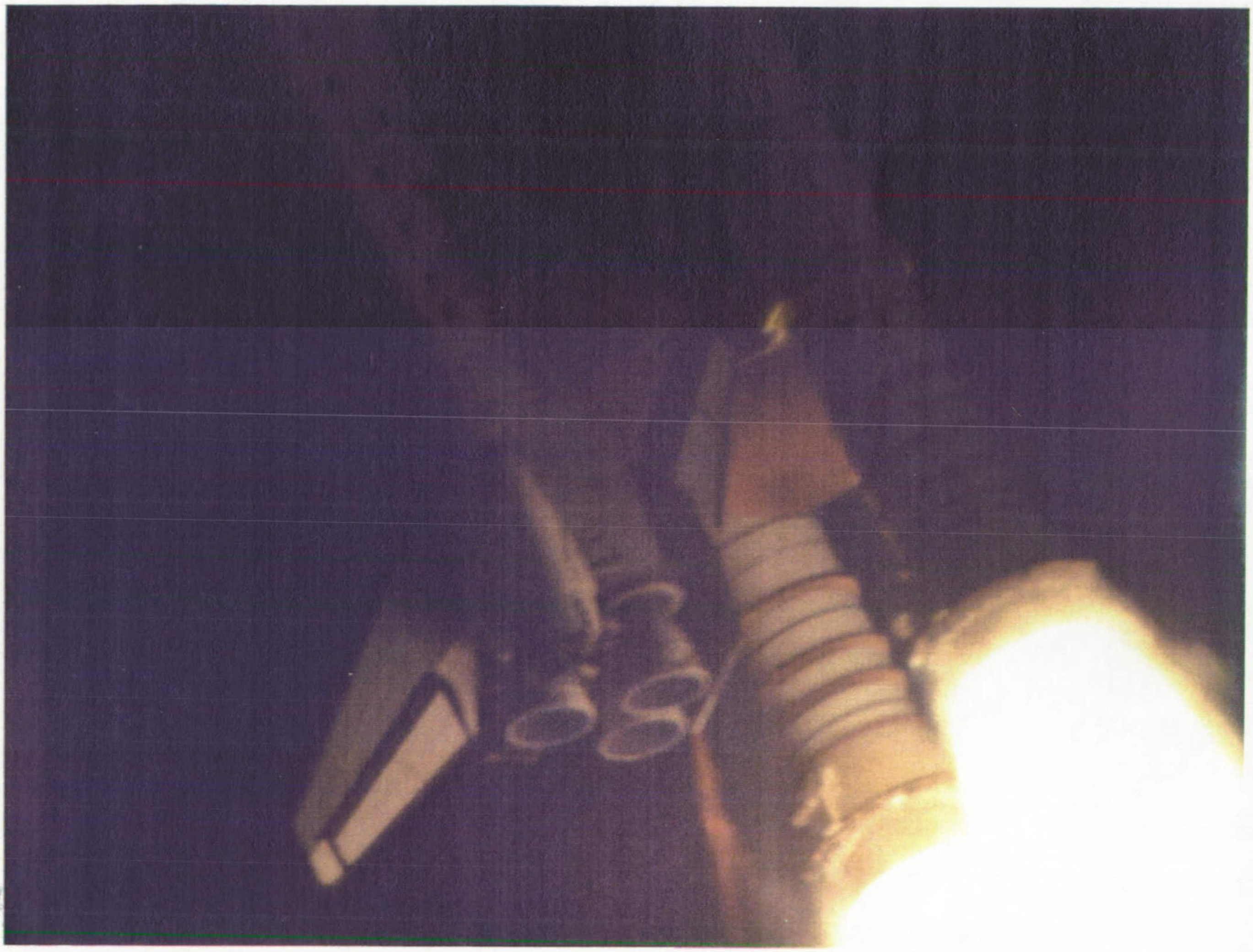


Two large orange flashes occurred in the SSME plume during ascent at T+29 seconds MET from SSME #2 and at T+31 seconds MET from SSME #1.

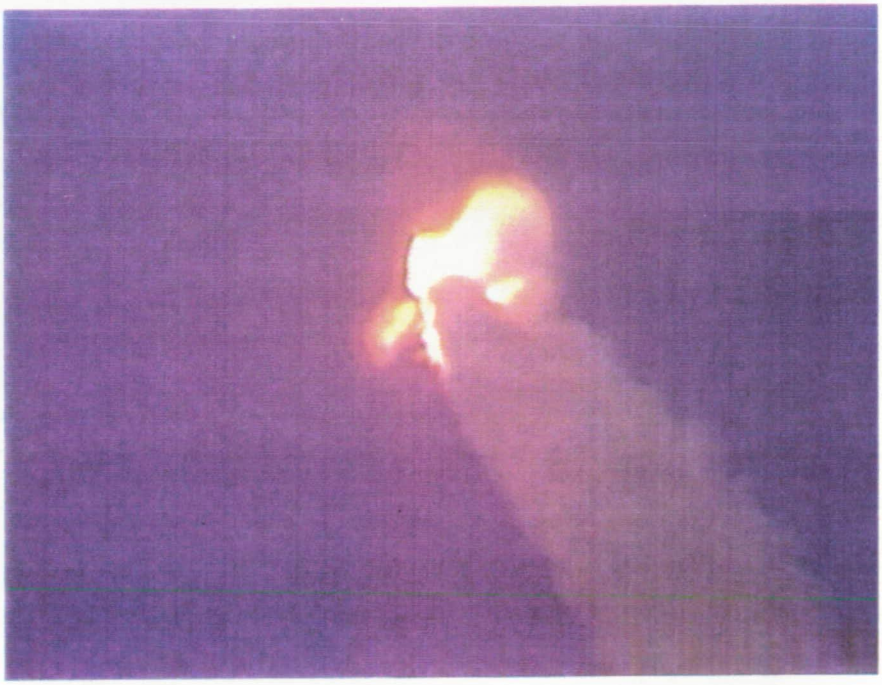




Pieces of paper covers from the LH FWD RCS fell past the aft end of the Orbiter (top photo). Orange streaks in the SSME plume are typically caused by debris particles, such as the RCS paper covers, entering the plume (bottom photo).



Orange flashes within the SSME plume itself may be indicative of fuel impurities.



At T+58 seconds MET, the vehicle passed through a layer of cirrus clouds containing moisture or ice particles and a bright cloud of condensation/reflection surrounded the vehicle. The event was caused by atmospheric effects and was not a vehicle problem.

6.2 ON-ORBIT FILM AND VIDEO SUMMARY

OV-103 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 (DTO-0312).

6.3 LANDING FILM AND VIDEO SUMMARY

Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were nominal. Additional detail was not visible due to the dark conditions of a night landing. Infrared scanning of the Orbiter showed tire heat soak, APU exhausts, and nosecap/wing leading edge RCC panels were all normal.

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 15 September 1991 from 0900 to 1230 hours. In general, the SRB's appeared to be in good condition.

7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum had no areas of missing TPS but had 26 MSA-2 debonds over fasteners. 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).

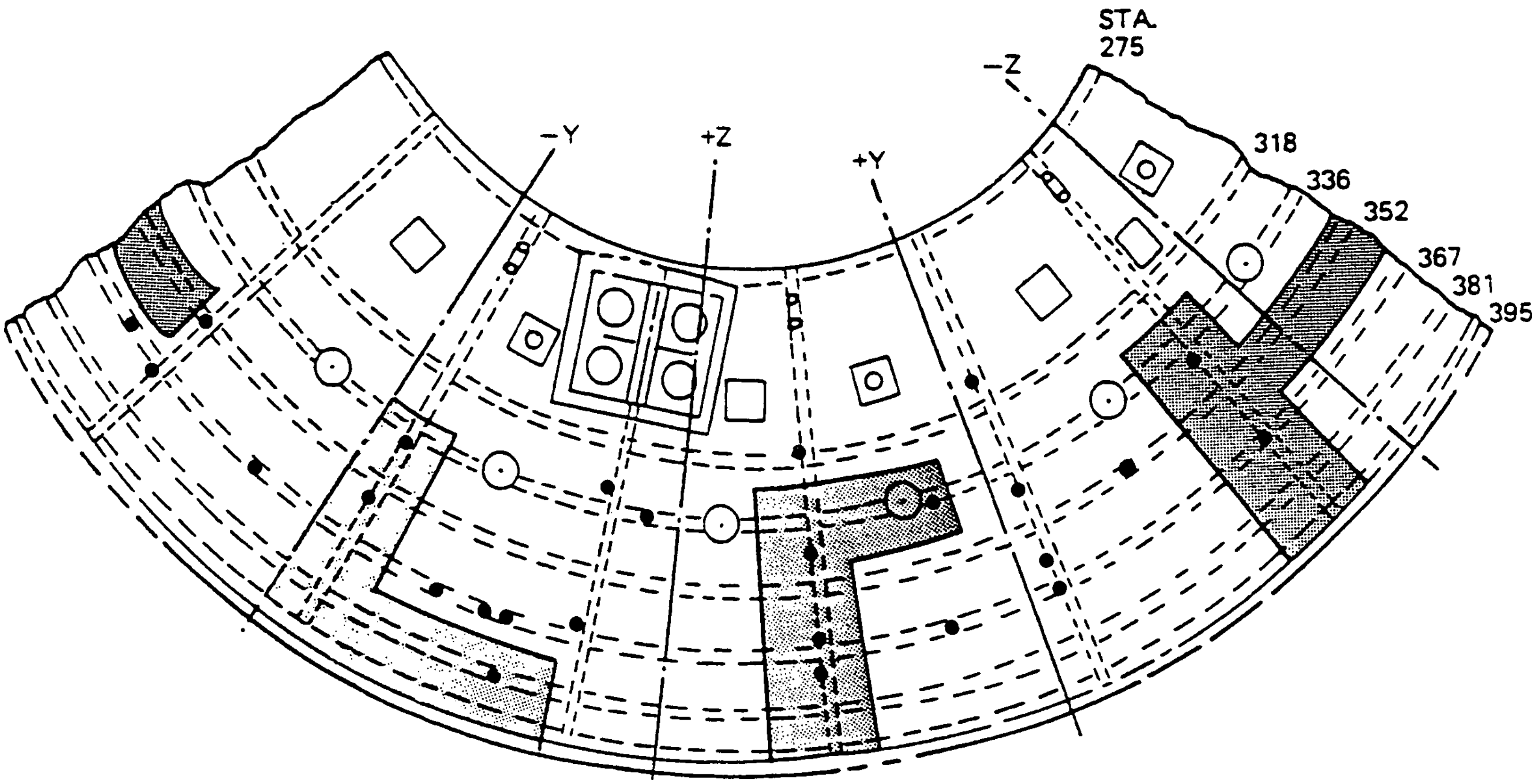
The Field Joint Protection System (FJPS) closeouts were generally in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, and IEA appeared undamaged. All three aft booster stiffener rings sustained water impact damage at approximately 270-360 degrees. Water impact damage also occurred on the upper strut fairing (milk can). The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing. However, some of the K5NA had been applied beyond the splice plate closeout and overlapped the instafoam. The foam erodes or shrinks leaving the K5NA overlap exposed, which creates a mechanism for debris.

The phenolic material on the kick ring was delaminated. Five K5NA protective domes between HDP #1 and #3 were lost from bolt heads on the aft side of the phenolic kick ring prior to water impact (sooted substrate). The aft skirt acreage TPS was in good condition (Figure 7). K5NA was missing from all aft BSM nozzles.

All four HDP Debris Containment System (DCS) plungers were seated. This was the third flight utilizing the optimized link. There was no sign of broaching in any of the stud holes. HDP #3 and HDP #4 EPON shim sidewall material was lost prior to water impact. MSFC will review the bonding process.

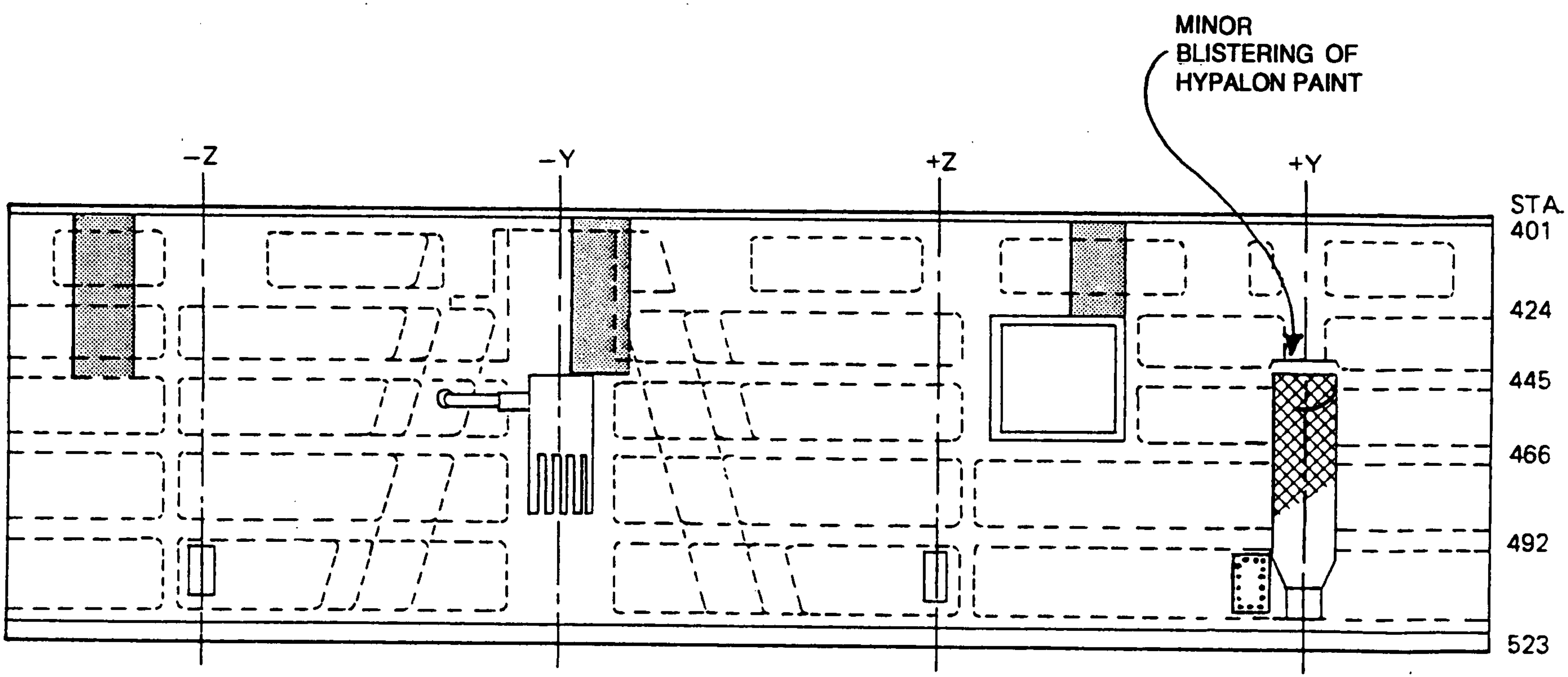
FIGURE 5. RIGHT SRB FRUSTUM



MISSING TPS
NONE

DEBONDS
26

FIGURE 6. RIGHT SRB FWD SKIRT



TPS MISSING

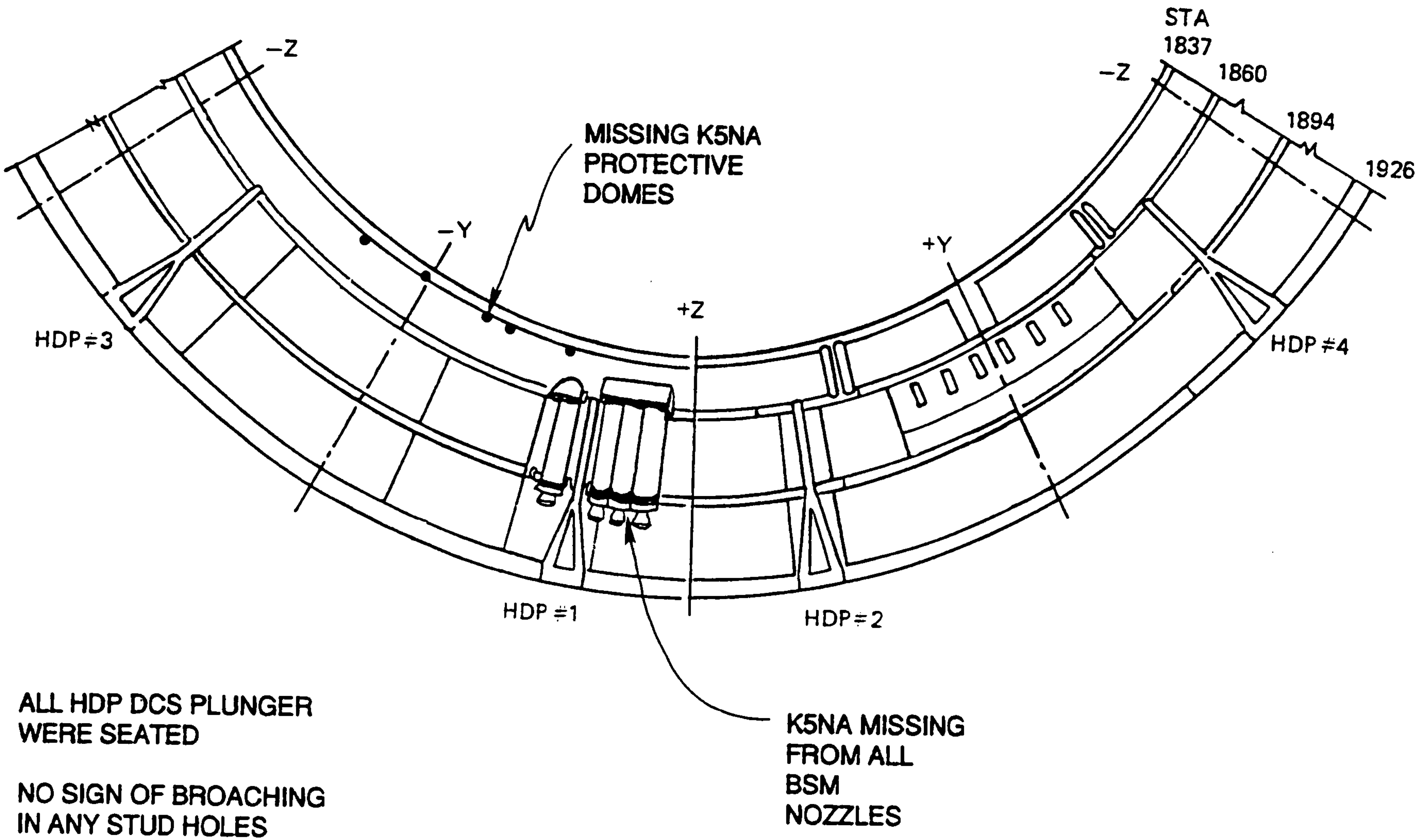
NONE

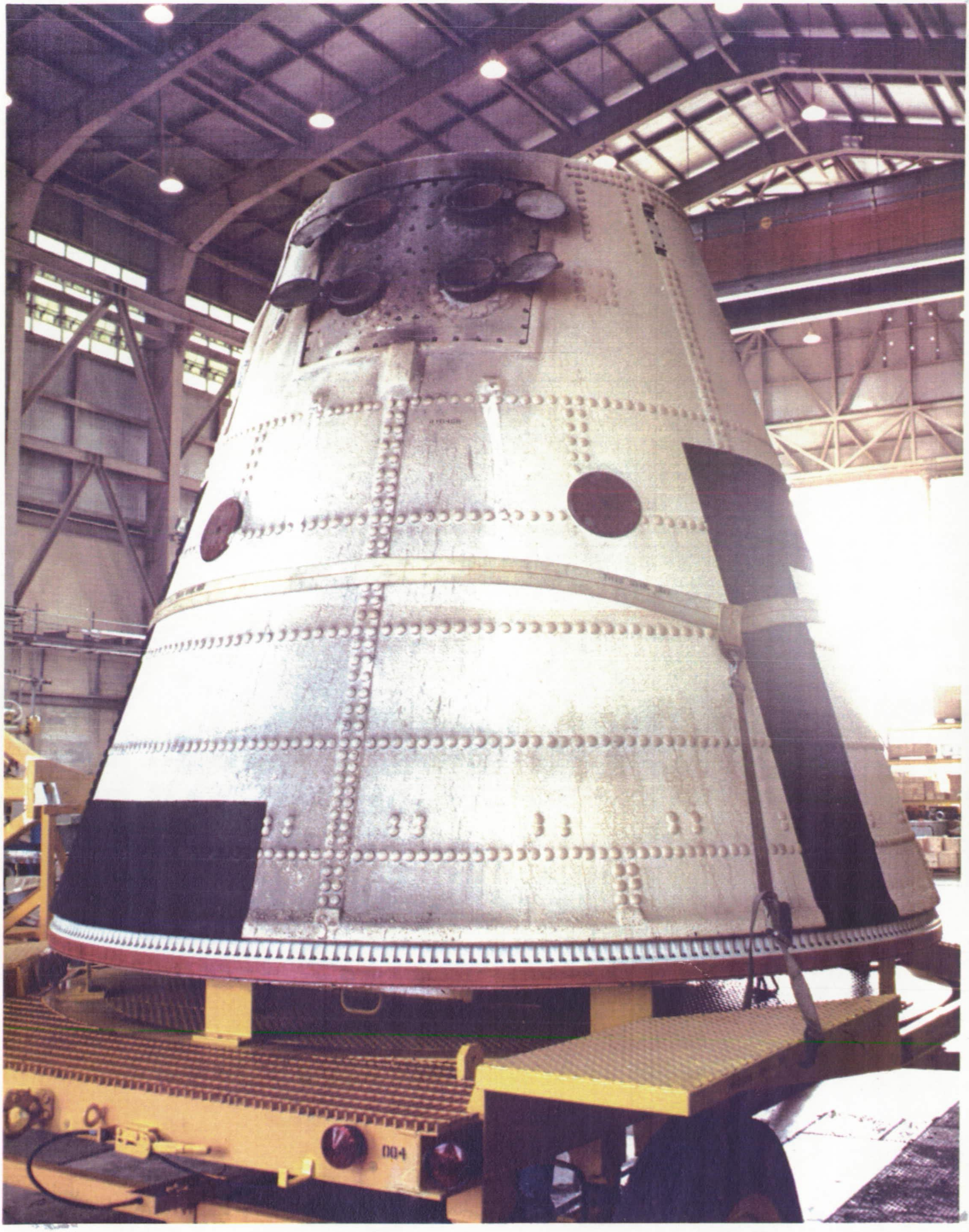
DEBONDS

NONE

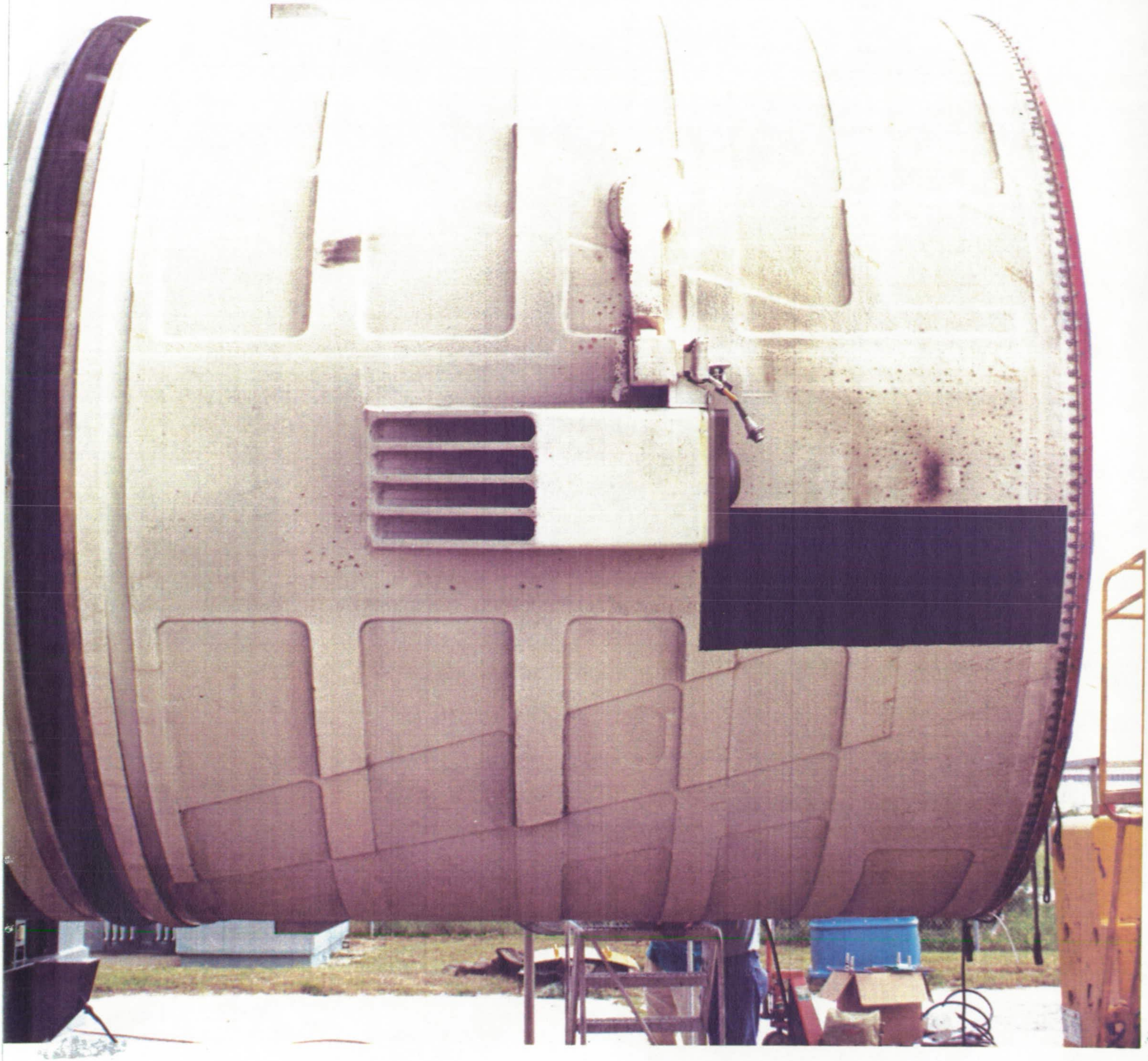
EGG/V 326A

FIGURE 7. RIGHT SRB AFT SKIRT EXTERIOR TPS





The RH frustum was missing no TPS but had 26 MSA-2 debonds over fasteners.



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.

Overall view of the RH SRM cases. The Field Joint Protection System closeouts were generally in good condition.

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

K5NA protective domes were lost from bolt heads on the aft side of the phenolic kick ring prior to water impact and exhibited a sooted substrate.

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum had 51 MSA-2 debonds over fasteners (Figure 8). A 2.9"x2.75" area of MSA-2 was missing from two fasteners on the stiffener below the BSM's near the 381 ring. The MSA-2 had separated completely from the substrate. The MSA-2 fracture edges and surrounding Hypalon paint were not sooted/charred, the exposed MSA-2 material was clean, and no unusual heating effects were visible. Samples were taken for laboratory analysis at MSFC. There was minor localized blistering of the Hypalon paint on the acreage areas of the frustum.

The upper left and lower right BSM covers had locked in the fully opened position and then had been subsequently deformed. The lower right attach ring was fractured at one location. The upper right BSM cover was missing. The substrate at the fracture planes, including the threads of the exposed screws, were sooted. Curved TPS cuts/substrate indentations near the location of the missing cover matched the size of a BSM cover lip. There was no evidence that unusual aerodynamic loading had occurred on the frustum. The fractured attach rings were removed for laboratory analysis at MSFC.

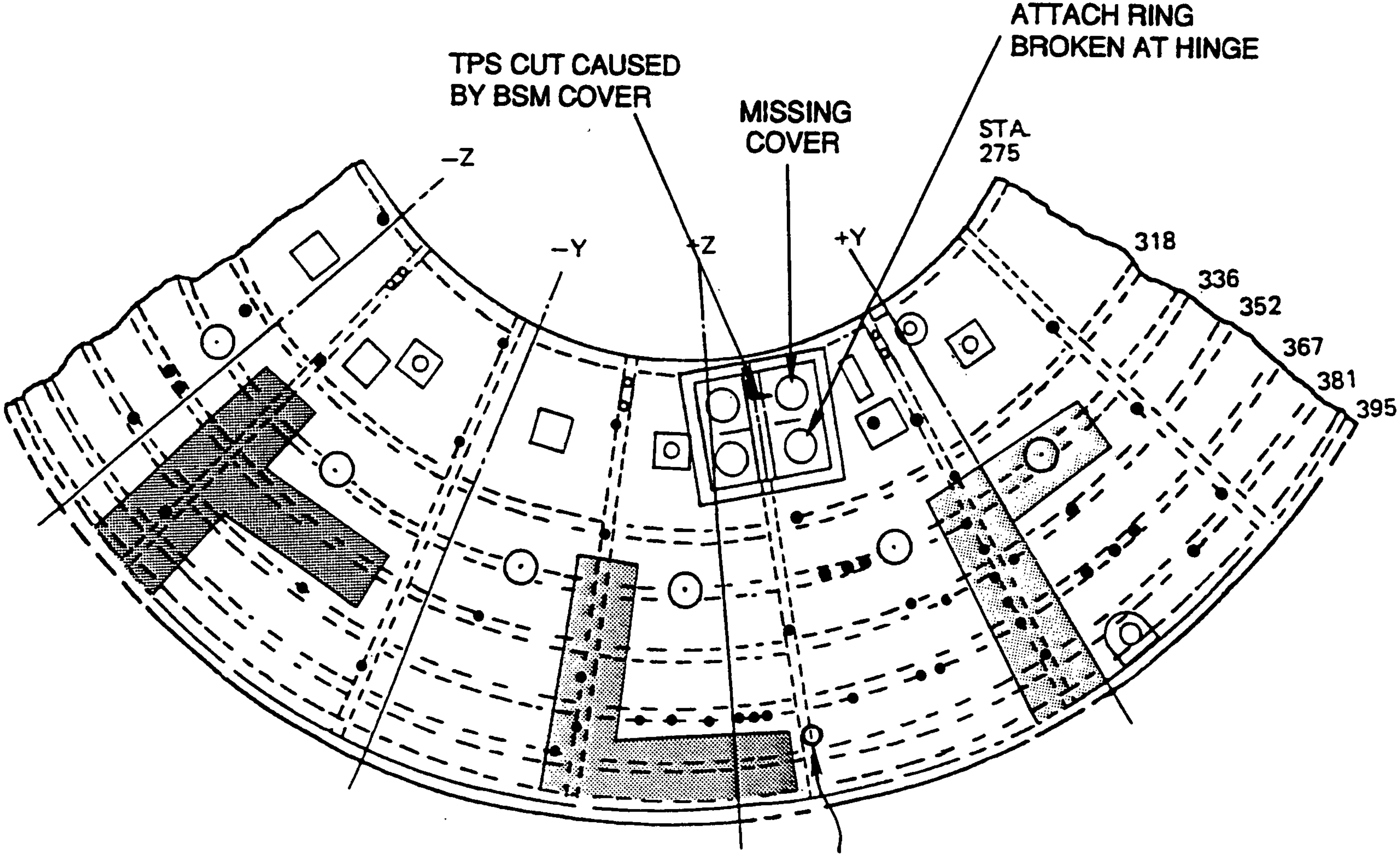
The LH forward skirt exhibited no debonds or missing TPS. The phenolic plates on both RSS antennae were intact. The forward separation bolt and electrical cables appeared to have separated cleanly. No pins were missing from the frustum severance ring. Minor blistering of the Hypalon paint occurred forward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

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, ETA ring, and IEA appeared undamaged. All three aft booster stiffener rings sustained water impact damage at approximately 210-270 degrees. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing. However, some of the K5NA had been applied beyond the splice plate closeout and overlapped the instafoam. The foam erodes or shrinks leaving the K5NA overlap exposed, which creates a mechanism for debris.

The phenolic material on the kick ring delaminated at several locations. Thirty-three K5NA protective dome were missing from bolt heads on the aft side of the phenolic kick ring. Five of these domes were lost prior to water impact (charred substrate). The aft skirt acreage TPS was in good condition. K5NA was missing from all aft BSM nozzles (Figure 10).

FIGURE 8. LEFT SRB FRUSTUM



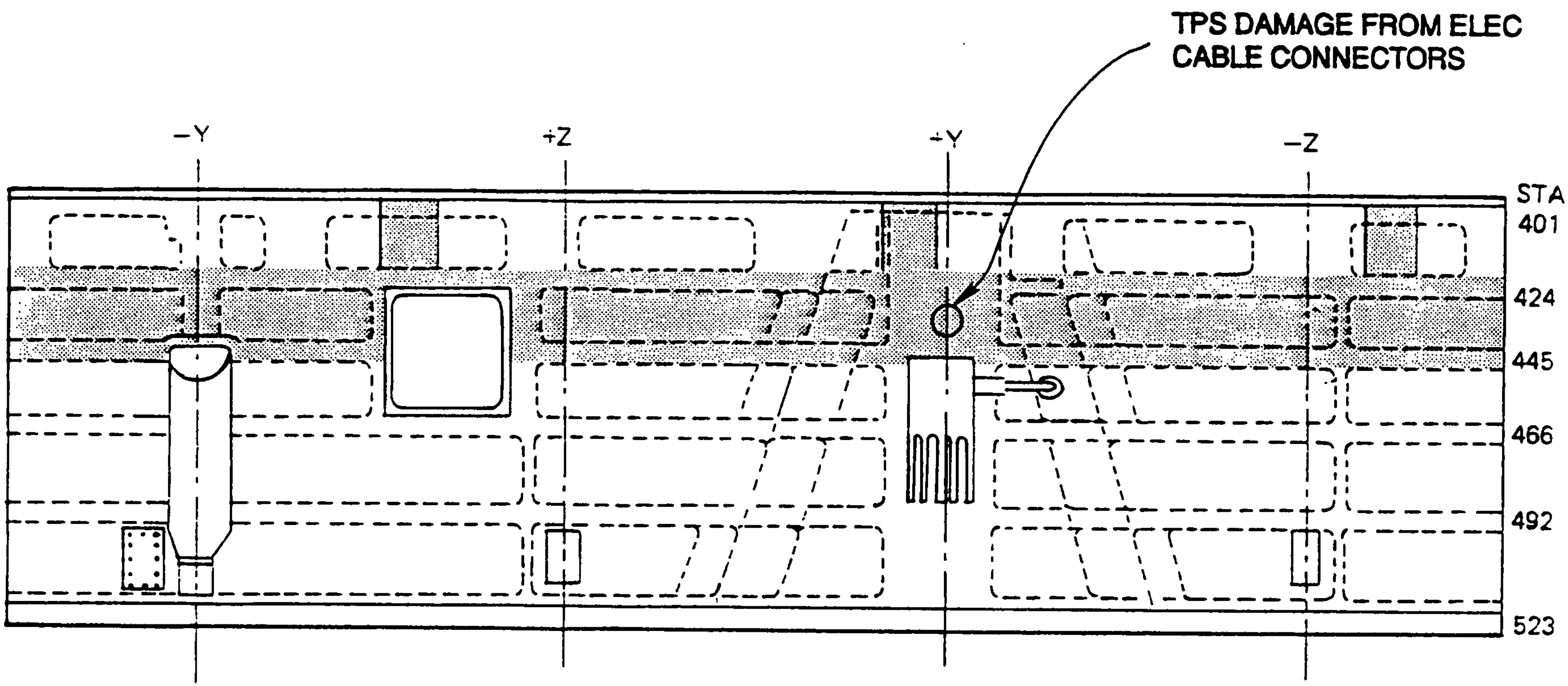
MISSING TPS

1 (2.9" x 2.75")

DEBONDS

51 (3 LARGER THAN 2" LENGTH)

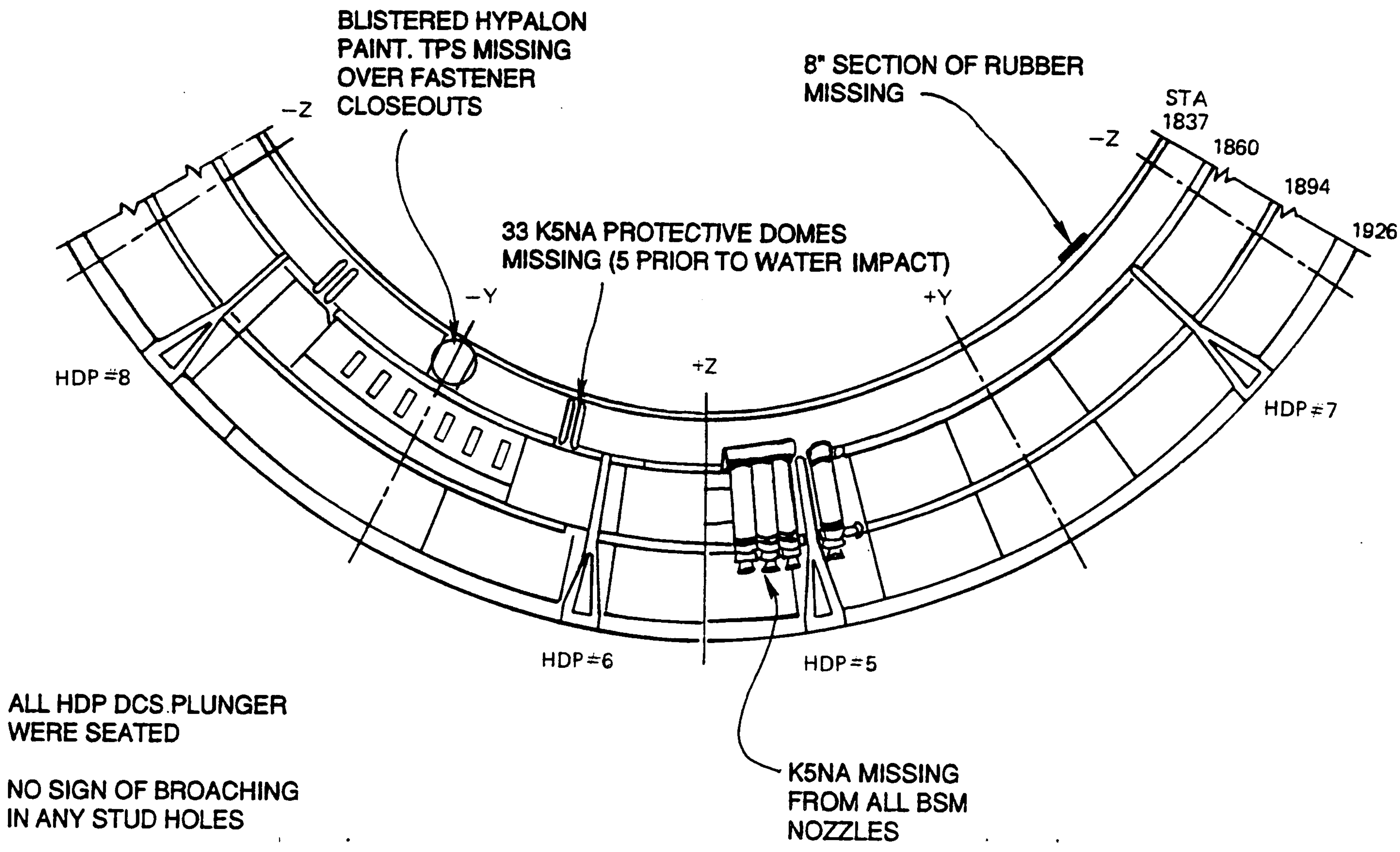
FIGURE 9. LEFT SRB FWD SKIRT



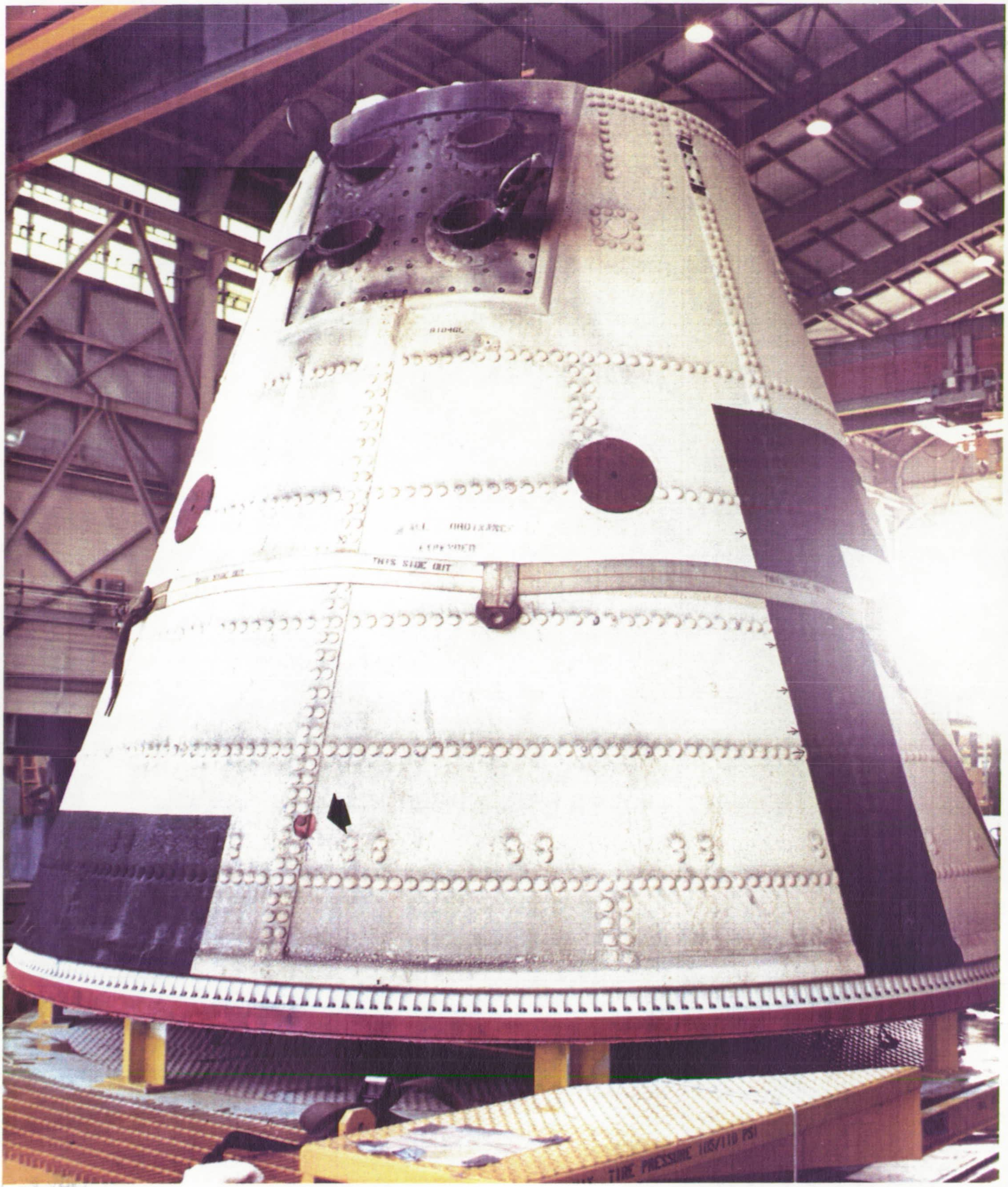
TPS MISSING	DEBONDS
NONE	NONE

SOME LOCALIZED BLISTERING OF HYPALON PAINT AROUND PROTUBERANCES

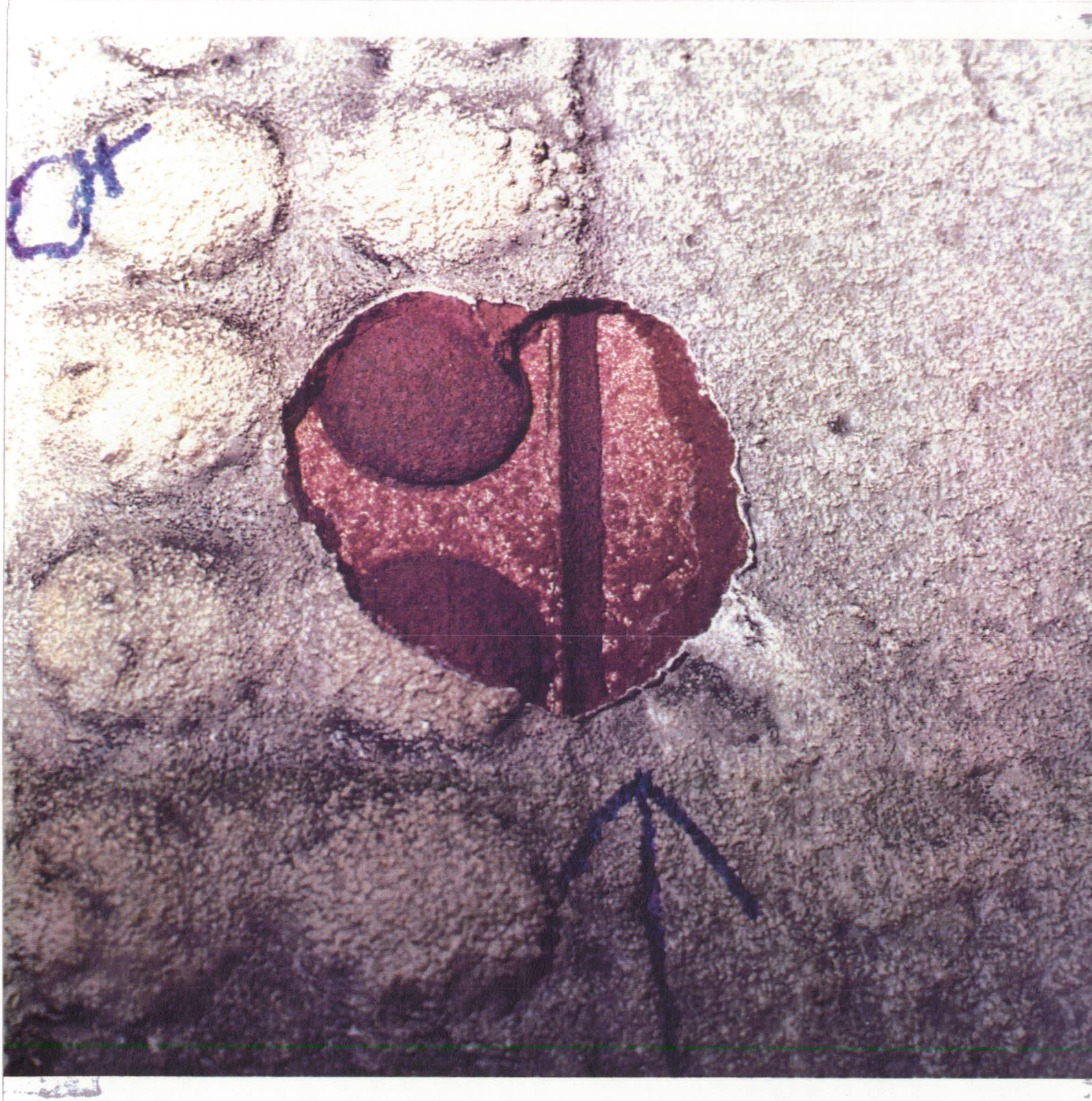
FIGURE 10. LEFT SRB AFT SKIRT EXTERIOR TPS



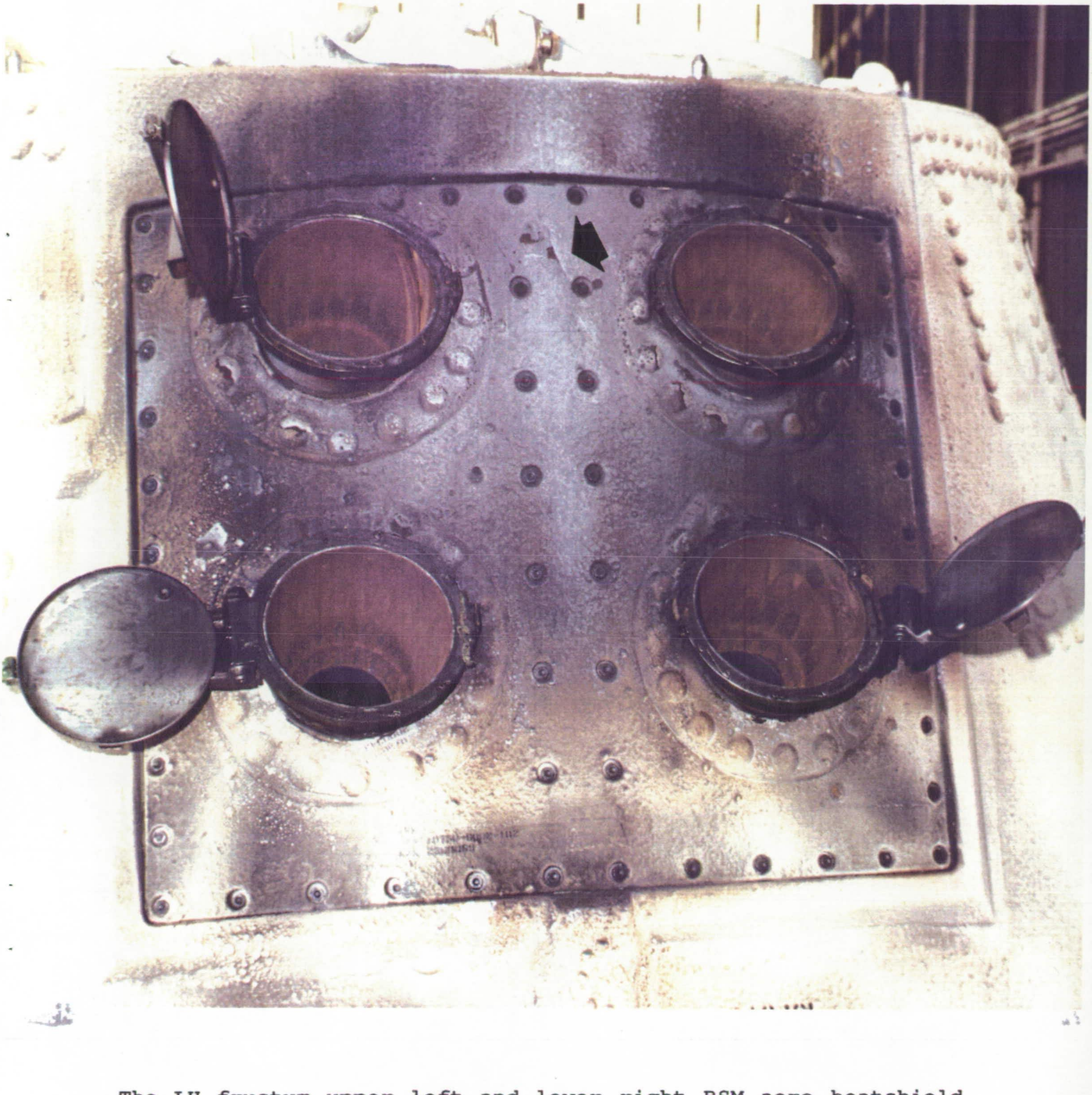
All four HDP Debris Containment System (DCS) plungers were seated. This was the third flight utilizing the optimized link. There was no sign of broaching in any of the stud holes. HDP #7 and HDP #8 EPON shim sidewall material was lost prior to water impact. MSFC will review the bonding process.



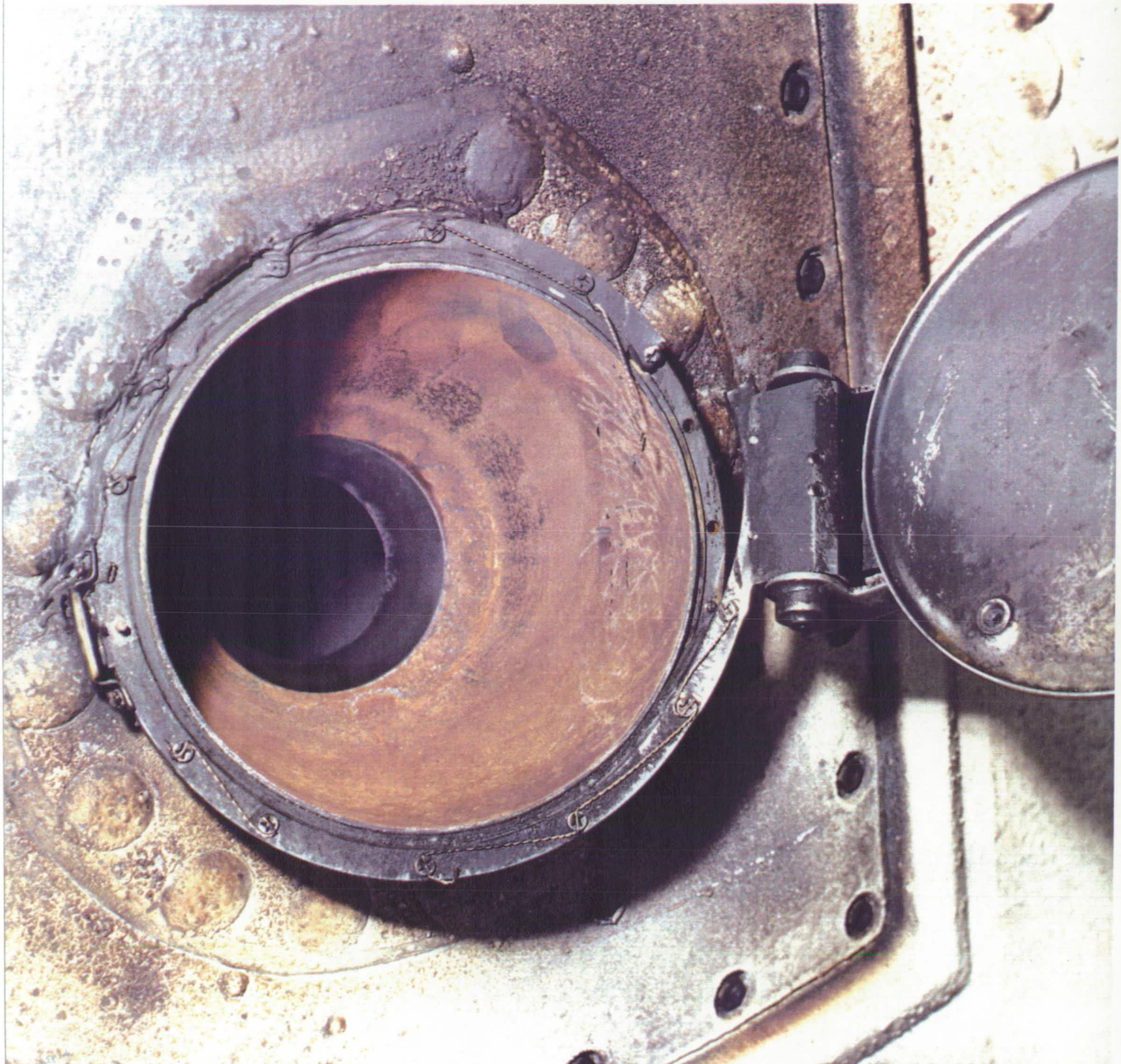
The LH frustum had 51 MSA-2 debonds over fasteners. Damage occurred to the forward BSM aero heatshield covers/attach rings and a piece of MSA-2 was missing near the 381 ring. BSM residue and sooting were typical. There was no evidence that unusual aerodynamic loading had occurred on the frustum.



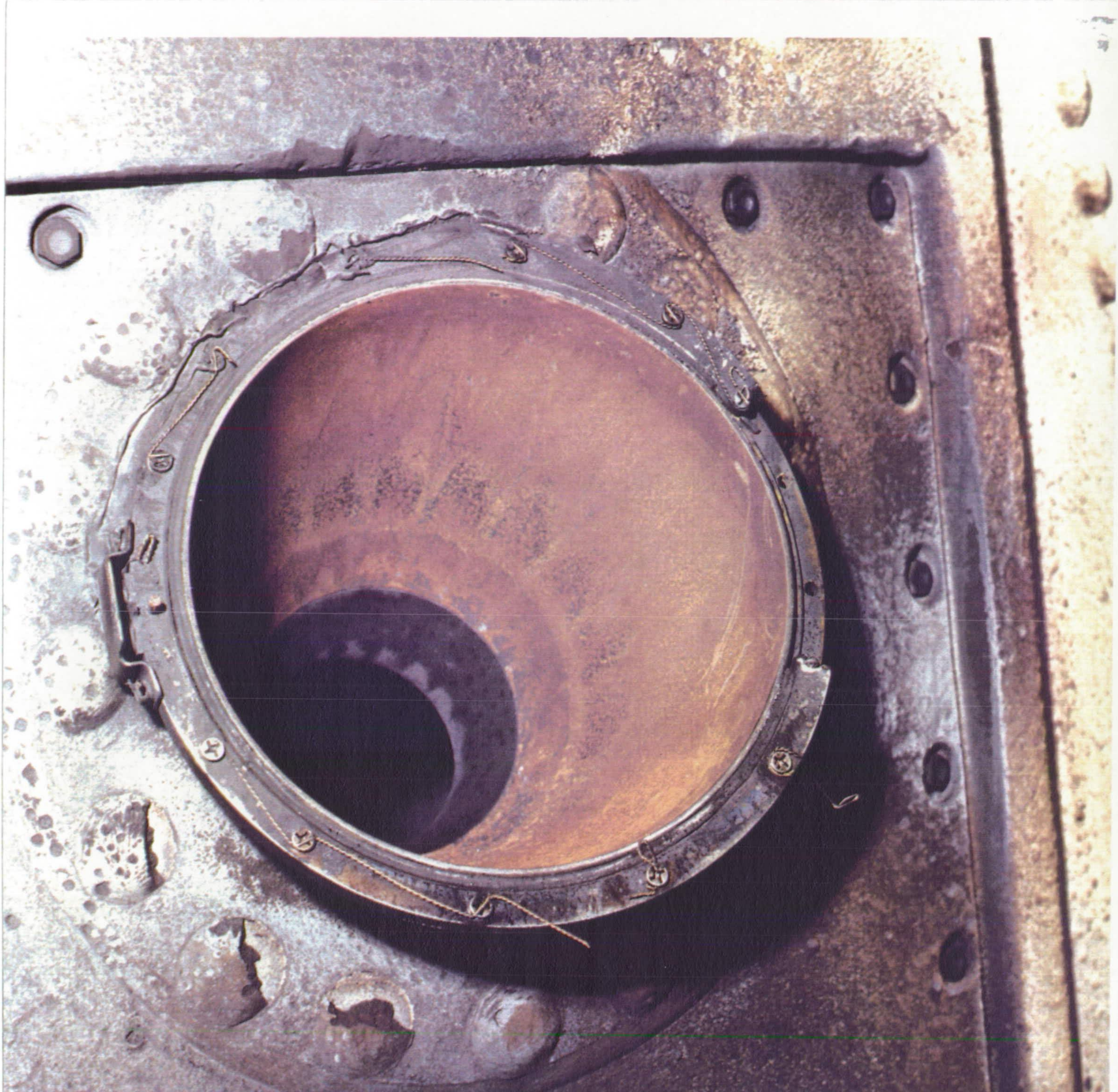
A 2.9" x 2.75" area of MSA-2 was missing near the 381 ring. The MSA-2 had separated completely from the substrate. The exposed surfaces of the surrounding material were clean and free of sooting/charring/heat effects. Hypalon peelback occurred laterally and was not in the direction of the nosecone. The MSA-2 was lost during the later stages of descent, at water impact, or during retrieval operations.



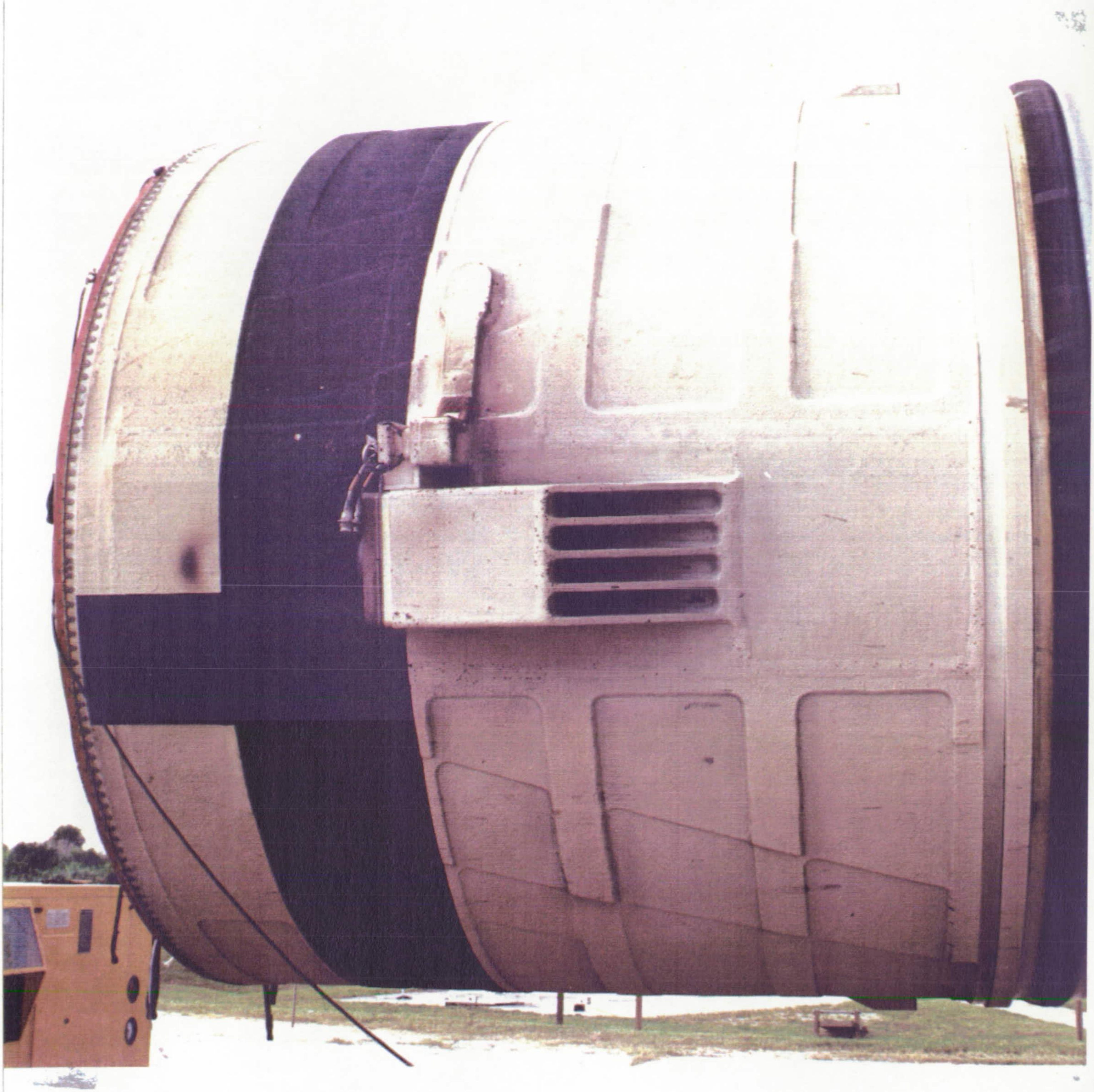
The LH frustum upper left and lower right BSM aero heatshield cover attach rings/hinges were deformed. The upper right cover was missing and the attach ring/hinge exhibited a ductile failure. Curved TPS cuts/substrate indentations (arrow) near the location of the missing cover matched the size of a BSM cover lip.



The lower right BSM aero heatshield cover attach ring/hinge had been deformed some time after being locked in the fully opened position. The attach ring was fractured at one location.

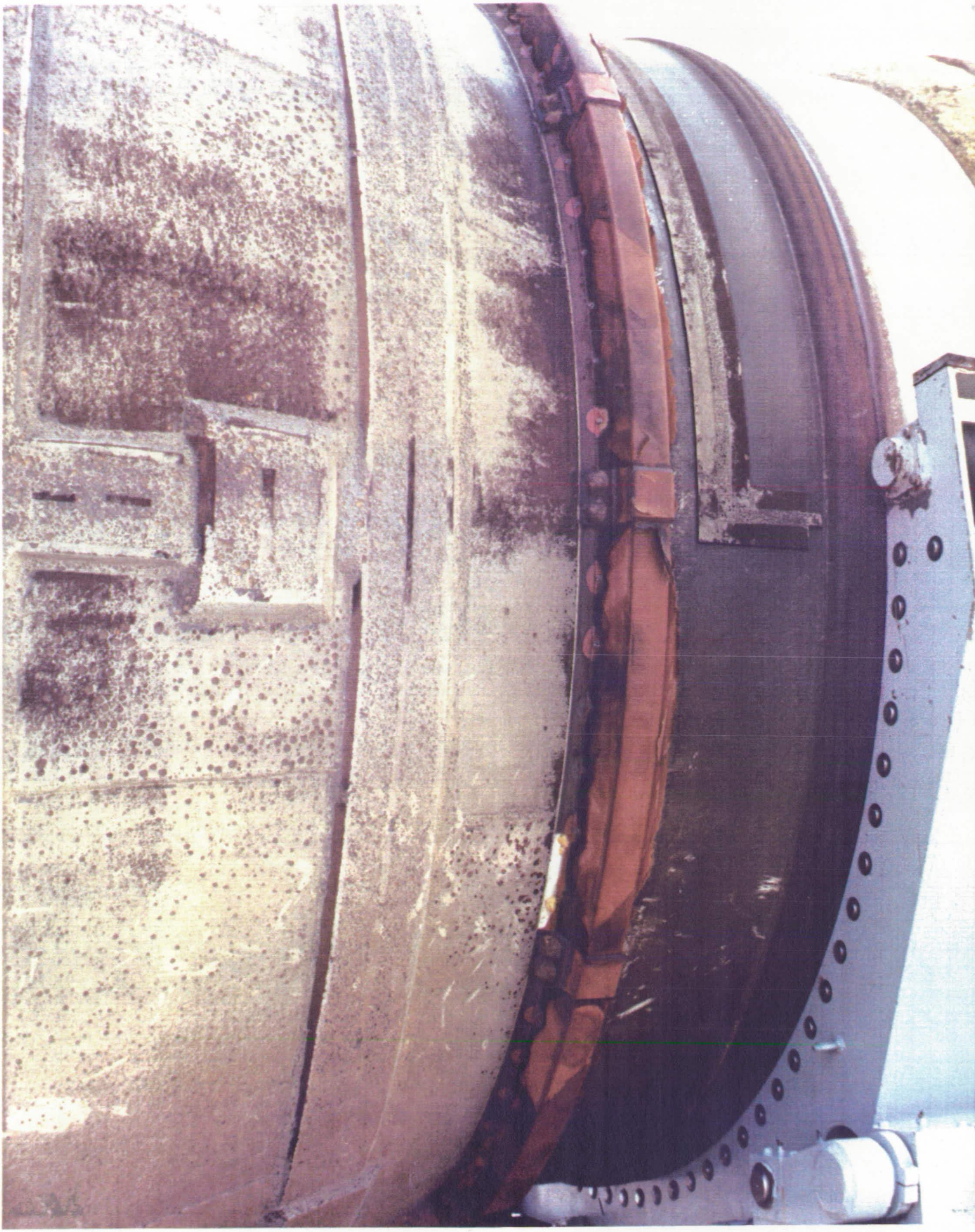


The substrate at the fracture planes, including the threads of the exposed screws, were sooted. MSFC laboratory analysis of the attach ring concluded the failure did not occur prior to or during BSM firing. There were no unusual aerodynamic loads during ascent or descent that could have caused the failure. SRB Max Q occurs during re-entry.



The left forward skirt exhibited no MSA-2 debonds. Minor blistering of Hypalon paint occurred forward of the ET/SRB attach point. The RSS antenna phenolic plates were intact.

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



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.

Aft skirt foot (sooted substrate) reveals part of the EPON shim material was missing prior to water impact.

7.3 RECOVERED SRB DISASSEMBLY FINDINGS

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 92 percent and individual holddown post retention percentages as listed:

HDP #	% of Nut without 2 large halves	% of Ordnance fragments	% Overall
1	99	99	99
2	84	95	88
3	99	93	99
4	99	97	99
5	73	32	58
6	99	97	99
7	99	92	98
8	99	99	99

STS-48 was the third 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 three flights utilizing the "optimized" link are:

HDP #	BI-044 STS-40	BI045 STS-43	BI-046 STS-48
1	99%	98%	99%
2	99%	31%	88%
3	38%	99%	99%
4	99%	99%	99%
5	23%	99%	58%
6	99%	99%	99%
7	62%	99%	99%
8	99%	99%	99%
TOTAL	78%	90%	92%
Debris Loss	58 oz	25 oz	19 oz

A laboratory analysis (ref USBI Rpt No. M&P-3033-059-91 dated Sept. 18, 1991) was performed at MSFC on the LH frustum MSA-2 divot area. Examination of the surrounding material showed that the exposed surfaces were clean and free of sooting/charring/ heat effects in an aero-thermal environment. Hypalon peelback occurred laterally and was not in the direction of the nosecone (forward flight). The report concluded the MSA-2 was lost either during the late stages of descent, at water impact, or during retrieval operations.

Laboratory analyses were also performed on the remaining attach hardware of the missing LH frustum BSM cover (ref USBI Rpt No. M&P-2017-053-91 dated October 1991 and the STS-48 BSM Aeroheat Shield Anomaly Investigation Strength Analysis Report). It should be noted that covers have been lost on seven previous flights (STS-2, 3, 4, 9, 11, 17, 28) and were attributed to re-entry, water impact, or retrieval operations. The analysis of the STS-48 damage showed that the cover did not fail prior to BSM firing. (Radar data at the time of BSM firing and SRB separation could not conclusively prove the forward BSM cover came off in the vicinity of the Orbiter). There were no unusual aero loads during the ascent and separation phases which could cause the loss of the cover. (SRB Max Q occurs during re-entry). A gouge in the cork, which was attributed to an impact from the lost cover, just forward and between the two upper cover positions precluded the possibility of losing the cover during ascent or separation while the SRB was in forward flight. The MSFC study concluded the cover came off during re-entry and was not a debris threat to the Orbiter. The IFA was closed based on the results of the study.

SRB Post Launch Anomalies are listed in Section 10.

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-103 (Discovery) was conducted on September 18 and 19, 1991, at Ames-Dryden (EAFB) 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 182 hits, of which 25 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. The following table breaks down the STS-48 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	14	100
Upper surface	9	66
Right side	0	5
Left side	1	6
Right OMS POD	0	2
Left OMS POD	1	3
TOTALS	25	182

The Orbiter lower surface had a total of 100 hits of which 14 had a major dimension of one inch or greater. 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 the total number of hits was slightly greater than average and the number of hits one inch or larger was slightly less than average. Figures 11 - 14 map the TPS debris damage for STS-48.

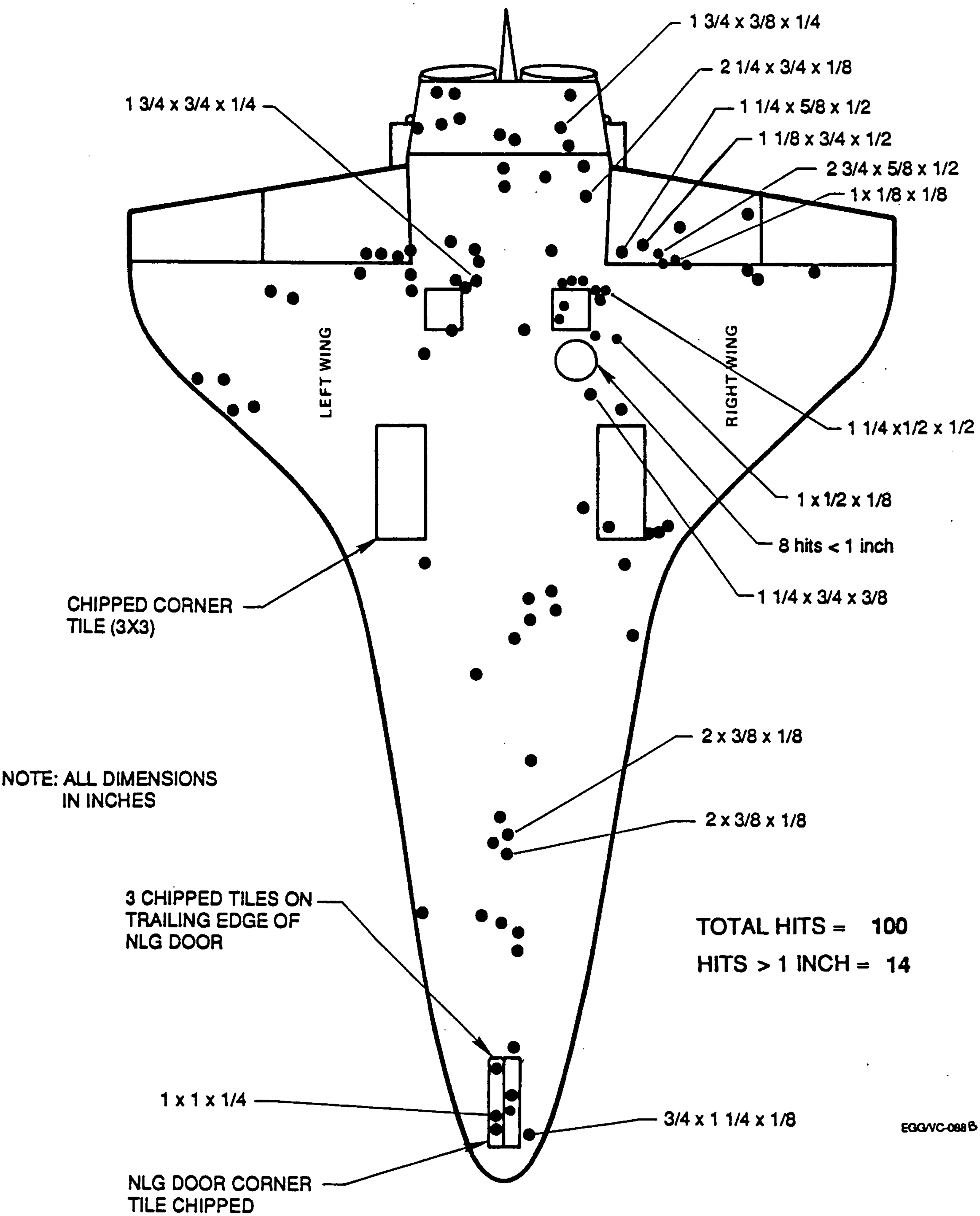
Twelve of the fourteen hits greater than an inch on the lower surface occurred to the right of the Orbiter centerline. This pattern is consistent with ice originating from the ET LO2 feedline bellows and support brackets (waived ET ice).

No TPS damage was attributed to material from the wheels, tires, or brakes. Although the inboard main landing gear tires exhibited some minor material loss, the main landing gear tires were considered to be in good condition for a concrete runway landing.

Damage to the base heat shield tiles was less than average. The main engine closeout blankets were in excellent condition with the only observed damage being minor fraying from 6:00 to 7:00 o'clock on SSME #1.

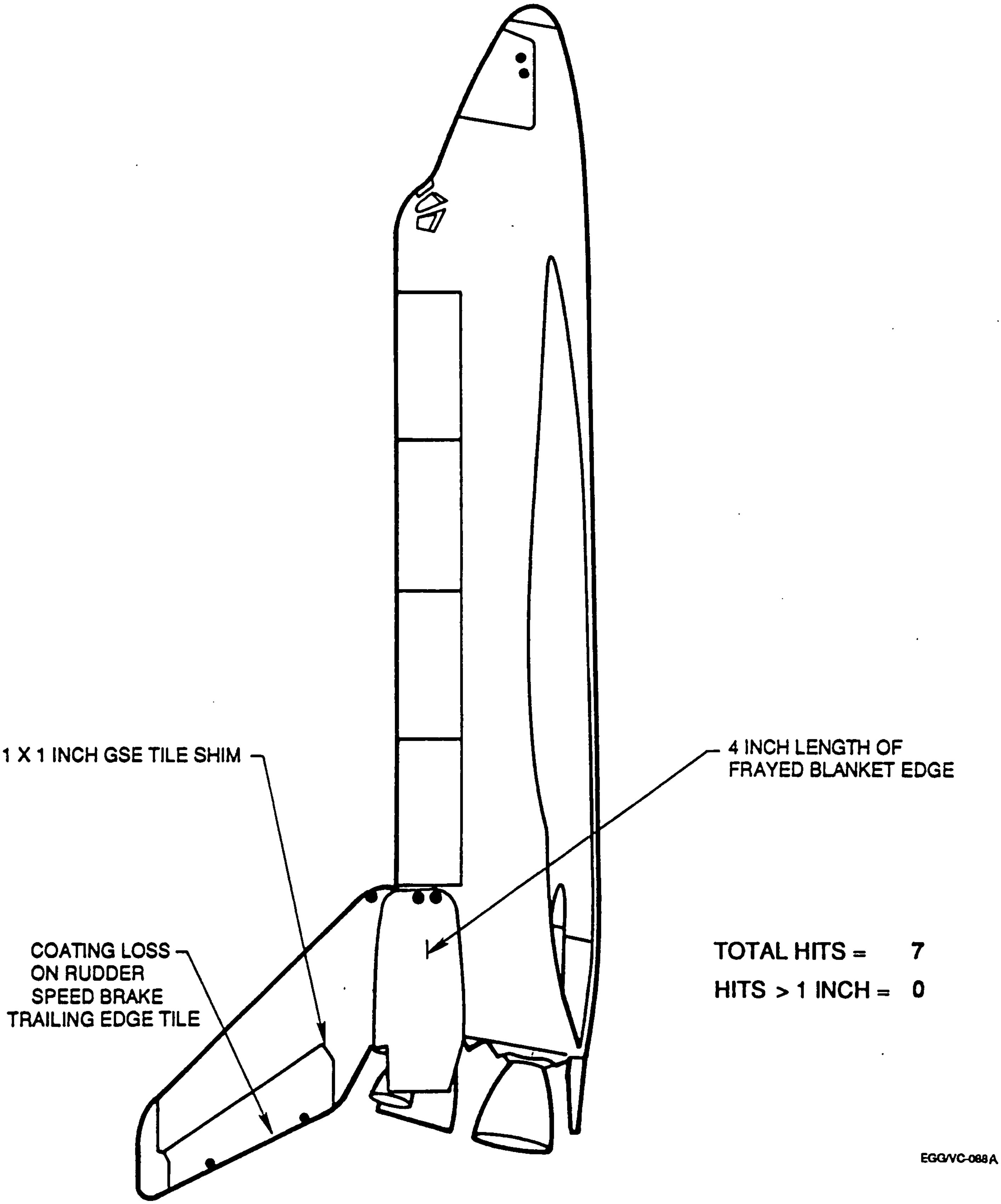
STS-48

FIGURE 11. DEBRIS DAMAGE LOCATIONS



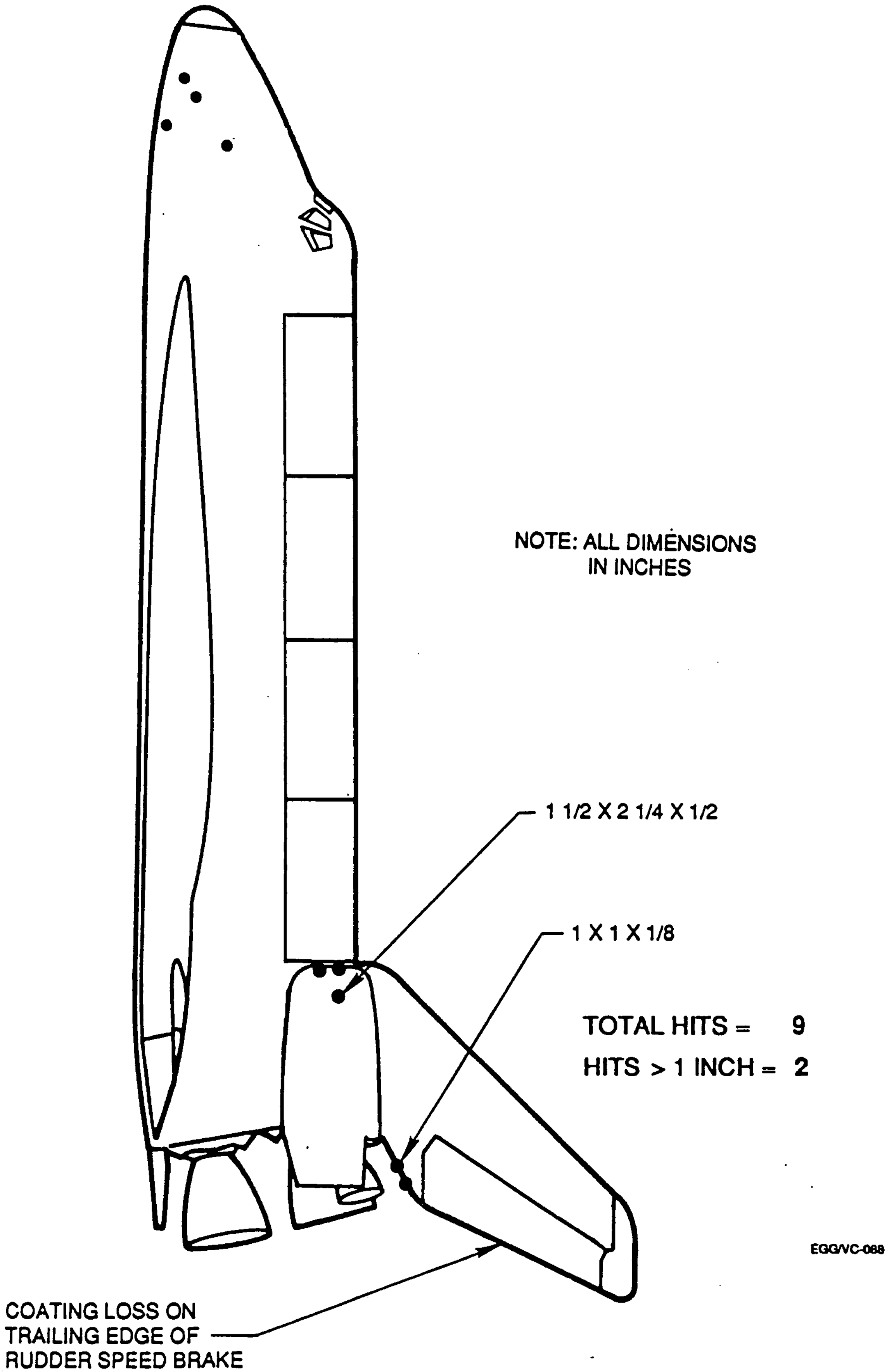
STS-48

FIGURE 12. **DEBRIS DAMAGE LOCATIONS**



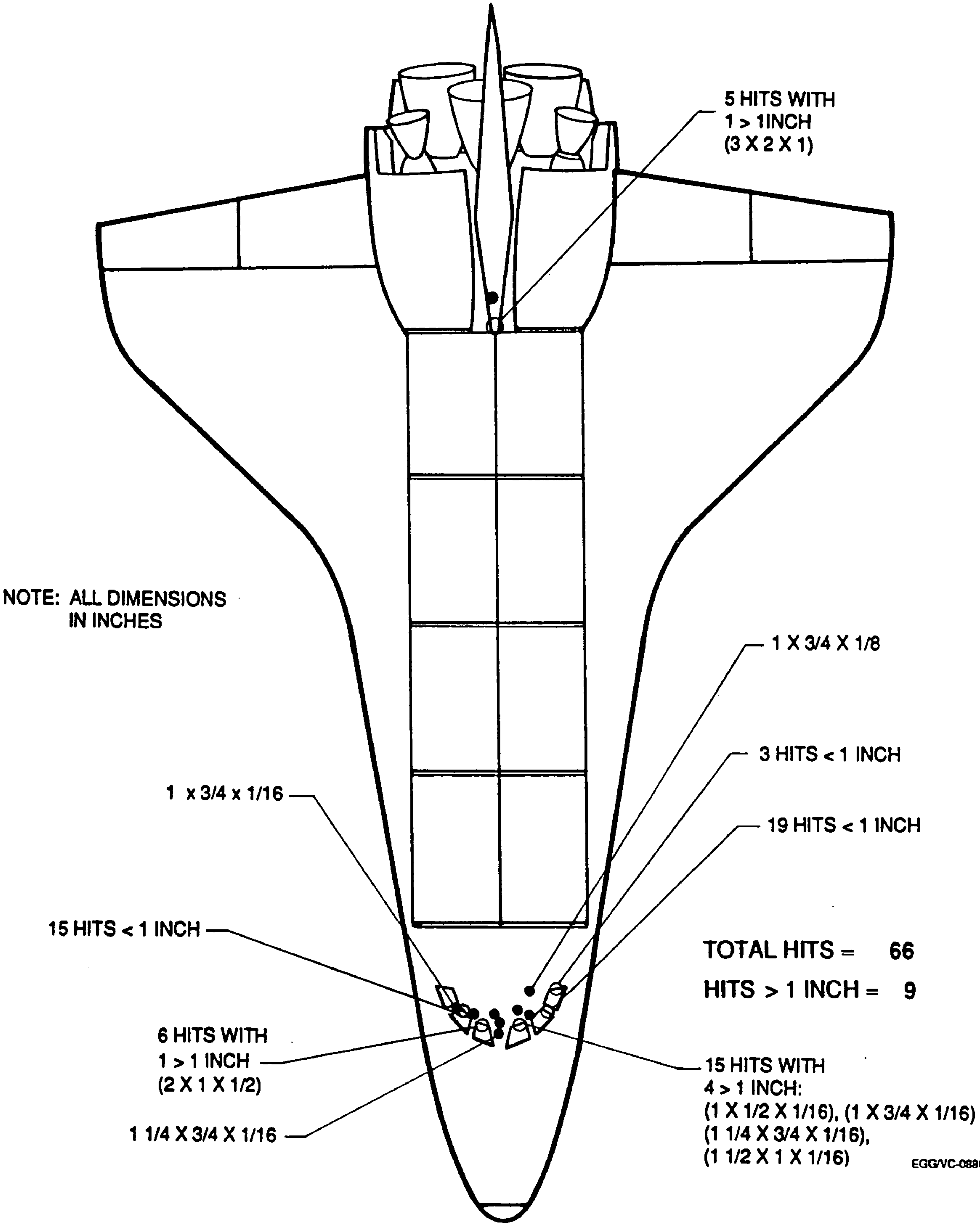
STS-48

FIGURE 13. **DEBRIS DAMAGE LOCATIONS**



STS-48

FIGURE 14. DEBRIS DAMAGE LOCATIONS



A thin orange GSE tile shim, approximately 1 inch by 1 inch in size, protruded from tiles at the bottom of the RH rudder speed brake near the hinge. GSE tile shim should not remain on the Orbiter for flight.

Orbiter windows #1, #2, #5, & #6 were lightly hazed. Windows #3 and #4 exhibited moderate to heavy hazing and had numerous streaks. Laboratory analysis was performed on samples taken from all windows (reference Figure 15 and Section 9.0).

A greater than previously observed number of damage sites were noted on the perimeter tiles of Orbiter windows #1 through #6. Most of the impact sites were only surface coating losses or were no more than 1/16th inch deep. This damage may have been caused by the RTV used to bond paper covers to the FRCS nozzles.

A cluster of 7 hits with one larger than one inch (3"x2"x1") was present on the leading edge of the vertical stabilizer near the root. Damage in this area is uncommon and may possibly be related to the damage around the forward facing windows.

All ET/Orbiter separation ordnance device plungers functioned properly. The EO-1 separation assembly stop bolts did not sustain any deformation. The LO2 ET/ORB umbilical face plate was wrinkled. This was probably caused by material shrinkage during cryogenic loading and was not considered to be an anomaly.

A portable infrared thermometer was used to measure the surface temperatures of three areas on the Orbiter TPS after landing (OMRSD V09AJ0.095). Seventy minutes after wheel stop, the Orbiter nosecap RCC was 112 degrees F, the RH wing leading edge RCC panel #9 was 89 degrees F, and the RH wing leading edge RCC panel #17 was 88 degrees Fahrenheit (reference Figure 16).

Runway 15/33 was inspected by LSOC personnel on September 17, 1991, and all potentially damaging debris was removed. Runway 22 was inspected and swept by Air Force personnel. Both runways were determined to be in acceptable condition.

In summary, the total number of Orbiter TPS debris hits was greater than average and the number of hits with a major dimension one inch or greater was near average when compared to previous flights as shown in the comparison charts (Figure 17-19). The distribution of hits on the Orbiter lower surface 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.

FIGURE 15.

STS-48 DEBRIS DAMAGE CHEMICAL SAMPLE LOCATIONS

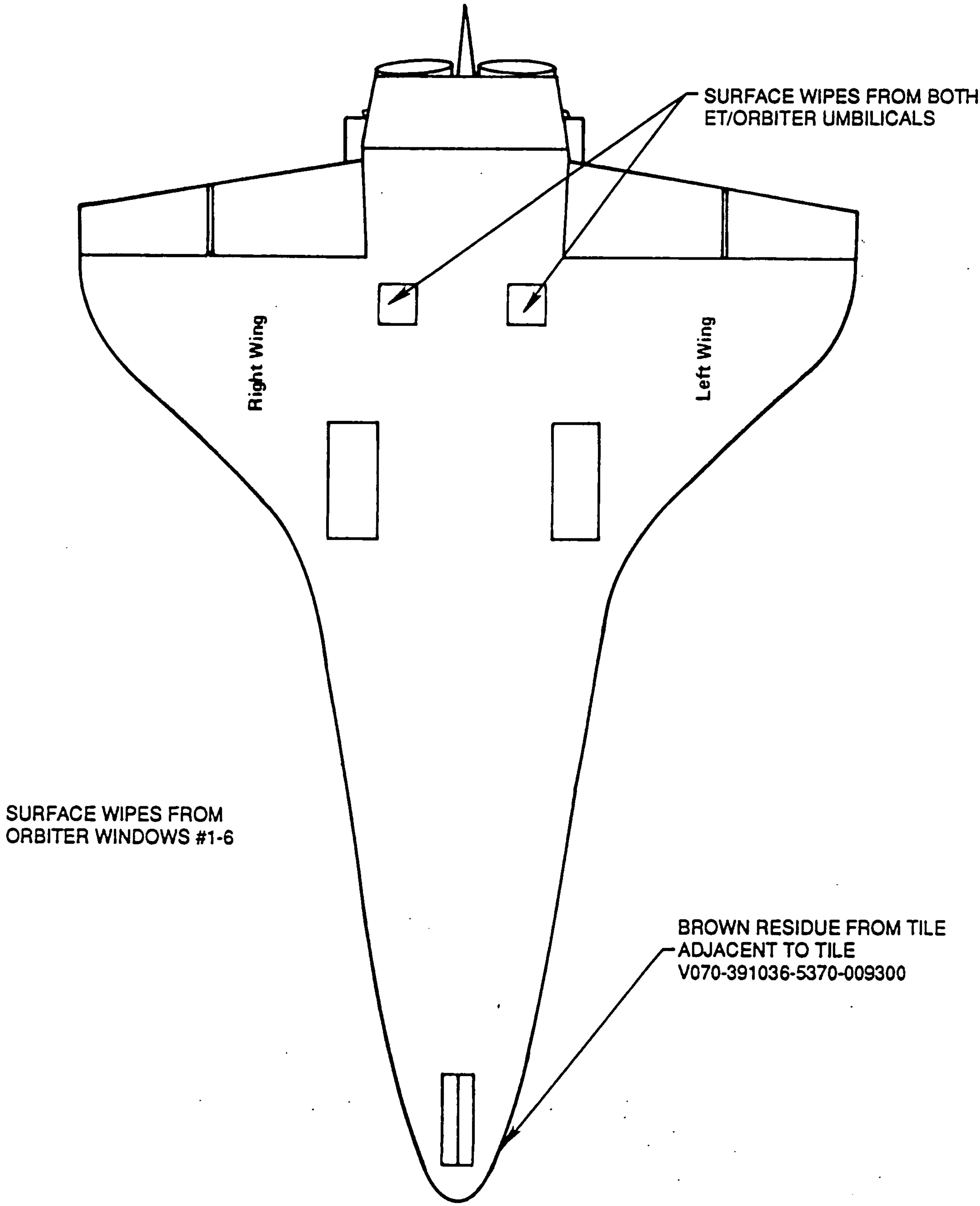


FIGURE 16. **STS-48 RCC TEMPERATURE MEASUREMENTS**

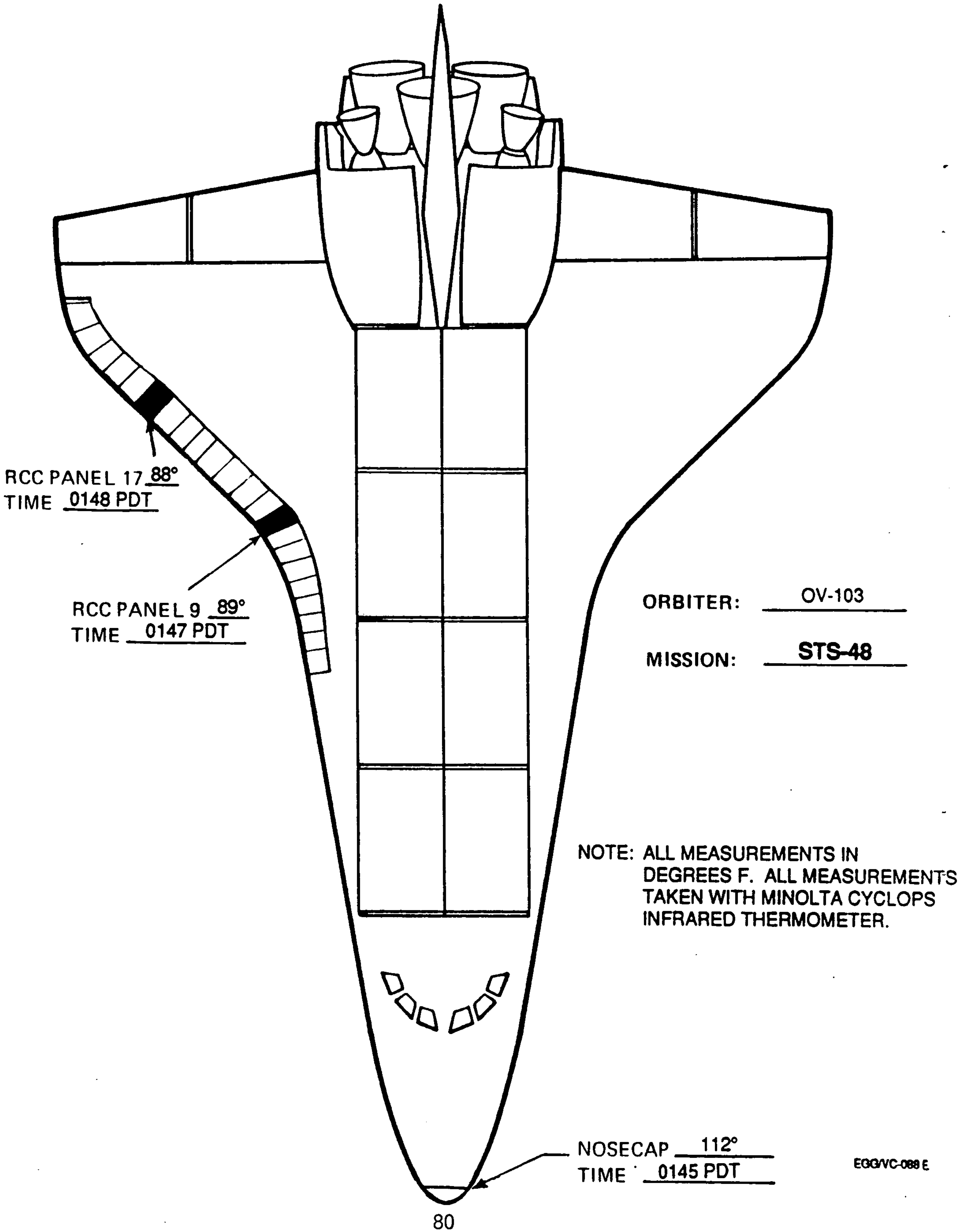


FIGURE 17: POST FLIGHT DEBRIS DAMAGE SUMMARY

	> 1 INCH	TOTAL	SINCE RETURN TO FLIGHT > 1 INCH	SINCE RETURN TO FLIGHT 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
SUM	709	3611	272	1808
AVERAGE	23.6	120.4	18.1	120.5
SIGMA	11.6	56	5.2	53

THIS ANALYSIS DOES NOT INCLUDE STS-24, 25, 26, 26R, 27R, AND 30R
THESE MISSIONS HAD DAMAGE CAUSED BY KNOWN SOURCES

FIGURE 18. COMPARISON TABLE

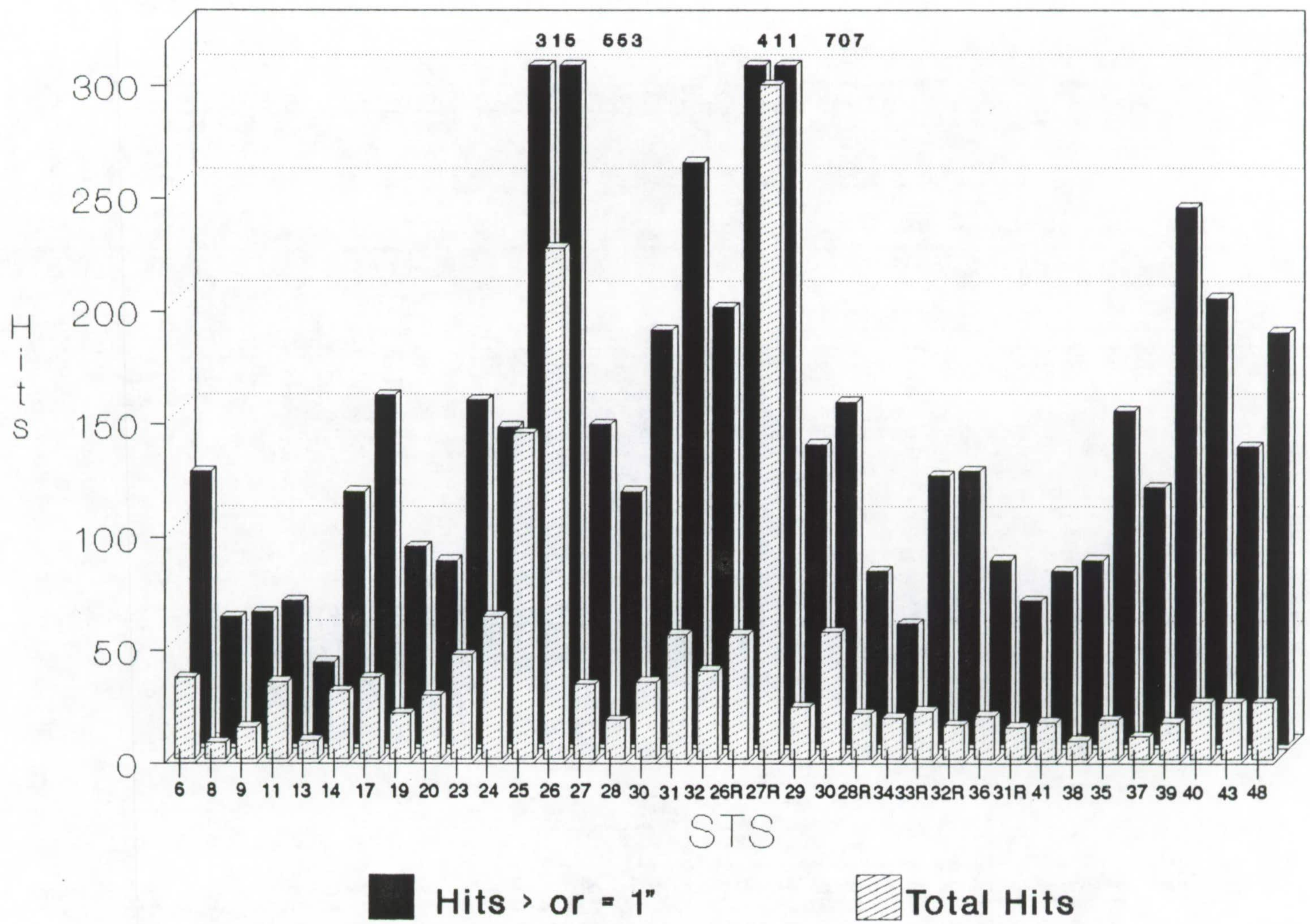
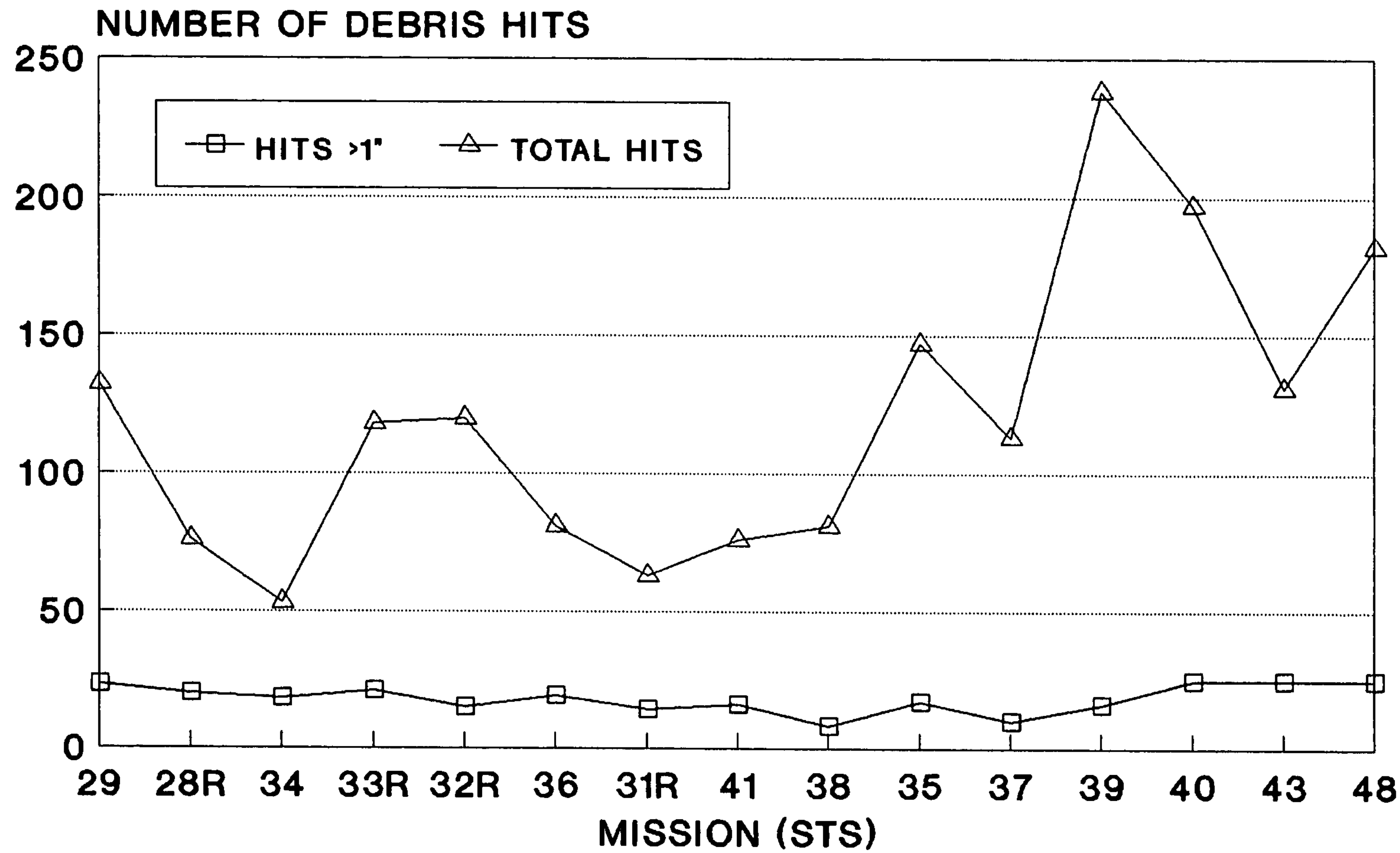


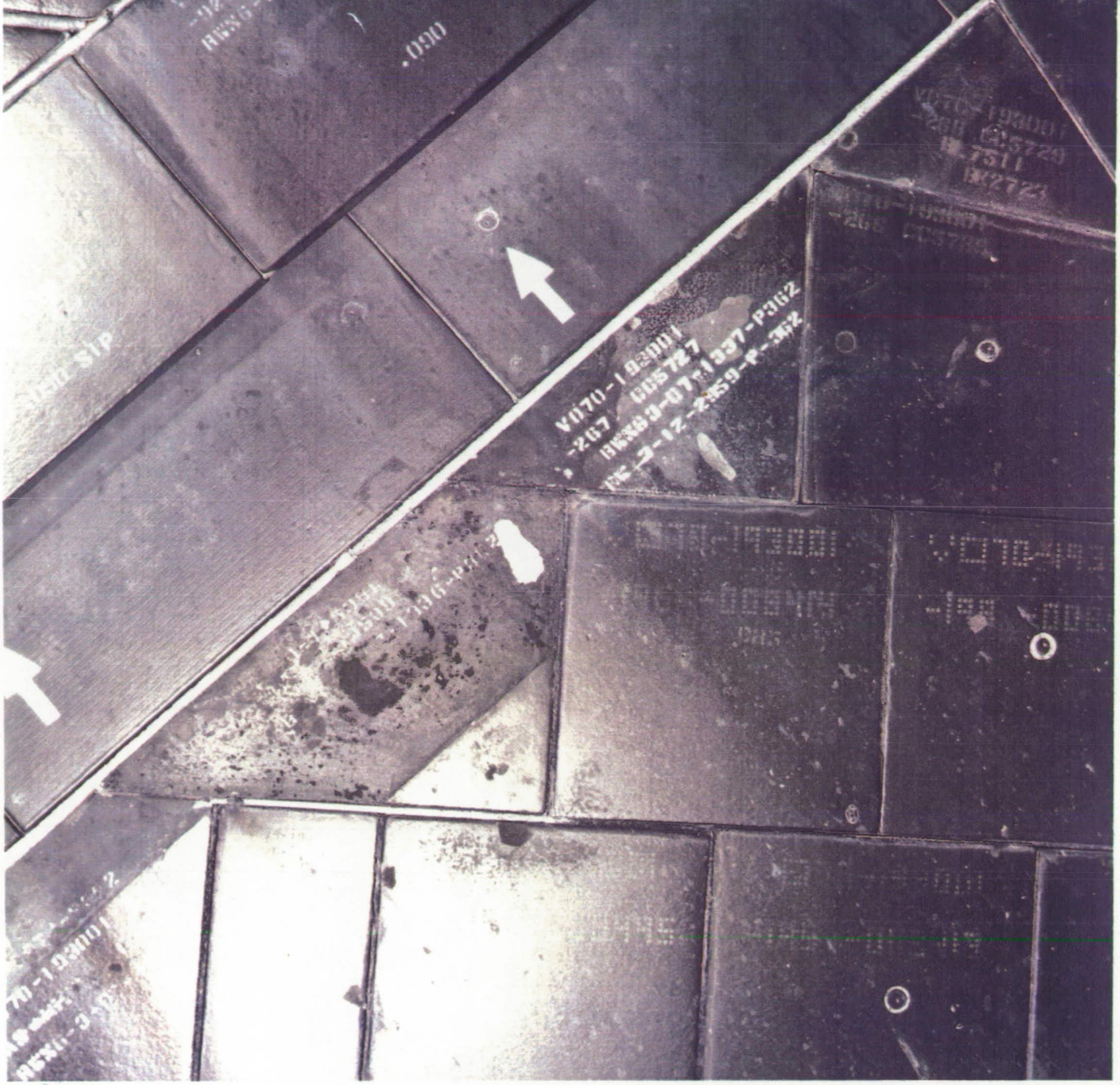
FIGURE 19. ORBITER TPS DEBRIS DAMAGE
STS-29 THROUGH STS-48



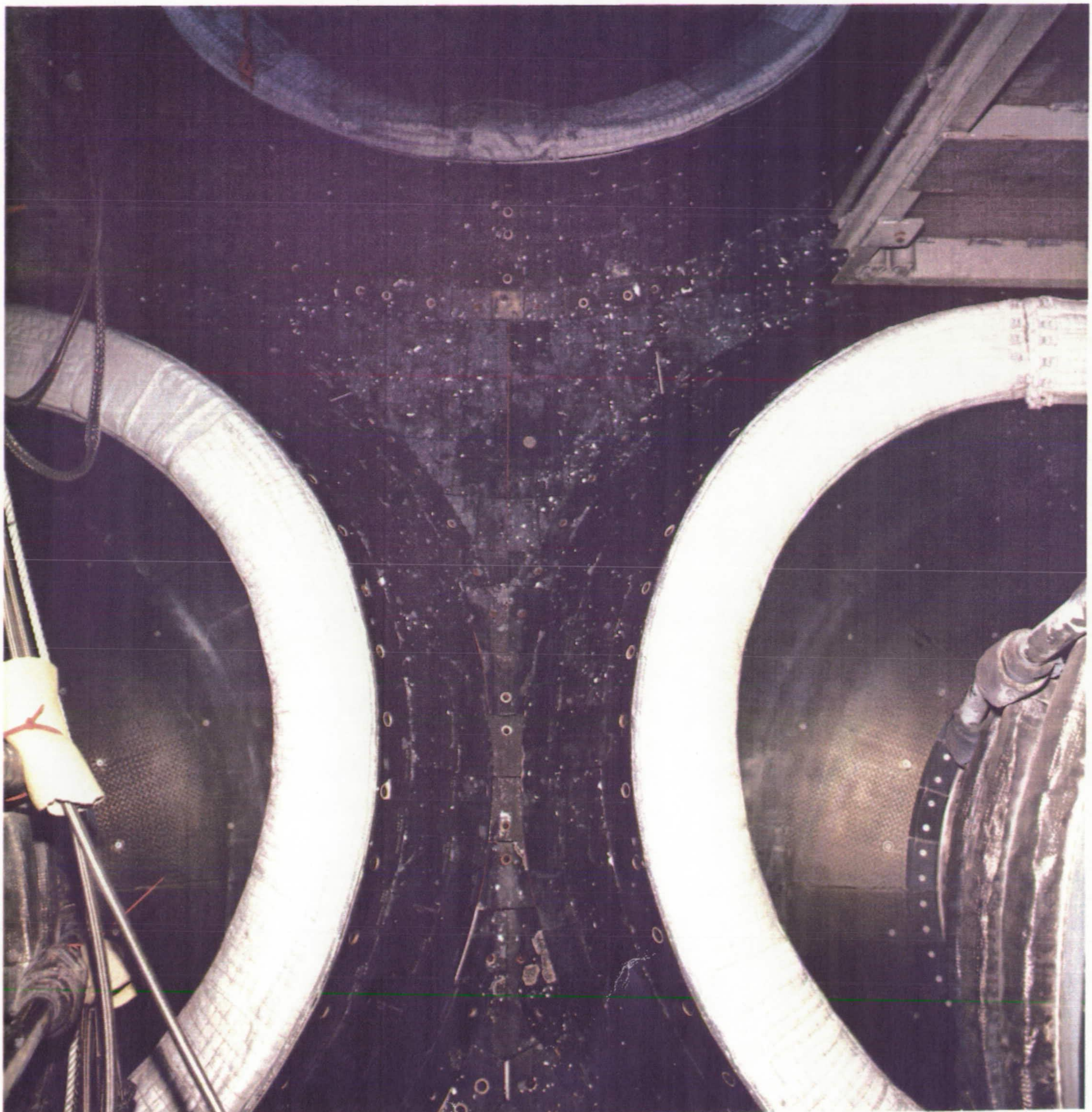
AVERAGES: > 1" = 18.1, TOTAL = 120.5

ORIGINAL PAGE
COLOR PHOTOGRAPH

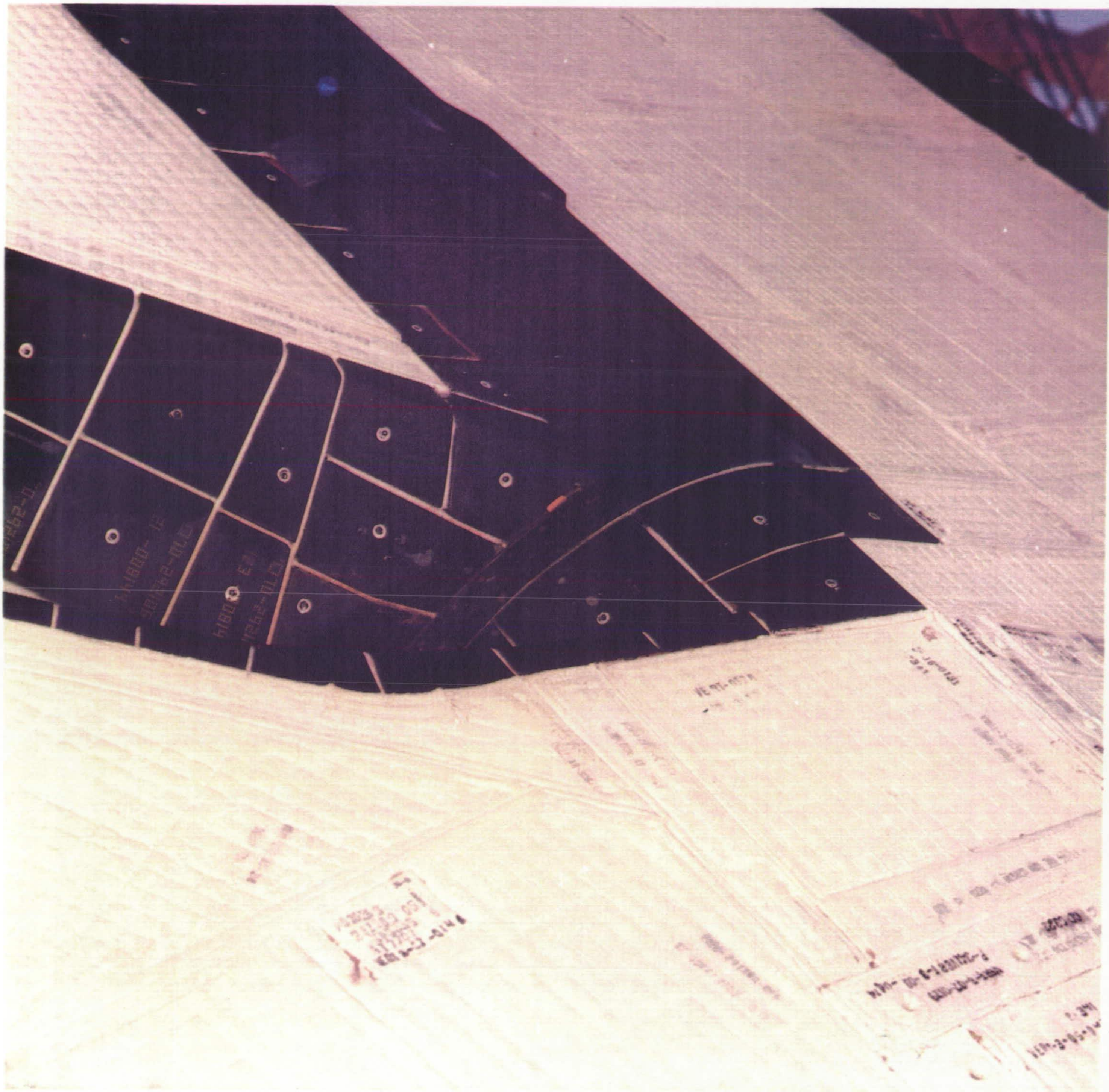
Typical tile damage on the Orbiter lower surface



Typical tile damage on the Orbiter lower surface

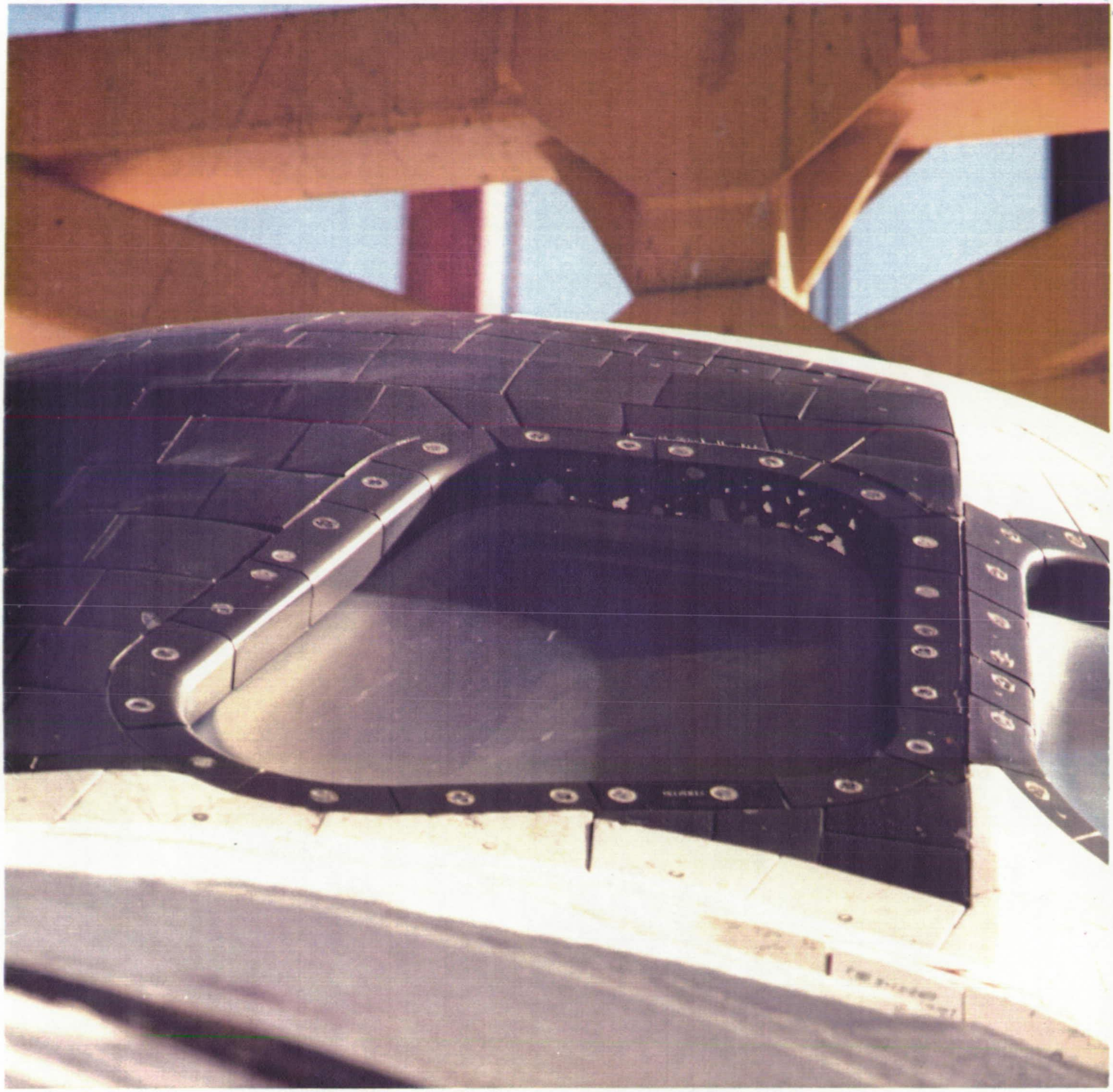


Damage to the base heat shield tiles was less than average. The main engine closeout blankets were in excellent condition with only minor fraying damage on the SSME #1 blanket.



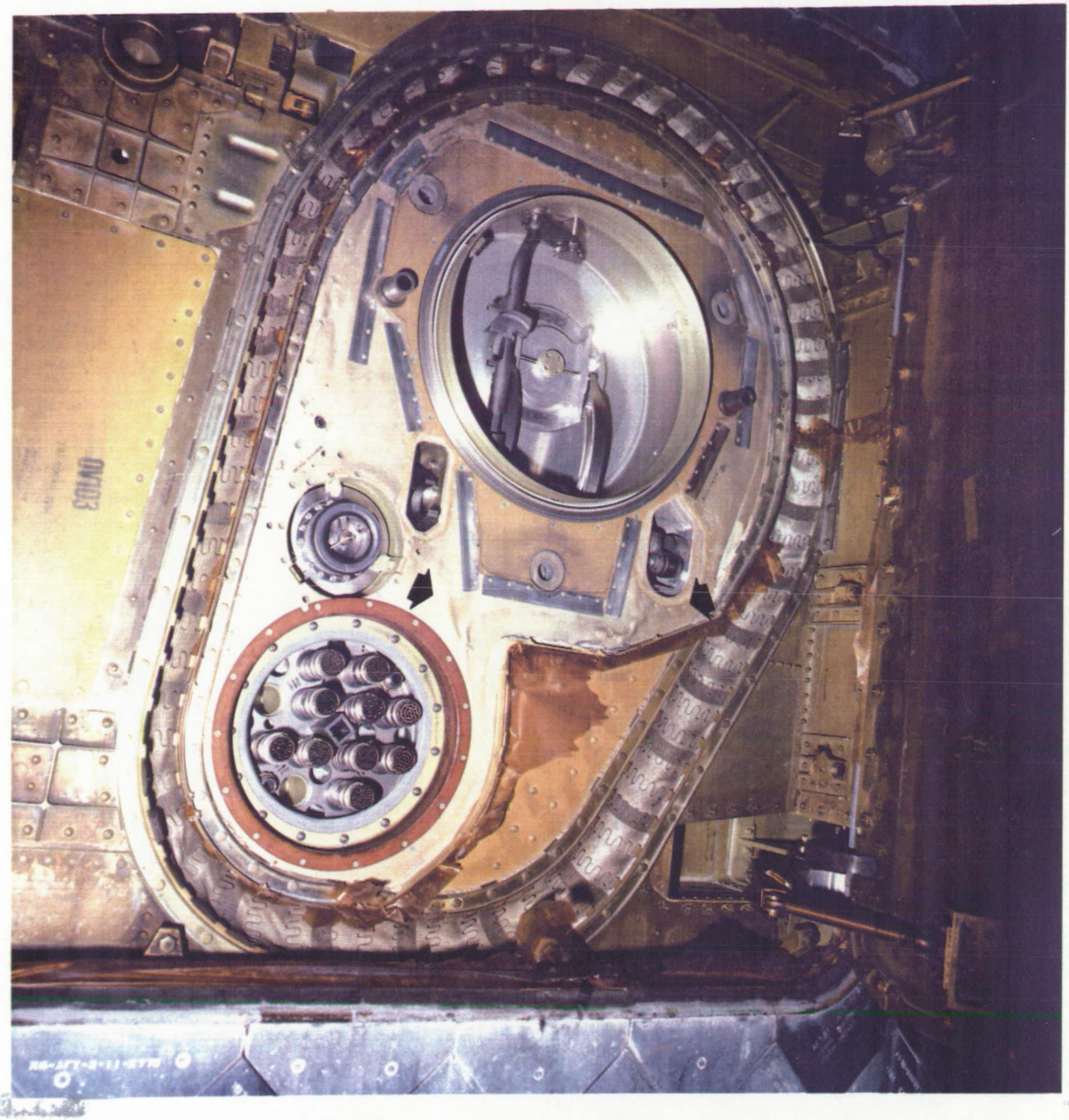
A thin, orange GSE tile shim, approximately 1 inch by 1 inch in size, protruded from tiles at the bottom of the RH rudder speed brake near the hinge.

A cluster of 7 hits with one larger than one inch (3"x2"x1") was present on the leading edge of the vertical stabilizer near the root. Tile damage in this area is uncommon and may possibly be related to tile damage around the forward facing windows.

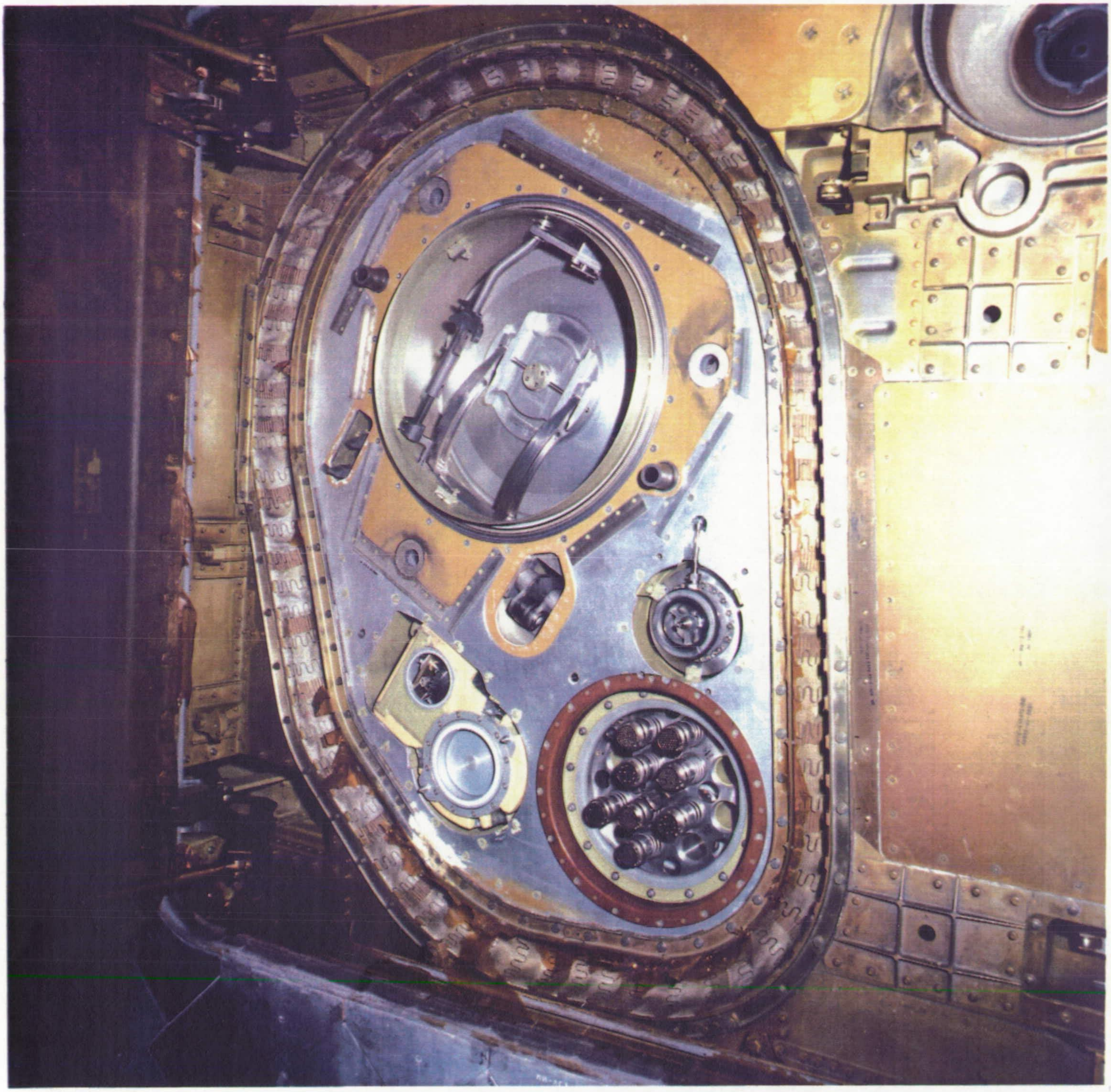


Orbiter windows #1 and #2 were lightly hazed. Window #3 exhibited moderate to heavy hazing and had numerous streaks. A greater than previously observed number of damage sites occurred on the perimeter tiles of windows #1-#6. Most of the impact sites did not exceed a depth of 1/16th inch. This damage may have been caused by the RTV used to bond paper covers to the FRCS nozzles.

Orbiter windows #5 and #6 were lightly hazed. Window #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 #1-#6. Most of the impact sites did not exceed a depth of 1/16th inch. This damage may have been caused by the RTV used to bond paper covers to the FRCS nozzles.



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. Wrinkling of the umbilical face plate (arrow) was probably caused by material shrinkage during cryo load and was not considered to be an anomaly.



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.

9.0 DEBRIS SAMPLE LAB REPORTS

A total of 13 samples were obtained from Orbiter OV-103 during the STS-48 post landing debris assessment at Ames-Dryden Flight Research Facility (ADFRF), California (Figure 15). The 13 submitted samples consisted of 8 Orbiter window wipes (W1-8), 1 tile residue sample, and 4 samples from the LOX and LH2 ET/Orbiter umbilicals. 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 placing and correlating 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.

Orbiter Windows

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

1. Metallic particles
2. Glass fibers (high-temperature insulation)
3. Cerium-rich materials
4. Paint, rust, dust and salt
5. Organics and organic fibers
6. Earth compounds
7. Silica-rich materials

Debris analysis provides the following correlations:

1. Metallic particles (aluminum, stainless, carbon, steel, and 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. Glass fibers (high-temperature 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; rust is an SRB/BSM exhaust residue; dust is of environmental origin; and salt is a naturally-occurring landing site product.

5. Organics were found to be carbohydrate, starch, ester, nylon and Teflon (adhesive/proteinaceous origin); organic fibers were cellulose (sample cloth origin).

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

7. Silica-rich material could be from Orbiter TPS or of landing site origin.

Orbiter Tile

Results of the tile sample chemical analysis revealed the presence of the following materials:

1. White silica-rich material
2. Metallics, rust, dust and salt
3. Organics and paint
4. Calcite

Debris analysis provides the following correlations:

1. White silica-rich material could originate from the Orbiter thermal protection system (TPS) or the landing site.

2. Metallics and rust originate from SRB/BSM exhaust residue; dust is of environmental origin; salt is a landing site product.

3. Organic material had an amorphous silica present (as in tile repair material); paint is of flight hardware/ facility/GSE origin.

4. Calcite is of landing site origin.

Orbiter/ET Umbilical

Samples from the ET-Orbiter umbilicals were obtained from LO2/LH2 umbilical plates and umbilical door inner surfaces. Results of the Orbiter/ET umbilical samples revealed the presence of the following materials:

LO2/LH2 umbilical plates

1. Trace metallics
2. Rust, dust and salt
3. Silica-rich material
4. Organics and paint

Umbilical door inner surface

1. Metallics
2. Organics

Debris analysis provides the following correlations:

LO2/LH2 umbilical plates

1. Trace metallic particles originate from SRB/BSM exhaust residue or ET/Orbiter separation residuals

2. Rust is common to SRB/BSM exhaust; dust and salt are natural environment products.

3. Silica-rich material could be of Orbiter TPS (thermal protection system) or landing site origin.

4. Organics were of umbilical closeout origin and Viton from umbilical MPS (main propulsion system) processing; paint is of flight hardware/facility/GSE origin.

Umbilical door inner surface

1. Metallics originate from SRB/BSM exhaust residue or ET/Orbiter separation residuals

2. Organics were of umbilical closeout origin and Krytox from umbilical MPS (main propulsin system) processing.

Conclusions

Orbiter TPS damage sustained on the STS-48 mission was somewhat greater than average. The chemical analysis results from post flight samples did not provide data that points to a single source of damaging debris.

Orbiter window samples provided evidence of SRB/BSM exhaust, Orbiter TPS, Orbiter window polishing compound residue, landing site products, organics, and paint. Also noteworthy was the absence of RTV (as from Orbiter TPS) in these samples.

The Orbiter tile sample results provided indication of thermal protection system (TPS) and landing site residual materials. The variety and trace amounts of non-TPS material did not provide a single source debris anomaly. Tile repair material was also present in the sample.

The Orbiter/ET umbilical samples contained a variety of residuals. The residual variety of metallics, TPS materials, environmental products, and organics provides an indication of this area's ability to collect and retain elements, which can be evaluated post flight. Residual sample location and material identification provided no evidence of a debris anomaly based on this chemical sampling.

10.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 8 Post Launch Anomalies, including one IFA candidate, were observed on the STS-48 mission.

10.1 LAUNCH PAD/FACILITY

1. No major items.

10.2 EXTERNAL TANK

1. No items.

10.3 SOLID ROCKET BOOSTERS

1. A 2.9x2.75 area of MSA-2 was missing from two fasteners on the stiffener below the BSM's near the 381 ring. This divot may have occurred during ascent. Samples were taken for laboratory analysis. (SRB project item)

2. The upper left and lower right BSM covers had locked in the fully opened position and then had been subsequently deformed. The lower right attach ring was fractured at one location. The upper right BSM cover was missing. The substrate at the fracture planes, including the threads of the exposed screws, were sooted. Laboratory analysis will be performed on the remaining attach hardware. (IFA candidate)

3. After liftoff, 5 ordnance fragments including two NSI booster pieces or frangible nut webs (3 inches in length), fell from the HDP #5 DCS/stud hole. (SRB project item)

4. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing. However, some of the K5NA had been applied beyond the splice plate closeout and over lapped the instafoam. The foam erodes or shrinks leaving the K5NA overlap exposed, which creates a mechanism for debris. (SRB project item)

5. The RH frustum was missing no TPS but had 26 MSA-2 debonds over fasteners. The LH frustum exhibited 51 MSA-2 debonds over fasteners. (SRB project item)

6. Ten K5NA protective dome were missing from bolt heads on the aft side of the phenolic kick rings. These domes were lost prior to water impact and exhibited a charred substrate. (SRB project item)

10.4 ORBITER

1. Fifteen orange streaks occurred in the SSME plume during ascent and included the two large streaks at T+29 and T+31 seconds MET. (Orbiter project item)

2. SSME ignition vibration/acoustics caused the loss of tile surface coating material from seven locations between the RH OMS and SSME's #1/#3, one location on the aft face of the RH RCS stinger, and one location at the base of the RH OMS nozzle. A 2"x1" piece of tile surface coating material fell from the aft surface of the LH RCS stinger. In addition, a 4-inch flexible strip of material, most likely a gap filler, appeared to originate from tiles on the aft face of the LH OMS pod near the OMS nozzle. (Orbiter project item)

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle

Debris/Ice/TPS Assessment and Photographic Analysis of Shuttle Mission STS-48

5. Report Date

November 1991

6. Performing Organization Code

7. Author(s)

Gregory N. Katnik
Scott A. Higginbotham
J. Bradley Davis

8. Performing Organization Report No.

10. Work Unit No.

9. Performing Organization Name and Address

NASA
External Tank Mechanical Systems Division
Mail Code: TV-MSD-22
Kennedy Space Center, Florida 32899

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

13. Type of Report and Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A Debris/Ice/TPS assessment and photographic analysis was conducted for Space Shuttle Mission STS-48. 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-48, and their overall effect on the Space Shuttle Program.

17. Key Words (Suggested by Author(s))

STS-48
Ice
Frost
Debris
Thermal Protection System (TPS)
Photographic Analysis

18. Distribution Statement

Publicly Available
Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified		