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Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-40

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DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-40

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TABLE OF CONTENTS

1.0 Summary 2

2.0 KSC Ice/Frost/Debris Team Activities . . 6

3.0 Scrub 11
3.1 Pre-Test Briefing 11
3.2 Pre-Launch SSV/Pad Debris Inspection . . 12
3.3 Ice/Frost Inspection 13
3.4 Orbiter 13
3.5 Solid Rocket Boosters 13
3.6 External Tank 20
3.7 Facility 23
3.8 Post Drain Inspection 33

4.0 Pre-Launch SSV/Pad Debris Inspection . . 37

5.0 Launch 45
5.1 Ice/Frost Inspection 45
5.2 Orbiter 45
5.3 Solid Rocket Boosters 45
5.4 External Tank 48
5.5 Facility 52

6.0 Post Launch Pad Debris Inspection . . . 64

7.0 Film Review Summary/Problem Reports. . . 70
7.1 Launch Film and Video Data Review . . . 86
7.2 On-Orbit Film Data Review. 118
7.3 Landing Film and Data Review 120

8.0 SRB Post Flight/Retrieval Assessment . . 125
8.1 RH SRB Debris Inspection 125
8.2 LH SRB Debris Inspection 129
8.3 Recovered SRB Disassembly Findings . . . 133

9.0 Orbiter Post Landing Debris Assessment . 149

10.0 Debris Sample Lab Reports 175

11.0 Post Launch Anomalies 179
11.1 Launch Pad/Facility 179
11.2 External Tank 179
11.3 Solid Rocket Boosters 180
11.4 Orbiter 180

Appendix A. Flight Problem Report 181
Appendix B. Microchemical Analysis Report . . . 184

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-40 was launched at 9:24 a.m. local 6/5/91

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1.0 Summary

STS-40 had been originally scheduled for launch in late May, 1991. The replacement of defective MPS LH2 and LO2 propellant temperature probes, general purpose computer (GPC #4), and a multiplexer/demultiplexer (MDM) unit FA-2 caused the launch date to slip. The launch was rescheduled for 1 June 1991.

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 31 May 1991. The detailed walkdown of Launch Pad 39B and MLP-3 also included the primary flight elements OV-102 Columbia (11th flight), ET-41 (LWT-34), and BI044. There were no vehicle anomalies. Facility discrepancies were resolved prior to cryoload.

The Ice/Frost/Debris Inspection of the cryoloaded vehicle was performed on 1 June 1991 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 vehicle anomalies.

The launch was scrubbed due to a failure of Orbiter IMU #2. The LH2 and LO2 tanks had been filled to 100 percent (stable replenish). No vehicle or facility anomalies were discovered during the post-drain walkdown.

A second pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 4 June 1991. Drops of hydraulic fluid were detected on the -Y-Z quadrant of the ET TPS as well as the LH SRB, MLP deck, GH2 vent arm, and intertank access structure. The hydraulic fluid had leaked from the GOX vent arm hinge area and was blown toward the vehicle by southwesterly winds. The Orbiter was enclosed by the RSS/OWP and was not affected. Engineering evaluation showed no adverse affect on TPS from exposure to hydraulic fluid according to previous compatibility tests. Minimal absorption occurs after 20 hours saturation with no degradation of insulative or ablative properties. The hydraulic fluid residue was also located in a low heating area. The evaluation concluded performance of the flight hardware TPS would not be degraded by the presence of the hydraulic fluid.

The ET -Y bipod jack pad closeout debonded and protruded from the adjacent foam surfaces sometime after the first launch attempt was scrubbed and the ET drained. The discrepant closeout was removed and PDL was applied. There were no discrepancies on the +Y jack pad closeout.

Orbiter IMU #2 was replaced and the vehicle was cryoloaded for flight on 5 June 1991. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no ice or debris conditions outside of the established data base. No TPS adverse effects resulted from the hydraulic fluid spill. There were no ET anomalies. Light condensate, but no ice or frost, was present on the acreage areas of the External Tank. Four

Ice/Frost console 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. At launch, the ET ice condition was well within the data base for ice formation.

A debris inspection of Pad 39B 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. An ordnance fragment (NSI cartridge) was present in the HDP #5 stud hole. A 3.25"x1"x0.5" frangible nut fragment lay on the MLP deck under the sound suppression pipe just east of HDP #5. The GH2 vent line had latched properly. The new Hydrogen Dispersal System structure welded to the MLP deck showed no sign of damage.

A total of 138 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. Real time down-link from OV-102 showed TCS blankets partially detached from the 1307 aft bulkhead and damage to the payload bay door environmental seal. Cause of this damage is believed to be airflow intrusion past the payload bay door seals during ascent. Three pieces of frangible nut and one NSI cartridge fell from the HDP #5 DCS/stud hole shortly after liftoff. A frangible nut web piece 2 inches long fell from the HDP #3 DCS/stud hole after the vehicle had gained 6-8 feet altitude. The new optimized frangible links were installed in the SRB DCS's for this mission. Although post flight inspection of the SRB's revealed HDP #7 DCS plunger was obstructed by frangible nut halves, no debris was visible in the launch films falling from the DCS/stud hole.

Shortly after ET separation, umbilical film showed a metallic cylinder drifting past the LH2 ET/ORB camera and moving away from the Orbiter. Inspection of OV-102 ET/ORB umbilicals after landing revealed no missing hardware. KSC identified the object as the outboard shear pin bushing from the ET half of the LH2 ET/ORB umbilical. On-orbit umbilical photography confirmed the inboard bushing on the LH2 umbilical and the two bushings on the LO2 umbilical were still in place after ET separation. KSC inspected the bushings on ET-47 prior to OV-104 umbilical mate. No anomalies were found. Presence of the bushings on ET-47 after separation from the Orbiter on STS-43 will not be confirmed due to lack of umbilical cameras on OV-104. Orbiter performance, landing gear extension, wheel touchdown and vehicle rollout after landing was nominal.

Two IFA's were generated as a result of the film and video data review. The IFA's were taken against the failure of two ET/ORB umbilical cameras and the appearance of a shear pin bushing from the ET LH2 umbilical after separation from the Orbiter.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums exhibited no missing TPS, but had a total of 62 debonds over fasteners. The frustum severance rings were missing no pins. The field joint protection system closeouts were in generally good condition. Three LH IEA cover bolts near the lower ET/SRB strut were bottomed out and the washers under the bolt heads could be rotated. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing. HDP Debris Containment System (DCS) plungers were seated with the exception of HDP #7, which was obstructed by frangible nut halves. Post flight disassembly of the DCS housings revealed an overall system debris retention of 78 percent. The new 'optimized' frangible links had been attached to the DCS plungers for this mission.

A detailed post landing inspection of OV-102 (Columbia) was conducted on June 14-15, 1991, at Ames-Dryden (EAFB) on Runway 22 and in the Mate-Demate Device. The Orbiter TPS sustained a total of 197 hits, of which 25 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 153 hits, of which 23 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 hits and the number of hits with a major dimension of 1 inch or larger was greater than average. The largest single damage site on the Orbiter lower surface occurred on the RH inboard elevon and measured approximately 7-3/4"x1-1/8"x1/2". This hit may have been the result of ice from the ET LO2 feedline bellows or support brackets. The RH ET/Orbiter (LO2) umbilical door centerline forward outboard latch fitting and adjacent tile sustained hot gas intrusion and exhibited significant melting and erosion due to the lack of or degradation of the RTV seal. This event was not considered to be a debris issue. No flight hardware was found on the runway below the ET/Orbiter umbilicals. The ET/ORB separation ordnance device plungers were seated and appeared to have functioned properly. Post landing disassembly of the EO-2 and EO-3 debris containers revealed no missing ordnance fragments.

There were no external visible indications associated with the payload bay door environmental seal anomaly. This seal had debonded at the splice point and protruded from the retainer while on-orbit. The door was successfully closed prior to re-entry. The seal anomaly may be the result of airflow intrusion during ascent or vehicle flexure due to payload weight.

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. Streaks/deposits were present on both wing leading edge RCC panels. Lab analysis revealed the streaks were composed of TPS materials (Orbiter tile), SRB BSM separation products, and foam residue from RCC protective covers. The lower surface tile samples indicated localized heating from re-entry, but the only

materials recovered from the damage sites were tile TPS elements. This 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 nine Post Launch Anomalies, including two IFA candidates, were observed during this mission assessment.

Overall, vehicle TPS subsystem performance and debris issues worked on the STS-40 mission were average compared to previous missions.

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 SCRUB

3.1 PRE-TEST BRIEFING

The Ice/Frost/Debris Team briefing for launch activities was conducted on 31 May 1991 at 0900 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
M. Young	LSOC - SPC	ET Processing, Ice Assess
R. Seale	LSOC - SPC	ET Processing, Ice Assess
J. Blue	LSOC - SPC	ET Processing, Ice Assess
D. Jenkins	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
G. Tamagno	RI - DNY	Debris Assess, LVL II Integ
K. Mayer	RI - LSS	Vehicle Integration
T. Brees	RI - LSS	Vehicle Integration
S. Otto	MMC - LSS	ET Processing
K. Lineberger	USBI - LSS	SRB Processing
B. Nguyen	USBI - LSS	SRB Processing
K. Parsons	MTI - LSS	SRM Processing
C. Cooper	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.

3.2 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

STS-40 had been originally scheduled for launch in late May, 1991. The replacement of defective MPS LH2 and LO2 propellant temperature probes, general purpose computer (GPC #4), and a multiplexer/demultiplexer (MDM) unit FA-2 caused the launch date to slip. The launch was rescheduled for 1 June 1991.

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 31 May 1991 from 1000 - 1100 hours. The detailed walkdown of Launch Pad 39B and MLP-3 also included the primary flight elements OV-102 Columbia (11th flight), ET-41 (LWT-34), and BI044. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

There were no vehicle anomalies.

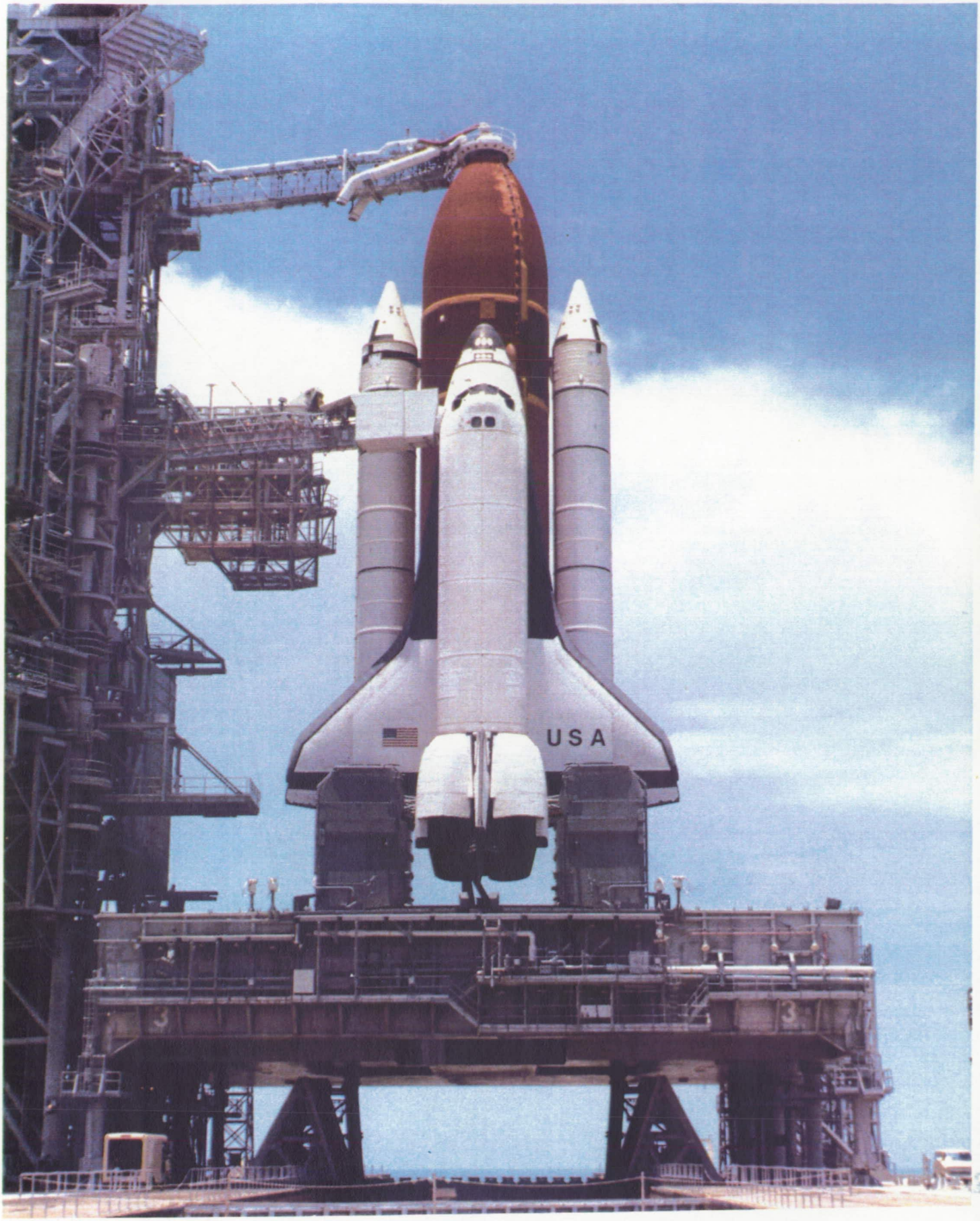
Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload/ launch, temporary hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical until a permanent sensor could be designed and installed. The tygon tubes are intended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

Three tie-wraps had been found attached to the LO2 TSM in the vicinity of the RH aft RCS stinger tiles during the STS-37 Ice Inspection. The LH2 and LO2 TSM's on this MLP were carefully inspected, but no debris discrepancies were noted.

A bolt under the raised deck adjacent and south of the hydrogen dispersal system pipe on the MLP zero level was loose.

Cleanup of the MLP deck and pad surface was almost complete at the time of the inspection. Debris particles, such as safety wire, weld slag, and TPS trimmings, were visible in handrail holes, holddown post haunch areas, in the MLP rain gutters, and under the raised deck areas.

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



The STS-40 stack included OV-102 Columbia (11th flight), ET-41 (LWT 34), and BI044 SRB's

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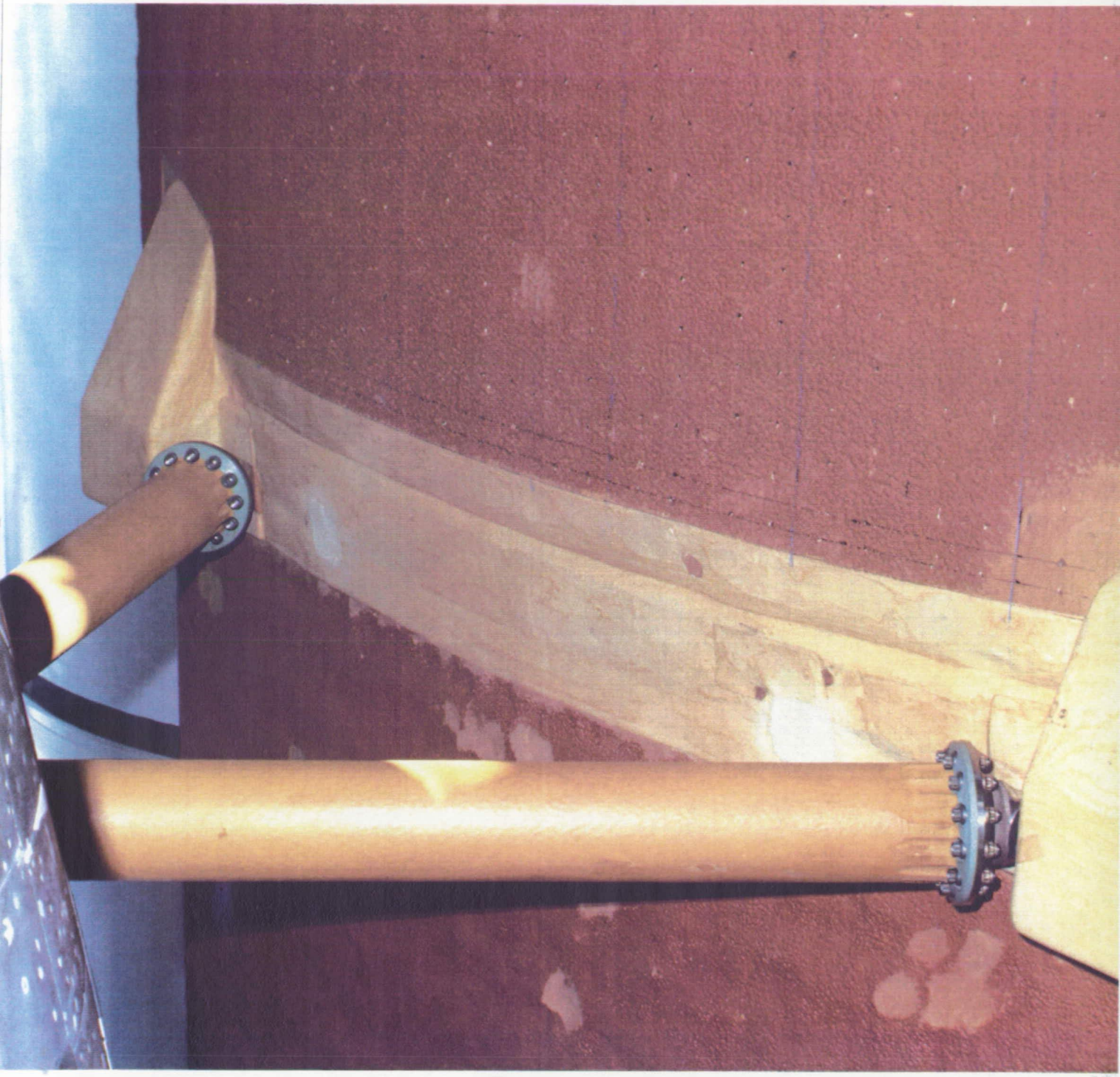

View of the External Tank forward attach point bipods, +Z side of the intertank and upper LH2 tank prior to cryoload. No anomalies were visible on the bipod jack pad closeouts.

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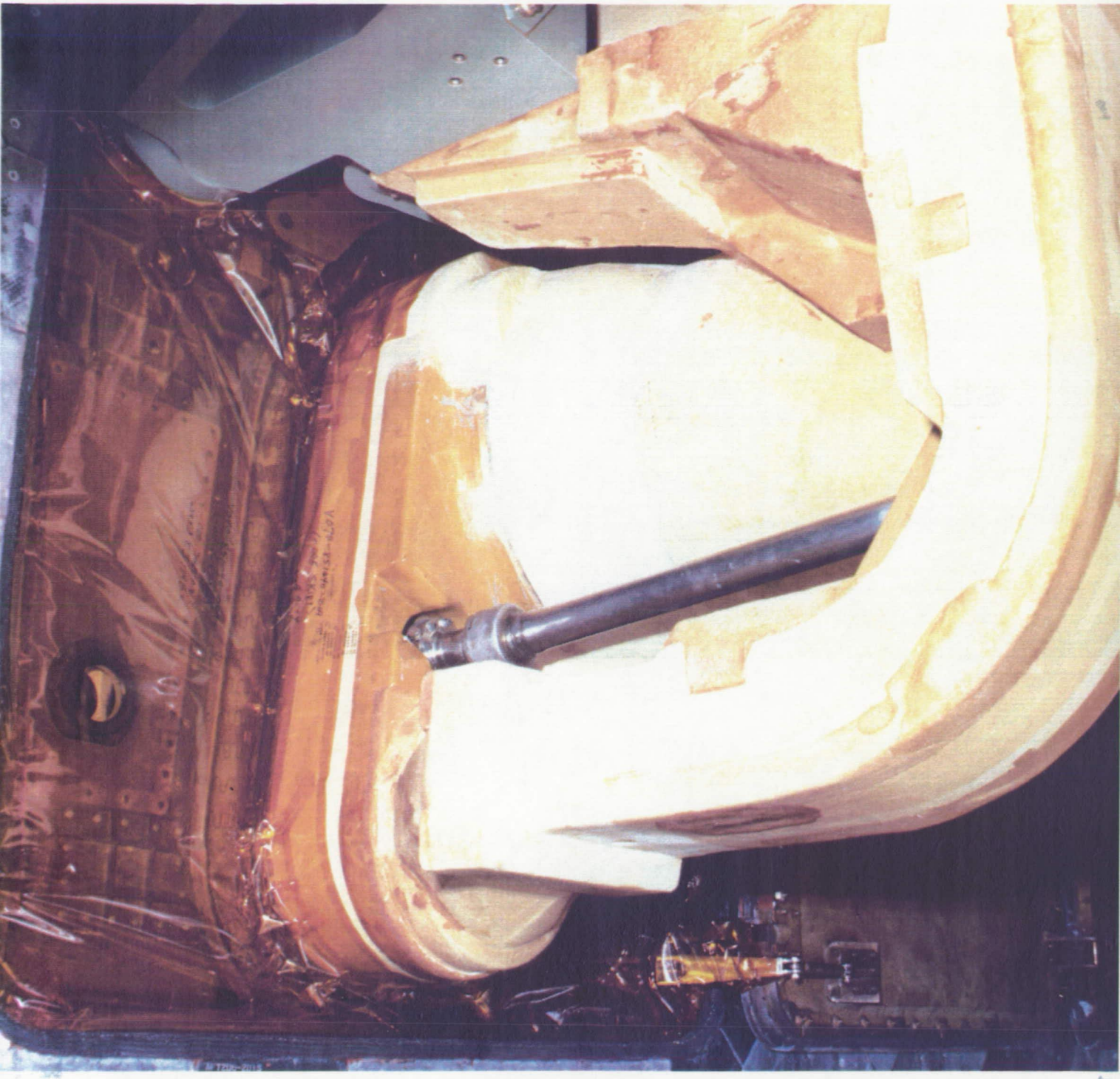

Overall view of the LO2 ET/ORB umbilical prior to cryoload

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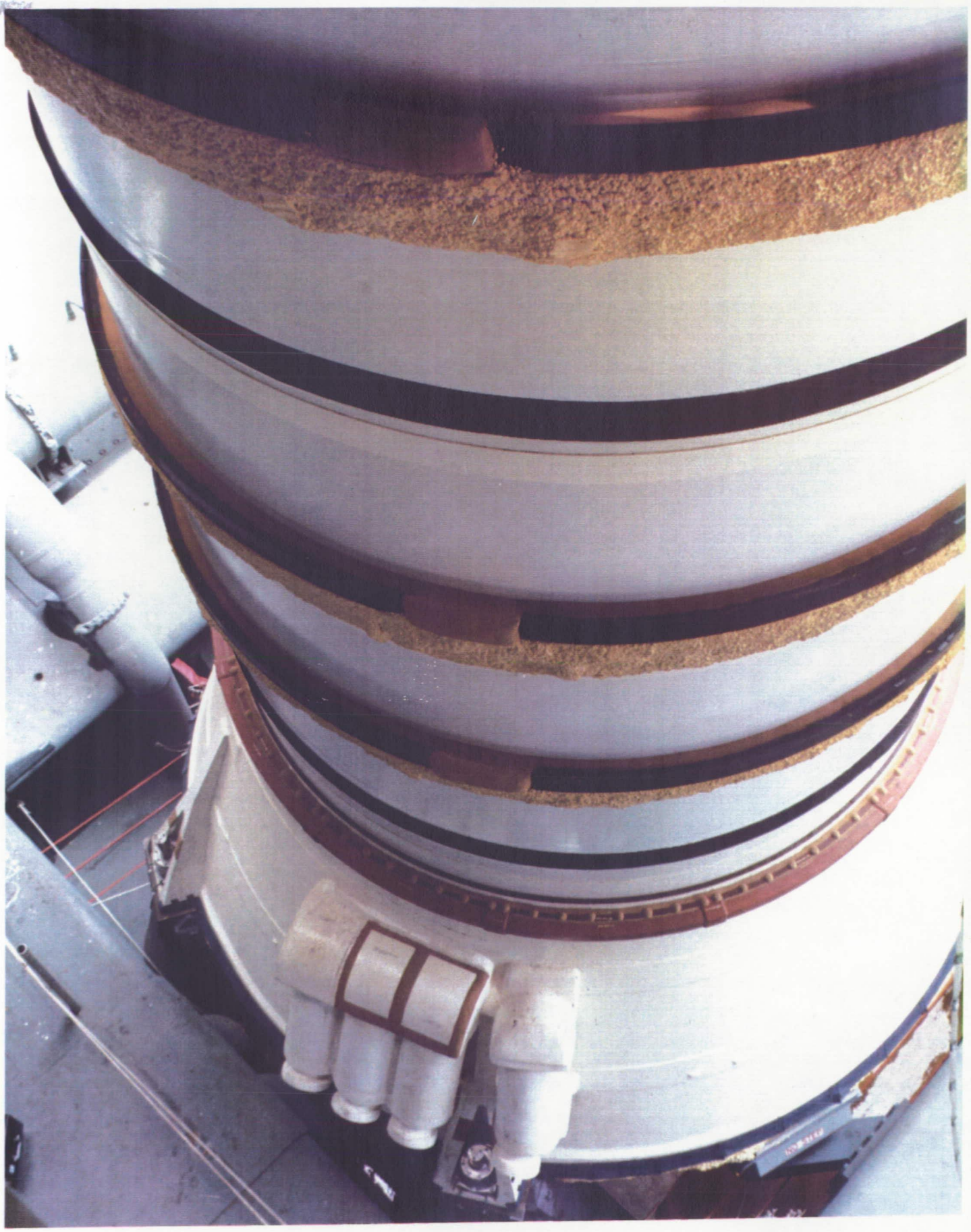

Aft booster stiffener ring splice plate K5NA closeouts were intact on the LH Solid Rocket Booster

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3.3 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 1 June 1991 from 0315 to 0500 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. Ambient weather conditions at the time of the inspection were:

Temperature:	71.0 F
Relative Humidity:	91.0 %
Wind Speed:	4.4 Knots
Wind Direction:	276 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.

3.4 ORBITER

No Orbiter tile anomalies were observed. All RCS paper covers were intact, but the L4L and F3L covers were wet. 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 72 degrees F. The average surface temperatures of the SSME engine mounted heat shields were measured at 72 degrees F for SSME #1, 71 degrees F for SSME #2, and 72 degrees F for SSME #3. The coldest area on the engine mounted heat shields was 63 degrees F (SSME #2). All of the SSME heat shields were wet with some condensate. Light frost coated the SSME #1 heat shield-to-nozzle interface at the 6 o'clock position and the SSME #2 heat shield-to-nozzle interface at the 3 o'clock and 6 o'clock positions. No LO2 vapors originated from inside the SSME nozzles. Some condensate was present on base heat shield tiles around SSME #2.

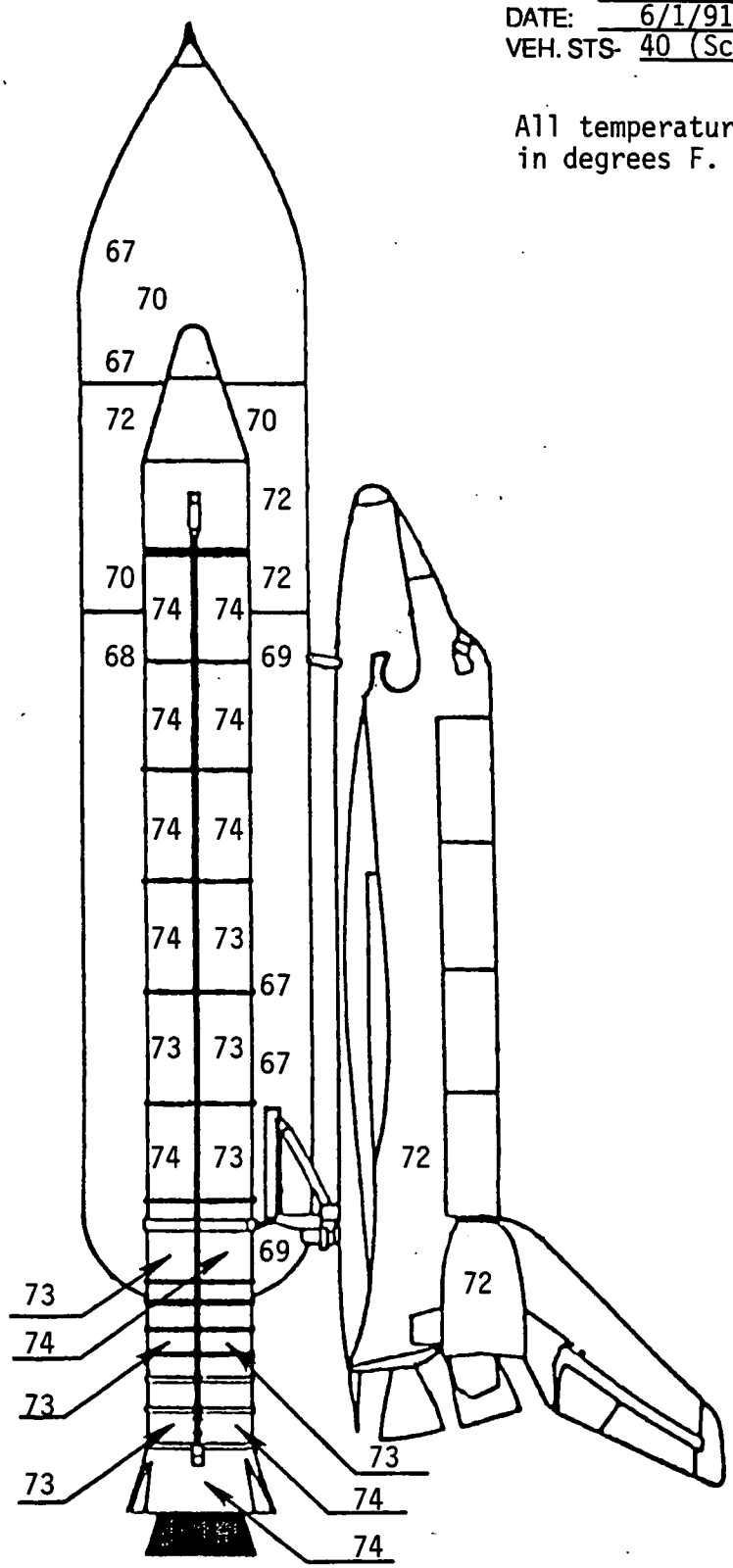
3.5 SOLID ROCKET BOOSTERS

No SRB anomalies or loose ablator/cork were observed. The aft booster stiffener ring splice plate K5NA closeouts were intact. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 72 and 74 degrees F. The Mikron IR gun and the GEI gave measurements of 72 and 80 degrees F, respectively, in comparison. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 78 degrees F, which was within the required range of 44-86 degrees F.

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

TIME: 0315 - 0500
DATE: 6/1/91
VEH. STS- 40 (Scrub)

All temperatures are in degrees F.



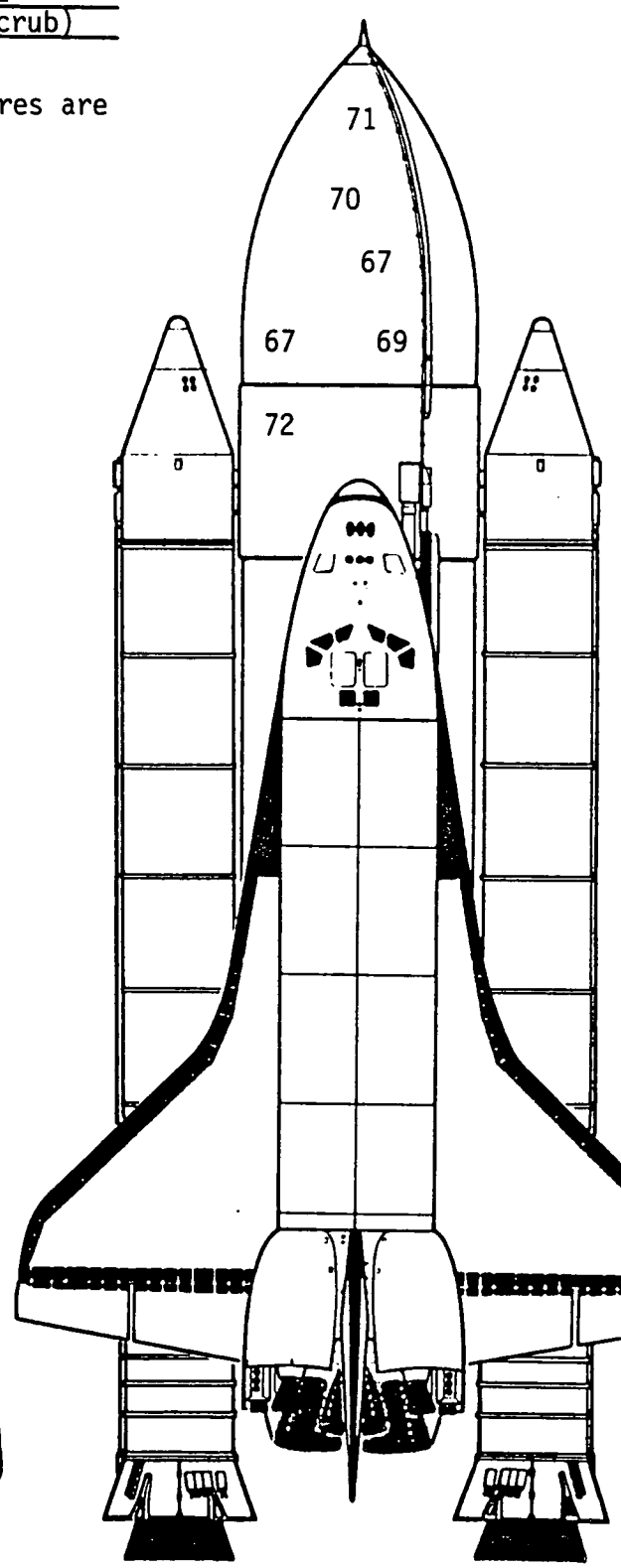


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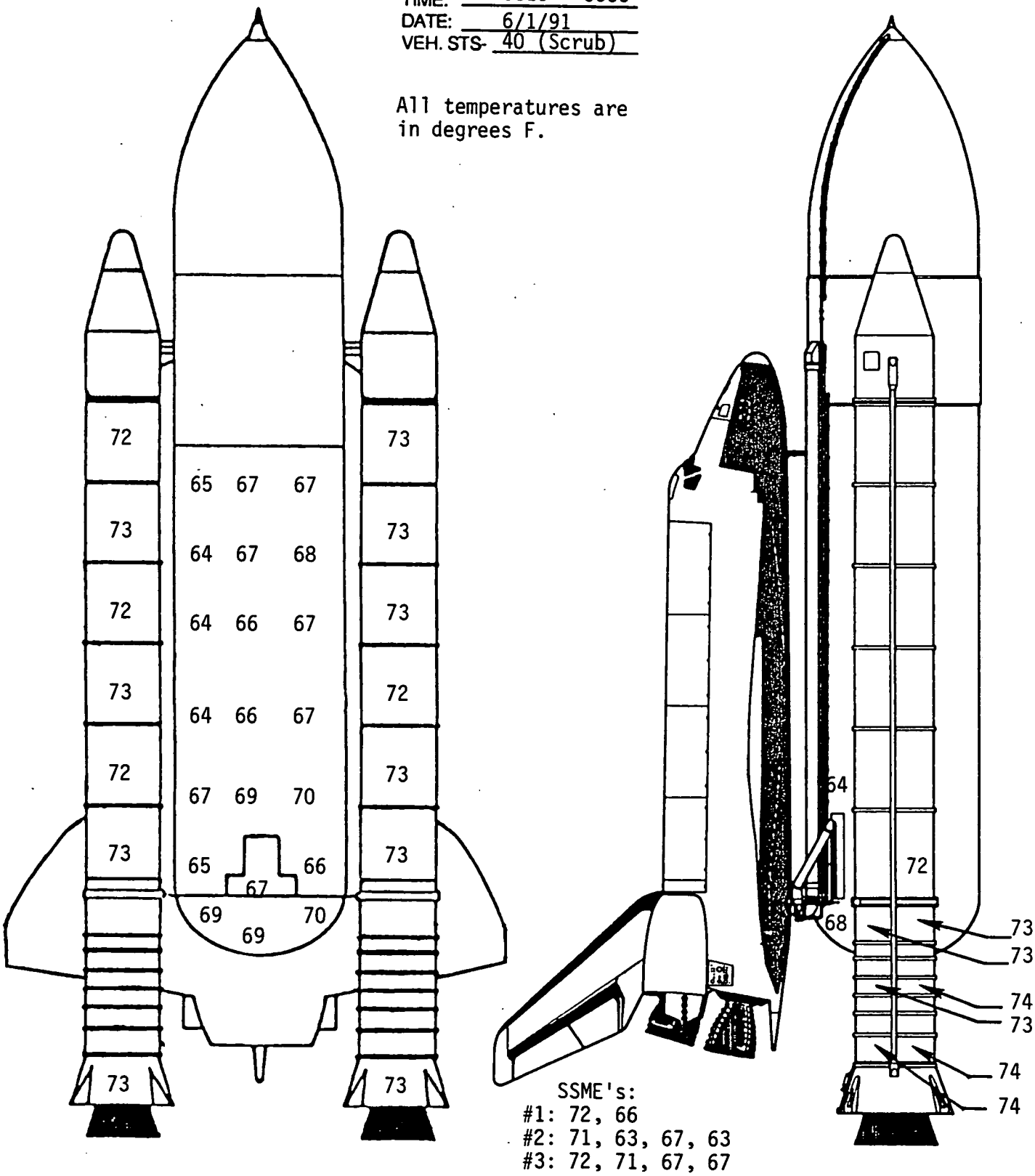
FIGURE 2. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0315 - 0500
DATE: 6/1/91
VEH. STS- 40 (Scrub)

All temperatures are in degrees F.



SSME's:
#1: 72, 66
#2: 71, 63, 67, 63
#3: 72, 71, 67, 67

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3.6 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0030 to 0715 hours and the results tabulated in Figure 3. The program predicted condensate with no ice accumulation on all TPS acreage surfaces.

Very light condensate, but no ice or frost, was present on the LO2 tank barrel TPS acreage. There was no ice/frost or condensate on the LO2 tank ogive. There were no TPS anomalies. The tumble valve cover was intact. There were no anomalies on the pressurization line and support ramps. STI measured 70 degrees F on the ogive and 67 degrees on the barrel section. SURFICE predicted 59 degrees F on the ogive and 52 degrees F on the barrel section. The Mikron IR gun measured 64 and 63 degrees F, respectively.

The intertank TPS acreage was wet with light run-off condensate. There were no TPS anomalies. Small frost spots appeared in the -Y-Z and +Y-Z stringer valleys at both LH2 and LO2 tank flanges. No unusual vapors or ice formations were present on the ET umbilical carrier plate. The STI IR scanner measured an average surface temperature of 71 degrees F compared to a Mikron IR gun measurement of 72 degrees F.

The LH2 tank and aft dome TPS acreage were covered with a moderate amount of condensate. There was no ice/frost on the acreage. The average surface temperatures as measured by the STI IR scanner were 66 degrees F on the upper LH2 tank and 68 degrees F on the lower LH2 tank compared to a Mikron IR gun measurements of 62 and 58 degrees F, respectively. SURFICE predicted 48 degrees F on the upper LH2 tank and 59 degrees F on the lower LH2 tank.

There were no anomalies on the bipods, PAL ramp, cable tray/press line ice/frost ramps, thrust struts, manhole covers, or aft dome apex with the exception of a small ice/frost spot at the +Y ET/SRB cable tray-to-LH2 tank closeout bondline. The ice/frost spot was emitting some vapors. Some ice/frost was present in the ET/SRB cable tray-to-upper strut fairing expansion joint. 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.

Normal 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. A small amount of ice/frost had accumulated on the outboard, aft, and inboard areas of the baggie. There was no ice/frost accumulation on the acreage areas of the umbilical. Ice/frost fingers 3-6 inches in length

STS- 40	TEST S0007 SCRUB, IMU FAILURE	DATE: 1 June 1991	T-0 TIME: DATE:	NASA KSC Ice/Frost/Debris Team

ORBITER	ET	SRB	MLP	PAD	LO2	LH2
102	41	BI-044	3	B	CHILLDOWN TIME: 00:11 FAST FILL TIME: 01:02 SLOW FILL TIME: 00:49 REPLENISH TIME: 03:03	CHILLDOWN TIME: 00:13 FAST FILL TIME: 00:46 SLOW FILL TIME: 00:22 REPLENISH TIME: 02:50

TIME (EDT)	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
030	72.40	90.6	69.60	6	239	II	3.54	62.69	0.0029	-0.1455	II	3.54	57.32	0.0046	-0.1153	II	1.92	49.22	0.0040	-0.0614	II	8.16	63.01	0.0056	-0.2607
045	72.20	92.0	69.84	6	248	II	3.54	62.76	0.0030	-0.1459	II	3.54	57.40	0.0046	-0.1158	II	2.58	52.85	0.0045	-0.0771	II	7.26	62.36	0.0057	-0.2327
100	71.60	91.4	69.06	6	261	II	3.54	61.95	0.0029	-0.1411	II	3.54	56.54	0.0045	-0.1111	II	2.58	51.95	0.0044	-0.0733	II	7.26	61.54	0.0056	-0.2248
115	71.00	91.8	68.58	7	254	II	4.13	62.17	0.0030	-0.1570	II	4.13	57.31	0.0047	-0.1267	II	3.01	53.05	0.0046	-0.0847	II	8.47	61.95	0.0056	-0.2564
130	71.00	91.6	68.52	7	251	II	4.13	62.13	0.0030	-0.1567	II	4.13	57.27	0.0047	-0.1264	II	3.01	53.01	0.0046	-0.0845	II	8.47	61.90	0.0056	-0.2559
145	70.80	90.8	68.08	6	239	II	3.54	60.91	0.0028	-0.1350	II	3.54	55.44	0.0044	-0.1052	II	1.92	47.19	0.0038	-0.0529	II	8.16	61.27	0.0055	-0.2421
200	71.00	90.0	68.02	5	266	II	2.95	59.92	0.0027	-0.1160	II	2.95	53.69	0.0042	-0.0866	II	2.15	48.71	0.0040	-0.0547	II	6.05	59.23	0.0052	-0.1782
215	70.60	89.4	67.44	6	261	II	3.54	60.39	0.0027	-0.1320	II	3.54	54.89	0.0043	-0.1023	II	2.58	50.28	0.0042	-0.0663	II	7.26	59.96	0.0053	-0.2097
230	71.00	89.0	67.71	5	243	II	2.95	59.71	0.0027	-0.1149	II	2.95	53.47	0.0041	-0.0856	II	1.60	46.02	0.0036	-0.0526	II	6.80	59.86	0.0052	-0.1992
245	70.80	89.0	67.51	5	258	II	2.95	59.48	0.0026	-0.1137	II	2.95	53.23	0.0041	-0.0845	II	2.15	48.24	0.0039	-0.0530	II	6.05	58.77	0.0051	-0.1745
300	70.80	89.2	67.57	4	258	II	2.36	58.11	0.0025	-0.0945	II	2.36	50.88	0.0038	-0.0657	II	1.72	45.81	0.0036	-0.0517	II	4.84	56.97	0.0050	-0.1380
315	70.60	89.8	67.56	5	265	II	2.95	59.42	0.0027	-0.1134	II	2.95	53.16	0.0041	-0.0842	II	2.15	48.16	0.0039	-0.0527	II	6.05	58.72	0.0052	-0.1742
330	70.60	90.0	67.63	5	273	II	2.95	59.46	0.0027	-0.1137	II	2.95	53.20	0.0041	-0.0844	II	2.15	48.20	0.0040	-0.0529	II	6.05	58.77	0.0052	-0.1745
345	70.80	90.8	68.08	5	279	II	2.95	59.86	0.0027	-0.1157	II	2.95	53.62	0.0042	-0.0863	II	2.15	48.62	0.0040	-0.0544	II	6.05	59.18	0.0053	-0.1779
400	72.40	89.6	69.29	3	295	II	1.77	58.16	0.0024	-0.0911	II	1.77	49.73	0.0036	-0.0664	II	1.38	47.88	0.0038	-0.0606	II	3.69	56.43	0.0048	-0.1133
415	71.20	91.0	68.54	4	289	II	2.36	58.97	0.0026	-0.0982	II	2.36	51.78	0.0040	-0.0693	II	1.72	46.62	0.0037	-0.0552	II	4.84	57.85	0.0052	-0.1439
430	71.20	91.2	68.60	4	272	II	2.36	59.01	0.0026	-0.0984	II	2.36	51.83	0.0040	-0.0694	II	1.72	46.66	0.0038	-0.0554	II	4.84	57.90	0.0052	-0.1442
445	70.60	92.4	68.37	4	270	II	2.36	58.55	0.0027	-0.0964	II	2.36	51.33	0.0040	-0.0675	II	1.72	46.11	0.0038	-0.0531	II	4.84	57.45	0.0052	-0.1413
500	70.60	93.2	68.61	5	261	II	2.95	60.12	0.0029	-0.1171	II	2.95	53.91	0.0043	-0.0876	II	2.15	48.87	0.0041	-0.0554	II	6.05	59.48	0.0055	-0.1804
515	70.40	93.8	68.59	3	228	II	1.77	56.60	0.0025	-0.0836	II	1.77	48.05	0.0036	-0.0589	II	0.96	46.09	0.0038	-0.0531	II	4.08	55.93	0.0051	-0.1177
530	70.60	94.2	68.91	3	221	II	1.77	56.92	0.0025	-0.0850	II	1.77	48.39	0.0036	-0.0603	II	0.96	46.41	0.0038	-0.0545	II	4.08	56.27	0.0052	-0.1197
545	71.00	93.6	69.13	3	225	II	1.77	57.28	0.0025	-0.0867	II	1.77	48.78	0.0037	-0.0620	II	0.96	46.81	0.0038	-0.0562	II	4.08	56.62	0.0052	-0.1217
615	71.00	91.2	68.40	6	237	II	3.54	61.22	0.0029	-0.1369	II	3.54	55.77	0.0045	-0.1070	II	1.92	47.54	0.0039	-0.0543	II	8.16	61.58	0.0055	-0.2455
630	70.60	92.0	68.25	4	234	II	2.36	58.47	0.0027	-0.0960	II	2.36	51.24	0.0040	-0.0672	II	1.28	46.04	0.0037	-0.0528	II	5.44	58.36	0.0053	-0.1594
645	70.40	92.0	68.05	4	235	II	2.36	58.23	0.0027	-0.0950	II	2.36	50.99	0.0039	-0.0662	II	1.28	45.79	0.0037	-0.0517	II	5.44	58.13	0.0053	-0.1576
700	70.20	92.8	68.09	5	251	II	2.95	59.58	0.0028	-0.1143	II	2.95	53.33	0.0043	-0.0850	II	2.15	48.28	0.0041	-0.0532	II	6.05	58.93	0.0054	-0.1759
715	69.80	92.8	67.69	3	242	II	1.77	55.68	0.0024	-0.0796	II	1.77	47.06	0.0035	-0.0549	II	0.96	45.17	0.0037	-0.0492	II	4.08	54.99	0.0050	-0.1123
Avg.	70.93	91.30	68.36	4.8	SW		2.82	59.55				2.82	52.95				1.88	48.13				6.02	59.02		

Period of Ice Team Inspection

FIGURE 3. 'SURFICE' Computer Predictions

had formed on the three pyro 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 lower LH2 feedline bellows was filled with frost while the upper bellows was wet with condensate. There were no anomalies on the LH2 ET/ORB umbilical. The forward, outboard, and aft sides of the LH2 ET/ORB umbilical and purge barrier were covered by typical ice/frost formations. Ice/frost accumulation on the inboard area of the baggie was light. Ice/frost fingers 4-7 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 pyro canister 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 visible 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 4 OTV recorded items:

Anomaly 001 documented an ice/frost formation at the +Y ET/SRB cable tray-to-LH2 tank closeout. The condition was acceptable per NSTS-08303.

Anomaly 002 (documentation only) recorded ice/frost formations on the LH2 and LO2 ET/ORB umbilical separation bolt purge canister purge vents and on the purge barrier baggie material. These formations were acceptable per NSTS-08303.

Anomaly 003 (documentation only) noted ice/frost accumulations in the LH2 feedline bellows and recirculation line bellows, which were acceptable per NSTS-08303.

Anomaly 004 (documentation only) recorded ice/frost formations in the LO2 feedline bellows and support brackets, which were acceptable per NSTS-08303.

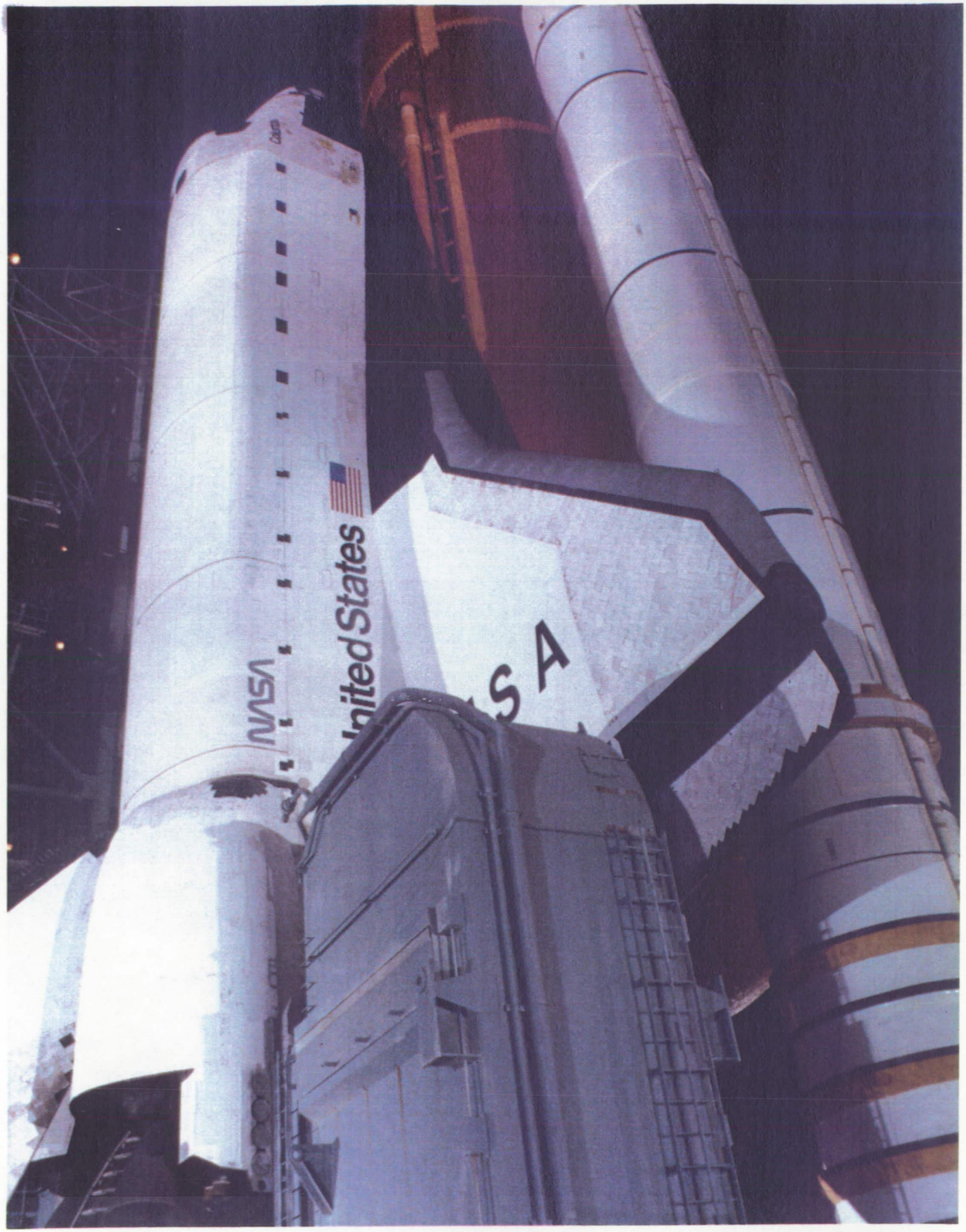
3.7 FACILITY

No new debris concerns had been identified during the ice/frost inspection of the vehicle.

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.



There was no ice/frost or TPS anomalies on the ET +Y+Z acreage

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Light condensate was present on the SSME engine mounted heat shields. Light ice/frost had accumulated on the SSME #1 and #2 heat shield-to-nozzle interfaces.

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Typical amounts of ice/frost had accumulated in the upper LO2 feedline support brackets

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Typical ice/frost was present in the lower LO2 feedline bellows and support brackets

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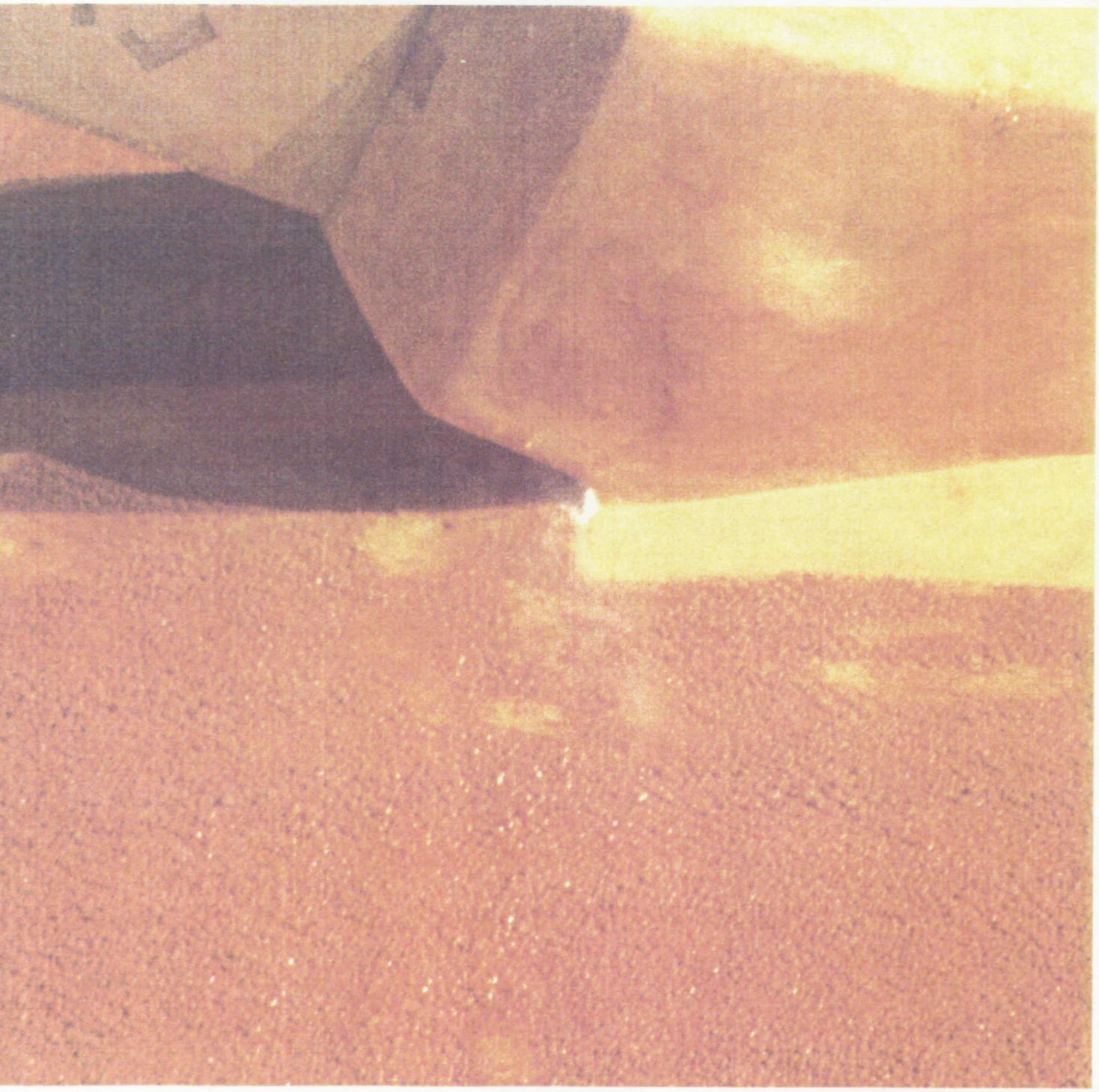

A small ice/frost spot with venting vapors formed at the +Y ET/SRB cable tray-to-LH2 tank closeout bondline

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Ice/frost accumulations on the LO2 ET/ORB umbilical forward outboard pyrotechnic canister purge vent and outboard side of the purge barrier (baggie) were acceptable.

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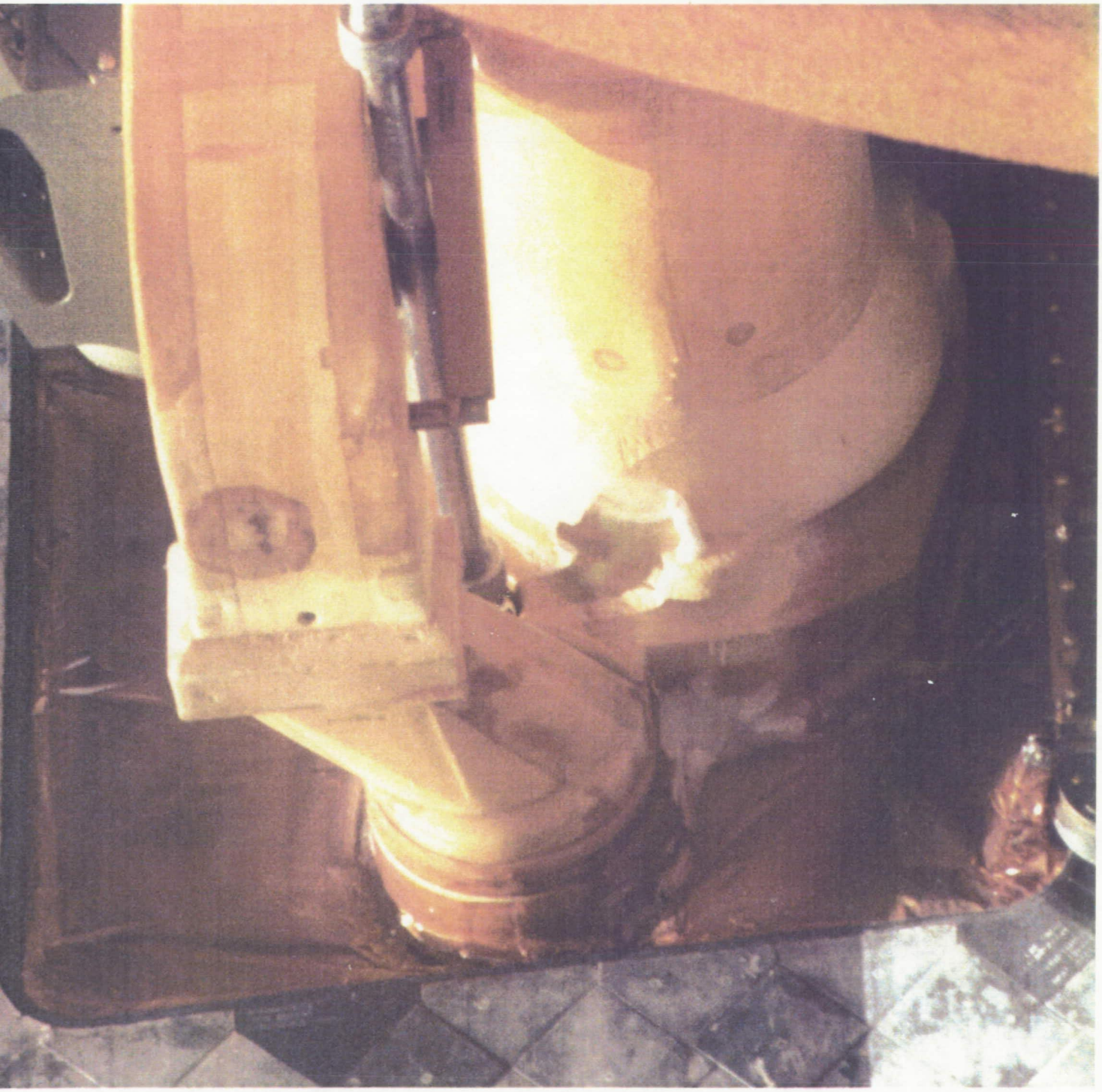

Ice/frost accumulations on the LO2 ET/ORB umbilical purge barrier (baggie) aft and inboard sides and the aft pyrotechnic canister purge vent were acceptable. Venting of nitrogen purge gas was normal.

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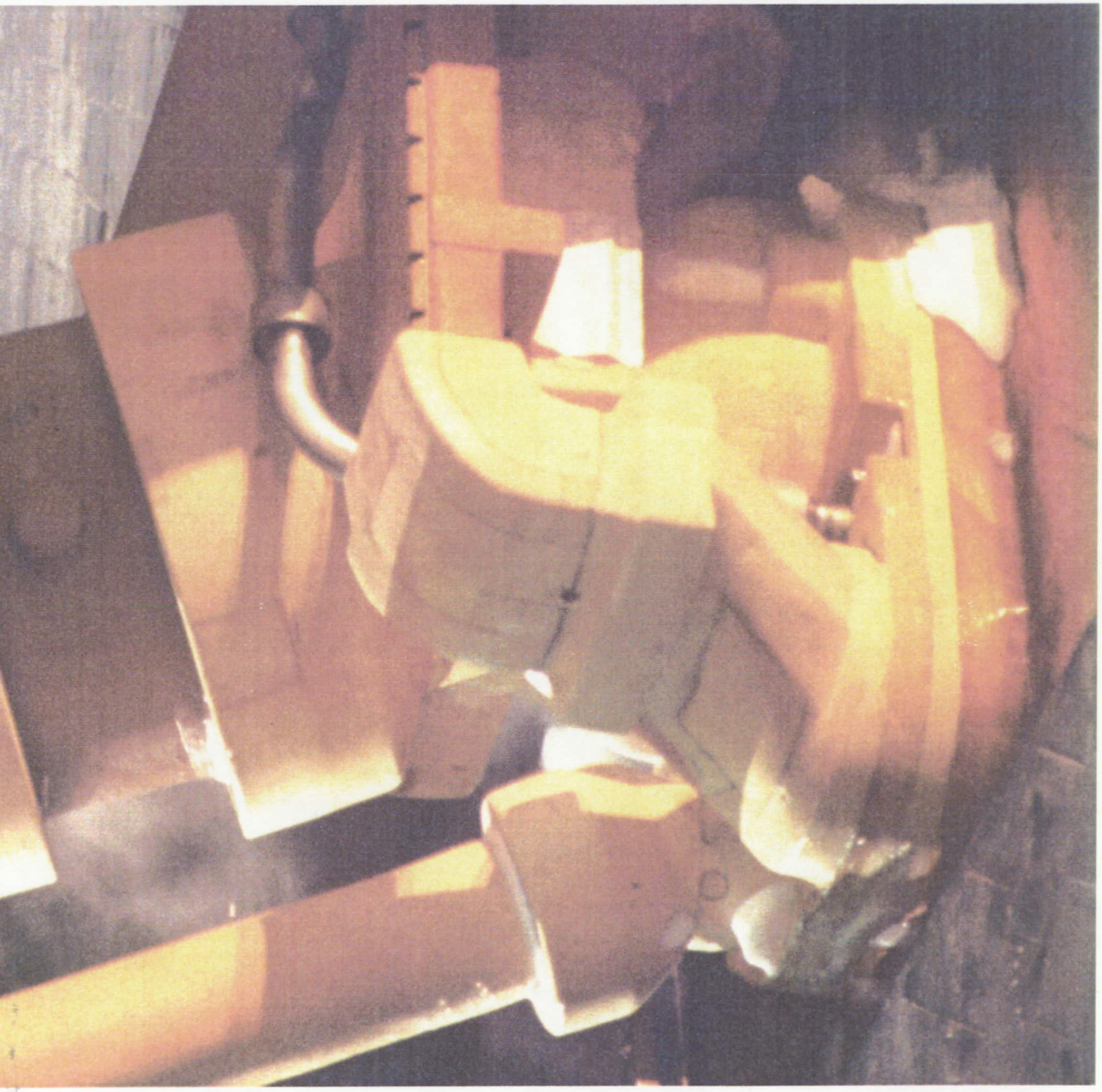

Ice/frost accumulations on the LH2 ET/ORB umbilical purge barrier (baggie) top, outboard, and aft sides were somewhat less than usual. Ice/frost fingers on the pyrotechnic canister purge vents and the umbilical disconnect plate gap purge vents were typical.

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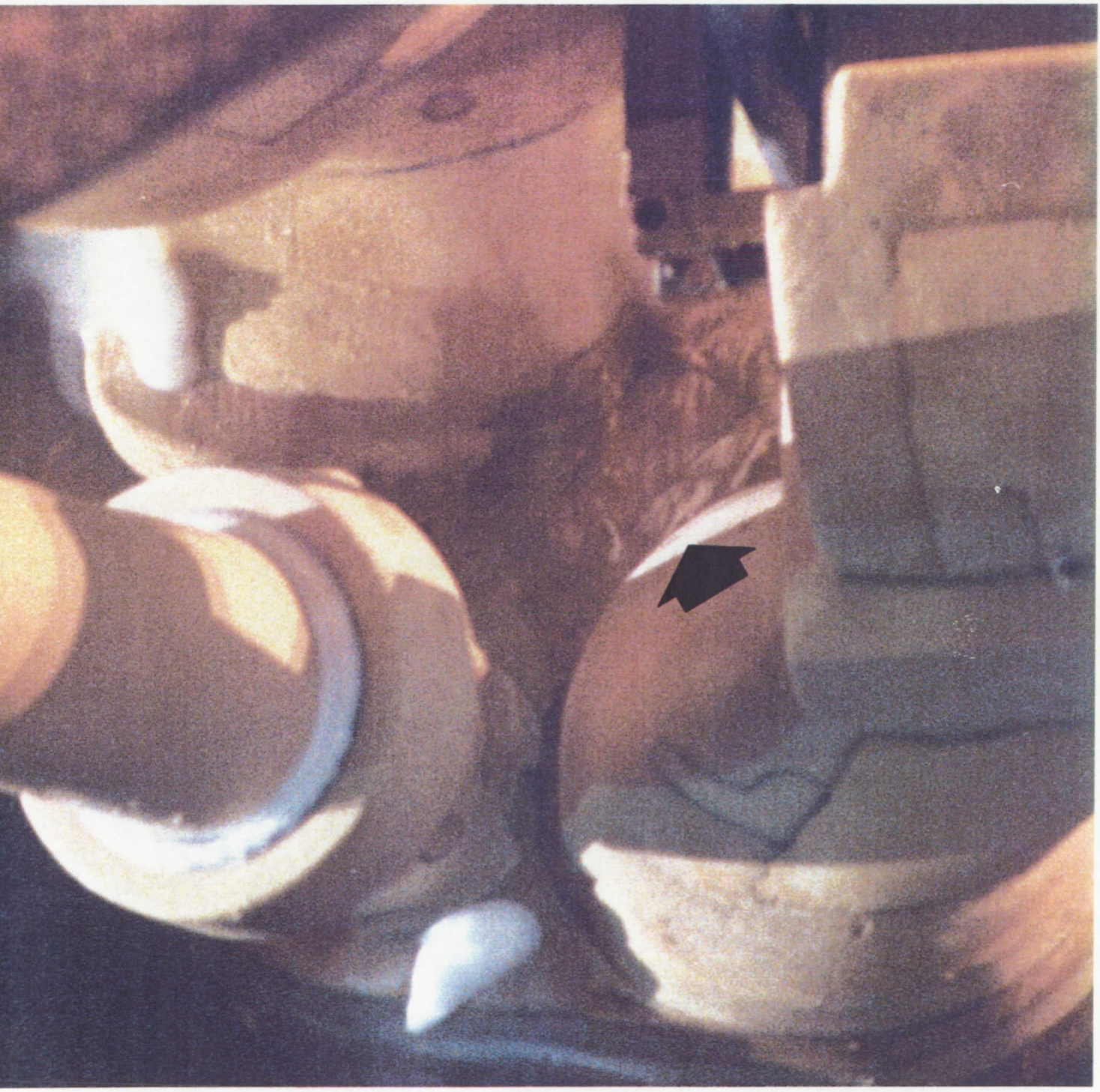

Ice/frost accumulations on the LH2 ET/ORB umbilical aft plate gap purge vent, aft pyrotechnic canister purge vent, and in the LH2 recirculation line upper bellows was typical. Venting of helium purge gas vapors was normal. No ice or frost had formed on the bondline of the 17-inch flapper valve actuator access port foam closeout.

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3.8 POST DRAIN INSPECTION

The STS-40 launch was scrubbed due to a failure of Orbiter IMU #2. The LH2 and LO2 tanks had been filled to 100 percent (stable replenish). A post-drain walkdown of the SSV and the MLP was performed at Pad-39B from 1240 to 1345 hours on 1 June 1991.

Most of the ice that had been visible on OTV during cryogenic loading had melted by the time the inspection was performed. There was no visible TPS damage, such as divots or cracks, on the ET LO2, intertank, or LH2 tank acreage.

The tumble valve cover was intact and exhibited no damage. Both GOX seals were in the proper configuration. Presence of the GOX vent hood for AADS environmental protection prevented the nosecone, fairing, and footprint areas from being inspected.

Some ice was present in the LO2 feedline support brackets. None of the brackets appeared to have damaged/loose foam. No ice remained in the LO2 feedline bellows.

No cracks were visible in either +Y or -Y thrust strut-to-longeron interfaces.

Neither the LO2 or LH2 ET/ORB umbilicals exhibited TPS anomalies or ice/frost accumulations. Ice fingers, 3-4 inches in length, remained on the umbilical pyrotechnic canister purge vents. Some ice remained in the LH2 feedline and recirculation line bellows. Vapors emanated from the LH2 feedline-to-LH2 tank interface (at the 1 o'clock position) during drain. No TPS anomalies were visible in this area during the post drain inspection.

Ice was still present in both left and right SRB cable tray to upper strut fairing interfaces. EB-7 and EB-8 fittings were still covered with ice.

All ice formations fell within the established data base and were acceptable per NSTS-08303.

No anomalies were visible on the Orbiter or SRB TPS.

SRB sound suppression water troughs were properly configured and filled with water. There were no facility discrepancies.

Post drain inspection of the LO2 feedline bellows and support brackets revealed no TPS anomalies

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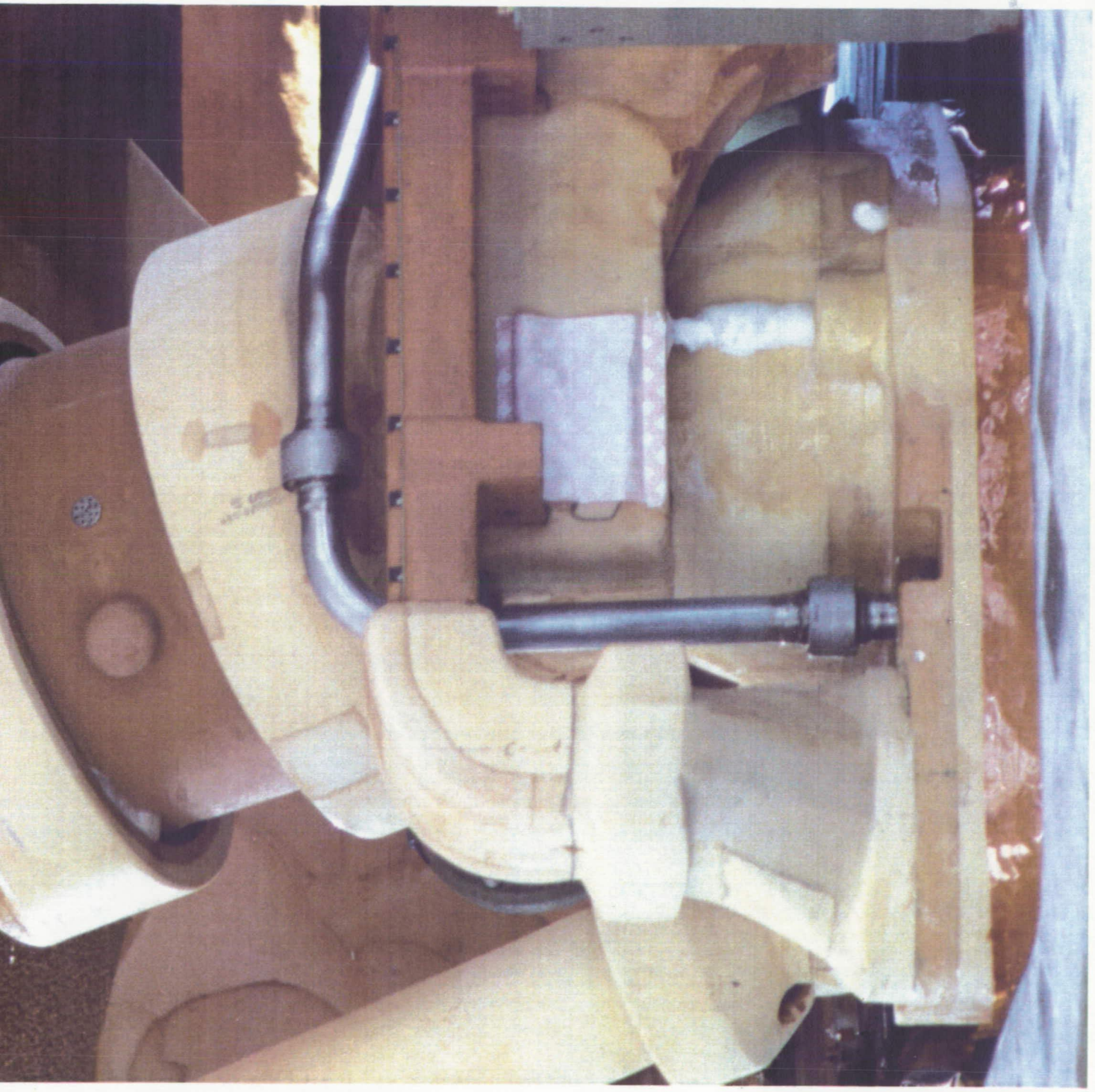

Post drain inspection of the LH2 ET/ORB umbilical revealed no anomalies. Some ice remained on the forward plate gap purge vent, forward outboard pyrotechnic canister purge vent, and LH2 feedline lower bellows - an expected occurrence.

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No anomalies were visible on the inboard side of the LH2 ET/ORB umbilical. Ice fingers were still present on the forward inboard and aft pyrotechnic canister purge vents.

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4.0 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A second pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 4 June 1991 from 0930 - 1130 hours. The walkdown of Launch Pad 39B and MLP-3 also included the primary flight elements OV-102 Columbia (11th flight), ET-41 (LWT-34), and BI044. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

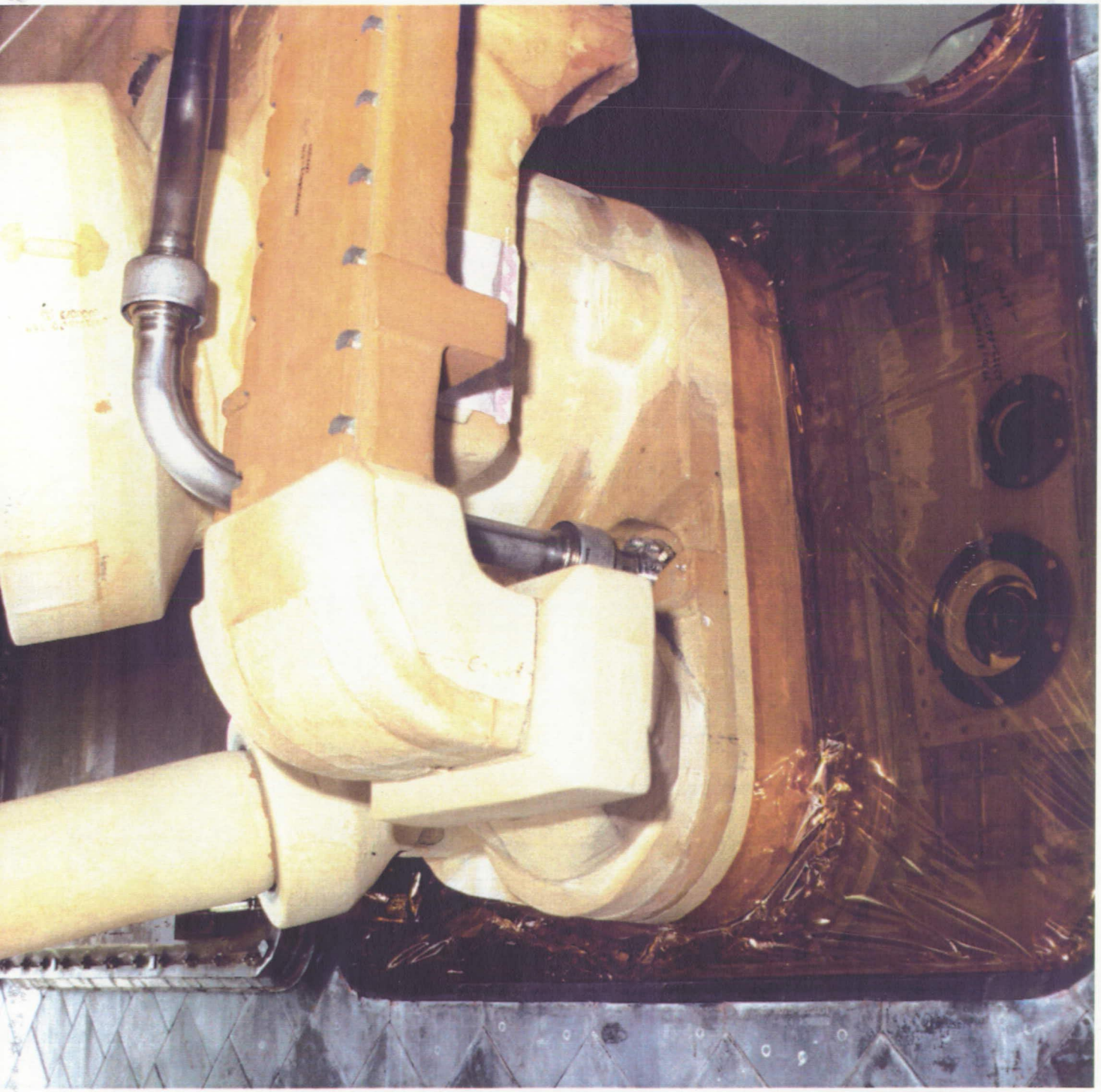
Drops of hydraulic fluid were detected on the -Y-Z quadrant of the ET and documented on PR ET-41-TS-0038. The hydraulic fluid leaked from the GOX vent arm hinge area and was blown toward the vehicle by southwesterly winds. Hydraulic fluid residue was visible on machined TPS closeout between the LH2 tank-to-intertank and on the 2058 frame as well as the LH SRB, MLP deck, GH2 vent arm, and intertank access structure. The Orbiter was enclosed by the RSS/OWP and was not affected. The potential existed for undetected fluid on the acreage SOFI. Evaluation showed no adverse affect on TPS from exposure to hydraulic fluid according to previous compatibility tests. Minimal absorption occurs after 20 hours saturation with no degradation of insulative or ablative properties. The hydraulic fluid residue was also located in a low heating area. Tank structure is tolerant to localized degradation/loss of foam in this area. The evaluation concluded that performance of the flight hardware TPS would not be degraded by the hydraulic fluid.

The ET -Y bipod jack pad closeout debonded and protruded 1/4-inch from the adjacent foam surfaces sometime after the first launch attempt scrub and subsequent detank. The anomaly was discovered during this inspection and documented on PR ET-41-TS-0039. The discrepant closeout, 4.75"x6.25"x2.00" was removed along with 0.50 inches of adjacent BX-250. PDL was applied and final trim was performed one hour after application (should be 2 hours minimum, though it should be noted rough trim is permissible after 1 hour). MRB approval was obtained on substitution of PDL for BX-250, repair area 2.55 inches larger than maximum closeout dimension (27.14 sq in), premature trim, and violation of an environmental parameter (Conathane adhesive was mixed at 88 deg F - should be 85 deg F max). There were no discrepancies on the +Y jack pad closeout.

The tygon tubes for hydrogen leak detection sensors LD 54 and 55, which had been removed during the first launch attempt, were re-installed on the vehicle.

No new debris issues were uncovered during this inspection. Small pieces of deck scale, paint flakes, and foam trimmings were present in the haunch areas and under the raised deck. The deck was vacuumed/washed down prior to cryoload.

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



Pre-launch configuration of the LH2 ET/ORB umbilical included two 16mm cameras with 5mm and 10mm lenses

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View of the External Tank forward attach point bipods, +Z side of the intertank and upper LH2 tank. Pre-launch inspection revealed a debond of the -Y bipod jack pad closeout, though the debond was not visible from this side of the vehicle.

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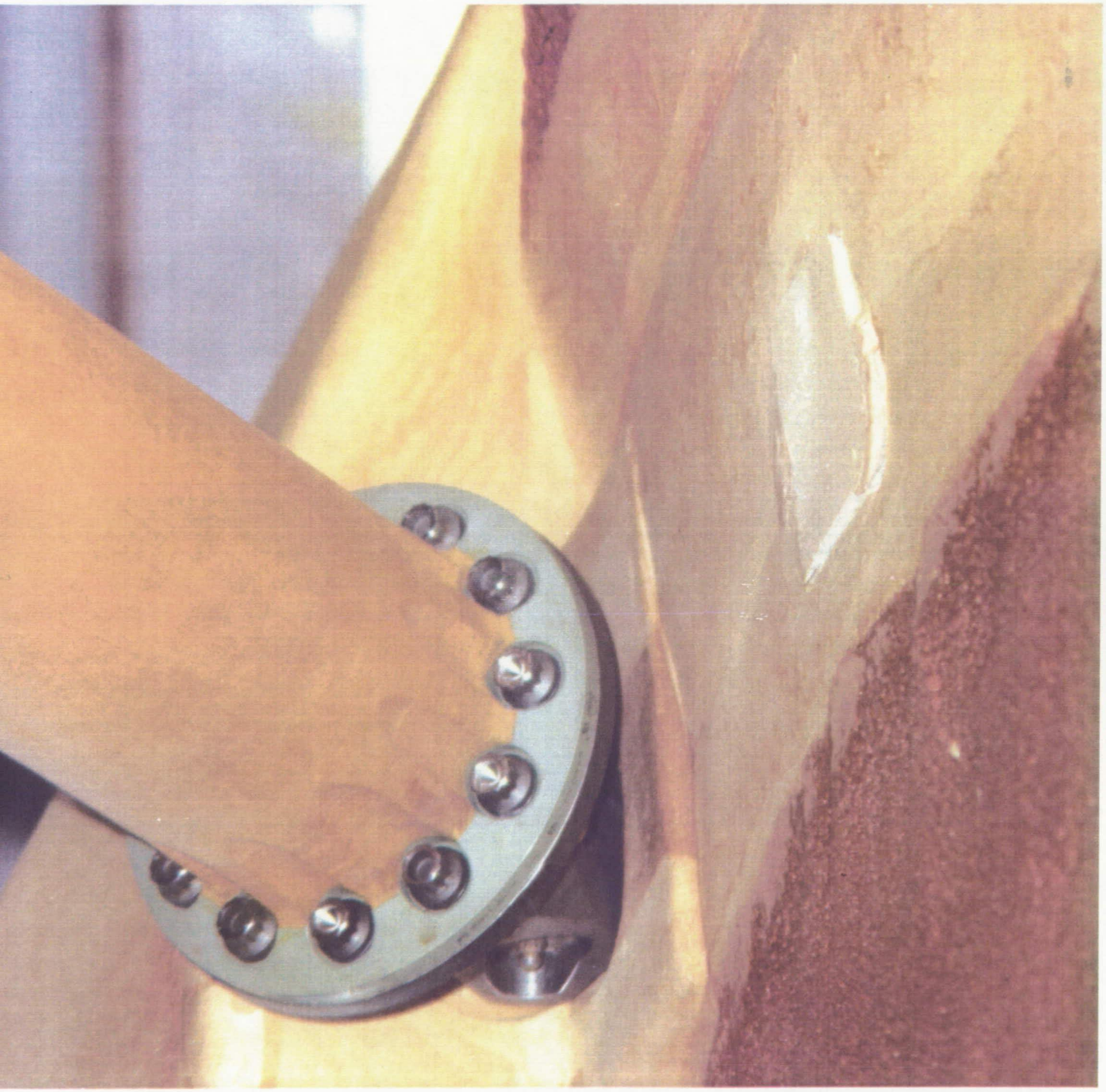

The ET -Y bipod jack pad closeout debonded and was protruding 1/4-inch above the adjacent foam surface. The discrepant closeout was removed and repaired with PDL prior to the second cryoload.

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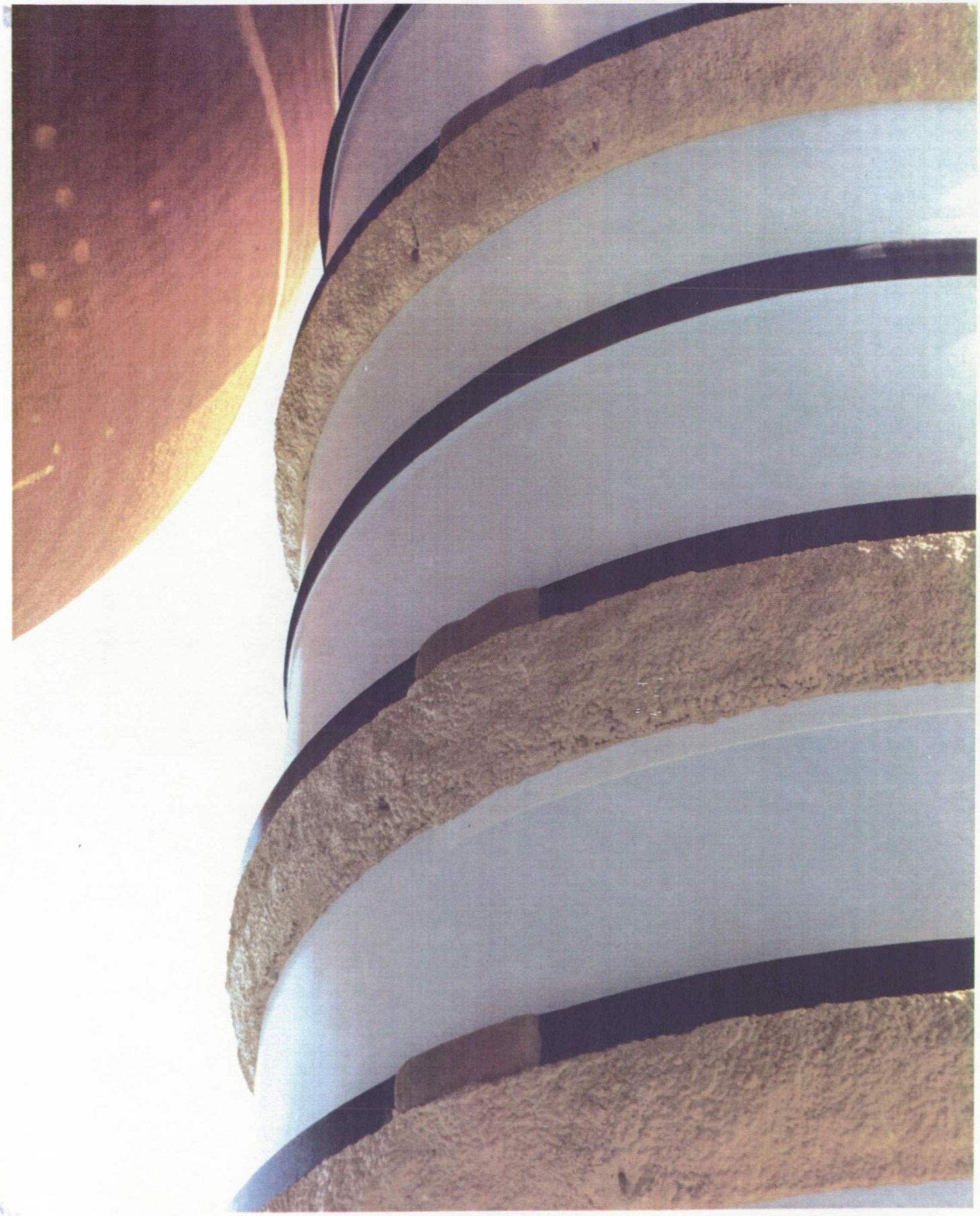

Three of nine aft booster stiffener ring splice plate K5NA closeouts are located on the Orbiter side of the RH Solid Rocket Booster

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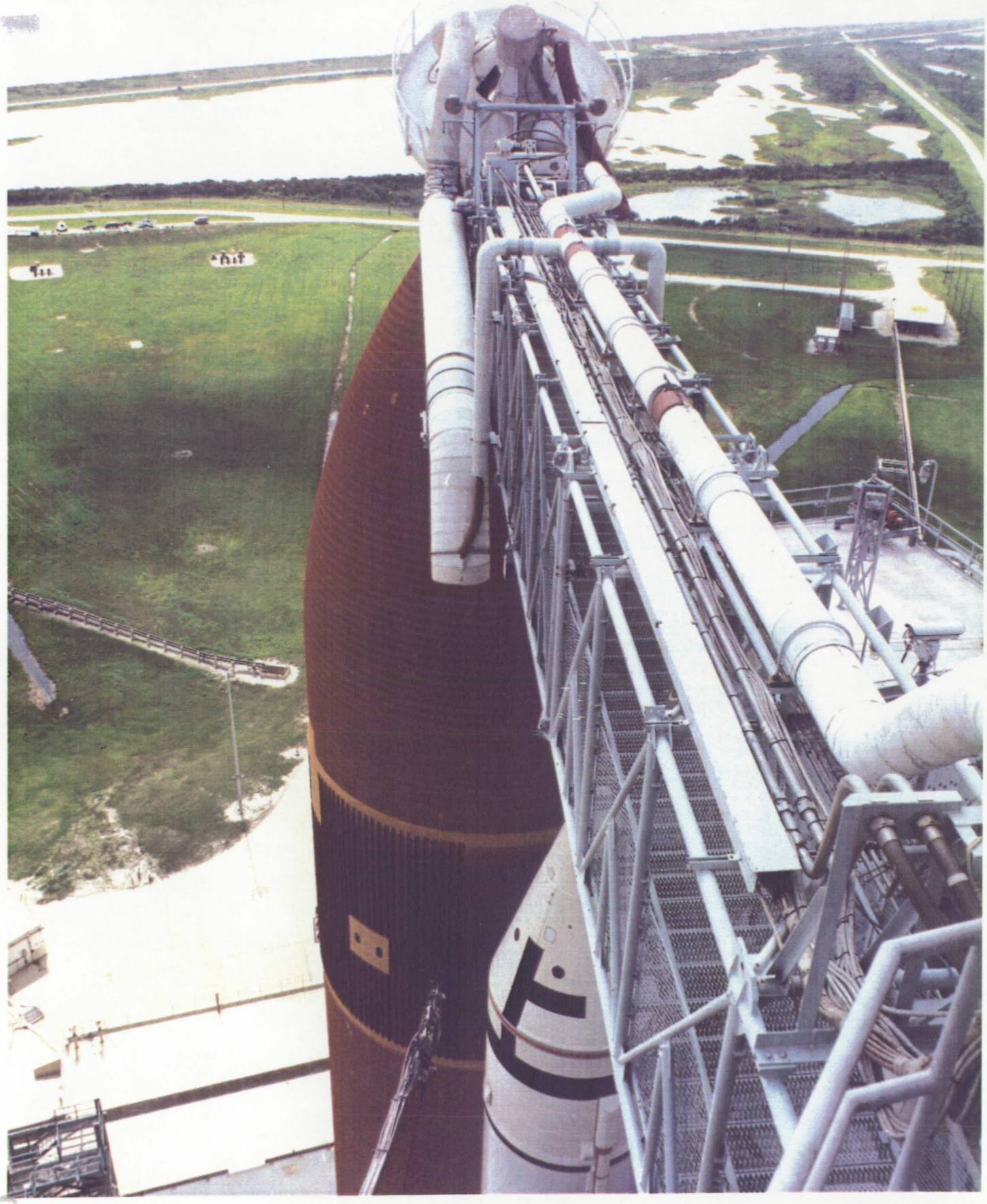

Hydraulic fluid leaked from the GOX vent arm hinge area and was blown toward the vehicle by prevailing winds. Hydraulic fluid drops were present on the -Y-Z quadrant of the External Tank and on the LH SRB. The Orbiter was sheltered by the RSS/OWP.

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Although not readily apparent on the External Tank acreage TPS, the hydraulic fluid drops that fell from the GOX vent arm hinge area were more visible on the ET intertank access structure. Engineering evaluation determined the presence of the hydraulic fluid would not adversely affect the flight hardware TPS.

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5.0 LAUNCH

Orbiter IMU #2 that caused the scrub during the first launch attempt had been replaced. STS-40 was launched at 5:13:24:51 GMT (9:24:51 a.m. local) on 5 June 1991.

5.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 5 June 1991 from 0250 to 0420 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. No adverse effects resulted from the hydraulic fluid spill. Ambient weather conditions at the time of the inspection were:

Temperature:	74.8 F
Relative Humidity:	88.6 %
Wind Speed:	8.3 Knots
Wind Direction:	233 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 4 and 5.

5.2 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 77 degrees F. The average surface temperatures of the SSME engine mounted heat shields were measured at 73 degrees F for SSME #1, 72 degrees F for SSME #2, and 73 degrees F for SSME #3. The coldest area on the engine mounted heat shields was 70 degrees F (SSME #2). All of the SSME heat shields were wet with some condensate. Light frost coated the SSME #1 heat shield-to-nozzle interface at the 6 o'clock position and the SSME #2 heat shield-to-nozzle interface at the 6-9 o'clock position. Some of the SSME drain lines were covered by frost. No LO2 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.

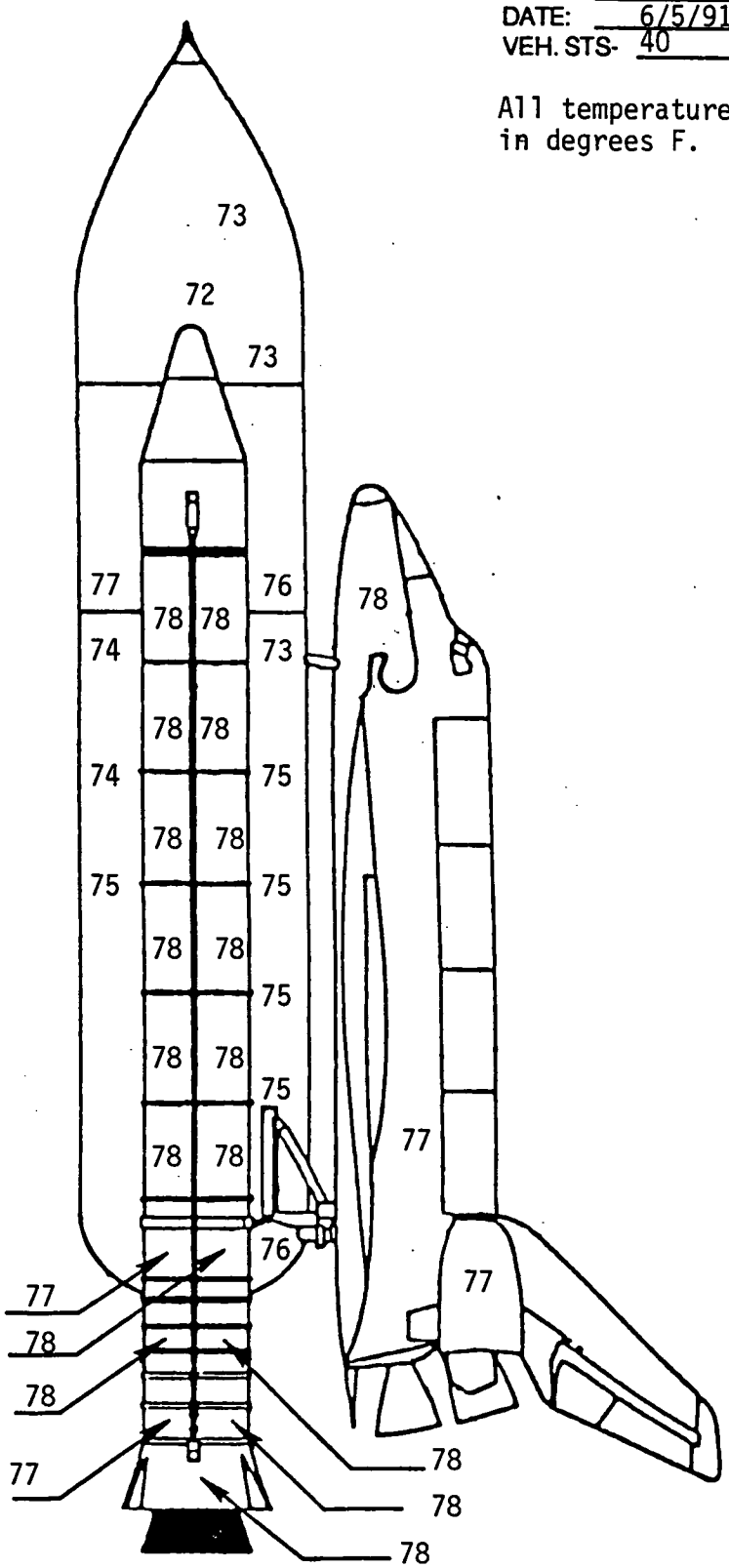
5.3 SOLID ROCKET BOOSTERS

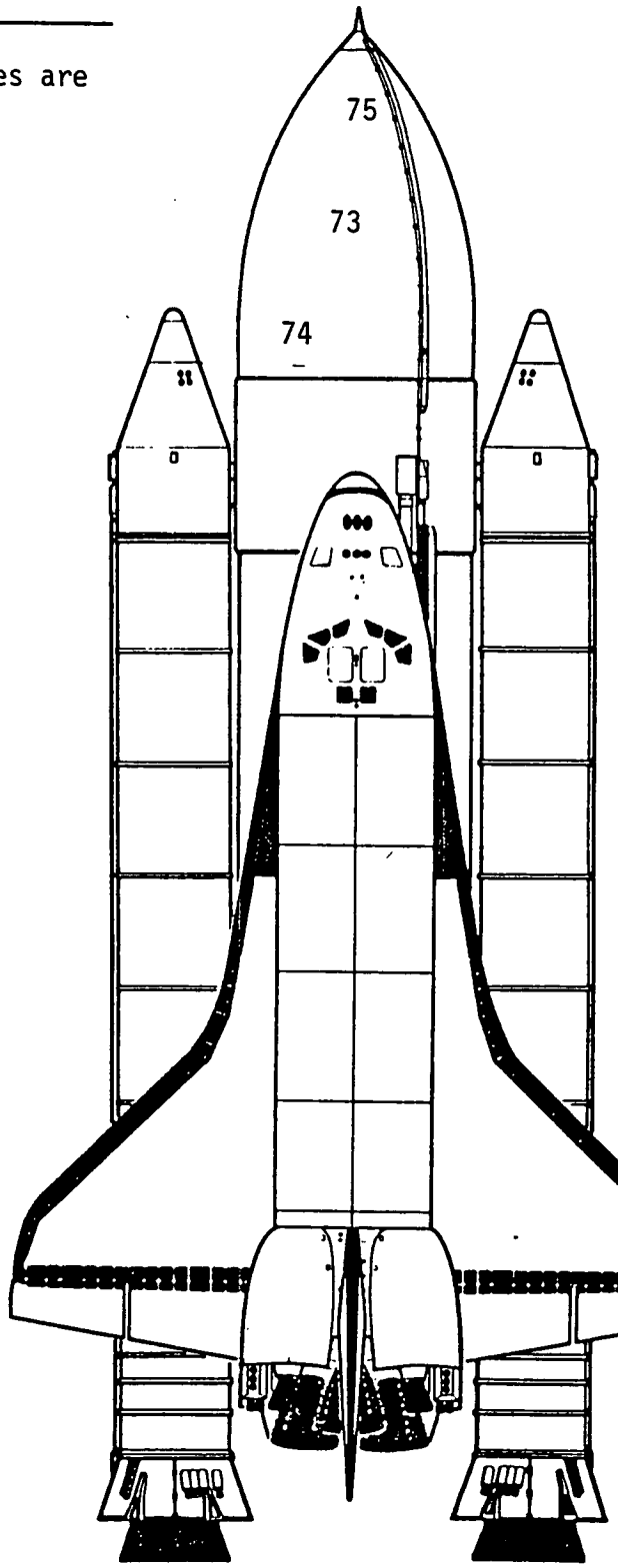
No SRB anomalies or loose ablator/cork were observed. The K5NA closeouts of the aft booster stiffener ring splice plates were intact. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 77 and 78 degrees F. The Mikron IR gun and the GEI gave measurements of 77 and 81 degrees F, respectively, in comparison. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 78 degrees F, which was within the required range of 44-86 degrees F.

FIGURE 4. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0250 - 0420
DATE: 6/5/91
VEH. STS- 40

All temperatures are in degrees F.



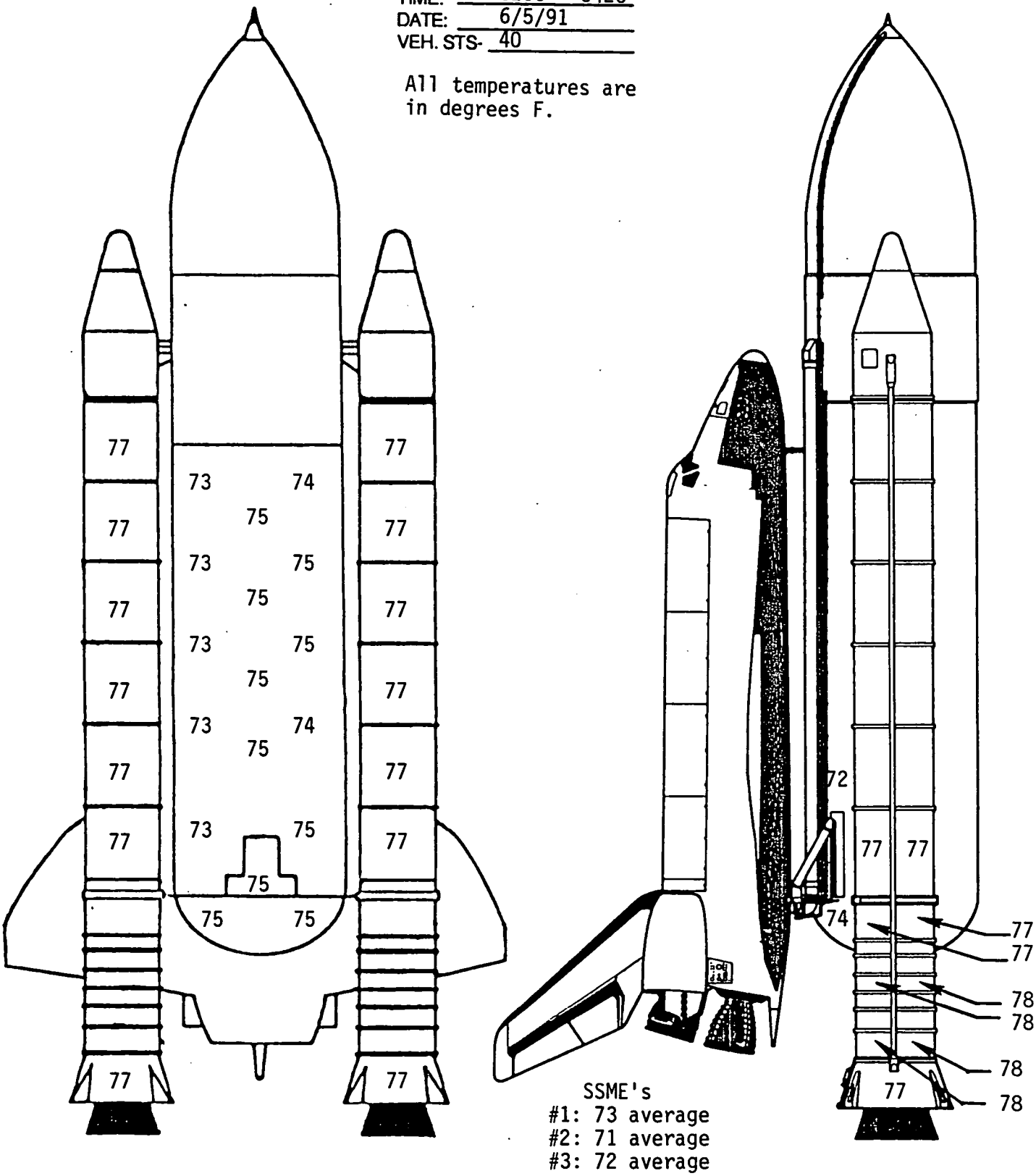


EGG/V-343

FIGURE 5. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0250 - 0420
DATE: 6/5/91
VEH. STS- 40

All temperatures are in degrees F.



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5.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0000 to 0915 hours and the results tabulated in Figures 6 and 7. The program predicted condensate with no ice accumulation on all TPS acreage surfaces.

Very light condensate, but no ice or frost, was present on the LO2 tank barrel TPS acreage. There was no ice/frost or condensate on the LO2 tank ogive. There were no TPS anomalies. The tumble valve cover was intact. There were no anomalies on the pressurization line and support ramps. STI measured a surface temperature of 75 degrees F on the ogive and 73 degrees F on the barrel section. SURFICE predicted 68 degrees F on the ogive and 65 degrees F on the barrel section. The Mikron IR gun measured 66 and 64 degrees F, respectively.

The intertank TPS acreage was wet with light run-off condensate. There were no TPS anomalies. Small scattered frost spots appeared in the stringer valleys at both LH2 and LO2 tank -Z flanges. No unusual vapors or ice formations were present on the ET umbilical carrier plate. The STI IR scanner measured an average surface temperature of 76 degrees F compared to a Mikron IR gun measurement of 71 degrees F.

The LH2 tank and aft dome TPS acreage were covered with a moderate amount of condensate. There was no ice/frost on the acreage. The average surface temperatures as measured by the STI IR scanner were 73 degrees F on the upper LH2 tank and 75 degrees F on the lower LH2 tank compared to a Mikron IR gun measurements of 68 and 64 degrees F, respectively. SURFICE predicted 60 degrees F on the upper LH2 tank and 69 degrees F on the lower LH2 tank.

There were no anomalies on the bipods, PAL ramp, cable tray/press line ice/frost ramps, thrust struts, manhole covers, or aft dome apex with the exception of a small ice/frost spot at the +Y ET/SRB cable tray-to-LH2 tank closeout bondline. 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.

The repair to the -Y bipod jack pad closeout was intact. The PDL repair was flush with the surrounding foam. No ice or frost was present on the TPS or adhesive bondline. There was no venting of vapor. STI infrared data showed the repair area was the same temperature as the surrounding TPS and there were no thermal shorts.

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

STS- 40	TEST S0007 LAUNCH																											DATE: 5 June 1991	T-0 TIME: 09:24:51 DATE: 6-5-91	NASA KSC Ice/Frost/Debris Team
ORBITER 102	ET 41	SRB BI-044	MLP 3	PAD B	LO2 CHILLDOWN TIME: 23:53 SLOW FILL TIME: 00:20 FAST FILL TIME: 00:33 REPLENISH TIME: 02:34											LH2 CHILLDOWN TIME: 23:42 SLOW FILL TIME: 23:50 FAST FILL TIME: 00:16 REPLENISH TIME: 02:17														
TIME (EDT)	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
0000	78.20	80.0	71.83	8	225	II	4.72	68.01	0.0023	-0.2153	II	4.72	63.95	0.0043	-0.1836	II	2.56	57.44	0.0042	-0.0964	II	10.88	68.26	0.0044	-0.3994
0015	78.20	79.6	71.69	8	225	II	4.72	67.91	0.0023	-0.2145	II	4.72	63.84	0.0043	-0.1828	II	2.56	57.34	0.0042	-0.0959	II	10.88	68.16	0.0044	-0.3978
0030	78.20	80.2	71.90	10	229	II	5.90	68.91	0.0022	-0.2599	II	5.90	65.52	0.0044	-0.2273	II	3.20	59.76	0.0044	-0.1212	II	13.60	69.23	0.0041	-0.4960
0045	77.20	79.6	70.70	12	232	II	7.08	68.33	0.0020	-0.2903	II	7.08	65.37	0.0042	-0.2574	II	3.84	60.12	0.0045	-0.1373	II	16.32	68.69	0.0036	-0.5653
0100	76.40	84.0	71.44	10	231	II	5.90	67.93	0.0026	-0.2506	II	5.90	64.47	0.0047	-0.2183	II	3.20	58.53	0.0046	-0.1149	II	13.60	68.30	0.0047	-0.4794
0115	76.20	86.0	71.91	7	237	II	4.13	66.69	0.0028	-0.1877	II	4.13	62.11	0.0046	-0.1565	II	2.24	54.94	0.0043	-0.0797	II	9.52	66.98	0.0053	-0.3431
0130	76.00	87.0	72.03	8	229	II	4.72	67.30	0.0028	-0.2098	II	4.72	63.17	0.0048	-0.1782	II	2.56	56.40	0.0045	-0.0920	II	10.88	67.66	0.0054	-0.3911
0145	76.20	88.0	72.56	9	234	II	5.31	68.24	0.0029	-0.2357	II	5.31	64.50	0.0050	-0.2035	II	2.88	58.17	0.0048	-0.1065	II	12.24	68.64	0.0055	-0.4461
0200	76.40	87.4	72.56	8	230	II	4.72	67.83	0.0029	-0.2141	II	4.72	63.73	0.0049	-0.1823	II	2.56	57.00	0.0046	-0.0946	II	10.88	68.19	0.0055	0.0000
0215	75.60	88.4	72.09	9	242	II	5.31	67.68	0.0030	-0.2308	II	5.31	63.91	0.0050	-0.1987	II	2.88	57.52	0.0047	-0.1034	II	12.24	68.09	0.0055	-0.4370
0230	75.60	88.6	72.15	8	234	II	4.72	67.22	0.0030	-0.2093	II	4.72	63.09	0.0049	-0.1777	II	2.56	56.28	0.0046	-0.0915	II	10.88	67.61	0.0056	-0.3905
0245	75.40	88.8	72.02	7	232	II	4.13	66.44	0.0029	-0.1860	II	4.13	61.84	0.0048	-0.1548	II	2.24	54.57	0.0044	-0.0783	II	9.52	66.79	0.0056	-0.3407
0300	75.00	89.2	71.75	8	229	II	4.72	66.70	0.0030	-0.2052	II	4.72	62.53	0.0049	-0.1737	II	2.56	55.67	0.0046	-0.0888	II	10.88	67.11	0.0057	-0.3830
0315	75.20	88.8	71.82	8	228	II	4.72	66.83	0.0030	-0.2062	II	4.72	62.67	0.0049	-0.1746	II	2.56	55.83	0.0046	-0.0894	II	10.88	67.23	0.0056	-0.3848
0330	75.40	88.0	71.76	12	235	II	7.08	68.44	0.0029	-0.2920	II	7.08	65.46	0.0051	-0.2588	II	3.84	60.07	0.0050	-0.1372	II	16.32	68.89	0.0052	-0.5707
0345	74.80	88.2	71.23	10	239	II	5.90	67.18	0.0029	-0.2439	II	5.90	63.68	0.0050	-0.2117	II	3.20	57.59	0.0048	-0.1101	II	13.60	67.63	0.0054	-0.4677
0400	74.20	89.2	70.95	6	240	II	3.54	64.42	0.0029	-0.1559	II	3.54	59.17	0.0046	-0.1255	II	1.92	51.25	0.0041	-0.0703	II	8.16	64.70	0.0056	-0.2791
0415	73.40	88.0	69.78	7	227	II	4.13	64.03	0.0028	-0.1693	II	4.13	59.29	0.0046	-0.1387	II	2.24	51.83	0.0041	-0.0676	II	9.52	64.41	0.0054	-0.3101
0430	72.40	85.6	68.00	8	228	II	4.72	63.03	0.0026	-0.1774	II	4.72	58.67	0.0044	-0.1468	II	2.56	51.60	0.0041	-0.0714	II	10.88	63.45	0.0049	-0.3308
0445	72.40	83.4	67.27	8	239	II	4.72	62.54	0.0024	-0.1737	II	4.72	58.15	0.0042	-0.1433	II	2.56	51.09	0.0040	-0.0693	II	10.88	62.93	0.0046	-0.3236
0500	72.20	82.6	66.80	8	235	II	4.72	62.14	0.0024	-0.1708	II	4.72	57.73	0.0041	-0.1405	II	2.56	50.66	0.0039	-0.0675	II	10.88	62.53	0.0045	-0.3181
0515	71.20	83.0	65.95	7	237	II	4.13	60.49	0.0024	-0.1459	II	4.13	55.55	0.0040	-0.1161	II	2.24	47.93	0.0037	-0.0529	II	9.52	60.84	0.0045	-0.2666
0530	71.40	84.0	66.48	7	262	II	4.13	60.93	0.0024	-0.1487	II	4.13	56.02	0.0041	-0.1188	II	3.01	51.79	0.0041	-0.0789	II	8.47	60.61	0.0047	-0.2416
0545	71.00	83.8	66.02	4	276	II	2.36	57.22	0.0023	-0.0906	II	2.36	49.98	0.0035	-0.0620	II	1.72	45.10	0.0034	-0.0486	II	4.84	55.97	0.0045	-0.1313
0600	71.00	83.6	65.95	6	282	II	3.54	59.59	0.0024	-0.1273	II	3.54	54.05	0.0039	-0.0979	II	2.58	49.49	0.0039	-0.0631	II	7.26	59.08	0.0046	-0.2013
0615	71.20	83.0	65.95	5	274	II	2.95	58.64	0.0023	-0.1095	II	2.95	52.36	0.0037	-0.0805	II	2.15	47.43	0.0036	-0.0501	II	6.05	57.84	0.0046	-0.1670
0630	71.00	84.6	66.29	5	242	II	2.95	58.76	0.0024	-0.1101	II	2.95	52.49	0.0038	-0.0811	II	1.60	45.24	0.0034	-0.0492	II	6.80	58.85	0.0047	-0.1901
0645	70.80	85.8	66.48	4	232	II	2.36	57.41	0.0024	-0.0914	II	2.36	50.17	0.0036	-0.0628	II	1.28	45.21	0.0035	-0.0491	II	5.44	57.19	0.0047	-0.1506

FIGURE 6. 'SURFICE' Computer Predictions

STS- 40	TEST S0007 LAUNCH																											DATE: 5 June 1991	T-0 TIME: 09:24:51 DATE: 6-5-91	NASA KSC Ice/Frost/Debris Team
ORBITER 102	ET 41	SRB BI-044	MLP 3	PAD B	LO2 CHILLDOWN TIME: 23:53 SLOW FILL TIME: 00:20 FAST FILL TIME: 00:33 REPLENISH TIME: 02:34											LH2 CHILLDOWN TIME: 23:42 SLOW FILL TIME: 23:50 FAST FILL TIME: 00:16 REPLENISH TIME: 02:17														
TIME (EDT)	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
0700	70.80	86.0	66.55	4	257	II	2.36	57.45	0.0024	-0.0916	II	2.36	50.21	0.0036	-0.0630	II	1.72	45.25	0.0035	-0.0493	II	4.84	56.25	0.0047	-0.1331
0715	70.80	86.6	66.74	6	248	II	3.54	60.02	0.0026	-0.1298	II	3.54	54.50	0.0041	-0.1003	II	2.58	49.91	0.0040	-0.0648	II	7.26	59.55	0.0050	-0.2058
0730	71.00	87.2	67.14	5	240	II	2.95	59.33	0.0025	-0.1129	II	2.95	53.07	0.0040	-0.0838	II	1.60	45.71	0.0036	-0.0512	II	6.80	59.45	0.0050	-0.1955
0745	71.40	87.0	67.47	4	224	II	2.36	58.36	0.0024	-0.0955	II	2.36	51.17	0.0037	-0.0668	II	1.28	46.17	0.0036	-0.0532	II	5.44	58.16	0.0049	-0.1577
0800	71.80	86.6	67.74	3	232	II	1.77	56.83	0.0023	-0.0853	II	1.77	48.32	0.0034	-0.0606	II	0.96	46.59	0.0036	-0.0549	II	4.08	56.00	0.0047	-0.1179
0815	72.00	86.4	67.87	4	245	II	2.36	58.93	0.0024	-0.0980	II	2.36	51.80	0.0037	-0.0692	II	1.28	46.81	0.0036	-0.0558	II	5.44	58.72	0.0049	-0.1618
0830	72.80	86.6	68.73	5	228	II	2.95	61.25	0.0026	-0.1228	II	2.95	55.13	0.0041	-0.0932	II	1.60	47.84	0.0037	-0.0603	II	6.80	61.35	0.0051	-0.2124
0845	72.80	86.4	68.66	4	234	II	2.36	59.86	0.0025	-0.1021	II	2.36	52.78	0.0038	-0.0731	II	1.28	47.80	0.0037	-0.0601	II	5.44	59.64	0.0050	-0.1686
0900	73.60	85.4	69.13	5	252	II	2.95	61.89	0.0025	-0.1261	II	2.95	55.83	0.0041	-0.0965	II	2.15	51.01	0.0039	-0.0636	II	6.05	61.13	0.0050	-0.1937
0915	74.60	84.0	69.65	5	261	II	2.95	62.71	0.0025	-0.1304	II	2.95	56.71	0.0041	-0.1007	II	2.15	51.96	0.0039	-0.0679	II	6.05	61.93	0.0049	-0.2003
T-0	74.80	82.2	69.24	5	247	II	2.95	62.53	0.0024	-0.1294	II	2.95	56.52	0.0039	-0.0997	II	1.60	49.50	0.0036	-0.0674	II	6.80	62.53	0.0048	-0.2231
Avg.	73.81	85.46	69.34	6.8	WSW		4.04	63.33				4.04	58:19				2.31	52.16				9.15	63.35		

Period of Ice Team Inspection

FIGURE 7. 'SURFICE' Computer Predictions

There were no anomalies on the LO2 ET/ORB umbilical. The purge barrier (baggie) was configured properly and was holding positive purge pressure. Small scattered accumulations of ice/frost were present of the outboard and aft areas of the baggie. There was no ice/frost accumulation on the acreage areas of the umbilical. Ice/frost fingers 4 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.

Ice/frost had formed in the LH2 recirculation line bellows and on both burst disks. The LH2 feedline bellows were wet with condensate. The forward and outboard sides of the LH2 ET/ORB umbilical were covered by typical ice/frost formations. Ice/frost accumulation on the inboard and aft areas of the baggie was light. Ice/frost fingers 3-7 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 pyro canister 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 4 OTV recorded items:

Anomaly 001 (documentation only) noted ice/frost accumulations in the LO2 feedline bellows and support brackets, and in the LH2 recirculation line bellows. All of these accumulations were acceptable per NSTS-08303.

Anomaly 002 (documentation only) recorded frost spots in the -Z intertank stringer valleys at the LO2 and LH2 tank flange closeouts. Frost spots in these locations were acceptable per NSTS-08303.

Anomaly 003 (documentation only) noted ice/frost formations on the LH2 and LO2 ET/ORB umbilical pyro canister purge vents and purge barrier baggie material. These formations were acceptable per NSTS-08303.

Anomaly 004 (documentation only) recorded ice/frost formations on a repair bondline and on the +Y ET/SRB cable tray doghouse drain hole. These formations were acceptable per NSTS-08303.

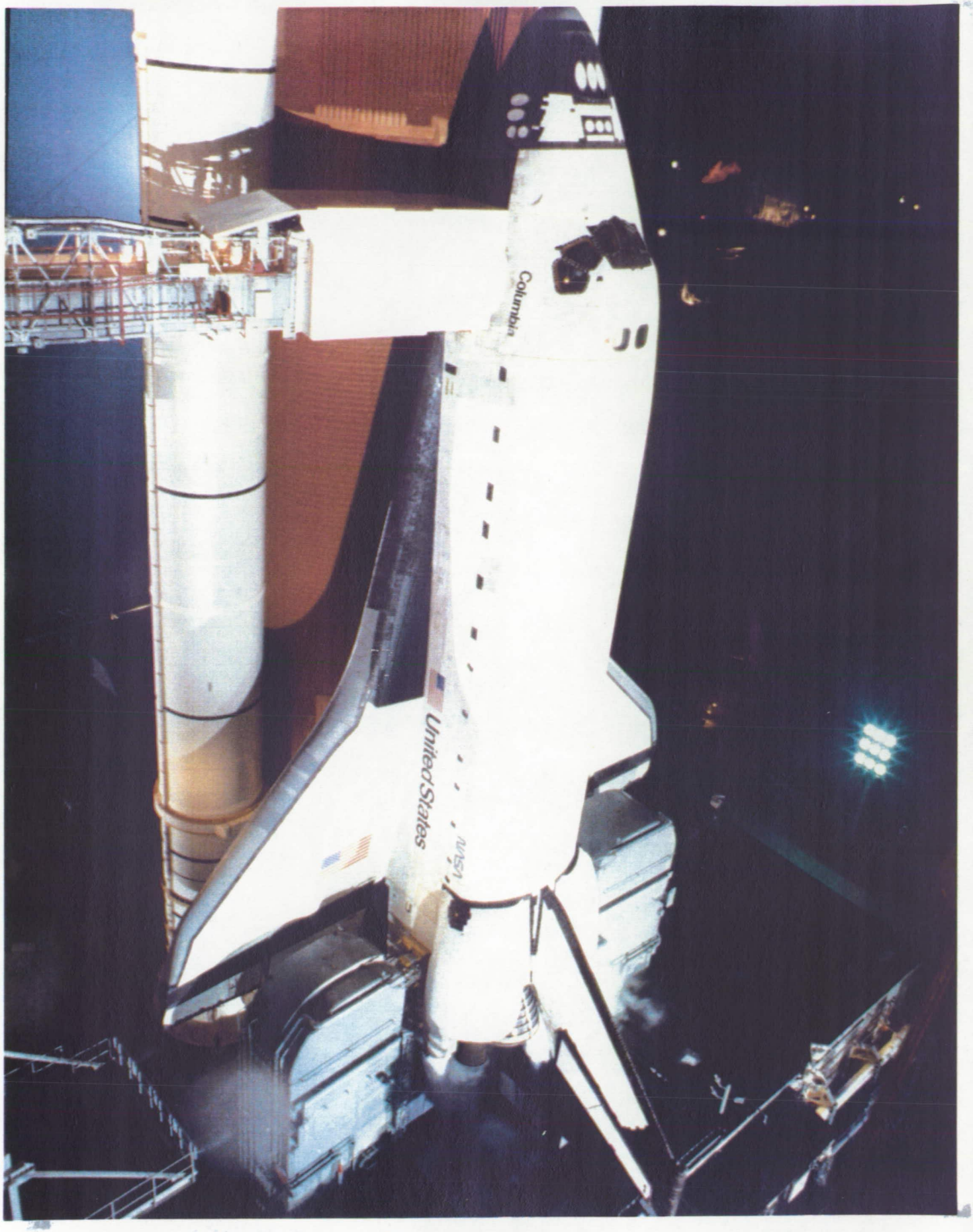
5.5 FACILITY

No new debris concerns had been identified during the ice/frost inspection of the vehicle.

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.



TPS and RCS paper covers on OV-102 were in proper configuration

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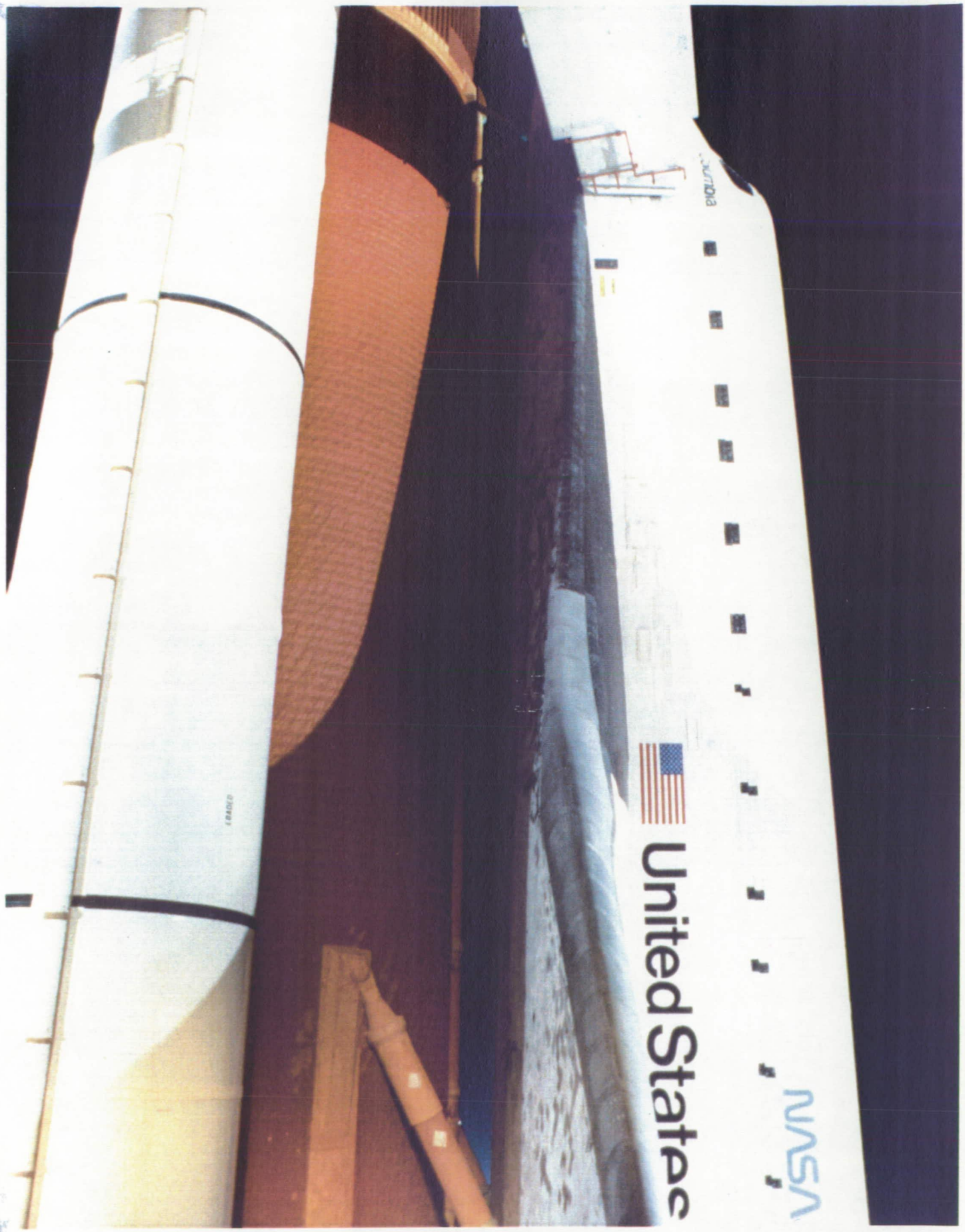

A moderate amount of condensate, but no acreage ice or frost, was present on the +Z side of the External Tank

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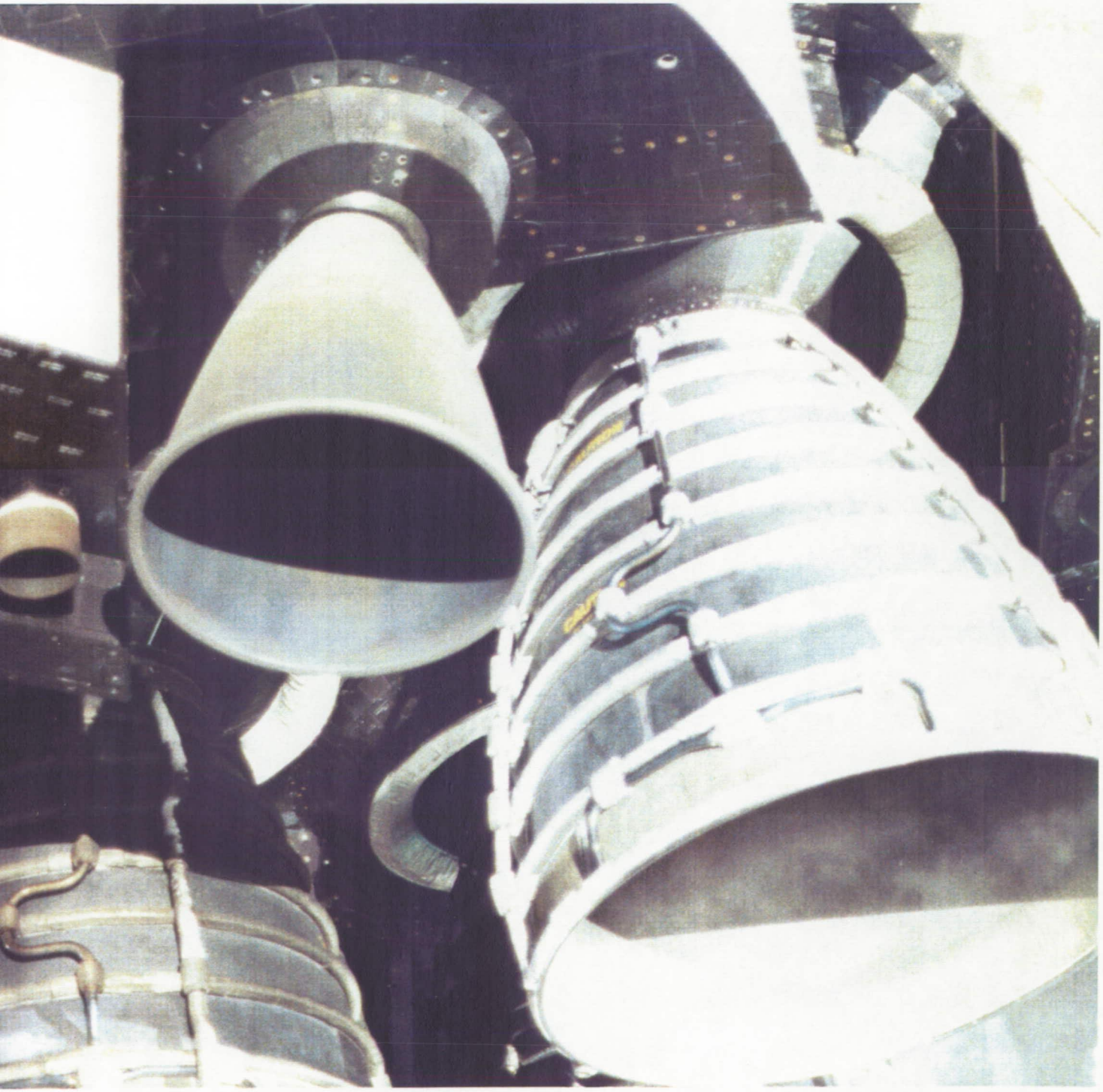

Light condensate was present on the SSME engine mounted heat shields. Light frost had accumulated on the SSME #1 and #2 heat shield-to-nozzle interfaces.

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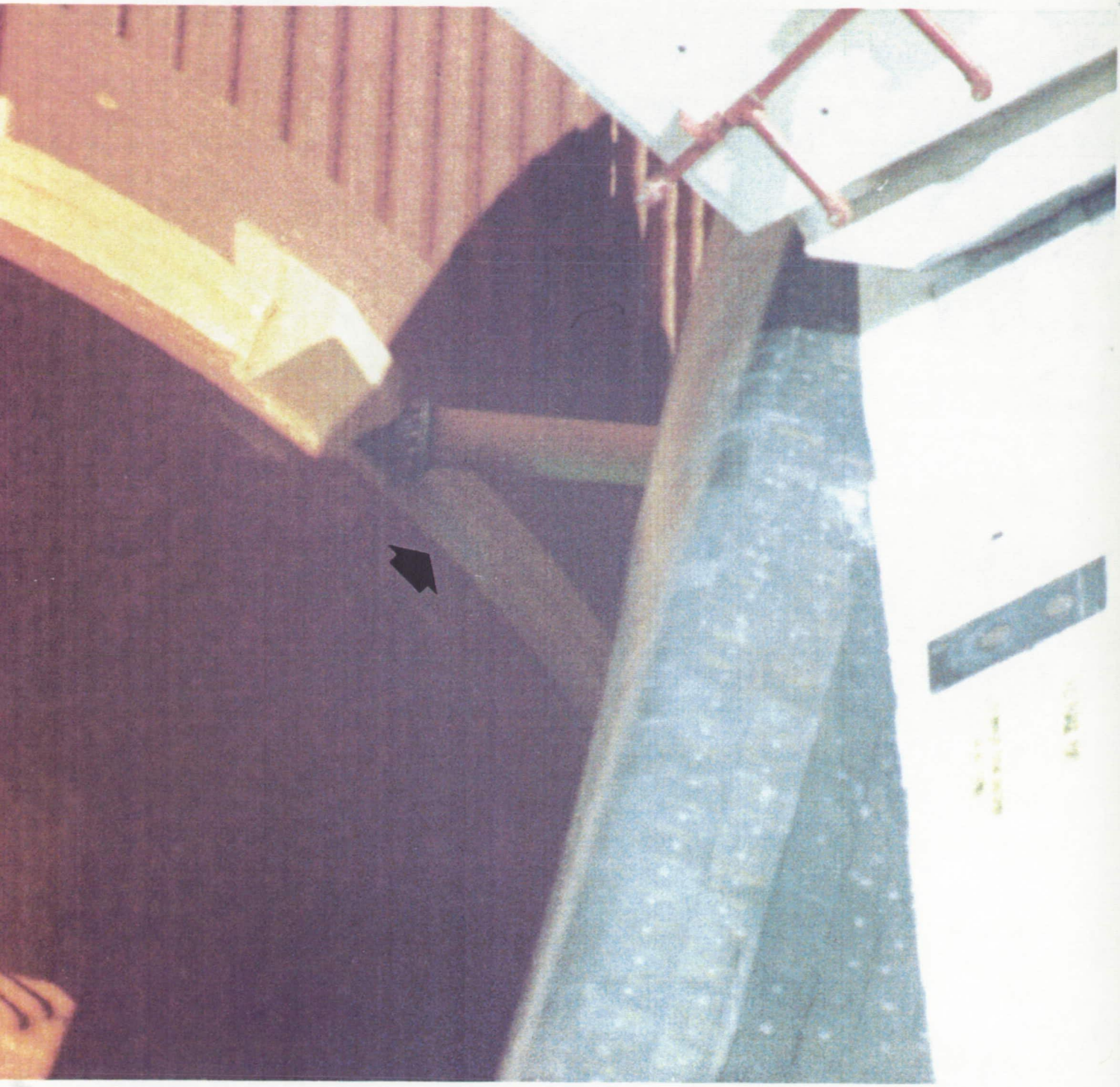

The PDL repair to the ET -Y jack pad closeout was intact after cryogenic loading. The repair was flush with the surrounding foam. No ice or frost was present on the TPS or adhesive bond line. There was no venting of vapor.

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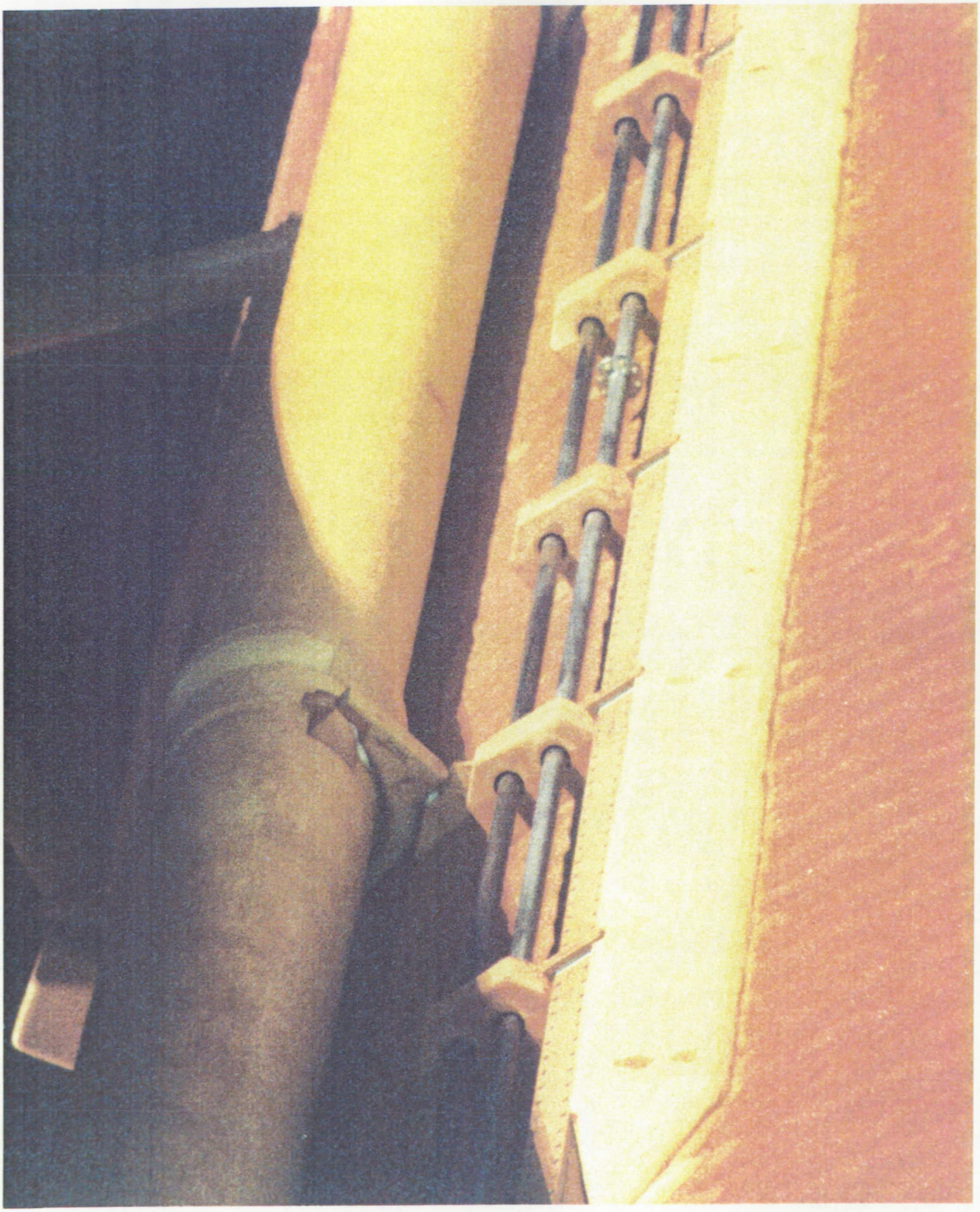
Typical amounts of ice/frost had accumulated in the LO2 feedline upper bellows and support brackets

ORIGINAL PAGE
COLOR PHOTOGRAPH



Typical amounts of ice/frost had accumulated on the LO2 feed line support brackets. There were no anomalies on the PAL ramps, cable tray, or pressurization line ramps.

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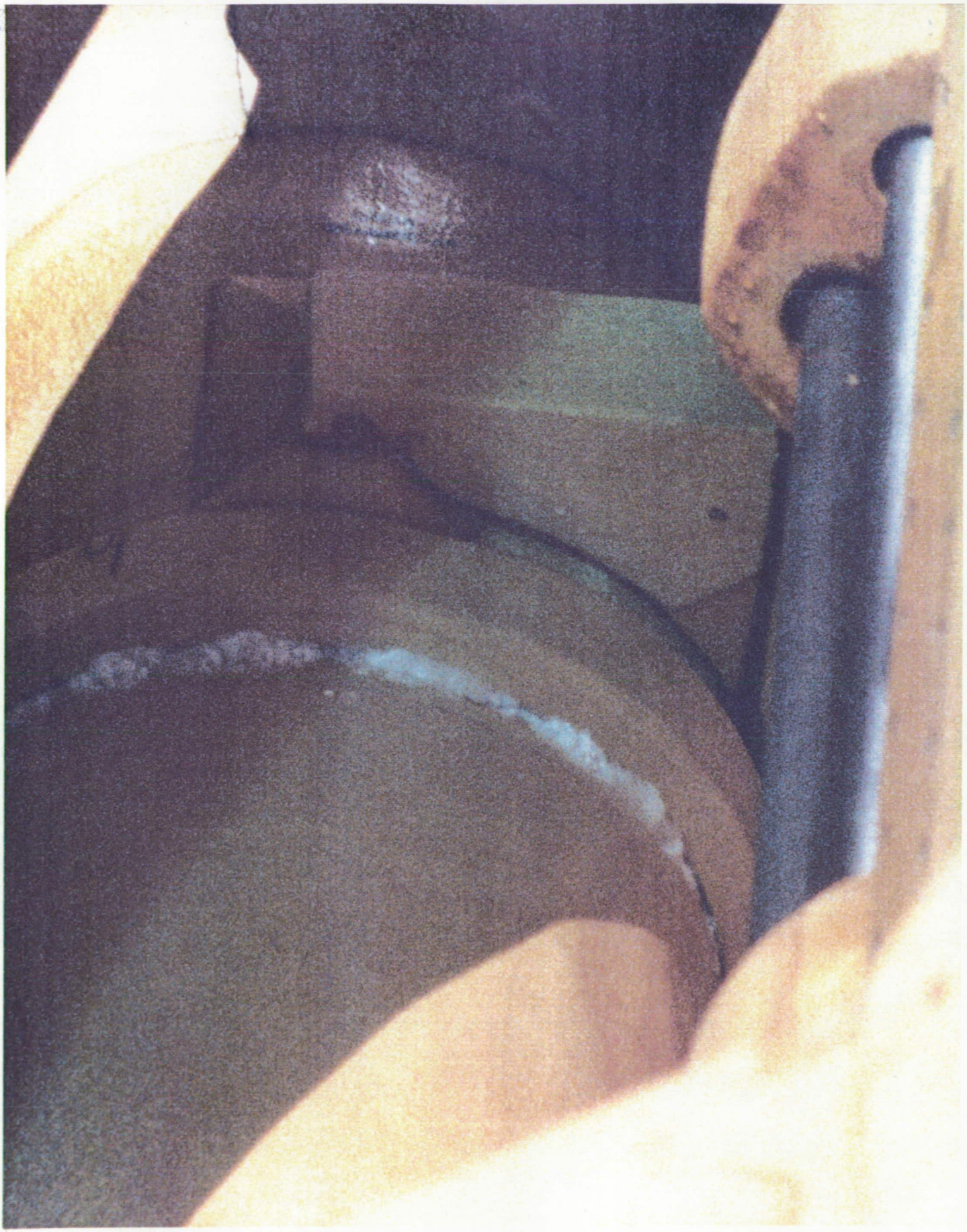

Typical amounts of ice/frost were present in the LO2 feedline lower bellows and support brackets

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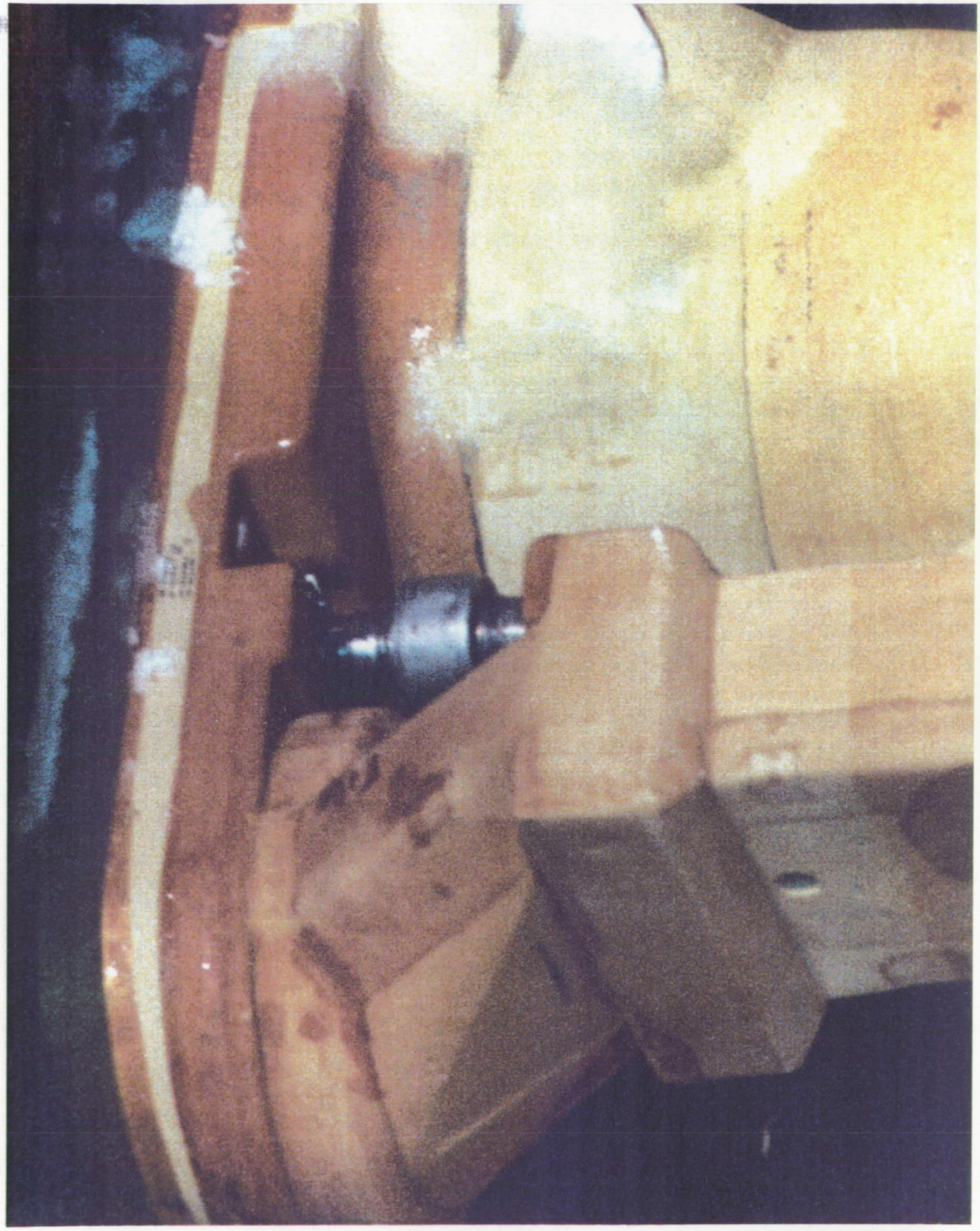

Ice/frost accumulations on the LO2 ET/ORB umbilical forward outboard pyrotechnic canister purge vent and outboard side of the purge barrier (baggie) were typical.

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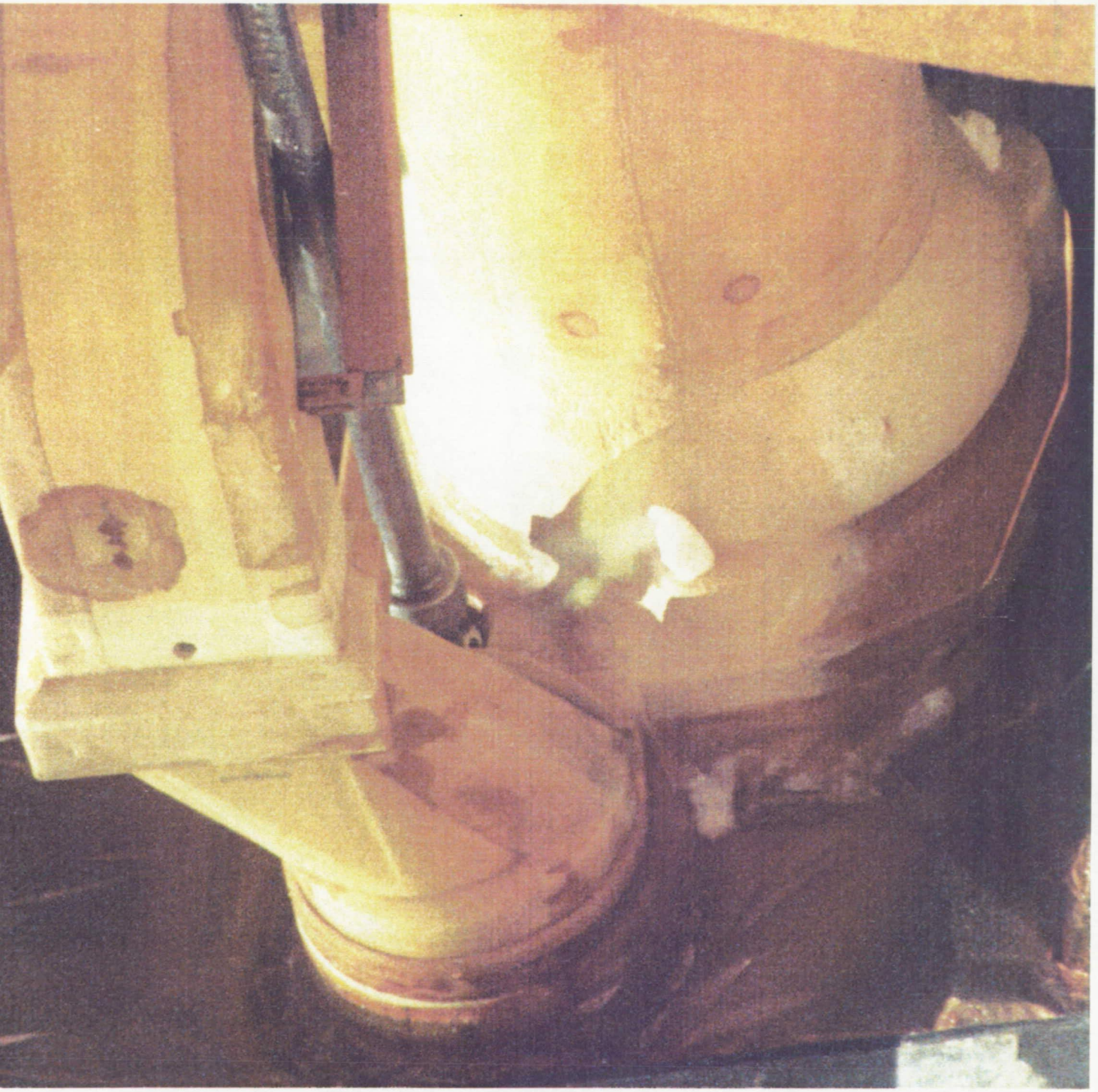

Ice/frost accumulations on the LO2 ET/ORB umbilical purge barrier (baggie) aft side and the forward inboard and aft pyrotechnic canister purge vents were typical. Venting of nitrogen purge gas was normal.

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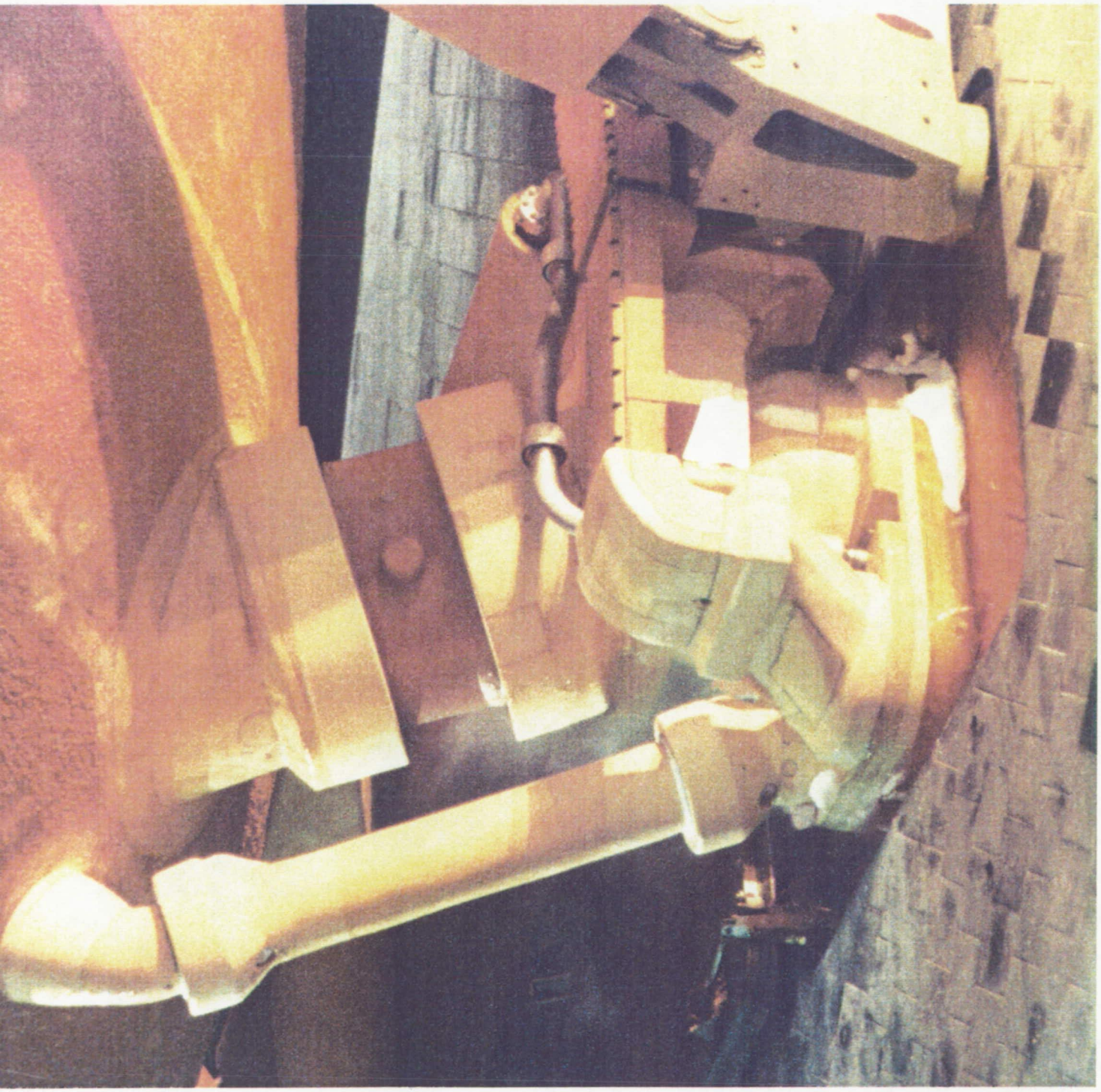

Ice/frost accumulations on the LH2 ET/ORB umbilical purge barrier (baggie) top, outboard, and aft sides were somewhat less than usual. Ice/frost fingers on the pyrotechnic canister purge vents and the umbilical disconnect plate gap purge vents were typical. There were no unusual vapors or cryogenic drips.

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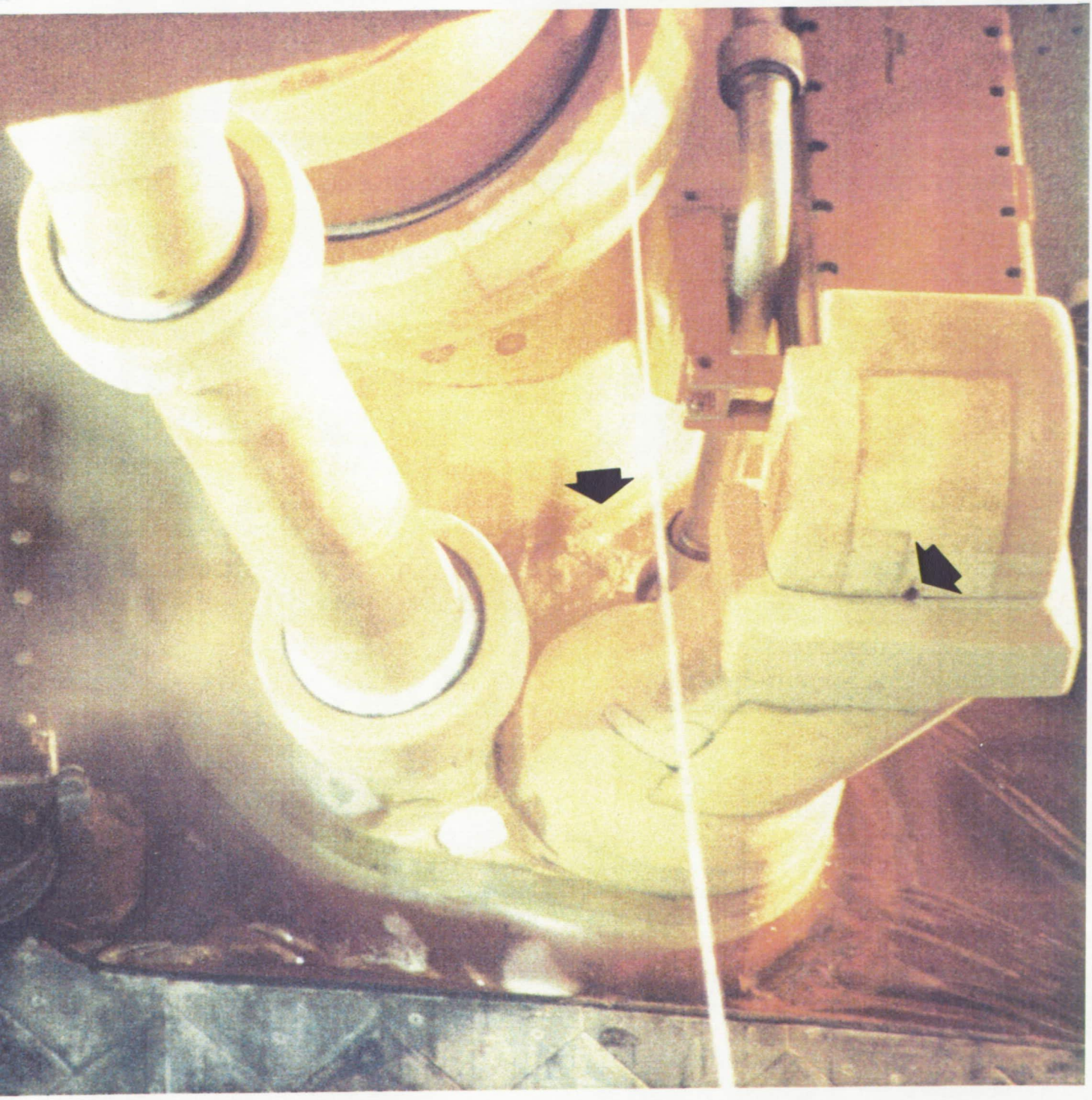

Ice/frost accumulations on the LH2 ET/ORB umbilical aft plate gap purge vent and in the LH2 recirculation line bellows were acceptable. Venting of helium purge gas vapors was normal. No ice or frost had formed on the bondline of the 17-inch flapper valve actuator access port foam closeout or on the cable tray vent hole. Note light-colored pulldown cord for the LD54 and LD55 leak detector tygon tubes.

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6.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, pad surface and pad acreage, except for the perimeter area north of the flame trench, was conducted on 5 June 1991 from Launch + 3 to 6 hours. No flight hardware or TPS materials were found.

Plume erosion of the south SRB holddown posts was typical. Shim sidewall material was intact, but the sidewall on HDP #6 was debonded slightly. Shim bottom plate material on all holddown posts was intact. An ordnance fragment (NSI cartridge) lay on the stud in the HDP #5 stud hole. A 3.25" x 1" x 0.5" frangible nut fragment lay on the MLP deck under the sound suppression pipe just east of HDP #5. There was no 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 less than usual erosion. The SRB aft skirt purge lines were in place but slightly damaged. Half of a connector shell on the LH SRB joint heater T-0 umbilical was missing. The other cable connector savers (sacrificial pieces) on both SRB joint heater T-0 umbilicals were in place and 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, though the west window was broken. 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, which was less than usual, included 1) a phone box cover on the RSS 207 foot level torn from its hinges, 2) an OIS box on the access platform for the LH SRB forward skirt detached from its mount and hanging by a cable, 3) a section of cable tray, approximately 100 feet long, on the east pad apron torn from its mounting, 4) a 4"x7" metal placard from an unknown origin found on the MLP deck southwest of the LH2 TSM, 5) a light fixture from the 135 foot level of the -Y Orbiter weather protection structure found on the FSS 115 foot level.

No emergency egress slidewire baskets had released during launch.

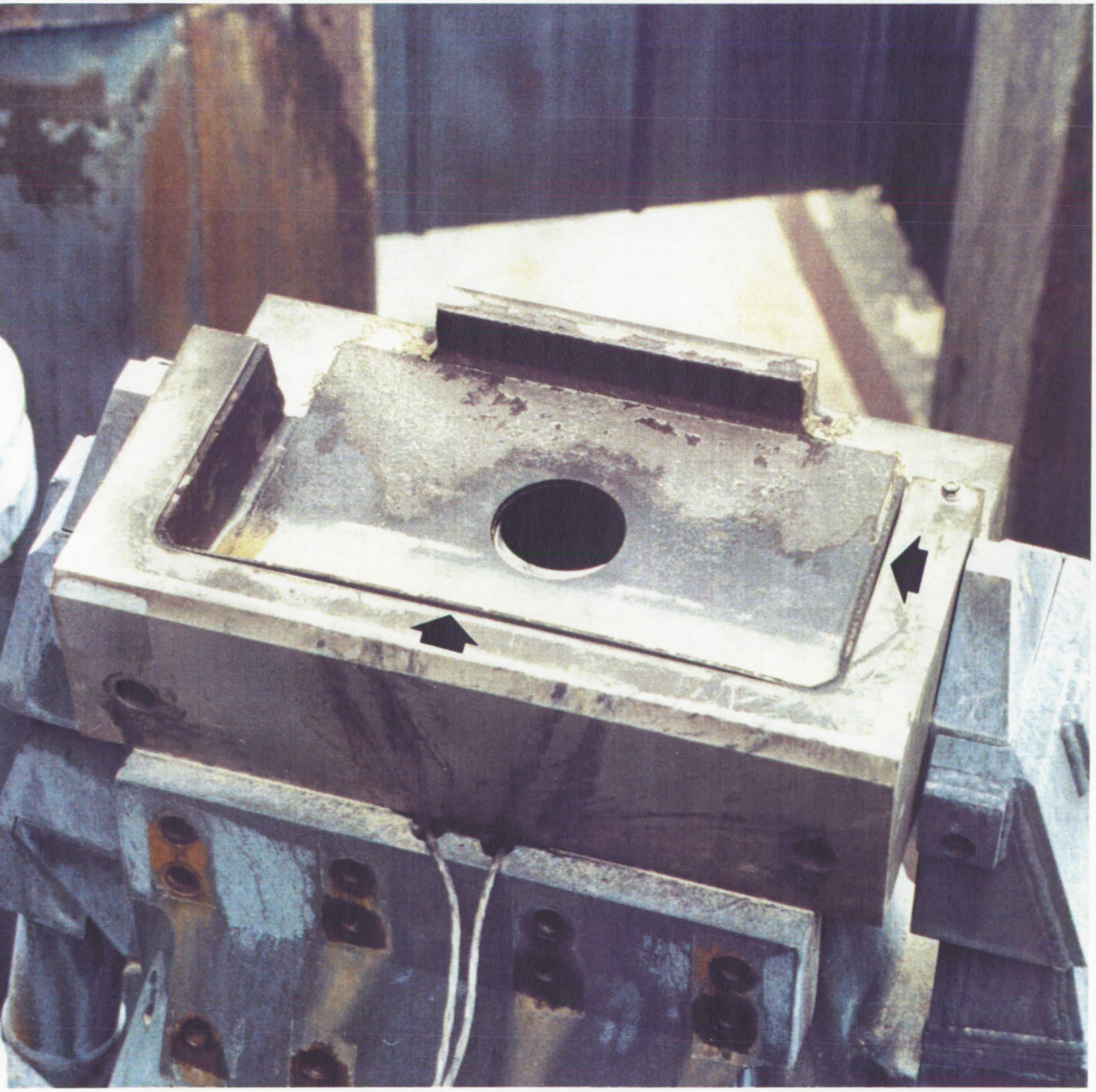
Debris inspections scheduled for 6 June 1991, including an overflight of the pad/water areas by helicopter, completion of the pad perimeter inspection, and a beach walkdown, were delayed due to inclement weather.

Inspection of the pad perimeter was completed on 7 June 1991 along with the areas outside the pad perimeter, railroad tracks, the beach from UCS-10 to Titan Complex 40, the beach

access road, and the ocean areas under the vehicle flight path. Several pieces of Delta and Atlas launch vehicles, but no Shuttle flight hardware, 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 42 particles were imaged in the T+140 to 295 second time period. Twenty-nine of the particles were imaged by only one radar, 12 particles were imaged by two radars, and 1 particle was imaged by all three radars. One discernible, perhaps somewhat larger, particle was visible at T+165.7 seconds. Signal returns for the particles were in the same range that has become typical for previous missions.

Post launch pad inspection anomalies are listed in Section 11.



EPON shim material on the south holddown posts was intact, but the sidewall material was debonded to various degrees.

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North holddown post doghouse blast covers were in the closed position and exhibited less than usual SRB plume erosion

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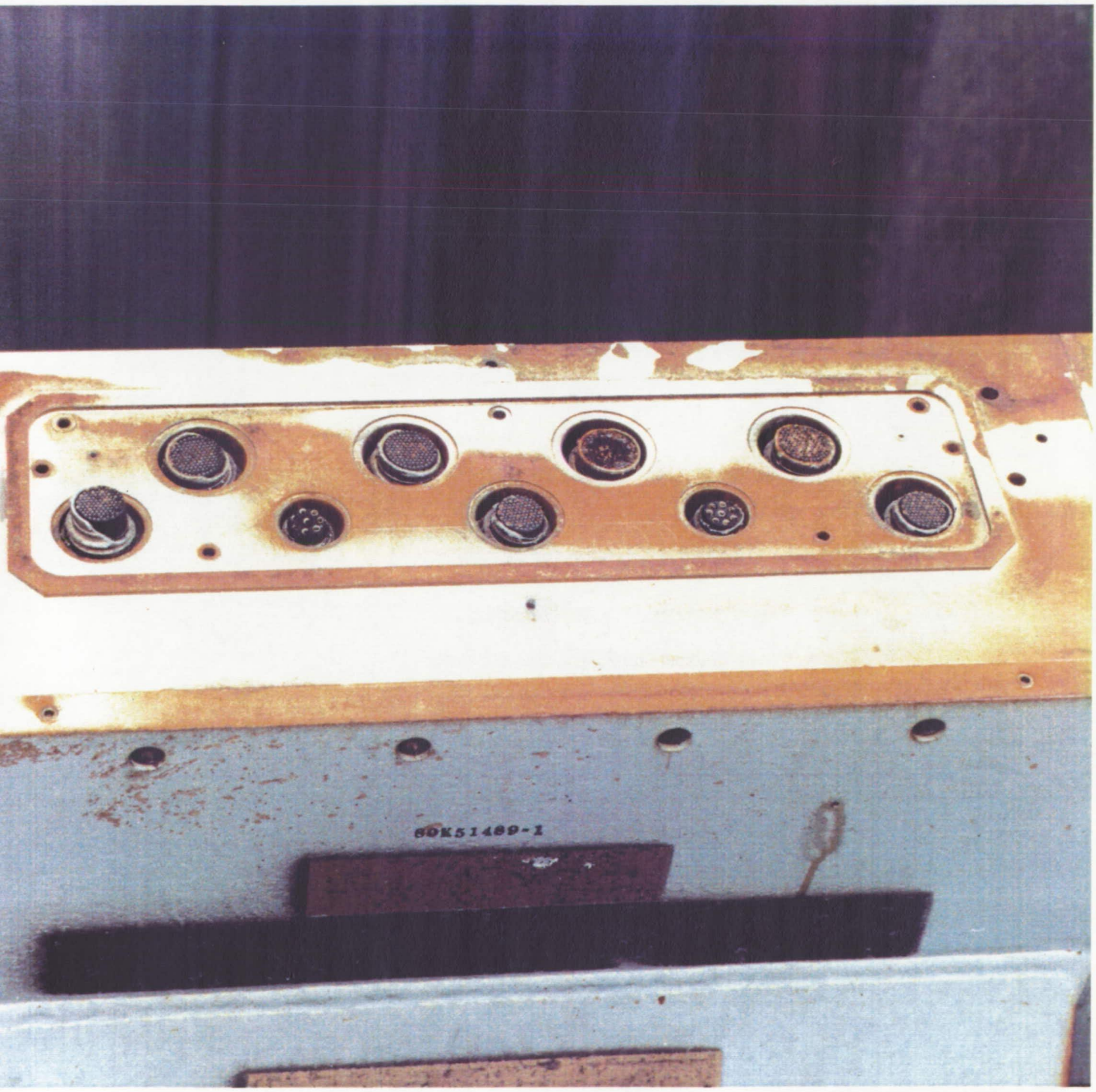

The cable connector savers (sacrificial pieces) on both SRB T-0 umbilicals showed typical plume impingement effects

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Typical facility debris was found on the pad after launch. A frangible nut fragment 3.25" x 1" x 0.5" from holddown post #5 (arrow) lay on the MLP deck under a sound suppression water pipe just east of the HDP #5 haunch. No flight hardware or TPS materials were found.

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7.0 FILM REVIEW SUMMARY/PROBLEM REPORT DISPOSITION

A total of 138 film and video data items, which included 45 videos, 57 16mm films, 29 35mm films, 7 70mm films; and 104 on-orbit still frames, were reviewed starting on launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission. Real time down-link from OV-102 showed TCS blankets partially detached from the 1307 aft bulkhead and damage to the payload bay door environmental seal. Cause of this damage is believed to be airflow intrusion past the payload bay door seals during ascent. Observations of the seal during shade- and sun-induced thermal environments, as well as ground tests with similar hardware in the OPF, showed the payload bay doors could be closed/latched for re-entry. No further action, such as an EVA, was required.

Helium purge vapors and ice build-up on the LH2 umbilical had been typical during tanking, stable replenish, and launch. There were no unusual vapors or cryogenic drips during liftoff.

Rusty deluge water from the ET intertank access structure was blown onto the LH SRB by southwesterly winds and ran down the segment case (E-35, 36, 40).

Light frost was present in the SW louver, but there was no TPS damage to the ET nosecone acreage, footprint, or fairing (OTV 013, 061).

SSME ignition and gimbal profile appeared normal.

SSME ignition vibration/acoustics caused ice to fall from the LO2 and LH2 ET/ORB umbilicals. No tile damage was visible (OTV 109, 154, 163). Ice from the umbilicals continued to fall during early ascent with one possible contact (glancing impact) before tower clear (E-34). No damage was apparent. Tile surface coating material was lost from the base heat shield at one location outboard of SSME #3 and at 3 locations outboard of SSME #2 (E-6, 17, 18, 24). Surface coating material was also lost from tiles on the upper surface of the RH outboard elevon (E-5, 25, 26). SSME ignition vibration/acoustics caused three small light colored particles, possibly pieces of tile material, to shake loose from a location above the EO-3 fitting (E-6).

Appearance of a brief stream of light-colored vapor/liquid from the gaps of some lower surface tiles outboard of the EO-2 fitting coincided with the time of SSME ignition. The event did not appear to be related to a debris impact and was most likely water backlit by Xenon lights/early morning sun (OTV 109, 163, 164).

Water vapor trailed the split rudder/speed brake during early ascent (E-40).

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 (E-33, 41, 42, 50).

Three pieces of frangible nut and one NSI cartridge fell from the HDP #5 DCS/stud hole shortly after liftoff (EX4, E-12). A frangible nut web piece 3 inches long fell from the HDP #3 DCS/stud hole after the vehicle had gained 6-8 feet altitude (E-10, 15). The new optimized frangible links were installed in the SRB DCS's for this mission. Although post flight inspection of the SRB's revealed HDP #7 DCS plunger was obstructed by frangible nut halves, no debris was visible in film item E-11 falling from the DCS/stud hole.

Numerous particles were ejected out of the SRB exhaust holes after T-0. Many film and video items recorded various amounts of flying debris on and around the pad as the vehicle cleared the tower. This debris is SRB throat plug material and shredded sound suppression water troughs - an expected occurrence.

A dark debris particle was visible between the Orbiter fuselage and the LO2 T-0 umbilical carrier plate during retraction (E-17). A second dark object, 1"x1" in size, appeared near the +Z side of the body flap hinge (E-17). A light colored particle fell aft of the speed brake. Another light colored particle appeared against the left wingtip black tiles (E-34). None of the particles appeared to contact the vehicle.

A light colored, blurred, object passed over the RH wing tip and moved aft of the vehicle just after completion of the roll program. The object may not have been near the vehicle (E-221).

The -Y bipod jack pad closeout repair was intact through the roll maneuver and early ascent. Although resolution of this area decreased as the vehicle gained altitude, no material fell aft from this location while the area was in view (E-213).

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. Later in flight, orange streaks were visible in the SSME plume. These streaks are typically caused by debris particles, such as RCS paper covers (E-207, 221, 223).

ET/ORB umbilical purge barrier baggie material came loose shortly after the roll maneuver and appeared to flap against Orbiter tiles aft of the umbilical (E-207, 212, 213, 220). This may account for some tile damage that has typically occurred in this area on previous missions. Purge barrier material

separated from the vehicle, was caught in turbulent air flow aft of the ET, and moved in the +Z direction until it entered the SSME plume (E-221, 223).

Well over 100 light colored particles dropped out of the LH SRB plume during ascent (E-213, 221, 222). These particles are believed to be pieces of SRB aft skirt instafoam or SRB propellant/inhibitor.

Body flap motion, both bending and torsion modes, was similar to that observed on previous missions (E-207, 221, 223).

Shock wave formation caused localized supersonic flow condensation to become visible on the ET/SRB forward attach structure, bipods, Orbiter forward fuselage, SRB ETA rings, wing tips, leading edges of the OMS pods, vertical stabilizer, and SILTS pod (E-207, 223).

Plume recirculation and ET aft dome charring appeared normal.

SRB separation appeared nominal (E-207, 221). No unusual SRB plume events, such as localized brightening, were visible.

Review/analysis of on-orbit ET separation photography included 103 70mm still frames taken by the flight crew, one 16mm high speed film from the LH2 ET/ORB umbilical camera, and one 35mm frame from the LO2 ET/ORB umbilical camera.

Shortly after ET separation, the 16mm film showed a metallic cylinder drifting past the LH2 ET/ORB camera and moving away from the Orbiter. Inspection of OV-102 ET/ORB umbilicals after landing revealed no missing hardware. KSC identified the object as the outboard shear pin bushing from the ET half of the LH2 ET/ORB umbilical. Dimensions of the bushing are shown in Figure 8. On-orbit umbilical photography confirmed the inboard bushing on the LH2 umbilical and the two bushings on the LO2 umbilical were still in place after ET separation. KSC inspected the bushings on ET-47 prior to OV-104 umbilical mate. No anomalies were found. Presence of the bushings on ET-47 after separation from the Orbiter (STS-43) can not be confirmed due to lack of umbilical cameras on OV-104. The Flight Problem Report is summarized in Appendix A.

Three TPS divots were visible on the LH2 tank-to-intertank flange closeout. Two divots, approximately 8-10 inches in diameter, were located below the intertank access door and GH2 vent line QD, and the third divot, 6-8 inches in diameter, was located below the +Y ET/SRB forward attach point. A fourth divot occurred on the -Z side of the tank in the aft hardpoint closeout. Bright spot in the intertank TPS acreage near the -Y side of the LO2 feedline fairing was a PDL repair, not a divot.

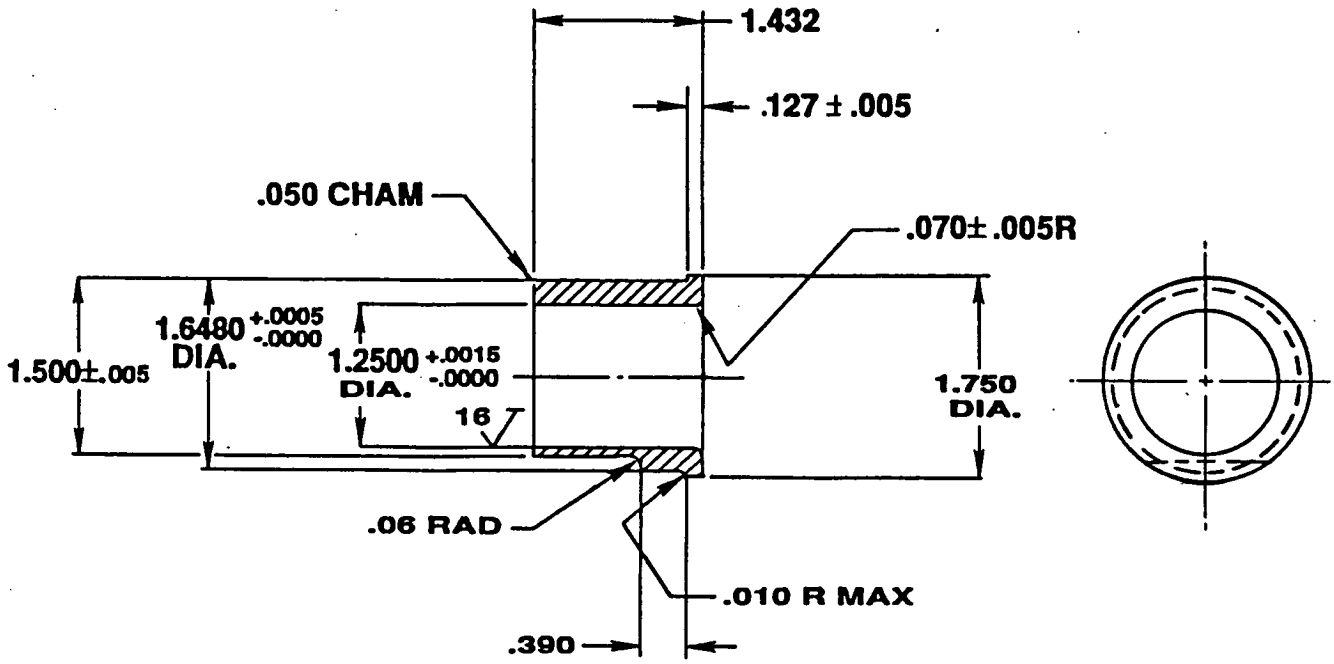


FIGURE 8.

ET/ORB SHEAR PIN BUSHING

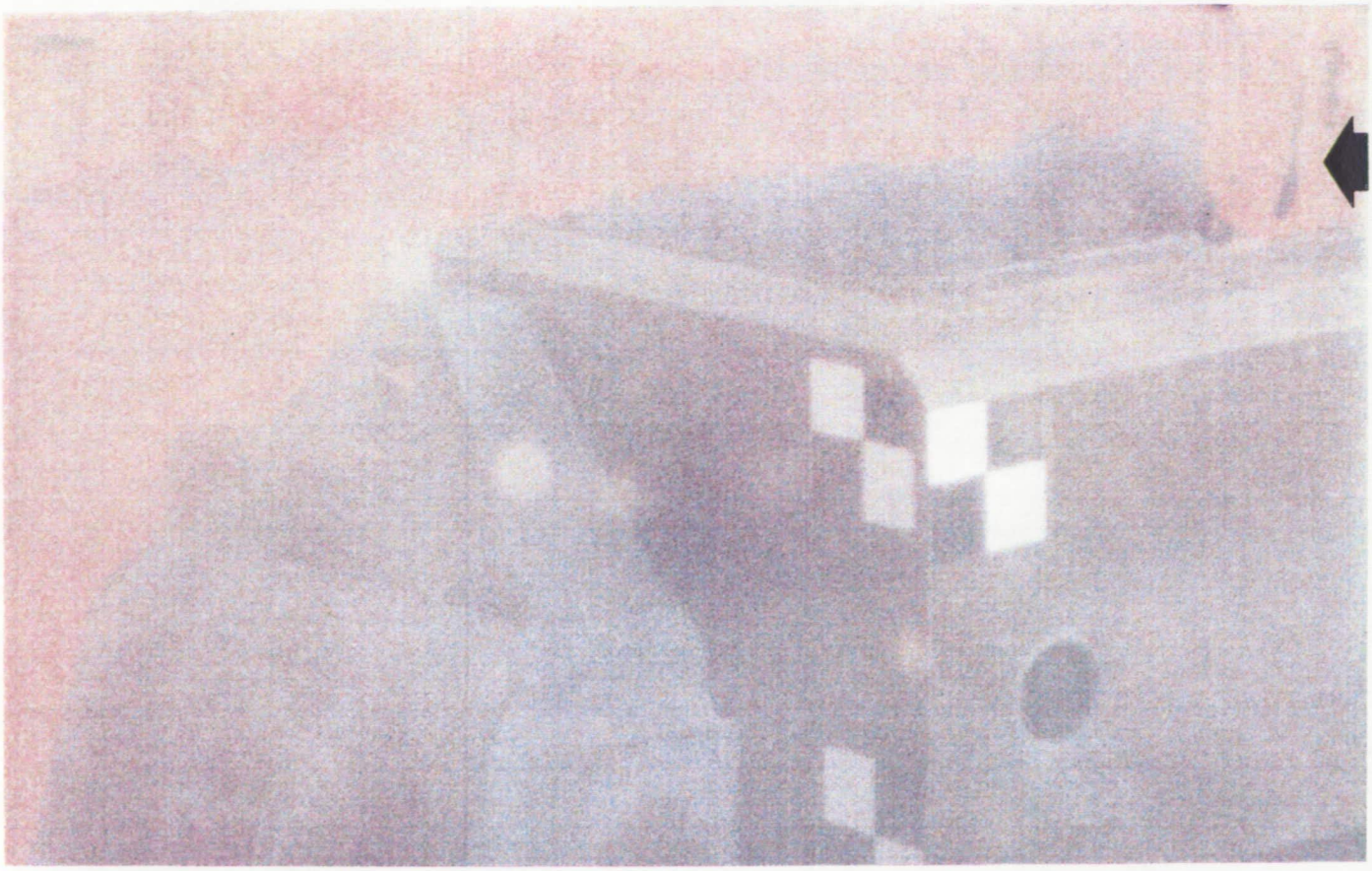
P. H. DWG 5753322

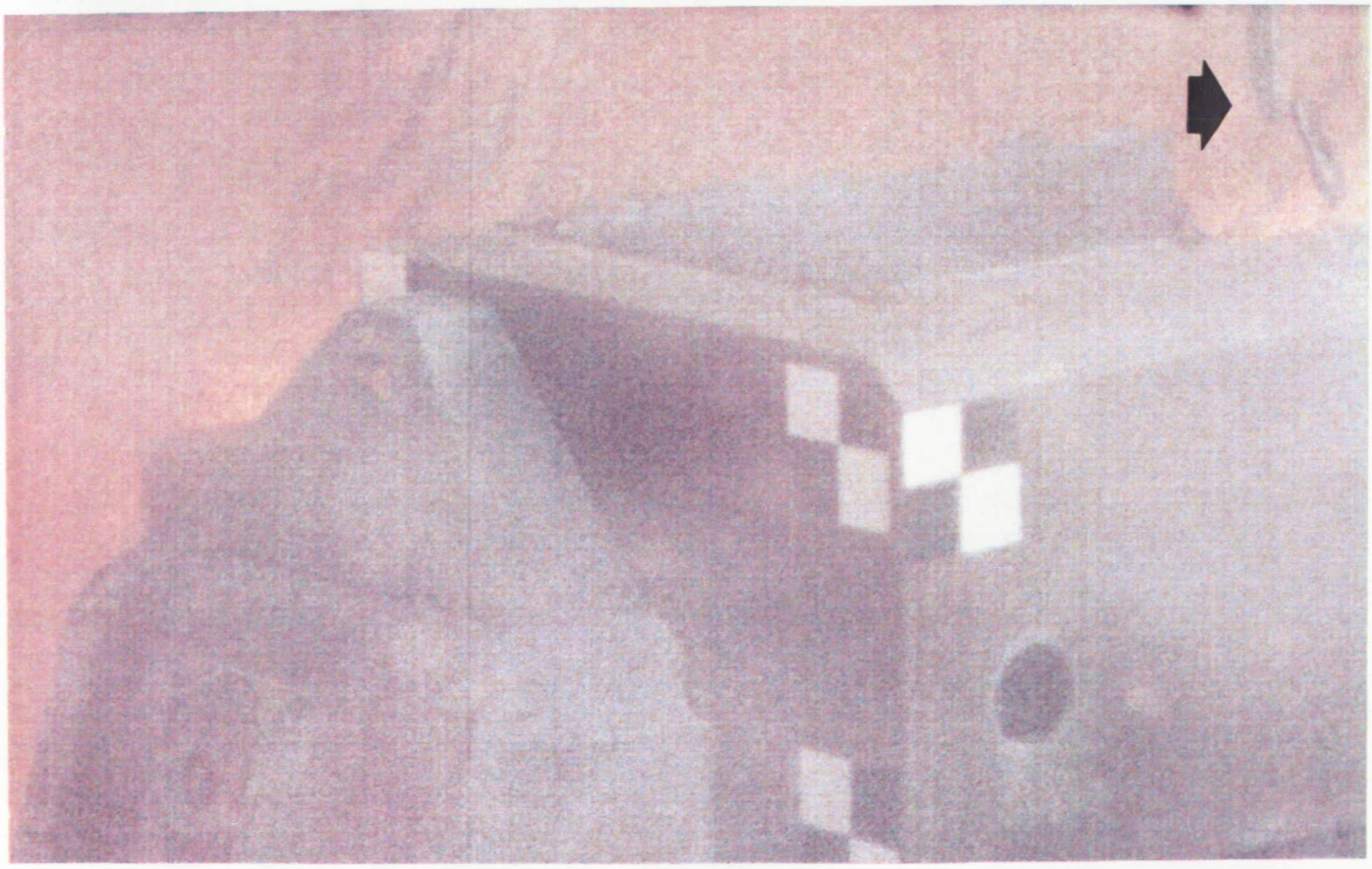
TPS and purge seal damage, located on the forward end of the LH2 ET/ORB umbilical, occurred when the umbilical disconnect plates separated and residual hydrogen between the flapper valves vented. Frozen hydrogen adhered to the 17-inch flapper valve and LH2 umbilical disconnect plate. Small pieces of ice and foam drifted by the camera lens.

On-orbit photography verified the repair to the -Y bipod jack pad closeout was in place and intact.

Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were nominal.

Two IFA's were generated as a result of the film and video data review. The IFA's were taken against the failure of two ET/ORB umbilical cameras and the appearance of a shear pin bushing from the ET LH2 umbilical after separation from the Orbiter. 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 11.





Three pieces of frangible nut and one NSI cartridge fragment fell from the HDP #5 DCS/stud hole shortly after liftoff

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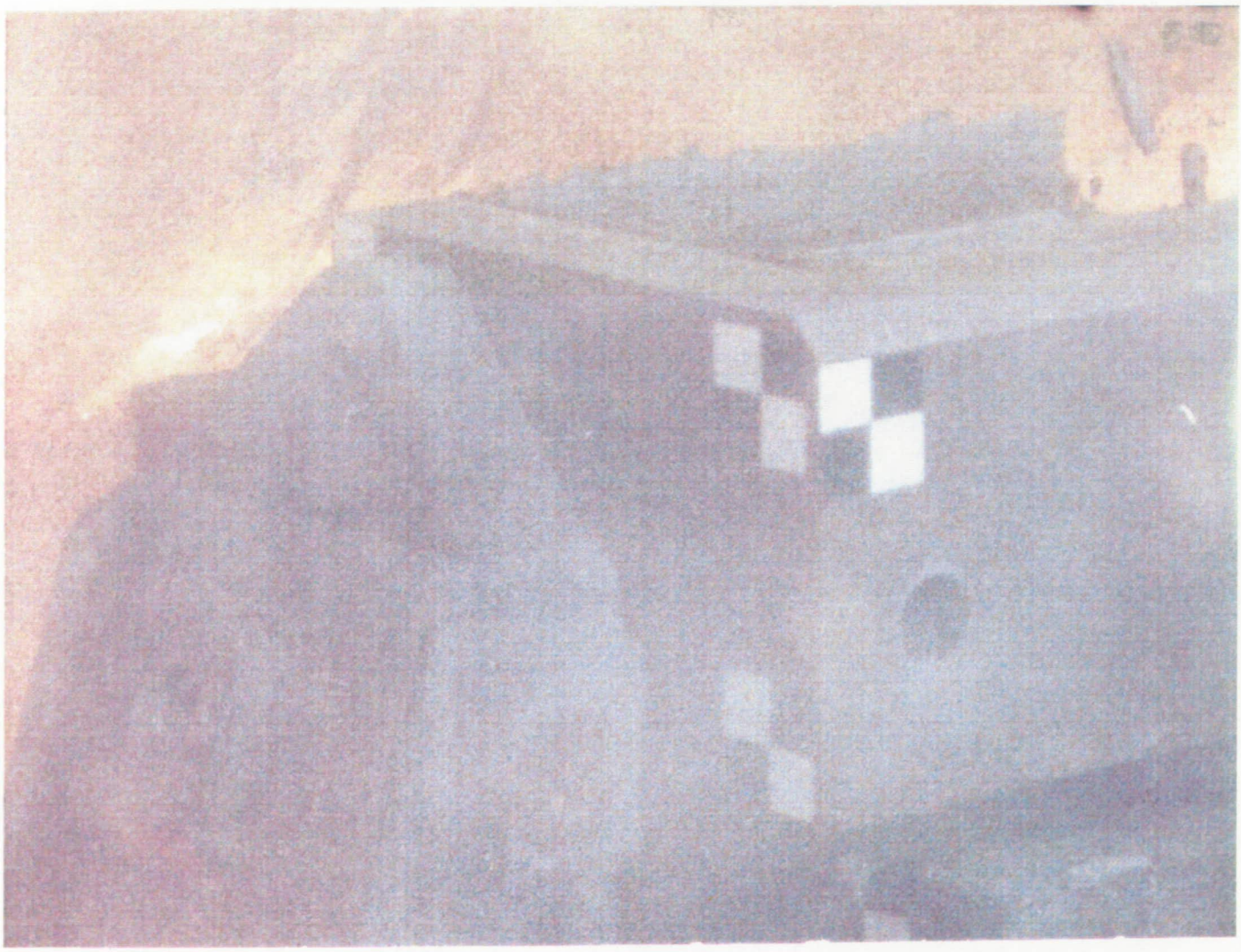

The largest frangible nut fragment measured 3.25" x 1.0" x 0.5" and was found on the MLP deck under the sound suppression water pipe just east of HDP #5 during the post launch pad inspection.

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Ice continued to fall from the ET/ORB umbilicals as the vehicle cleared the tower. There were no unusual vapors or cryogenic drips in the area of the umbilicals. No anomalies were visible on the LH SRB aft skirt. Thermal curtain tape was intact.

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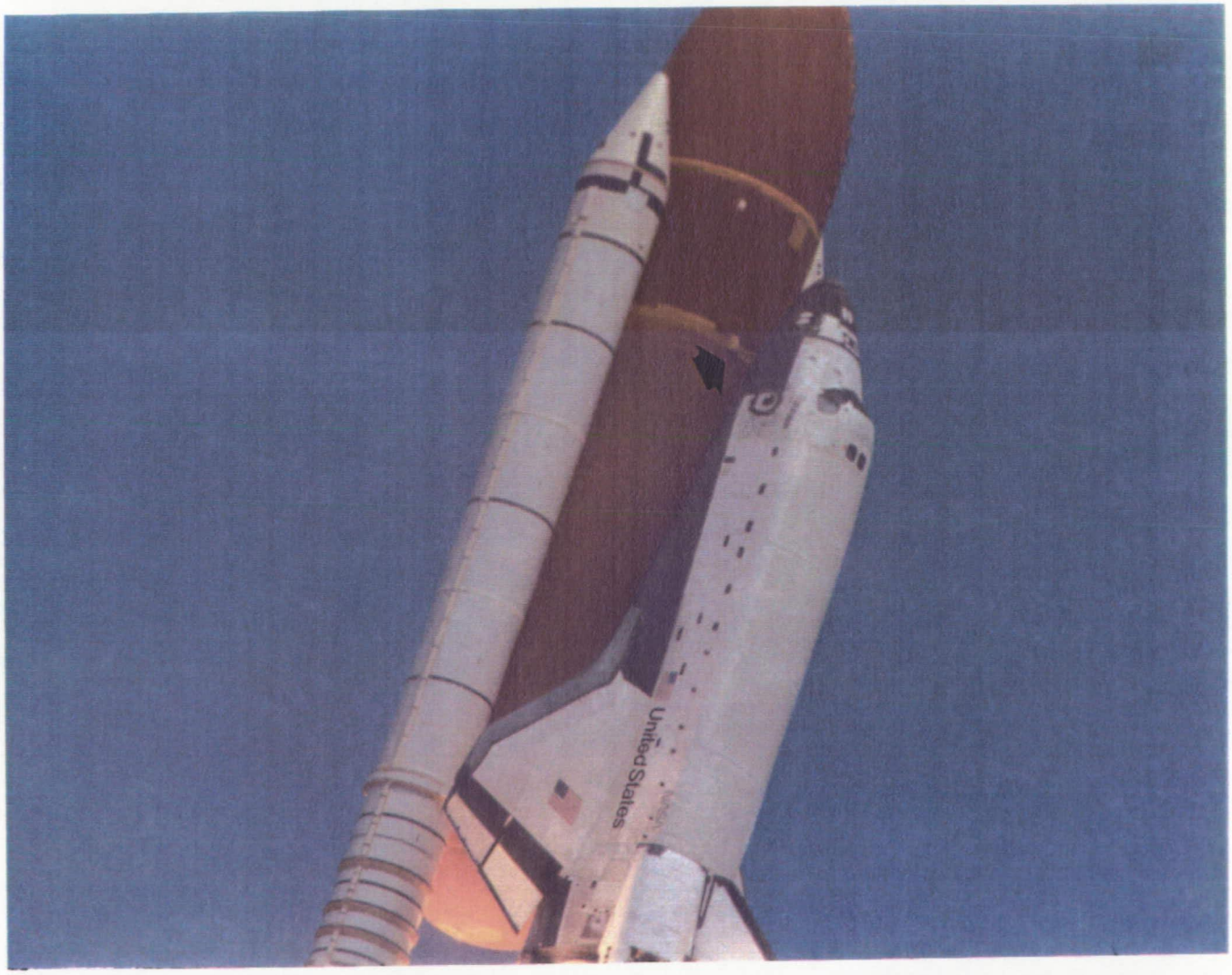

PDL repair to the ET -Y jack pad closeout was intact through the roll maneuver and early ascent. Although resolution of this area decreased as the vehicle gained altitude, no material fell aft from this location while the area was in view.

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Shock wave formation caused localized flow condensation to become visible on the forward ET/SRB attach points, SRB ETA rings, ET/ORB forward attach point, bipods, Orbiter forward fuselage, wing tips, OMS pod leading edges, and SILTS pod on the vertical stabilizer.

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ET/ORB LH2 umbilical camera showed typical heating effects and erosion of the TPS on the ET aft dome and ET/SRB cable tray. Separation of the LH SRB from the External Tank appeared nominal. The ET/SRB upper and diagonal struts are visible near the left edge of the frame. No anomalies were apparent on the LH SRB cases and segment joints.

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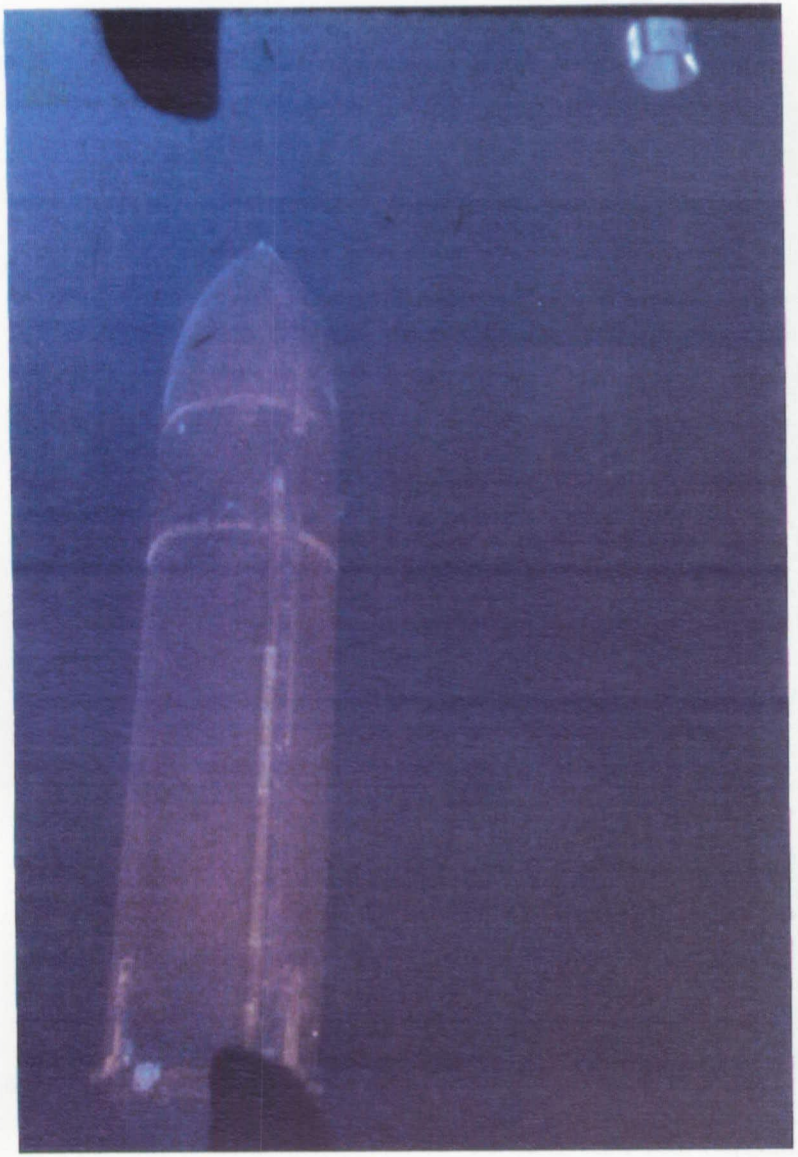

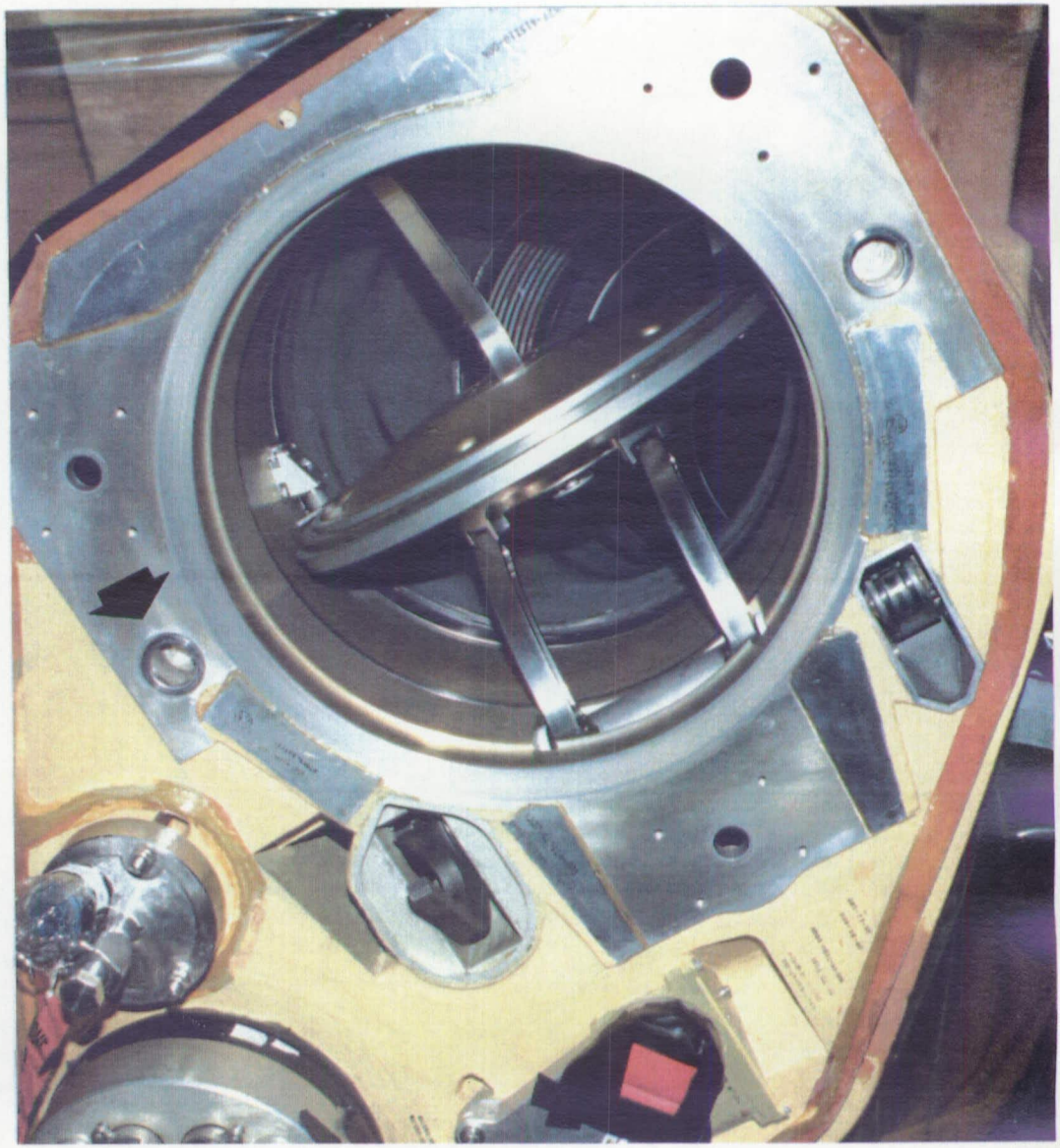

16mm camera in the LH2 ET/ORB umbilical recorded the presence of the outboard shear pin bushing/sleeve from the ET half of the LH2 umbilical. Pre-flight closeout photo shows the bushing (arrow) in the umbilical disconnect plate near the LH2 17-inch feedline.

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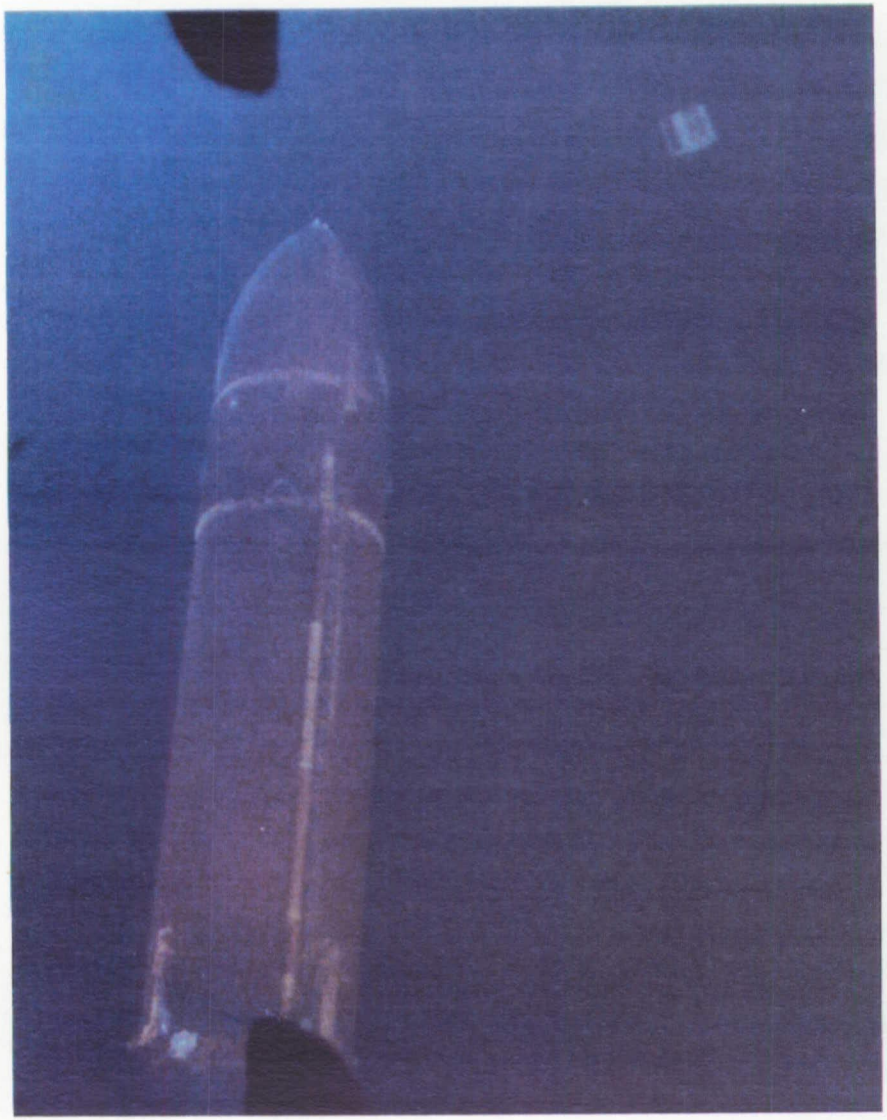

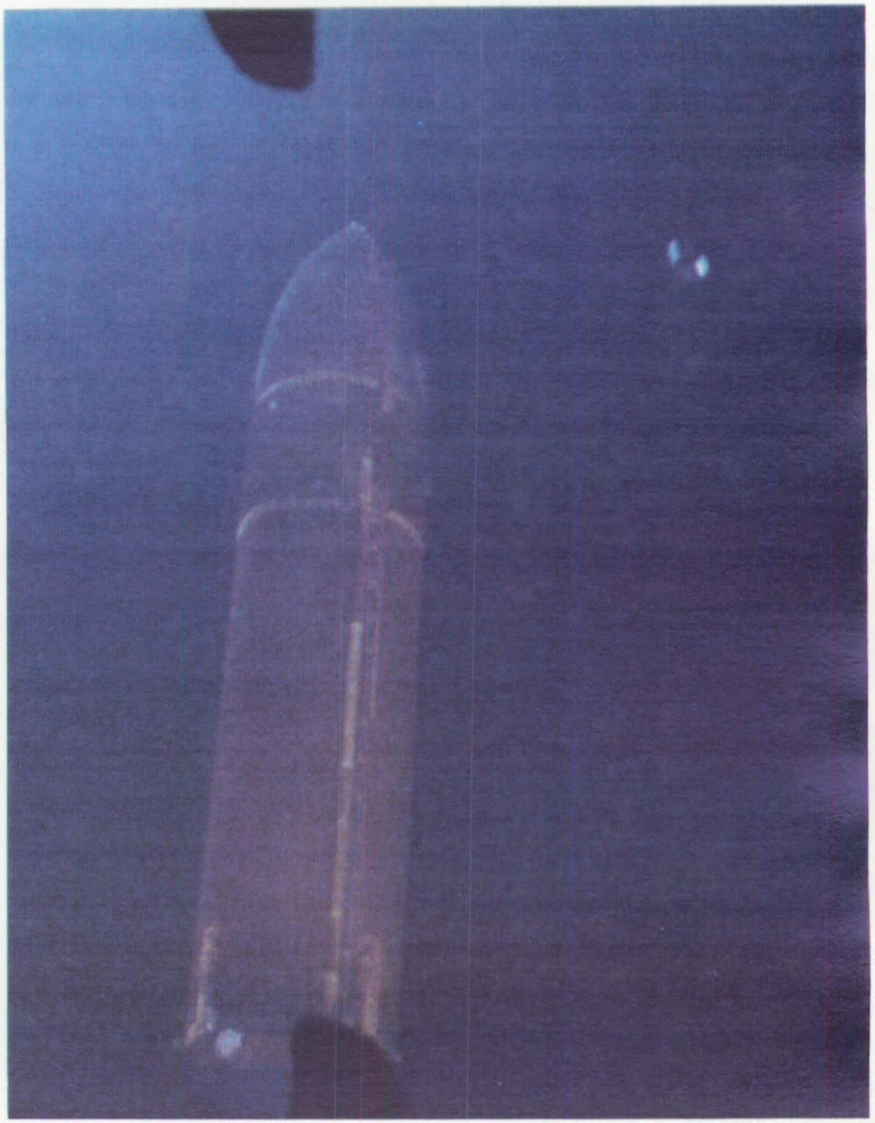

The Inconel-718 shear pin bushing from the ET half of the LH2 ET/ORB umbilical drifted past the camera lens approximately 44 seconds after separation and was visible for 2.5 seconds. The bushing measured 1.432 inches long with an outer diameter of 1.750 inches and an inner diameter of 1.250 inches.

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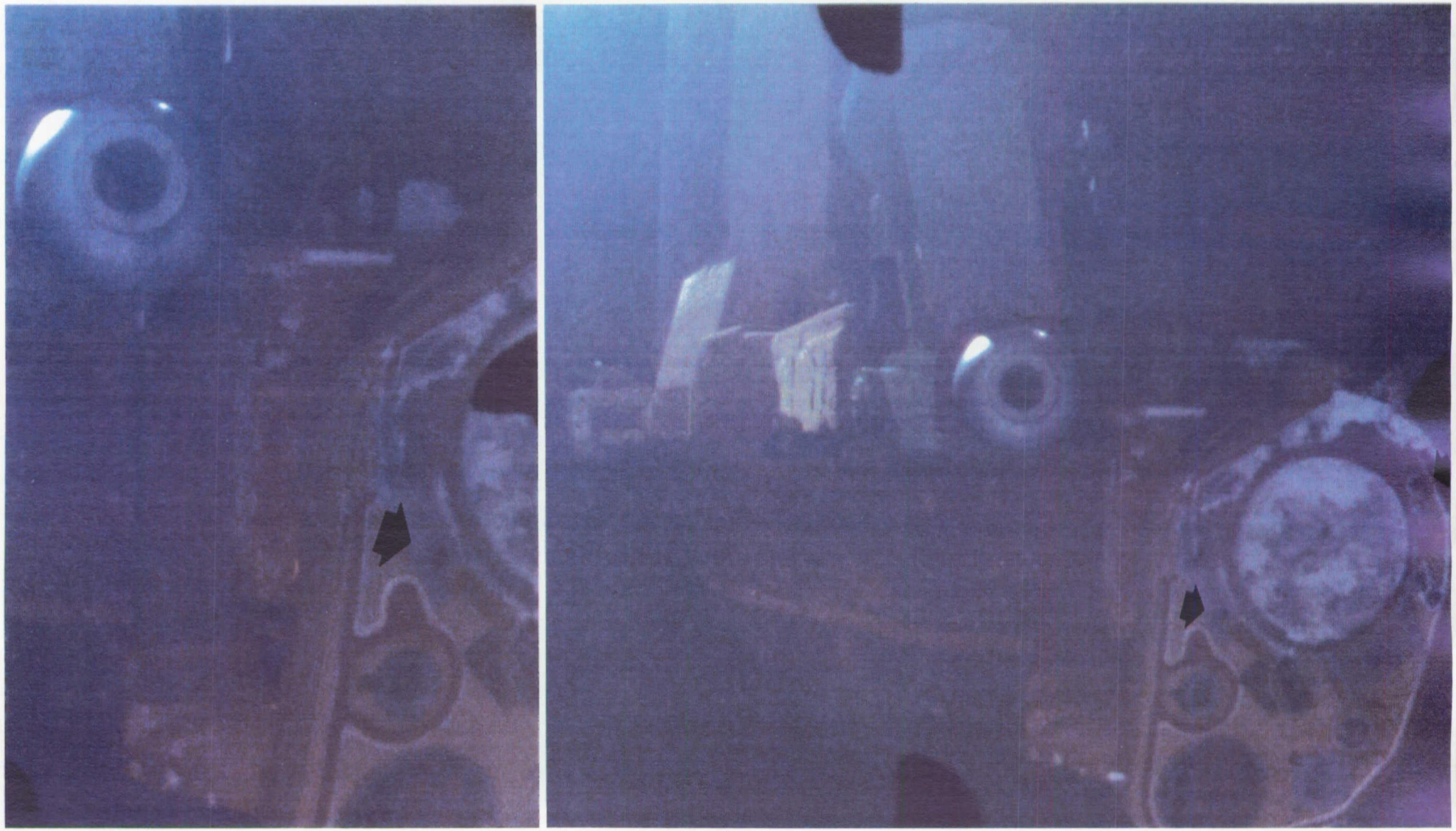

The shear pin bushing was missing from the outboard location of the LH2 ET/ORB umbilical shear pin hole. Note the difference in sheen between the outboard and inboard locations

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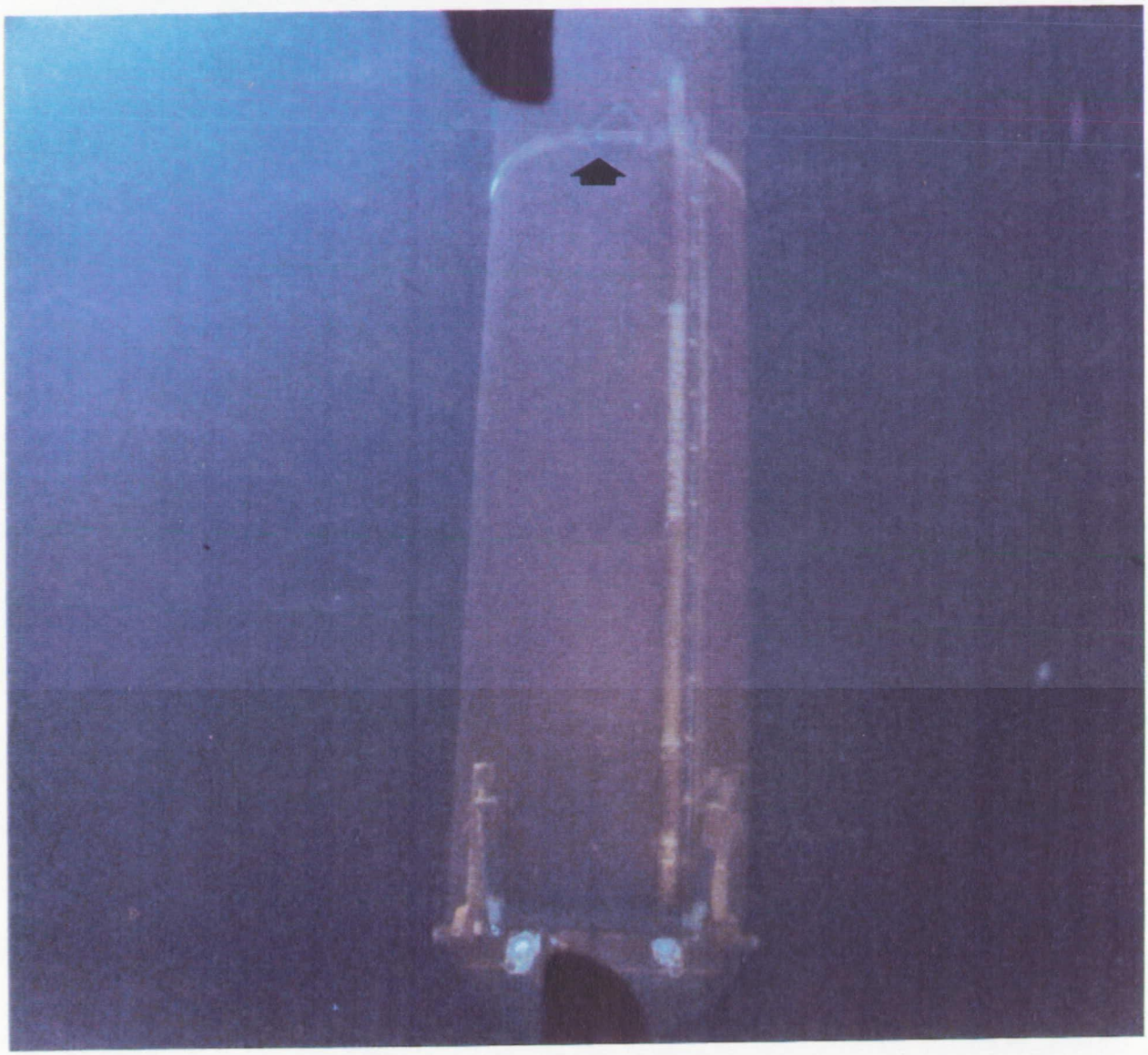

There were no significant TPS divots on the LH2 tank acreage. No anomalies were visible on the LO2 feedline, PAL ramp, and pressurization lines/ramps. Top-coated crossbeam and thrust struts have been charred by ascent aeroheating - an expected occurrence. PDL repair to the -Y jack pad closeout was in place and intact (arrow).

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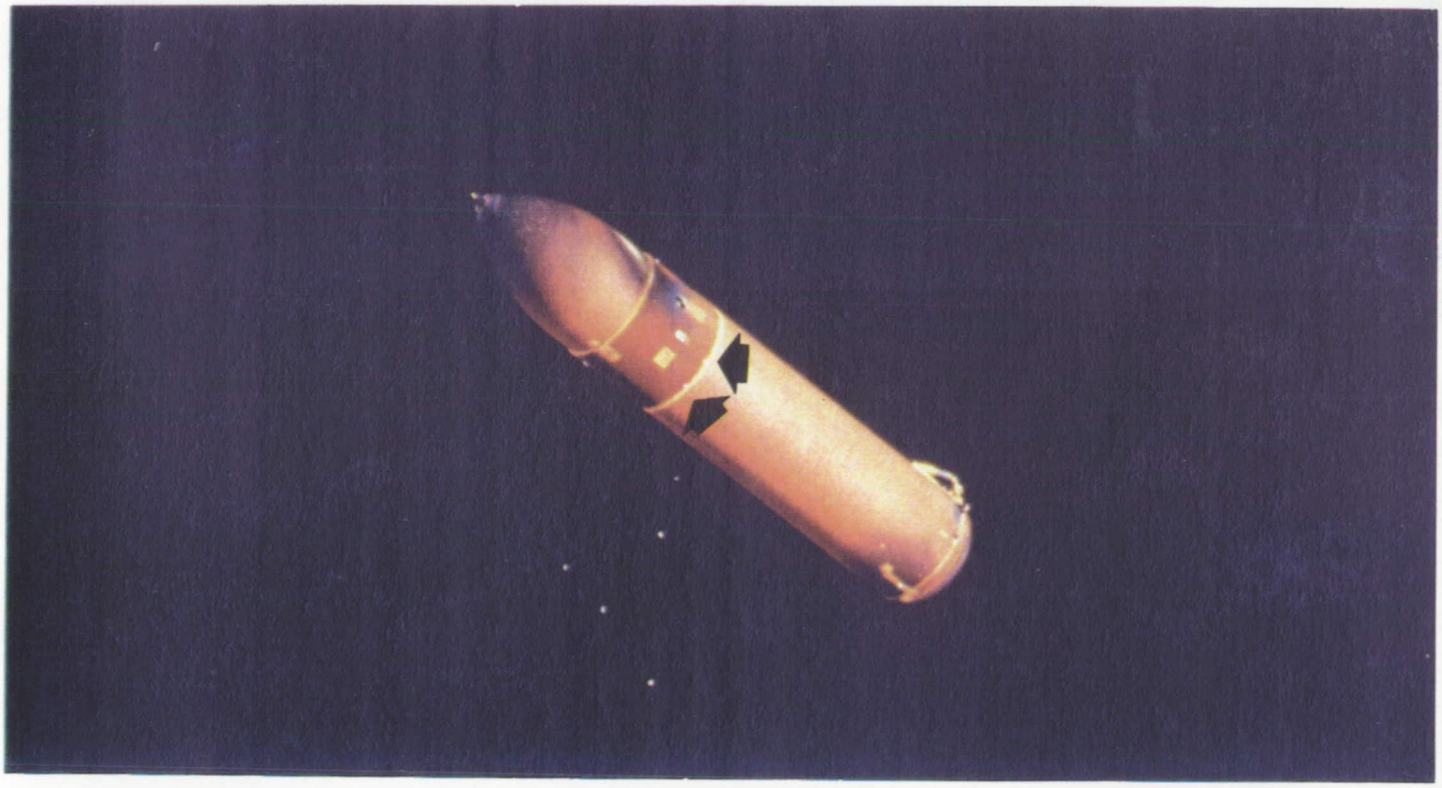

Two TPS divots, approximately 8-10 inches in diameter, were located on the LH2 tank-to-intertank flange below the intertank access door and GH2 vent line QD. There were no visible anomalies on the TPS acreage. Pieces of MPS ice reflected sun light as the ET drifted away from the Orbiter.

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7.1 LAUNCH FILM AND VIDEO DATA REVIEW

FILM ITEMS

EX1
400 FPS
16mm

Camera is located on MLP deck south of RH SRB exhaust duct and looks north to view SRB T-0 Umbilical during ignition and liftoff.

Focus : O.K.
F. O. V.: O.K., but camera shake was excessive
Exposure: O.K.

Comments: Smoke from SSME visible after ignition. Shoe rocked backward slightly at separation. SRB throat plug and Instafoam trimmings appeared after T-0.

EX2
400 FPS
16mm

Camera is located on the MLP deck west of RH SRB flame duct and looks east to view SRB Heater Umbilical during ignition and liftoff.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Condensate dripped onto MLP deck. MLP debris, SRB throat plug, and Instafoam trimmings appeared after T-0. North side of SRB T-0 umbilical disconnected first.

EX3
400 FPS
16mm

Camera is located on the MLP deck east of LH SRB flame duct and looks west to view SRB Heater Umbilical during ignition and liftoff.

Focus : O.K.
F. O. V.: O.K., camera shake was excessive
Exposure: O.K.

Comments: SRB rain curtain appeared loose. Separation between disconnect was similar as in EX-2. Six pieces of instafoam trimmings were ejected out of SRB exhaust hole after T-0. Facility debris was visible on deck during liftoff.

EX4
400 FPS
16mm

Camera is located on MLP deck south of LH SRB flame duct and looks north to view LH SRB Heater Umbilical during ignition and liftoff.

Focus : O.K.
F. O. V.: O.K., but camera shake was excessive
Exposure: O.K.

Comments: Ice particles fell onto MLP deck after SSME ignition. Facility debris and instafoam trimmings appeared after SSME ignition. Three ordnance fragments and one piece of NSI cartridge fell from the HDP #5 DCS/stud hole.

E-1
400 FPS
16mm

Camera is located on the NE corner of the MLP deck and views the lower ET, SRB's, and Orbiter.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice/frost particles fell from ET LH2 umbilical at SSME ignition and through T-0 and liftoff. Facility rainbirds operated properly. Four light-colored particles were ejected out of RH SRB exhaust hole and traveled 30 feet above the MLP deck (frame 5216). Ice particles fell from the GUCP to the west of the LH SRB. Water trough material was ejected out of the SRB exhaust hole toward the camera.

E-2
400 FPS
16mm

Camera is located on the SE corner of the MLP deck and views Orbiter SSME and OMS engine nozzles.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Aft RCS paper covers were torn loose by SSME ignition. Ice particles fell from LO2 T-0 umbilical and contacted the SSME #3 nozzle. No damage was apparent. After SSME ignition, a particle was visible on the +Z side of the wing trailing edge (Frame 2368, ref. film item E-5). Condensate in SRB stiffener rings vaporized during liftoff. HPU exhaust was visible during liftoff. Residual vapors emanated from the LH2 T-0 umbilical.

E-3
400 FPS
16mm

Camera is located on the SW corner of the MLP deck and views Orbiter SSME and OMS engine nozzles.

Focus : O.K.
F. O. V.: O.K., but camera shake was excessive
Exposure: O.K.

Comments: SSME ignition tore the aft RCS paper covers. Orbiter elevon movement at T-0 was typical. LOX TSM door rebounded 2-3 inches before closing. Residual GOX vapors emanated from the T-0 disconnect.

E-4
400 FPS
16mm

Camera is located on the NW corner of the MLP deck and views lower ET, SRB's, and Orbiter.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from LO2 umbilical prior to T-0. Immediately after T-0, a dark object entered the FOV from left to right but did not contact the vehicle (Frames 4503 - 4538).

E-5
400 FPS
16mm

Camera is located on the east side of the MLP deck and views the Orbiter RH wing, body flap, and lower ET/SRB.

Focus : O.K.
F. O. V.: O.K., but camera shook at ignition
Exposure: O.K.

Comments: Condensate on SSME nozzle vaporized during ignition. Residual vapors emanated from LO2 TSM carrier plate. After ignition, several particles fell from above TSM from +Z side of RH wing. Numerous flashes in SSME plume were caused by RCS paper cover fragments. HPU exhaust visible during liftoff.

E-6
200 FPS
16mm

Camera is located on the east side of the MLP deck and views the RH lower Orbiter wing, body flap, ET lower LOX feedline, and ET/Orbiter umbilical area.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: At SSME ignition ice particles fell from LO2 umbilical and feedline bellows. White tile coating material fell from +Z side of RH wing. Elevon movement at SSME ignition was typical. At liftoff, ice particles fell from LH2 umbilical and ET/SRB cable tray. Three small light-colored particles appeared to originate from lower surface tiles above EO-3.

E-7
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB northeast holddown post (HDP #4).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: HDP doghouse blast covers closed nominally. SRB throat plug and water trough material was ejected out of SRB exhaust hole after T-0. No ordnance fragments fell from DCS/stud hole.

E-8
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB southeast holddown post (HDP #2).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Bright flash from ordnance firing was visible under DCS at ignition. At liftoff, the SRB HDP shoe rocked slightly. No debris fell from the DCS/stud hole. Ice particles continued to fall during vehicle ascent.

E-9
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB southwest holddown post (HDP #1).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell on MLP deck from ET/ORB umbilicals. Facility debris entered FOV at T-0. A particle appeared from area behind DCS at T-0. After the aft skirt exited the FOV a particle, ice measuring 2" x 10" fell into SRB exhaust hole.

E-10
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB northwest holddown post (HDP #3).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: At piece of frangible nut web fell from HDP #3 DCS/ stud hole (frame 4179). Numerous pieces of SRB throat plug material were ejected out of SRB exhaust hole after T-0. HDP doghouse blast covers closed properly.

E-11
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB northeast holddown post (HDP #7).

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SRB HDP doghouse blast cover closed nominally. Numerous pieces of SRB throat plug material were ejected out of SRB exhaust hole. A one inch long piece of shim putty (epoxy) detached from HDP foot when vehicle had risen approximately 5 feet (Frame 4443). Facility debris tumbled across MLP deck after T-0.

E-12 Camera is located on the MLP deck and views the
400 FPS LH SRB southeast holddown post (HDP #5).
16mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Debris was drawn across MLP deck by SSME aspiration. ET/Orbiter umbilical ice particles fell at SSME ignition onto the deck. Prior to T-0, a moth flew from left to right and contacted the deck. SRB throat plug material was ejected out of exhaust hole and onto deck after T-0. A 2-inch NSI cartridge fragment fell from HDP #5 DCS/stud hole onto the holddown post shoe.

E-13 Camera is located on the MLP deck and views the
400 FPS LH SRB southwest holddown post (HDP #6).
16mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: DCS rocked slightly at T-0. SRB HDP shoe rocked during liftoff. No debris fell from the HDP #6 DCS/stud hole. SRB throat plug and water trough material were ejected out of SRB exhaust hole after T-0. Ordnance fragments fell from the HDP #5 DCS/stud hole.

E-14 Camera is located on the MLP deck and views the
400 FPS LH SRB northwest holddown post (HDP #8).
16mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Prior to T-0, a particle passed very close to lens and moved upward (Frame 2747). Facility water system was activated properly prior to T-0. SRB HDP doghouse blast covers closure was nominal. No debris fell from the HDP #8 DCS/stud hole. After T-0, sound suppression water trough and throat plug material were ejected out of SRB exhaust hole.

E-15
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB skirt, sound suppression water troughs, and RH lower Orbiter body flap.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Exhaust smoke from SRB HPU's was visible prior to T-0. SSME ignition tore RCS paper covers from the aft RCS nozzles. Umbilical ice particles fell at SSME ignition. SRB holddown post blast covers closed properly. SRB throat plug material was ejected out of SRB exhaust hole at T-0. A 2-inch frangible nut web fragment fell from HDP #3 DCS/stud hole after vehicle had risen 6-8 feet.

E-16
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB skirt, sound suppression water troughs, and LH lower Orbiter body flap.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell onto MLP deck from ET/ORB umbilicals. A piece of instafoam appeared from area behind DCS at T-0. SRB HDP doghouse blast covers closed normally. Facility debris appeared in FOV after vehicle cleared frame.

E-17
400 FPS
16mm

Camera is located on the MLP deck and views the -Z side of the LO2 T-0 Umbilical and TSM.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from LO2 T-0 disconnect and ET/ORB umbilicals during SSME ignition and liftoff. Residual vapors emanated from LO2 T-0 disconnect. Body flap moved slightly during SSME ignition. One tile chip appeared on outboard side of SSME #3. One dark particle appeared between the Orbiter and the T-0 disconnect carrier plate during retraction. A dark particle, 1"x 1", fell from +Z side of body flap near hinge (frame 2365).

E-18
400 FPS
16mm

Camera is located on the MLP deck and views the -Z side of the LH2 T-0 umbilical and TSM.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Motion of Orbiter body flap during SSME ignition was typical. Aft RCS paper covers tore during SSME ignition. Residual vapors emanated from LH2 T-0 disconnect. Three tile chips appeared outboard of SSME #2 on the base heat shield. Ice fell from LH2 umbilical during liftoff.

E-19
400 FPS
16mm

Camera is located on the SE side of the MLP deck and views the SSME/OMS nozzles and Orbiter aft heat shield area.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SSME ignition tore aft RCS paper covers. Ice particles fell from T-0 disconnect during SSME ignition. Umbilical ice fell during T-0. LH2 TSM door rebounded before final closure. Residual GOX vapors emanated from the disconnect after T-0.

E-20
400 FPS
16mm

Camera is located on the SW side of the MLP deck and views the SSME/OMS nozzles and Orbiter aft heat shield area.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SSME ignition tore the aft RCS paper covers. Ice particles fell from the T-0 disconnect during SSME ignition. LO2 TSM door rebounded before final closure. Residual LH2 vapors emanated from the disconnect after T-0.

E-21
400 FPS
16mm

Camera is located inside the LO2 TSM and views the disconnection of the T-0 umbilical.

Comments: Film not available due to an access problem.

E-22
400 FPS
16mm

Camera is located inside the LH2 TSM and views the disconnection of the T-0 umbilical.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K., but film rate slowed twice while recording

Comments: TSM purge barrier came partially loose after SSME ignition. TSM door rebounded 0.5 inches before final closure. Liftoff caused TSM door to shake slightly. Ice particles fell from T-0 during retraction.

E-23
400 FPS
16mm

Camera is located on the MLP deck and views the RH OMS engine nozzle.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Free burning hydrogen drifted past SSME's. Ice particles fell from SSME nozzles and T-0 umbilical. RH OMS nozzle motion during SSME ignition was typical. Tile surface coating material entered FOV from above OMS nozzle. Residual vapors emanated from LO2 T-0 disconnect. Three pieces of tile surface coating material fell from base heat shield due to SSME acoustics/vibration LO2 T-0 umbilical retracted nominally.

E-24
400 FPS
16mm

Camera is located on the MLP deck and views the LH OMS engine nozzle.

Focus : Soft.
F. O. V.: O.K.
Exposure: O.K.

Comments: Free burning hydrogen drifted past SSME's. OMS nozzle movement during SSME ignition was typical. Light colored particles, probably tile surface coating material from the OMS pod area, were visible falling past the elevon. Residual vapors emanated from the LH2 T-0 umbilical. Ice particles fell from LH2 umbilical during liftoff.

E-25
400 FPS
16mm

Camera is located on the east side of the MLP and views between Orbiter and ET/SRB during liftoff.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: White particles, probably tile surface coating material from the upper surface of the RH elevon, fell during SSME ignition. SRB throat plug material was ejected out of SRB exhaust hole after T-0. Ice particles fell from ET/ORB umbilicals during SSME ignition and T-0.

E-26
400 FPS
16mm

Camera is located on the west side of the MLP and views between Orbiter and ET/SRB during liftoff.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles from ET/ORB umbilicals fell during liftoff. Elevon motion during liftoff was typical. At T-0, small particles fell from above the TSM, possibly from the upper surface of the Orbiter LH wing. Facility debris from the 135 foot level did not come near the vehicle (frame 4071). Condensate in SRB stiffener rings vaporized during liftoff. GH2 vent line separation appeared nominal. Residual vapors emanated from the LH2 T-0 disconnect.

E-27
400 FPS
16mm

Camera is located on the MLP deck and views RH SRB northwest holddown post (HDP #3) blast cover.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SRB HDP doghouse blast covers closed nominally. Instafoam overspray/trimmings were ejected out of SRB exhaust hole. Field of view was obscured by water after T-0.

E-28
400 FPS
16mm

Camera is located on the MLP deck and views LH SRB northeast holddown post (HDP #7) blast cover.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: SRB HDP doghouse blast covers closed nominally. Instafoam overspray/trimmings were ejected out of SRB exhaust hole. Field of view was obscured by water after T-0.

E-30
400 FPS
16mm

Camera is located on the FSS 195 foot level and views LH SRB and sound suppression water troughs.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from ET/ORB umbilicals during ignition and liftoff. Water deluge obscured view.

E-31
100 FPS
16mm

Camera is located on the FSS 95 foot level and views the LH Orbiter wing, body flap, and ET/Orbiter LH2 umbilical area.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from ET/ORB umbilicals during liftoff. Condensate on base heat shield tiles and SSME nozzles vaporized. Vapors were emitted outboard of EO-2 from tile gaps.

E-33
200 FPS
16mm

Camera is located on the FSS 235 foot level and views the ET GH2 vent line and GUCP.

Focus : Soft.
F. O. V.: O.K.
Exposure: O.K.

Comments: Numerous pieces of ice fell from GUCP the at SSME ignition. Residual vapors emanated from flight QD. Frost remained attached to un-insulated areas during liftoff. Frost was visible in the intertank-to-LH2 tank interface.

E-34
300 FPS
16mm

Camera is located on FSS at 255 foot level and views upper Orbiter tile surfaces.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice fell from GUCP interface at SSME ignition and T-0. Ice fell from ET/ORB umbilicals during liftoff, one particle may have lightly contacted the orbiter lower surface, but no damage was visible. Residual vapors emanated from LO2 T-0 disconnect. Condensate on ET aft dome and near umbilical area vaporized. A light-colored particle appeared below the speed brake (frame 4941). A light-colored particle also appeared against the LH wing tip in frame 5023. Vapors vented from the ET/SRB cable tray drain hole.

E-35
300 FPS
16mm

Camera is located on the FSS 255 foot level and views the mid-Orbiter/ET/SRB area.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice fell from the ET/ORB umbilicals and GUCP during ignition and liftoff. Residual vapors emanated from the LH2 T-0 disconnect.

E-36
300 FPS
16mm

Camera is located on the FSS 255 foot level and views lower Orbiter, ET, SRB's, and water trough.

Focus : Soft.
F. O. V.: O.K.
Exposure: O.K.

Comments: Rusty water from the facility deluge system was visible on SRB. Ice particles fell from the ET/ORB umbilicals during liftoff.

E-40
300 FPS
16mm

Camera is located on the FSS 275 foot level and views the ET ogive, SRB nosecone, and Orbiter tiled surfaces.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Residual GOX vapors emanated from +Y and -Y louvers. Light frost was present on the -Y louver. ET twang was typical. Condensate on ET aft dome and in SRB stiffener rings vaporized. Ice fell from ET/ORB umbilicals during liftoff. Vapor vented from the ET/SRB cable tray drain hole. Vapors trailed the Orbiter speed brake. FSS facility debris entered FOV after tower clear.

E-41
300 FPS
16mm

Camera is located on the FSS 255 foot level and views the GH2 vent line during rotation. Also shows clearance between structure and SRB aft skirt.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Dirty water flowed from FSS water deluge system. GUCP retraction and latchback was nominal

E-42
300 FPS
16mm

Camera is located on the FSS 185 foot level and views the GH2 vent line drop, deceleration, and latchback.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Dirty water flowed from FSS water deluge system. GUCP retraction and latchback was nominal.

E-44
300 FPS
16mm

Camera is located on the FSS 155 foot level and views the LH OMS Pod leading edge tiles during ignition and liftoff.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: LH2 TSM light was activated prior to T-0. Residual vapors emanated from Orbiter T-0. A particle fell in center of view close to camera (frame 3876).

E-48
300 FPS
16mm

Camera is located on the FSS 215 foot level (ET Intertank access arm structure) and views the GH2 vent line during GUCP disconnection, rotation, and latchback

Focus : O.K.
F. O. V.: O.K.
Exposure: Underexposed

Comments: Ice particles fell from GUCP after SSME ignition and T-0. GUCP retraction nominal. Ice fell from LH2 umbilical and from EB-7 during liftoff. Residual hydrogen vapors were visible in umbilical carrier plate and ice remained attached until out of view.

E-50
60 FPS
16mm

Camera is located at camera site 1 at NE pad perimeter and views entire GH2 vent line and GUCP during rotation and latchback.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Dirty water flowed from FSS water deluge system. Ice particles fell from ET/ORB umbilicals during liftoff. GUCP retraction and latchback was nominal with no slack in static retract lanyard. Ice fell from EB-8 during liftoff. Condensate on ET aft dome vaporized during liftoff.

E-52
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of lower one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice fell from ET/ORB umbilical during liftoff. GUCP retraction and latchback was normal. FWD RCS paper covers were torn loose by aerodynamic forces after roll maneuver. Numerous flashes occurred in the SSME plume.

E-53
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of middle one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Numerous birds were present in the field of view, but none were near the vehicle. Ice particles continued to fall from ET/ORB umbilicals through tower clear. Paper cover pieces fell from forward and aft RCS during and after roll maneuver.

E-54
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of upper one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Numerous birds were present in the field of view, but none were near the vehicle. Ice particles continued to fall from ET/ORB umbilicals through tower clear. Paper cover pieces fell from the forward and aft RCS during and after roll maneuver.

E-57
96 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of lower one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice was still attached to EB-7 during liftoff. Ice particles fell from GH2 vent line on the FSS. Ice continued to fall from LH2 ET/ORB umbilical after tower clear. Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff.

E-58
96 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of center one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice was still attached to EB-7 during liftoff. Ice particles fell from GH2 vent line on the FSS. Ice continued to fall from LH2 ET/ORB umbilical after tower clear. Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff.

E-59
96 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of upper one-third of launch vehicle from ignition to 1200 feet.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice was still attached to EB-7 during liftoff. Ice particles fell from GH2 vent line on the FSS. Ice continued to fall from LH2 ET/ORB umbilical after tower clear. Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff.

E-60
96 FPS
35mm

Camera is located on north pad perimeter at camera site 1 and views the entire launch vehicle, FSS, and MLP zero level.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Dark-colored water was sprayed from intertank access structure prior to T-0. Ice particles fell from GH2 vent line on the FSS. Residual vapors emanated from LO2 T-0 umbilical. GH2 vent line retraction and latchback was nominal. Ice particles fell from ET/ORB umbilicals at T-0. Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff.

E-61
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter and views the launch vehicle, FSS, and MLP.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Dark-colored water was sprayed from intertank access structure prior to T-0. Ice particles fell from GH2 vent line on the FSS. Residual vapors emanated from LO2 T-0 umbilical. GH2 vent line retraction and latchback was nominal. Ice particles fell from ET/ORB umbilicals at T-0. Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff. RCS paper covers were torn loose as vehicle cleared tower.

E-62
96 FPS
35mm

Camera is located on the SE pad perimeter at camera site 3 and views entire vehicle, FSS, and MLP.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from ET/ORB umbilicals during lift off. Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff. SRB throat plug material was ejected out of SRB exhaust hole after T-0. Water trough material was visible above LH2 TSM falling away to the south of the vehicle. A minimum of 4 dark/long particles appeared against the horizon after being ejected out of the SRB flame trench.

E-63
96 FPS
35mm

Camera is located on SW pad perimeter at camera site 4 and views entire launch vehicle, FSS, and MLP.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from ET/ORB umbilicals during lift off. Residual GOX vapors emanated from the LO2 T-0 disconnect. HPU exhaust was also visible during liftoff.

E-64
96 FPS
35mm

Camera is located on NW pad perimeter at camera site 6 and views entire launch vehicle, FSS, and MLP.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Dark-colored water was sprayed from the intertank access structure prior to T-0. Ice particles fell from the ET/ORB umbilicals during ignition and liftoff. Three large particles were ejected out of the north flame trench. SRB HPU exhaust was visible during liftoff. Condensate on the ET aft dome and in the SRB stiffener rings vaporized.

E-65A
6 FPS
16mm

Camera is located on east pad perimeter at camera site 2 and views ET LO2 feedline, ET intertank, and RH SRB as vehicle passes through the frame.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice particles fell from the ET/ORB umbilicals during liftoff. Residual vapors emanated from the LO2 T-0 disconnect. Aft RCS paper covers were torn by SSME ignition. Facility debris entered FOV after vehicle cleared pad.

E-76
96 FPS
35mm

Camera is located on SE pad perimeter at camera site 3 and views SSME engines #1 and #3 and the RH OMS engine nozzle.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Mass flow from SSME #1 appeared prior to SSME #2 and #3 but shock diamonds formed in the 3-2-1 order. Aft RCS paper covers tore during SSME ignition. Ice fell from LO2 T-0 umbilical. Residual GOX vapors emanated from T-0 and flight QD. SRB throat plug material was drawn by plume around the FSS side of LH2 TSM to south side. Condensate on the ET aft dome and in the SRB stiffener rings vaporized during liftoff. Reflection near the LH2 TSM was caused by the purge barrier. Small white particle above LO2 TSM was probably tile surface coating material.

E-77
96 FPS
35mm

Camera is located on SW pad perimeter at camera site 4 and views SSME engines #1 and #2 and the LH OMS engine nozzle.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Mass flow from SSME #1 appeared prior to SSME #2 and #3 but shock diamonds formed in the 3-2-1 order. Ice fell from LH2 T-0 disconnect during ignition. Aft RCS paper covers were torn loose by SSME ignition. Residual GOX/GH2 vapors emanated from TSM T-0 disconnects. Residual GH2 visible from flight QD. One dark particle appeared from behind the top of the LH2 TSM as vehicle rose and was probably silhouetted throat plug material.

E-78
400 FPS
16mm

Camera is located on SE pad perimeter at camera site 3 and views RH OMS Pod leading edge.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Residual GOX vapors emanated from LO2 T-0 disconnect. Ice particles fell from ET/ORB umbilicals during liftoff. A particle moved upward from RH portion of screen in frame 4130. A particle moved from left of vertical stabilizer to left field of view in frame 900-1039, but no visible contact occurred with the vehicle.

E-79A
6 FPS
16mm

Camera is located on east pad perimeter at camera site 2 and views the ET nosecone, louver, and ogive.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Frost and vapors were present on +Y nosecone louver. ET twang appeared nominal. Ice particles continued to fall from ET/ORB umbilicals as vehicle ascended.

E-201 UCS-9 IFLOT tracking of launch vehicle from ignition and early flight through LOV.
30 FPS
70mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: GUCP retraction and latchback nominal. FWD RCS paper covers were torn loose by aerodynamic forces after roll maneuver. Localized supersonic flow condensation visible on Orbiter leading edges and interfaces including bipods and ET/SRB thrust posts. No unusual vapors were present around the ET/ORB umbilicals.

E-202 U247L116 IFLOT tracking of launch vehicle from ignition and early flight through LOV.
30 FPS
70mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Condensate vaporized and foam outgassed from ET aft dome and SRB stiffener rings. Local supersonic flow condensation appeared on Orbiter leading surfaces, bipods, and ET/SRB forward attach points. RCS F3U paper cover was torn loose during roll maneuver. Orbiter umbilical purge barrier (baggie) material separated from the vehicle and fell aft.

E-203 UCS-16 IFLOT tracking of launch vehicle from ignition and early flight through LOV.
30 FPS
70mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Condensate vaporized and foam outgassed on ET aft dome and SRB stiffener rings. Local supersonic flow condensation formed on Orbiter leading edges, bipods, and ET/SRB forward attach points.

E-204 PAFB IGOR tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.
72 FPS
35mm

Comments: No data due to atmospheric haze.

E-205
72 FPS
35mm

Shiloh IFLOT tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Comments: No data due to atmospheric haze.

E-206
72 FPS
35mm

Melbourne Beach ROTI tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Comments: No data due to atmospheric haze.

E-207
96 FPS
35mm

UCS-10 MIGOR tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: ET/ORB umbilical purge barrier (baggie) material appeared to flap against Orbiter tiles. Movement of the Orbiter body flap was similar in frequency and amplitude to previous flights. SRB thermal curtain tape came loose near HDP #8. Local flow condensation formed on Orbiter leading surfaces. Numerous flashes occurred in the SSME plume. SRB separation appeared nominal with unusual events, such as plume brightening.

E-208
48 FPS
35mm

Cocoa Beach DOAMS tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Comments: No data due to atmospheric haze.

E-209
30 FPS
70mm

SHILOH IFLOT intermediate tracking of launch vehicle from acquisition to LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Vehicle in FOV for short period. No data due to distance and haze. No vehicle anomalies.

E-210 UCS-26 IFLOT intermediate tracking of launch vehicle from acquisition to LOV.
30 FPS
70mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Vehicle in FOV for short period of time. No data due to distance and haze. No vehicle anomalies.

E-211 UCS-13 IFLOT intermediate tracking of rear portion of launch vehicle from acquisition to LOV.
96 FPS
35mm

Focus : Soft.
F. O. V.: O.K.
Exposure: O.K.

Comments: No data due to focus and atmospheric haze.

E-212 UCS-23 MIGOR tracking of SRB nozzles from T+20 seconds to T+40 seconds.
64 FPS
35mm

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Condensate on ET aft dome and SRB stiffener rings vaporized during liftoff. Numerous flashes occurred in the SSME plume. FWD RCS paper covers were torn loose by aerodynamic forces after roll maneuver. Localized flow condensation formed on Orbiter leading edges and interfaces, bipods, and ET/SRB forward attach points. Movement of the Orbiter body flap was similar in frequency and amplitude to previous flights. A light-colored object appeared between the SRB aft skirts, moved near the body flap and in the +Z direction to the SSME nozzles (frames 47-02). ET/ORB umbilical purge barrier baggie material came loose and was caught in recirculation for several frames before contacting the body flap and falling aft into the plume (frame 84-04). SRB thermal curtain tape flapped near HDP #8 (frame 94-10). Clouds obscured SRB separation.

E-213
96 FPS
35mm

UCS-12 MOTS tracking of rear portion of launch vehicle from acquisition to LOV.

Focus : O.K.
F. O. V.: O.K., though film started late
Exposure: O.K.

Comments: Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff. Numerous flashes occurred in SSME plume. FWD RCS paper covers were torn loose by aerodynamic forces after roll maneuver. Numerous particles fell out of LH SRB plume. Localized flow condensation formed on Orbiter leading surfaces and interfaces, bipods, and ET/SRB forward attach points. Umbilical baggie material came loose and was caught in recirculation for several frames before contacting the body flap and falling aft into the plume (frame 198-05). Numerous particles fell out of SRB plume in frames 124-07, 199-08 and 240-00.

E-217
30 FPS
70mm

Beach Road IFLOT close-in tracking of launch vehicle during ignition, liftoff, and early portion of flight through LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff. Numerous flashes occurred in the SSME plume. FWD RCS paper covers were torn loose by aerodynamic forces after roll maneuver. Numerous particles fell out of RH SRB plume during ascent.

E-218
96 FPS
35mm

UCS-26 IFLOT intermediate tracking of launch vehicle from acquisition through LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Foam outgassed from ET aft dome and SRB stiffener rings during flight. Forward RCS paper covers were torn loose by aerodynamic forces during ascent.

E-219 30 FPS 70mm	UCS-3 IFLOT close-in tracking of launch vehicle during ignition, liftoff, and early portion of flight through LOV.

Focus : O.K.
F. O. V.: O.K., though film was dirty
Exposure: O.K.

Comments: Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff. Numerous flashes occurred in the SSME plume. FWD RCS paper covers were torn loose by aerodynamic forces after roll maneuver. Umbilical baggie material was torn loose and caught in recirculation for several frames before contacting the body flap and falling aft into the plume. SRB separation was normal with no unusual events, such as plume brightening.

E-220 96 FPS 35mm	UCS-15 IFLOT close-in tracking of rear portion of launch vehicle during ignition, liftoff, and early portion of flight through LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Condensate vaporized and foam outgassed from ET aft dome and SRB stiffener rings. Local flow condensation formed on Orbiter leading surfaces, bipods, and ET/SRB forward attach points. RCS F3U paper cover was torn loose during roll maneuver. Orbiter umbilical baggie material came loose shortly after the roll program.

E-221 96 FPS 35mm	UCS-3 IFLOT close-in tracking of forward portion of ORB and ET during ignition, liftoff, and early portion of flight through LOV.

Focus : O.K.
F. O. V.: O.K., though film was dirty
Exposure: O.K.

Comments: Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff. Numerous flashes occurred in the SSME plume. FWD RCS paper covers were torn loose by aerodynamic forces after roll maneuver. Umbilical baggie material came loose and was caught in recirculation for several frames before contacting the body flap and falling aft into the plume (frame 124-08). In frame 84-05, a particle appeared to pass over the RH wing, but no contact was apparent. Orbiter body flap motion during flight was typical. Particles fell out of the RH SRB plume in frames 139-09, 146-00, and 155-11. SRB separation was normal with no unusual events, such as plume brightening.

E-222
96 FPS
35mm

Beach Road IFLOT close-in tracking of rear portion of launch vehicle during ignition, liftoff, and early portion of flight through LOV.

Focus :
F. O. V.:
Exposure:

Comments: Three particles were ejected out of the north flame trench. A light colored particle appeared behind the aft center segment factory joint at 13:24:53.755, probably ice from EB-7. A second light particle appeared near the center stiffener ring at 13:24:53.875. Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff. Numerous flashes occurred in the SSME plume. FWD RCS paper covers were torn loose by aerodynamic forces after roll maneuver. Numerous particles fell out of the RH SRB plume during ascent.

E-223
96 FPS
35mm

UCS-9 IFLOT intermediate tracking of rear portion of launch vehicle during ignition, liftoff, and early portion of flight through LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: GUCP retraction and latchback were nominal. FWD RCS paper covers were torn loose by aerodynamic forces after roll maneuver. Localized flow condensation formed on the Orbiter leading surfaces and interfaces, bipods, and ET/SRB forward attach points. Umbilical baggie material came loose and was caught in recirculation for several frames before contacting the body flap and falling aft into the plume (frame 249-14). No unusual vapors appeared around the ET/ORB umbilicals. Orbiter body flap motion during flight was typical. Orange flashes occurred in the SSME plume (frames 268-15, 269-07, 284-15, 298-02 and 302-01).

E-224
100 FPS
35mm

UCS-16 IFLOT close-in tracking of entire launch vehicle during ignition, liftoff, and early flight through LOV.

Focus : O.K.
F. O. V.: O.K.
Exposure: O.K.

Comments: Condensate vaporized and foam outgassed from ET aft dome and SRB stiffener rings. Localized flow condensation formed on Orbiter leading surfaces and ET/SRB forward attach points.

VIDEO ITEMS

OTV 101 Views aft end of Orbiter from the FSS 255 foot
B/W M-II level.

Comments: Firex water flow began at T-13 sec. TSM camera light turned on at T-11. SSME ignition normal. LH2 T-0 disconnect and retraction were normal.

OTV 103 Views GUCP and GH2 vent line.
B/W M-II

Comments: Vehicle twang normal. GUCP disconnect and GH2 vent line retract nominal. Rusty water from intertank access structure was visible on SRB case. Ice particles fell from ET/ORB umbilicals. Condensate on ET aft dome vaporized.

OTV 104 Views GH2 vent line and GUCP.
B/W VHS

Comments: Vehicle twang appeared normal. Ice fell from GUCP during SSME ignition. GUCP disconnect and separation appeared nominal. No ET umbilical carrier plate anomalies. Small pieces of ice and residual vapors were present after disconnect.

OTV-109 Views ET/Orbiter LH2 umbilical area from the 95
B/W M-II foot level of the FSS.

Comments: Ice shook loose at SSME ignition and T-0. No tile damage was visible. Ice continued to fall from the umbilicals after T-0. A stream of whitish vapor or liquid originated from tiles outboard of EO-2.

OTV 113 Views ET nosecone and SW louver from the FSS.
U-Matic

Comments: Tumble valve cover was intact. Light frost coated the southwest louver. No TPS anomalies on nose cone, fairing or footprint. Ice continued to fall from ET/ORB umbilicals.

OTV 133 Views Orbiter and ET TPS (+Y side) and umbilicals.
B/W VHS

Comments: Facility water was activated properly. Vehicle twang appeared normal. No vehicle anomalies were visible.

OTV 141 Views and tracks vehicle from camera site 2.
B/W

Comments: SSME ignition was nominal. A flock of birds crossed FOV, not near vehicle. No anomalies visible through tower clear and roll maneuver.

OTV 143 Views east side of launch vehicle and pad from camera site 2.
B/W

Comments: Viewed hydrogen burn stack. No vehicle data.

OTV 148 Launch and tracking view from camera site 6.
B/W

Comments: Facility water activated properly. SSME ignition and T-0 appeared nominal. Shock waves to the north of the vehicle were less pronounced than previous flight.

OTV 149 Views Orbiter LO2 T-0 umbilical from MLP deck.
B/W M-II

Comments: LO2 T-0 disconnect and retraction normal. No vehicle anomalies.

OTV 150 Views Orbiter LH2 T-0 umbilical from SW MLP deck.
B/W M-II

Comments: LH2 T-0 disconnect/retraction normal. Residual vapors emanated from flight QD. No vehicle anomalies.

OTV 151 Views main engine cluster.
B/W M-II

Comments: SSME ignition and gimbal profile normal. Aft RCS paper covers tore loose and were drawn aft. Ice fell from LO2 T-0 umbilical. Residual GOX vapors were drawn into plume by aspiration.

OTV 154 Views ET/Orbiter LO2 umbilical and Orbiter RH wing
B/W M-II

Comments: SSME ignition caused ice to fall from ET/ORB umbilicals, but no tile damage was visible. Ice also fell from LO2 feedline support brackets.

OTV 155 Views RH SRB and underside of Orbiter RH wing.
B/W M-II

Comments: Ice particles fell from both ET/ORB umbilicals, but no tile damage was visible. Throat plug material was ejected upward out of exhaust hole after T-0.

OTV 156 Views LH SRB and underside of Orbiter LH wing.
B/W M-II

Comments: Ice particles fell from both ET/ORB umbilicals, but no tile damage was visible. Throat plug material was ejected upward out of exhaust hole after T-0.

OTV 160 Views ET nosecone and NE louver from water tower.
Color M-II

Comments: Ignition and liftoff appeared nominal. GH2 vent line latched properly. Facility water activated properly.

OTV 161 Views ET nosecone and SW louver from the FSS.
Color M-II

Comments: Light frost coated southwest louver. No TPS anomalies on nose cone, fairing or footprint. Ice continued to fall from ET/ORB umbilicals.

OTV 162 Views -Y side of vehicle.
B/W VHS

Comments: Light frost coated southwest louver. No TPS anomalies on nose cone, fairing or footprint. Ice continued to fall from ET/ORB umbilicals.

OTV 163 Views ET/Orbiter umbilical and Orbiter T-0
Color M-II umbilical from the FSS.

Comments: LH2 T-0 TSM light turned on. Free burning hydrogen was visible under body flap. SSME ignition caused ice to fall from ET/ORB umbilicals. Residual LH2 vapors emanated from T-0. No unusual vapors or cryo drips at liftoff. Normal orbiter wing motion occurred at T-0. Liquid or vapors were visible from tiles near EO-2.

OTV 164 Views LH2 ET/ORB umbilical.
B/W VHS

Comments: Vehicle twang appeared normal. Ice/frost shook loose from ET/ORB umbilicals during SSME ignition. Some ice was also shaken loose from the LH2 recirculation line -Z bellows. No unusual vapors or cryogenic drips were present. Whitish vapor/ liquid originating from tile gaps near the EO fitting coincided with the start of SSME ignition.

OTV 165 Views +Y-Z side of overall vehicle
B/W VHS

Comments: No lower surface tile anomalies. Facility water activated properly. Vehicle twang appeared normal.

OTV 166 Views +Y+Z side of overall vehicle
B/W VHS

Comments: Facility water was activated properly. Vehicle twang appeared normal. No vehicle anomalies were visible. Forward RCS paper covers were intact while in the FOV. Water on aft boosters vaporized.

OTV 167 Views -Y-Z side of overall vehicle.
B/W VHS

Comments: Facility water activated properly. Vehicle twang was normal. No vehicle anomalies. Third hardpoint closeout was intact. Water on ET aft dome and in SRB stiffener rings vaporized.

OTV 170 Views overall vehicle from SE direction.
Color M-II

Comments: SSME ignition appeared normal. Rusty water was visible on MLP south side. Dark objects on pad apron were tufts of grass. Residual GOX vapors from LO2 T-0 umbilical were drawn into SSME plume. Water on aft boosters vaporized shortly after liftoff.

OTV 171 Views overall vehicle from SW direction.
Color M-II

Comments: SSME ignition and gimbal profile appeared normal. Aft RCS paper covers tore and ice fell from umbilicals. LH2 T-0 disconnect and retraction were nominal. Residual LH2 vapors from the T-0 umbilical were drawn into SSME plume.

STI (C/S 2) Infrared view from camera site 2.
B/W M-II

Comments: Free burning hydrogen blown under body flap and rose past vertical stabilizer. SSME ignition appeared normal.

STI (RSS) Infrared view from RSS roof.
B/W M-II

Comments: SSME ignition appeared nominal. Cold residual LH2 vapors from T-0 were drawn into SSME plume.

TV-2 Views launch from SLF.
Color M-II

Comments: Too distant for detail. No plume anomalies.

TV-4B Views Pad B launch from Beach Road IFLOT site
Color M-II east of Pad A access road.

Comments: Ignition, liftoff and roll maneuver appeared normal. Water on aft boosters vaporized. Localized shock waves formed.

TV-5 Views launch from VAB roof.
Color M-II

Comments: Liftoff and roll maneuver were nominal. Localized shock waves formed. FOV obscured by clouds.

TV-7 Views launch vehicle from camera site 2 east
Color M-II of pad.

Comments: Flock of birds in FOV not near vehicle. No anomalies after tower clear. Condensate vapors were visible on ET aft dome and SRB stiffener rings.

TV-11 Views launch from TV Tower #1 east of SLF.
Color M-II

Comments: View too distant for detail. No plume anomalies. Camera operator tracked shadow instead of vehicle.

TV-13 Cocoa Beach DOAMS tracking of launch vehicle
Color M-II from acquisition to LOV.

Comments: Intermittent and unsteady tracking.

TV-16 Views launch from helicopter orbiting west of
Color M-II Pad and VAB.

Comments: Too distant for detail. No plume anomalies.

TV-18 Malabar ITEK tracking of launch vehicle from
Color M-II acquisition to LOV.

Comments: No tracking data.

ET-204 Patrick IGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: Vehicle obscured by haze/clouds.

ET-206 Melbourne Beach ROTI video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: Vehicle obscured by haze/clouds.

ET-207 UCS-10 MIGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: Ignition and liftoff normal. Condensate on ET aft dome vaporized. GH2 vent line latched properly. Shock condensation trailed vehicle near max Q. SRB separation appeared nominal.

ET-208 Cocoa Beach DOAMS video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: Vehicle obscured by haze/clouds.

ET-212 UCS-23 MIGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: Flashes occurred in SSME plume during ascent. Shock condensation trailed vehicle.

ET-213 UCS-12 MOTS video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: No vehicle anomalies. SRB separation was obscured.

7.2 ON-ORBIT FILM DATA REVIEW

Review/analysis of on-orbit ET separation photography included 103 70mm still frames taken by the flight crew, one 16mm high speed film from the LH2 ET/ORB umbilical camera, and one 35mm frame from the LO2 ET/ORB umbilical camera.

No major vehicle damage or lost flight hardware was observed that would have affected the mission. Real time down-link from OV-102 showed TCS blankets partially detached from the 1307 aft bulkhead and damage to the payload bay door environmental seal. Cause of this damage is believed to be airflow intrusion past the payload bay door seals during ascent. Observations of the seal during shade- and sun-induced thermal environments, as well as ground tests with similar hardware in the OPF, showed the payload bay doors could be closed and latched for re-entry. No further action, such as an EVA, was required.

Shortly after ET separation, the 16mm film showed a metallic cylinder drifting past the LH2 ET/ORB camera and moving away from the Orbiter. Inspection of OV-102 ET/ORB umbilicals after landing revealed no missing hardware. KSC identified the object as the outboard shear pin bushing from the ET half of the LH2 ET/ORB umbilical. On-orbit umbilical photography confirmed the inboard bushing on the LH2 umbilical and the two bushings on the LO2 umbilical were still in place after ET separation. KSC inspected the bushings on ET-47 prior to OV-104 umbilical mate. No anomalies were found. Presence of the bushings on ET-47 after separation from the Orbiter (STS-43) can not be confirmed due to lack of umbilical cameras on OV-104.

Three TPS divots were visible on the LH2 tank-to-intertank flange closeout. Two divots, approximately 8-10 inches in diameter, were located below the intertank access door and GH2 vent line QD, and the third divot, 6-8 inches in diameter, was located below the +Y ET/SRB forward attach point. A fourth divot occurred on the -Z side of the tank in the aft hardpoint closeout. Bright spot in the intertank TPS acreage near the -Y side of the LO2 feedline fairing was a PDL repair, not a divot.

TPS and purge seal damage, located on the forward end of the LH2 ET/ORB umbilical, occurred when the umbilical disconnect plates separated and residual hydrogen between the flapper valves vented. Frozen hydrogen adhered to the 17-inch flapper valve and LH2 umbilical disconnect plate. Small pieces of ice and foam drifted by the camera lens.

On-orbit photography verified the repair to the -Y bipod jack pad closeout was in place and intact.

There were no apparent anomalies on LO2 tank, LH2 tank, and aft dome TPS acreage. The BSM burn scars were typical. The nosecone, PAL ramps, intertank access door, GH2 umbilical carrier plate, RSS antennae, and LO2 feedline were in nominal configuration. The bright spot forward of EB-7 and forward of the -Z intertank vent were sanded repair areas. There was no TPS or purge barrier seal damage on the LO2 ET/ORB umbilical. Some ice still remained in the LO2 feedline lower bellows.

Separation of the LH SRB from the External Tank appeared nominal. No anomalies were visible on the diagonal and lower ET/SRB struts. Some pieces of ice fell from the EB-7 fitting. The -Y ET/SRB cable tray TPS exhibited typical erosion and heating affects. ET aft dome charring was also typical.

7.3 LANDING FILM DATA REVIEW

E-1001 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: OK
Exposure: Underexposed

Comments: Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible on landing gear doors and lower surface.

E-1002 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. No vehicle anomalies.

E-1005 Orbiter landing at Ames-Dryden Flight Research
35mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

E-1006 Orbiter landing at Ames-Dryden Flight Research
35mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

E-1007 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

E-1009 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

E-1010 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

E-1011 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : Camera slur
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

E-1012 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : Camera slur
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. No tile damage or anomalies were visible.

E-1017 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

E-1019 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. No vehicle anomalies.

E-1024 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. No vehicle anomalies.

TV-1 Orbiter landing at Ames-Dryden Flight Research
Video Facility

Comments: Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

TV-2 Orbiter landing at Ames-Dryden Flight Research
Video Facility

Comments: Too distant for detail. No vehicle anomalies.

TV-3 Orbiter landing at Ames-Dryden Flight Research
Video Facility

Comments: Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

TV-4 Orbiter landing at Ames-Dryden Flight Research
Video Facility

Comments: Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

LRO-1	Orbiter landing at Ames-Dryden Flight Research
Video	Facility

Comments: Landing gear deployment was nominal. MLG touchdown was almost simultaneous with the right side contacting the runway first. There were no unusual control surface deflections. Touch down of nose landing gear was smooth. No tile damage or anomalies were visible.

8.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 7 June 1991 from 1230 to 1500 hours. In general, the SRB's appeared to be in good condition.

8.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nosecap was not recovered. The RH frustum was missing no areas of TPS but had 32 MSA-2 debonds over fasteners. There was minor blistering of the Hypalon paint (Figure 9). The BSM covers were locked in the open position, but the two RH covers were bent upward by parachute riser entanglement.

The RH forward skirt exhibited no debonds or missing TPS. The phenolic plates on both RSS antennae were intact (Figure 10). 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.

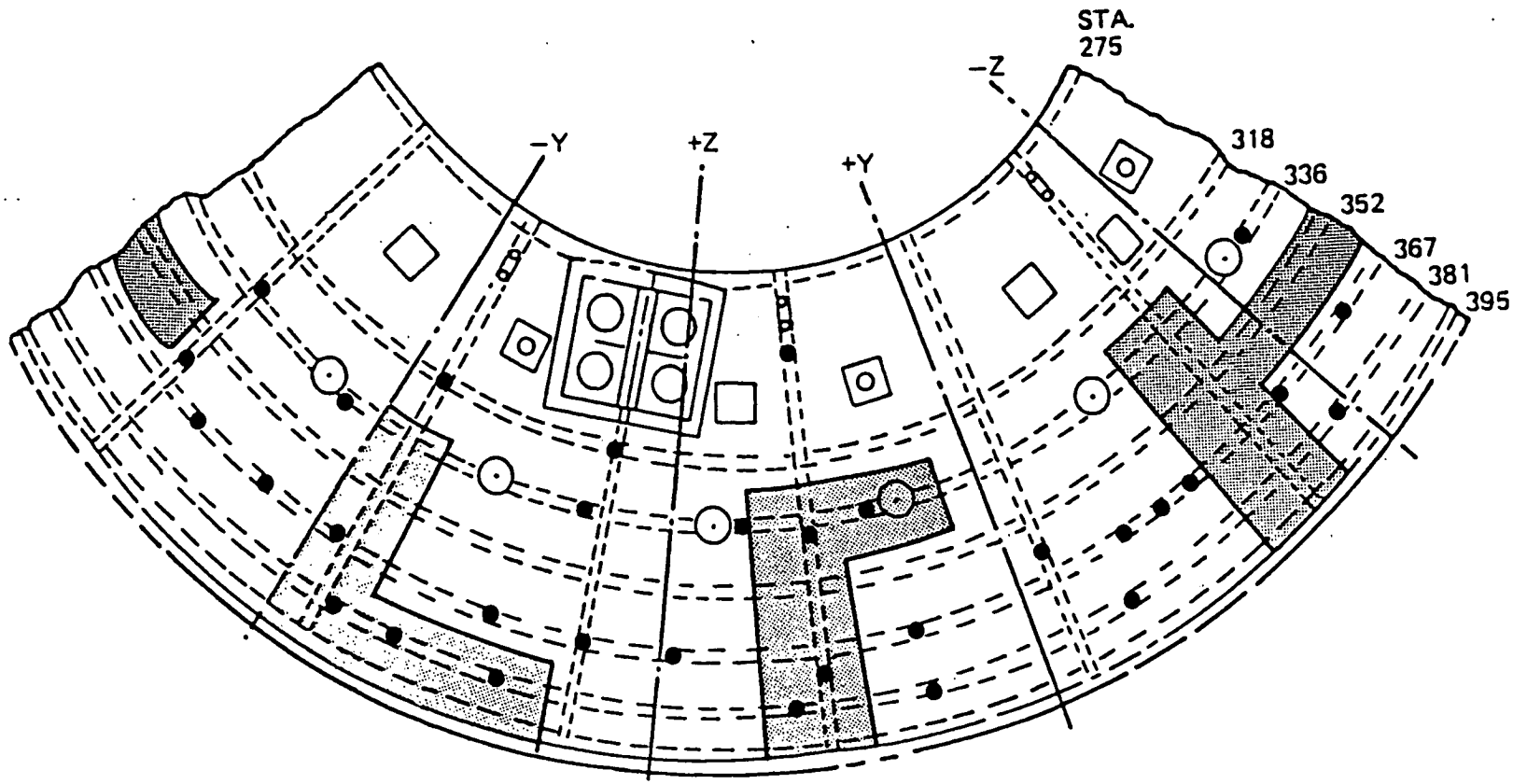
The Field Joint Protection System (FJPS) closeouts were generally in good condition. Two spongy areas occurred on the RH center FJPS at zero degrees and measured 0.5 inches in diameter. A third spongy area occurred on the RH aft FJPS at 290 degrees and measured 0.8 inches in diameter. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris hits from the nozzle extension severance.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, and IEA appeared undamaged. All stiffener rings and K5NA were cracked at the 22 degree location. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing. There were no EPDM weather seal unbonds on any of the aft booster factory joints.

The phenolic material on the kick ring delaminated in only a few locations. One of the K5NA protective domes was lost from a bolt head on the aft side of the phenolic kick ring prior to water impact since the substrate was sooted. The aft skirt TPS acreage was in good condition. K5NA was missing from all aft BSM nozzles (Figure 11).

All four HDP Debris Containment System (DCS) plungers were seated. Most of the EPON shim material was missing from the aft skirt after water impact, but none of the substrate was charred.

FIGURE 9. **RIGHT SRB FRUSTUM**



MISSING TPS

NONE

DEBONDS

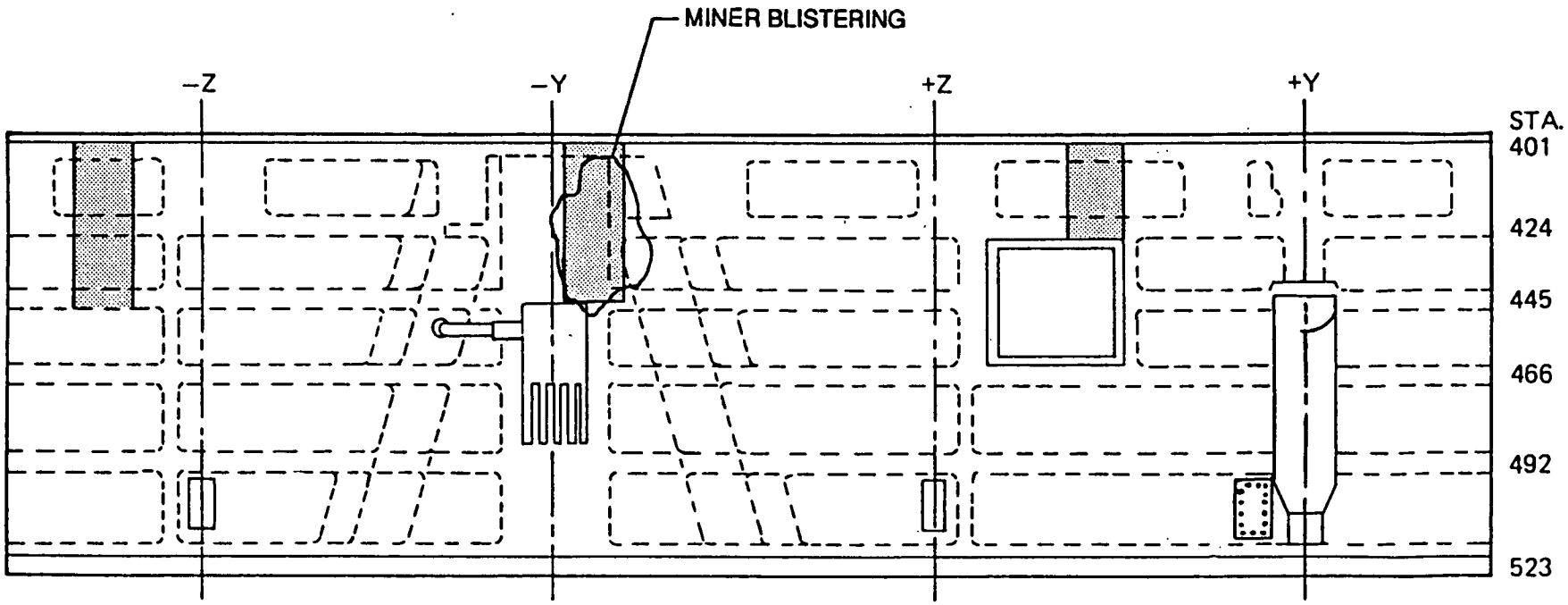
32 MSA-2 DEBONDS
OVER FASTENERS

NOTE:

2 RIGHT BSM COVERS WERE IN
THE LOCKED OPEN POSITION
BUT WERE BENT UPWARD BY
PARACHUTE RISER ENTANGLEMENT

EGG/V-326

FIGURE 10. **RIGHT SRB FWD SKIRT**



TPS MISSING

NONE

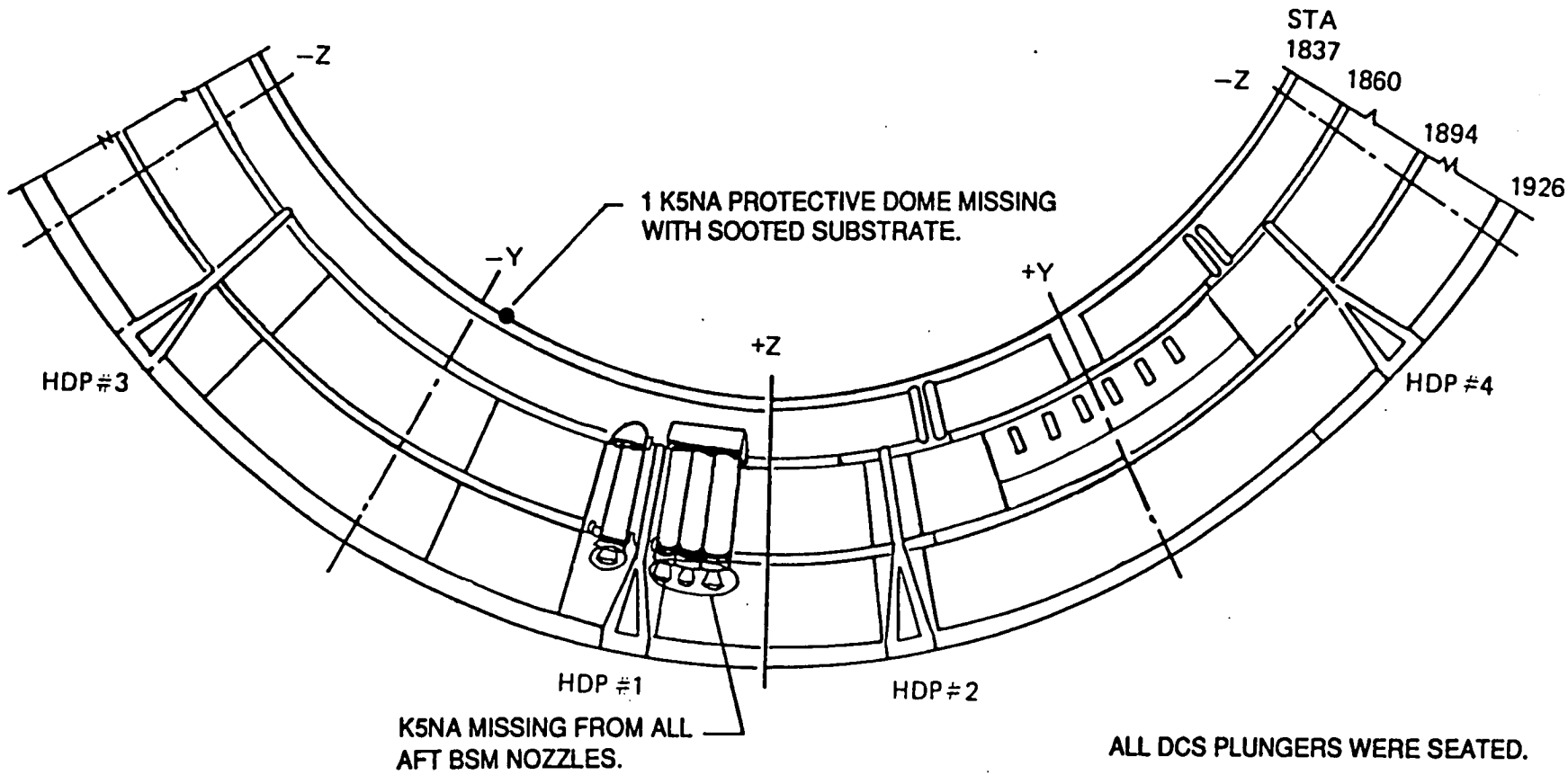
DEBONDS

NONE

NOTES:

BLISTERING OF HYPALON PAINT WAS MINIMAL.
RSS ANTENNA PHENOLIC PLATES WERE INTACT.

FIGURE 11. RIGHT SRB AFT SKIRT EXTERIOR TPS



8.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nosecap was not recovered. The LH frustum was missing no TPS but had 30 MSA-2 debonds over fasteners (Figure 12). Minor blistering of the Hypalon paint occurred at three locations. All BSM covers were locked in the fully opened position.

The LH forward skirt exhibited no debonds or missing TPS. The phenolic plates on both RSS antennae were intact (Figure 13). 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.

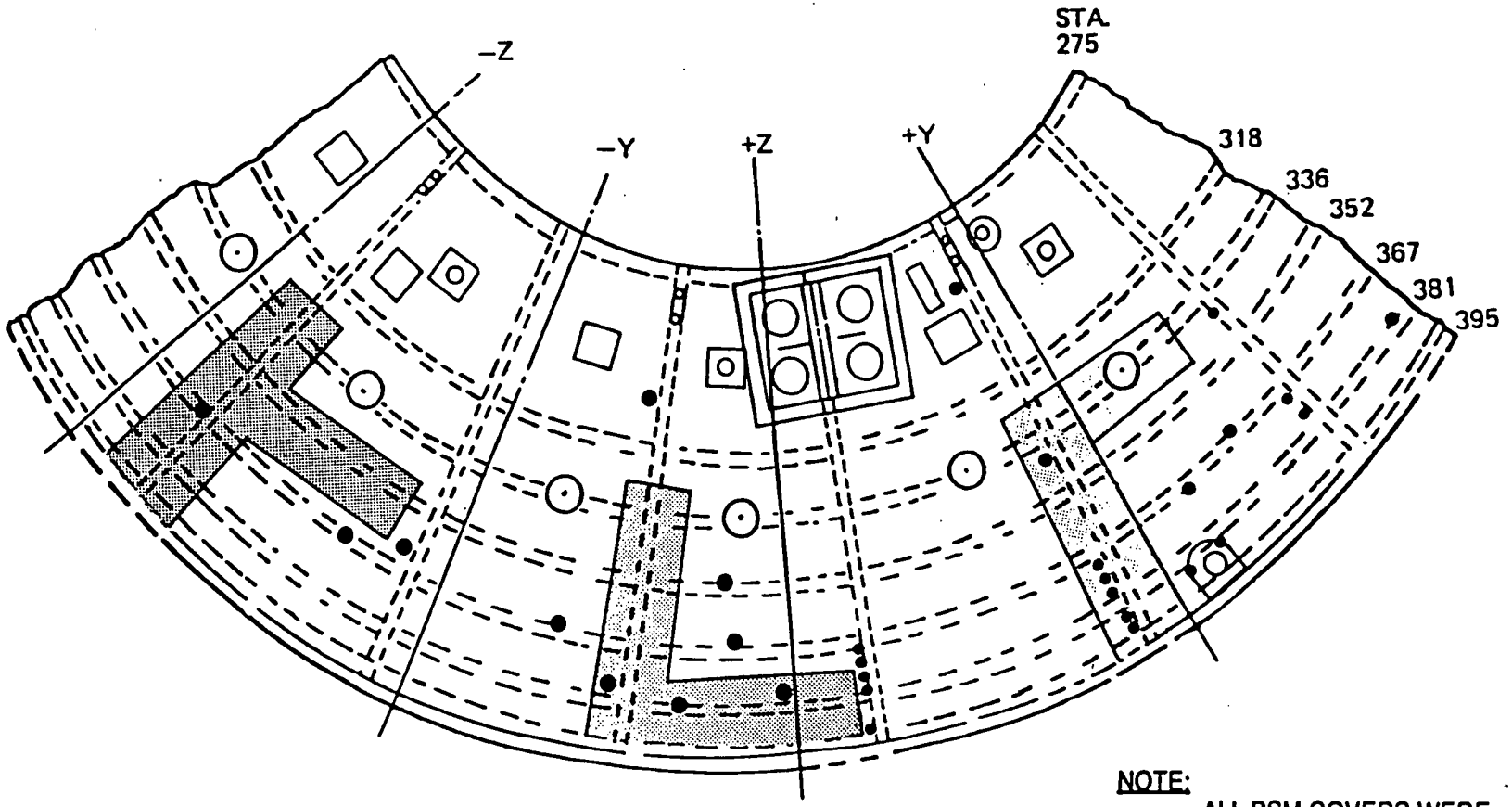
The Field Joint Protection System (FJPS) closeouts were in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris hits from the nozzle extension severance.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and aft booster stiffener rings appeared undamaged. Three IEA cover bolts near the lower ET/SRB strut were bottomed out and the washers under the bolt heads could be rotated. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing. No K5NA was cracked on the aft booster stiffener rings. There were no EPDM weather seal unbonds on any of the aft booster factory joints.

The phenolic material on the kick ring delaminated in only a few locations. Some K5NA protective domes were lost from bolt heads on the aft side of the phenolic kick ring prior to water impact. The aft skirt TPS acreage was in good condition. K5NA was missing from all aft BSM nozzles (Figure 14).

The HDP Debris Containment System (DCS) plungers were seated with the exception of HDP #7, which was obstructed by frangible nut halves. EPON shim material was missing from the aft skirt after water impact, but none of the substrate was charred.

FIGURE 12. LEFT SRB FRUSTUM



MISSING TPS

NONE

DEBONDS

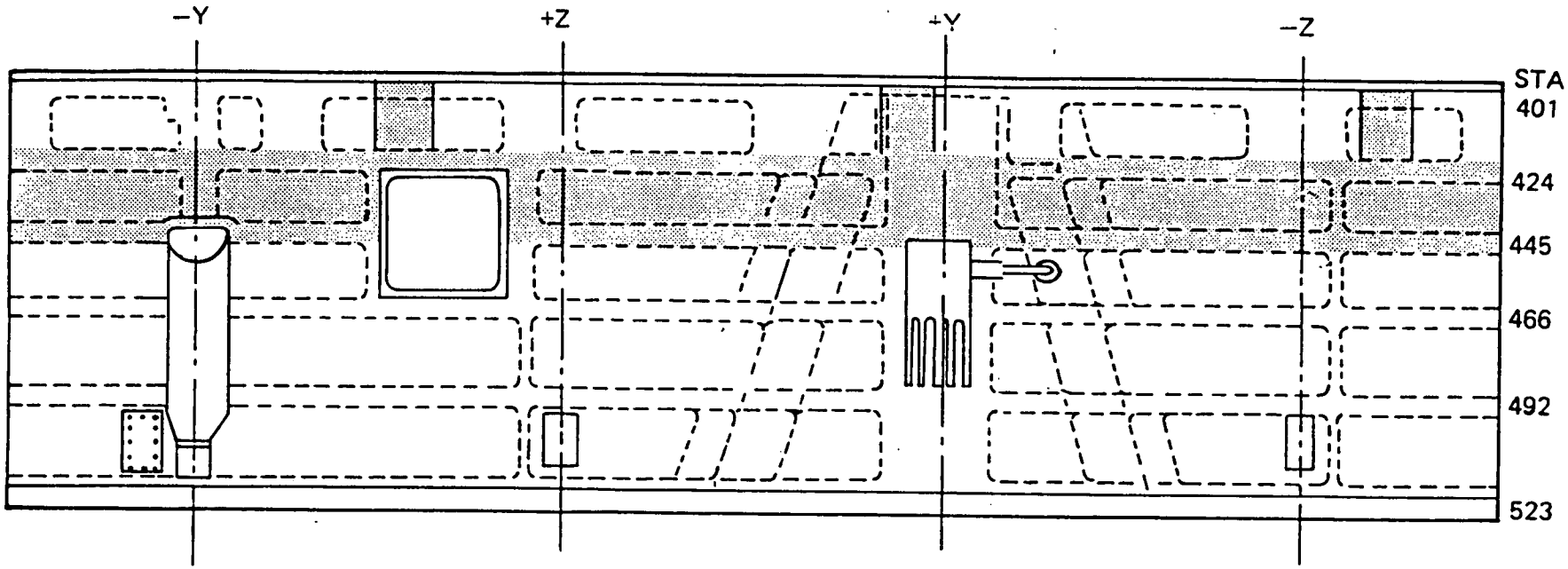
30 MSA-2 DEBONDS
OVER FASTENERS

NOTE:

ALL BSM COVERS WERE LOCKED IN THE OPEN POSITION.
BLISTERING OF HYPALON PAINT WAS MINIMAL.

EGG/V-326E

FIGURE 13. LEFT SRB FWD SKIRT

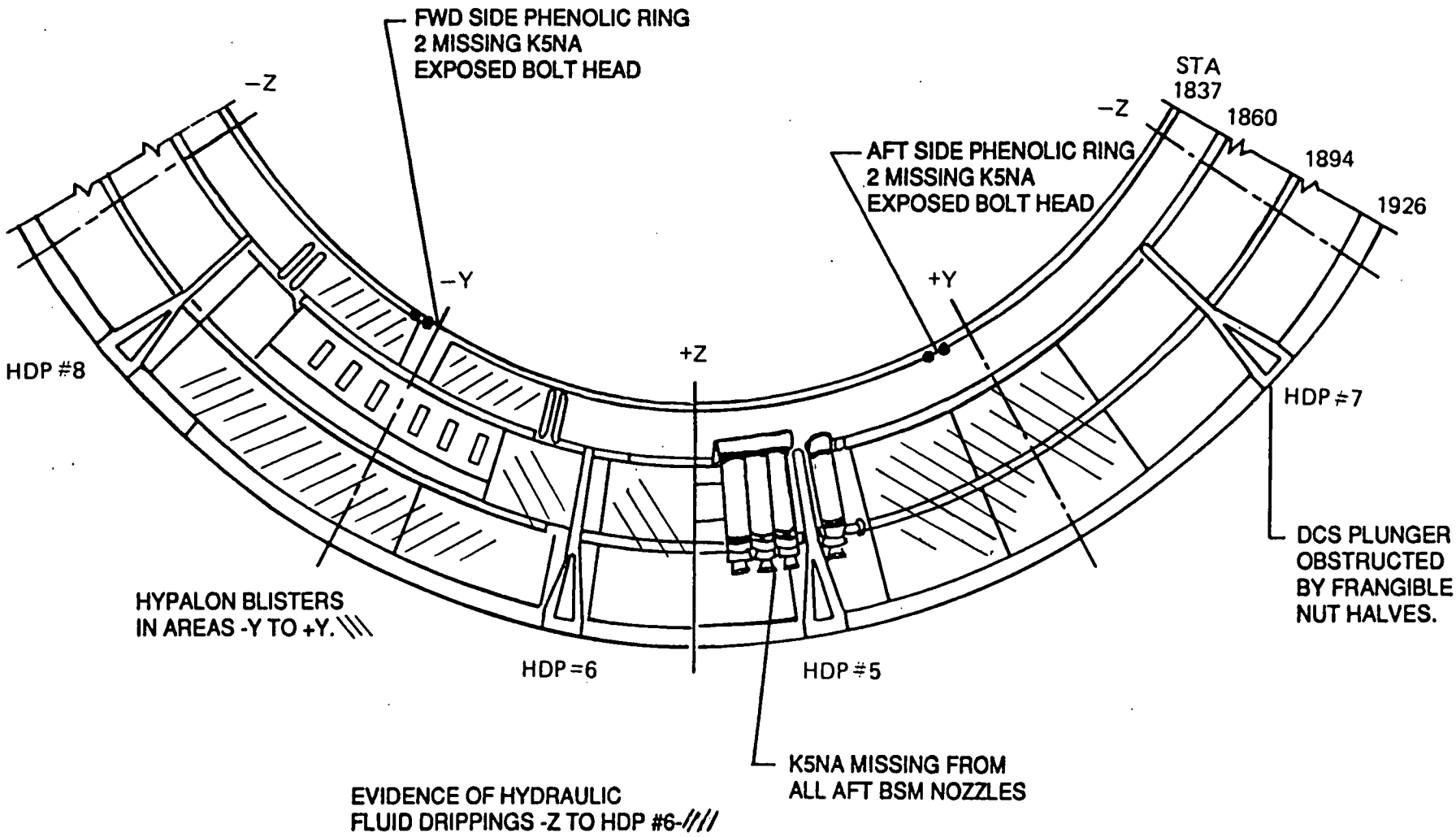


TPS MISSING	DEBONDS
NONE	NONE

NOTES:

BLISTERING OF HYPALON PAINT WAS MINIMAL.
PHENOLIC PLATES ON RSS ANTENNAE WERE INTACT.

FIGURE 14. LEFT SRB AFT SKIRT EXTERIOR TPS



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8.3 RECOVERED SRB DISASSEMBLY FINDINGS

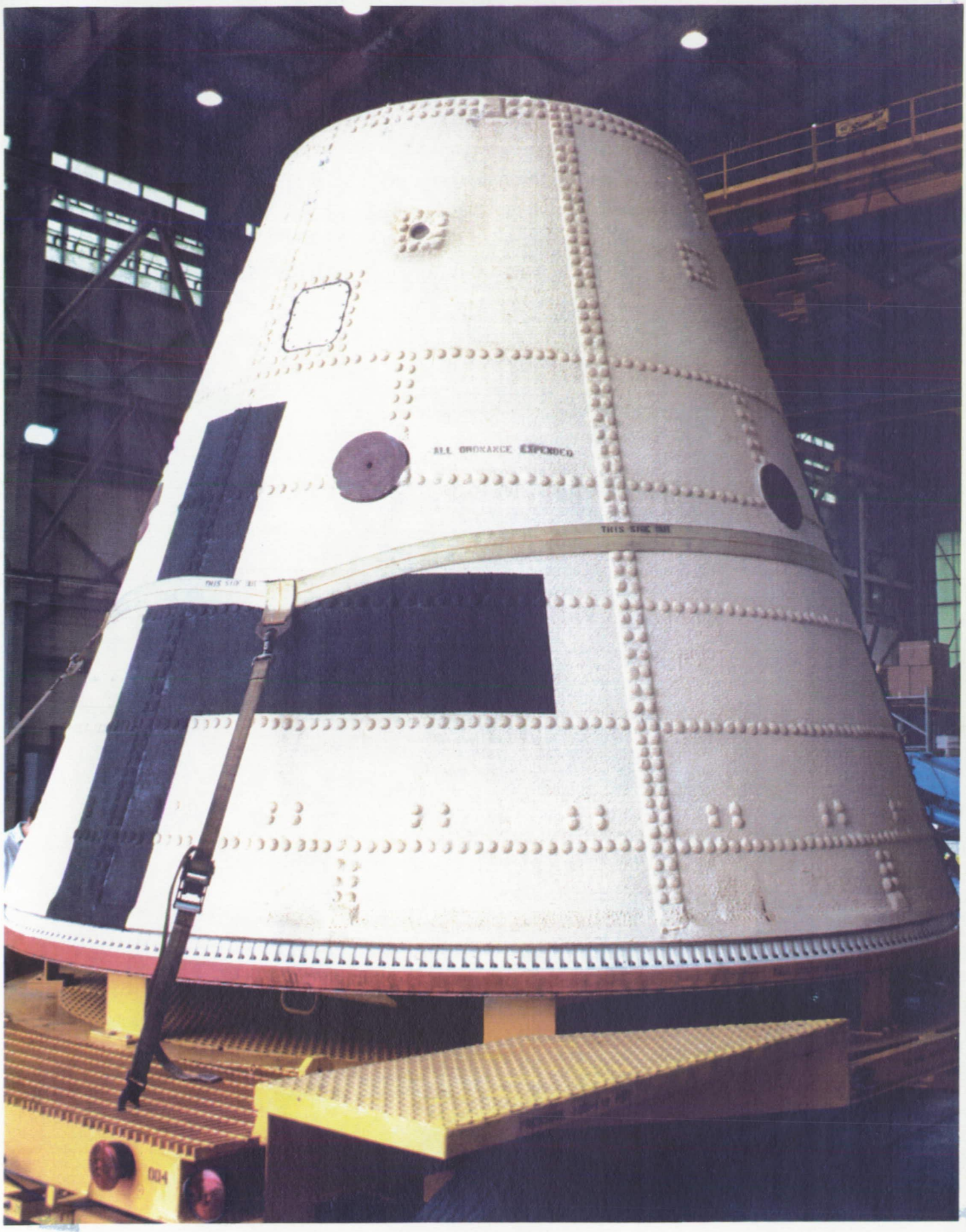
STS-40 was the first flight to utilize the new 'optimized' frangible links in the holddown post DCS's. The link was designed to increase the DCS plunger velocity and improve the seating alignment while leaving the stud ejection velocity the same. The design was intended to prevent ordnance debris from 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.

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 78 percent and individual holddown post retention percentages as listed:

HDP #	Overall %	% of Nut without 2 large halves	% of Ordnance
1	99+	99+	98
2	99+	99+	96
3	38	38	38
4	99+	99+	98
5	23	23	24
6	99+	99+	98
7	62	65	52
8	99+	99+	97

Post flight inspection of BI043 (STS-39) revealed K5NA missing from two locations on RH aft booster stiffener ring splice plates. Although no material was missing from the splice plate closeouts on BI044 (STS-40), K5NA samples were taken during disassembly operations at Hangar AF. The samples showed distinct regions of the 'pancake' application method with some delaminated areas, though none of these areas were considered to be a concern during ascent. A PR was taken to remove similar closeout areas on BI045 (STS-43) currently stacked in the VAB and reapply the K5NA. During the removal process, some of the areas exhibited delaminations. Suspect PR's have also been written against subsequent flight sets including BI043 (STS-44). Technical information/certification involving multiple layer applications for all future ablator processes will be reinforced.

SRB Post Launch Anomalies are listed in Section 11.



The RH frustum was not missing any TPS but had 32 MSA-2 debonds over fasteners.

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The BSM covers were locked in the open position, but two covers were bent upward by parachute riser entanglement.

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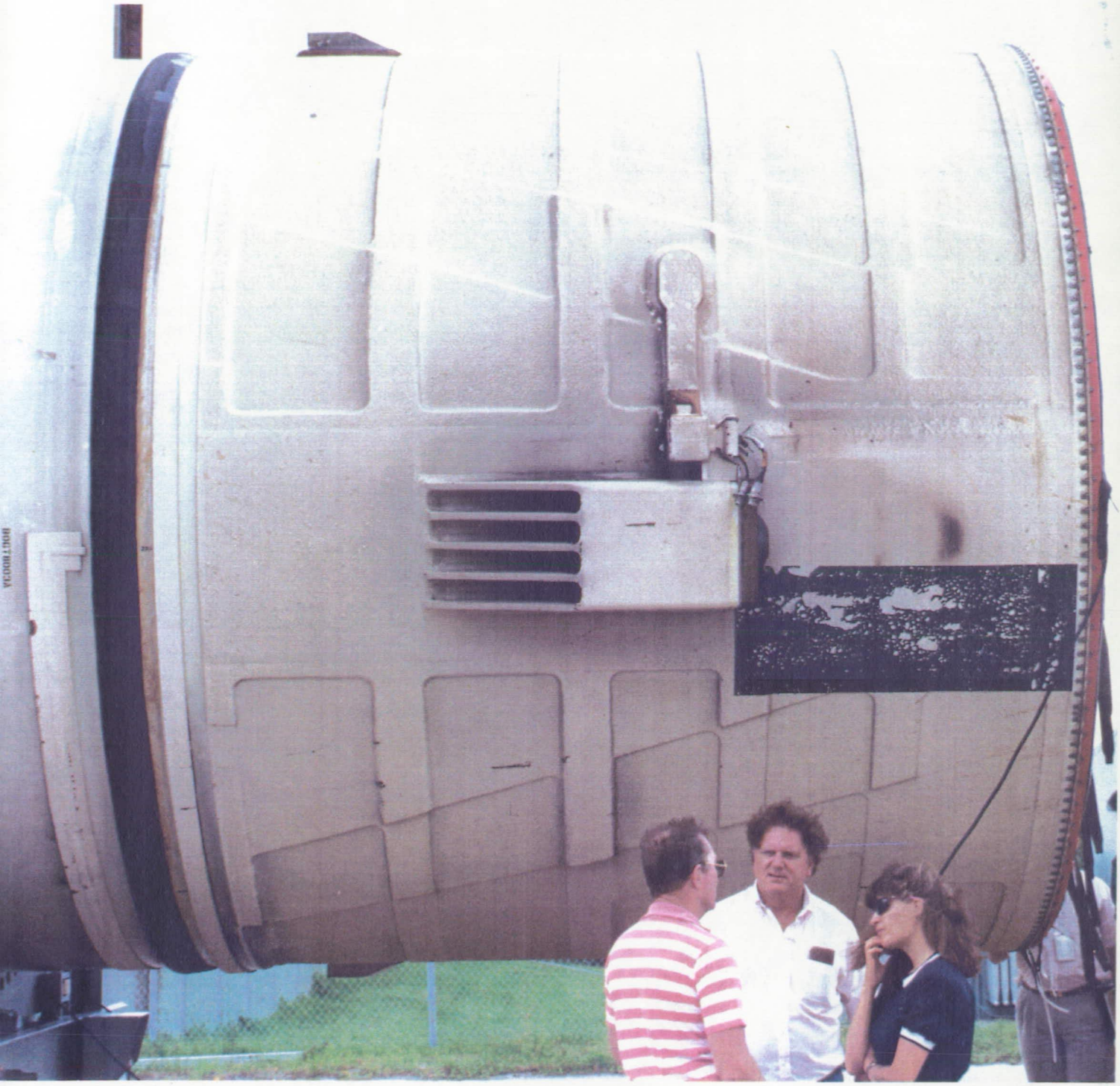

The RH forward skirt exhibited no debonds or missing TPS.
The RSS antenna phenolic plates were intact.

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Overall view of the RH SRM segment cases. The field joint protection system closeouts were generally in good condition.

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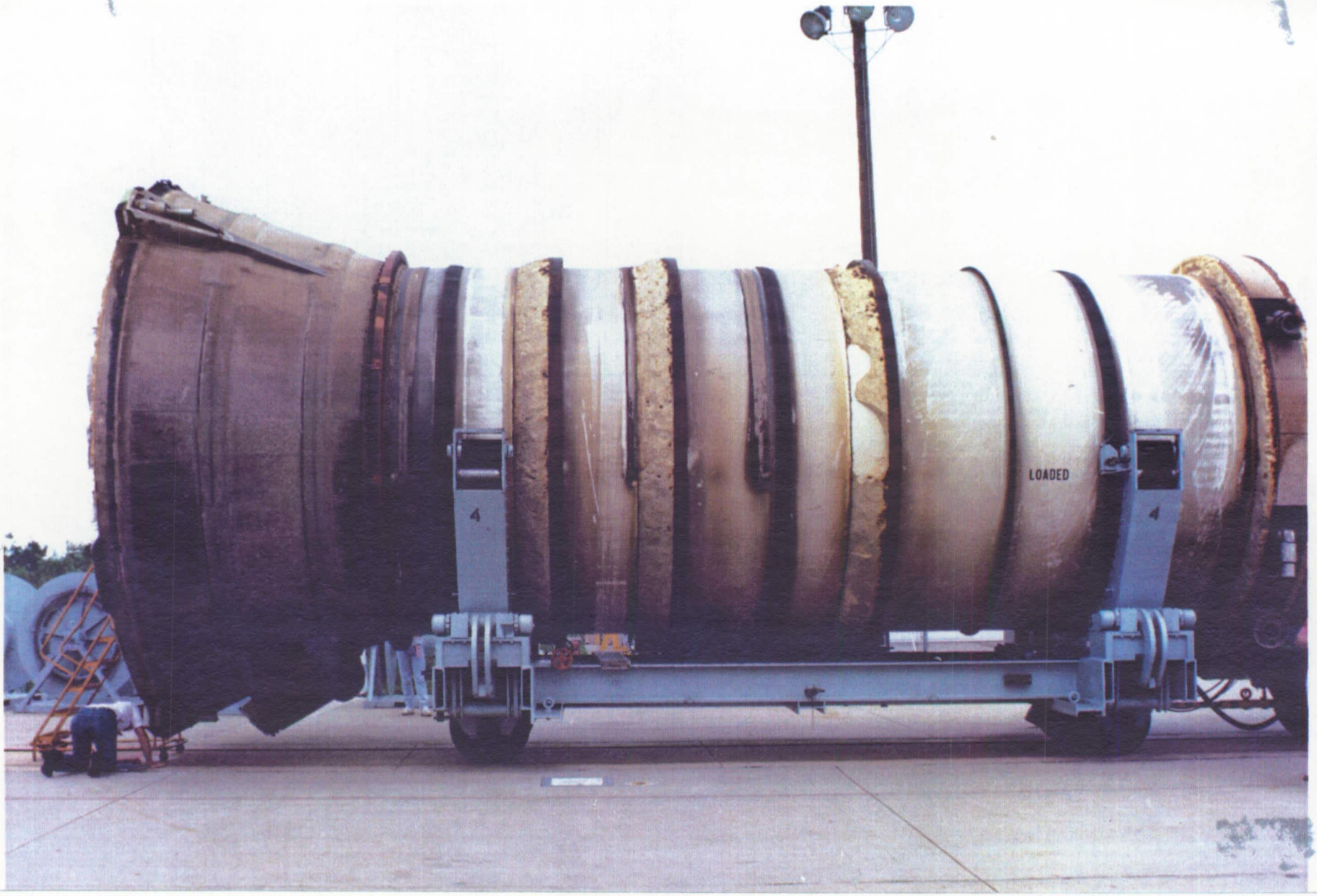

Post flight condition of the RH aft booster and aft skirt

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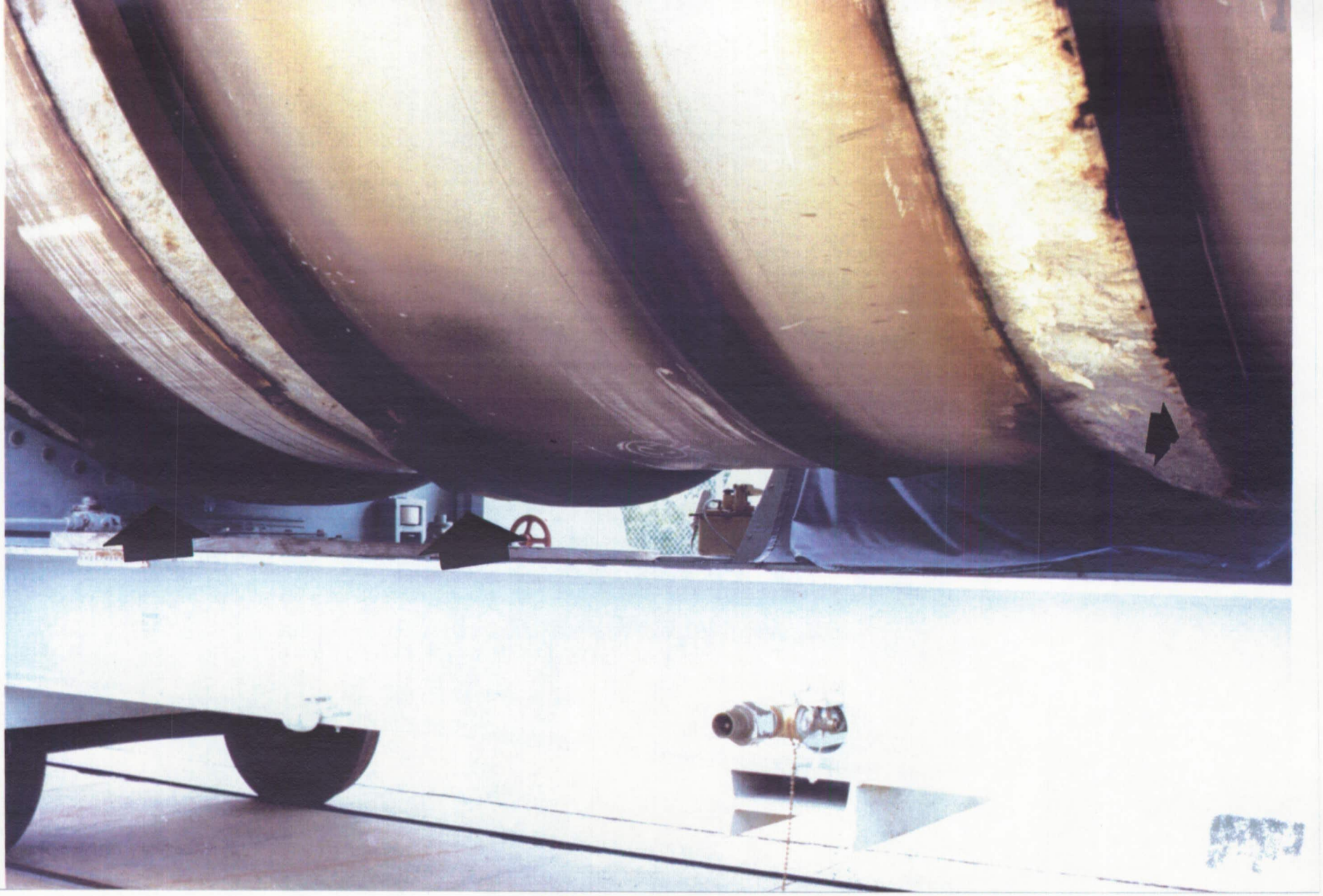

The RH aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing

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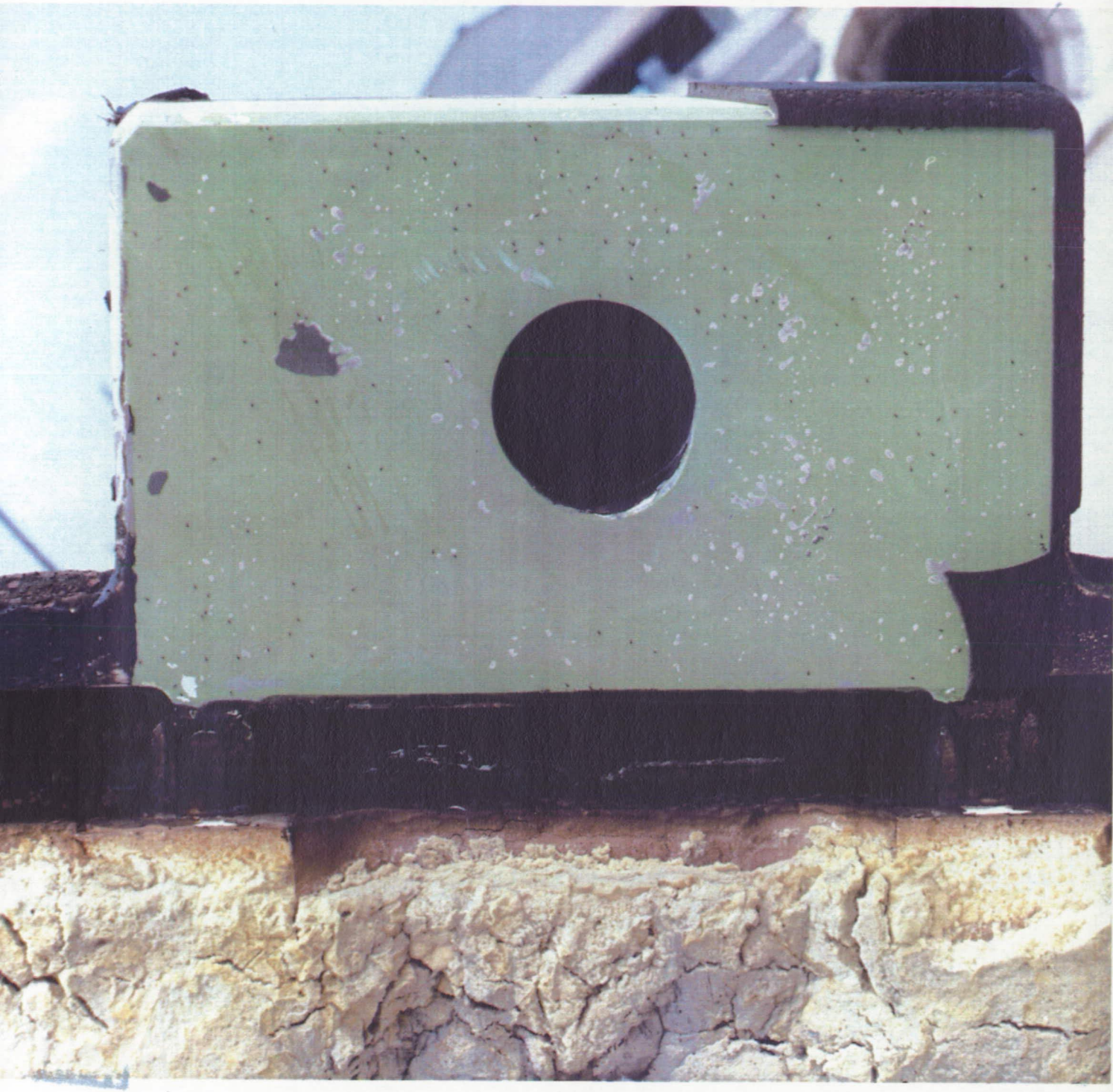

All four HDP Debris Containment System plungers were seated. Most of the EPON shim material was missing from the aft skirt after water impact, but none of the substrate was charred.

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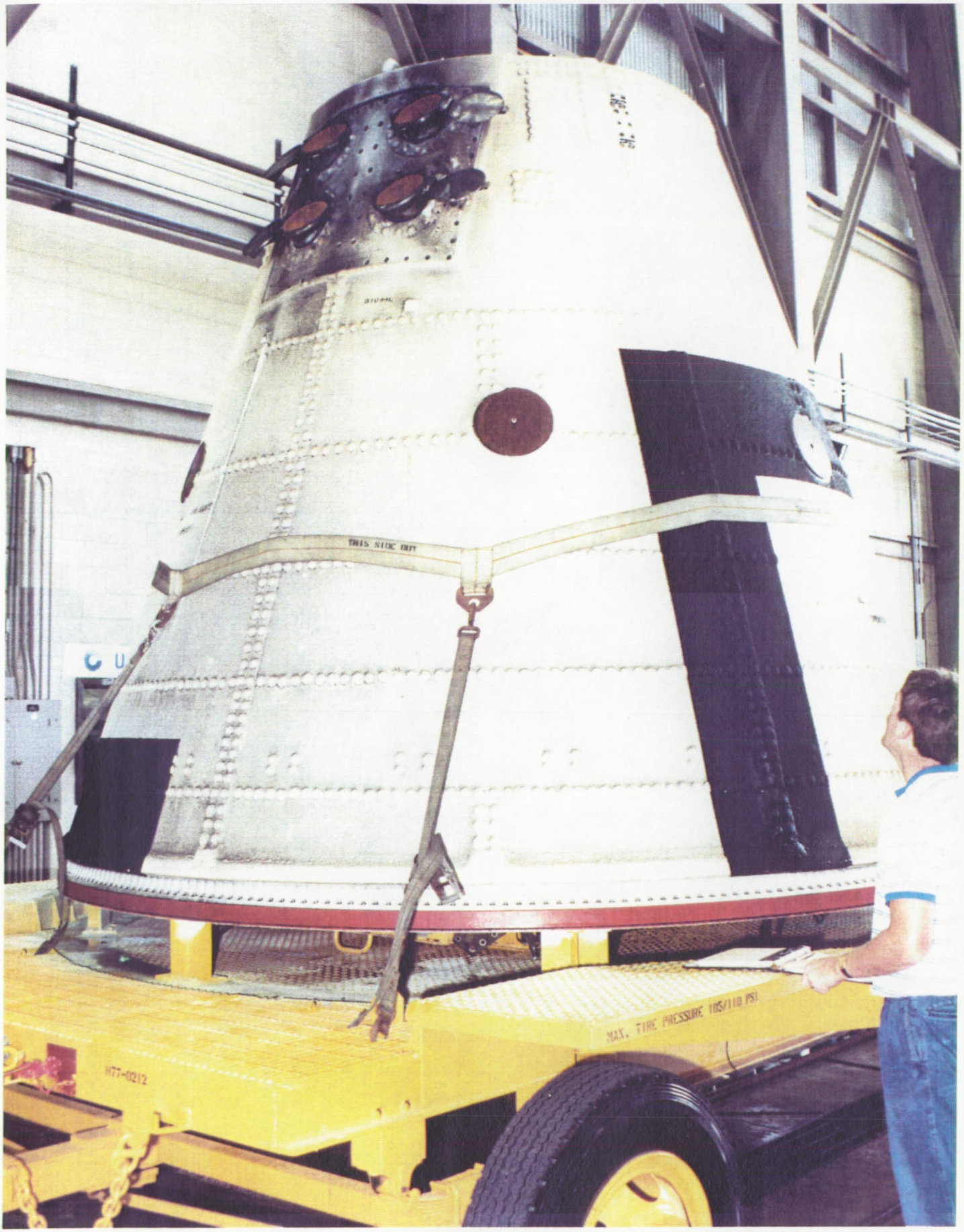

The LH frustum was not missing any TPS but had 30 MSA-2 debonds over fasteners

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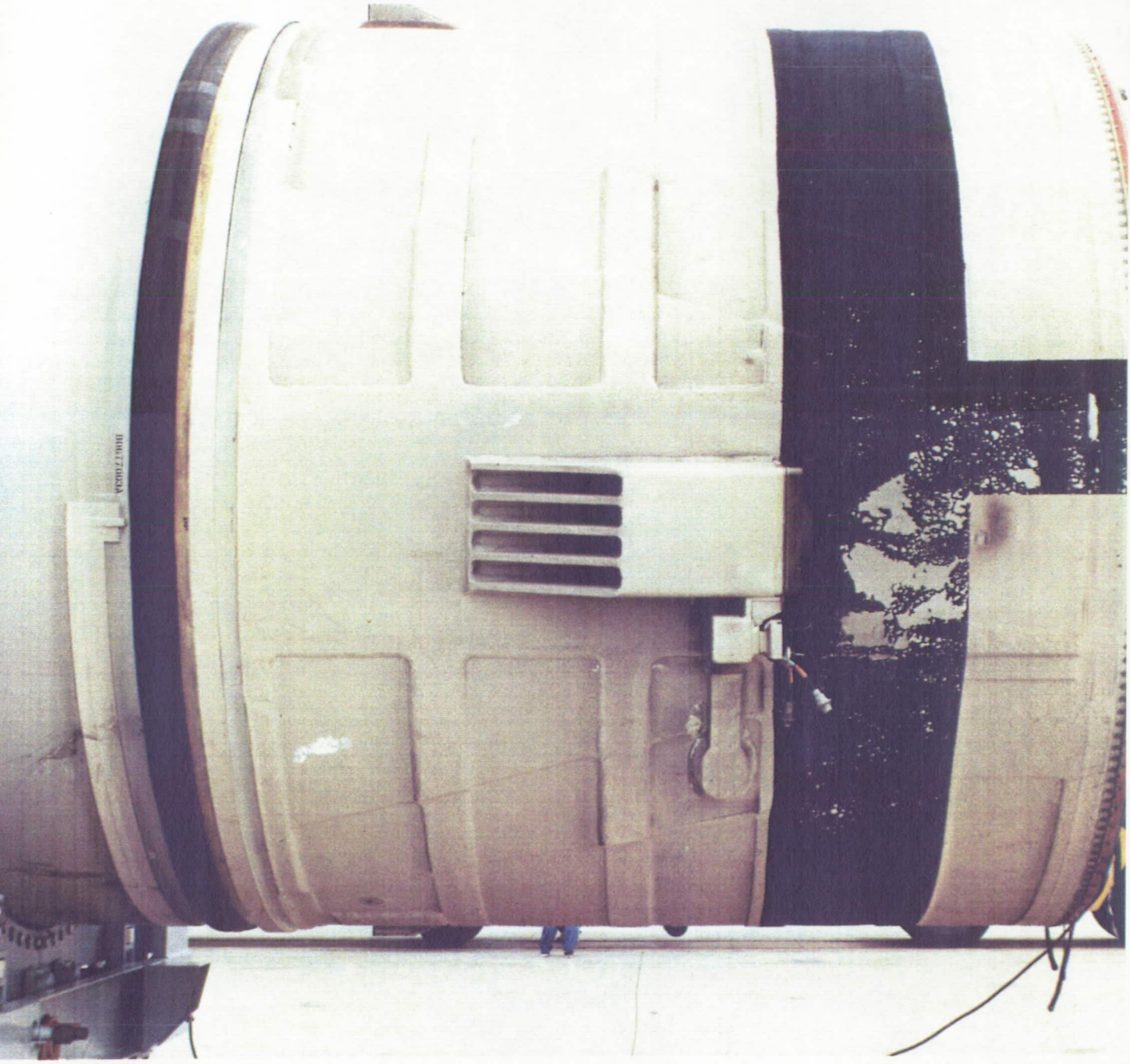

The LH forward skirt exhibited no debonds or missing TPS.
The RSS antenna phenolic plates were intact.

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Overall view of the LH SRM segment cases. The field joint protection system closeouts were generally in good condition.

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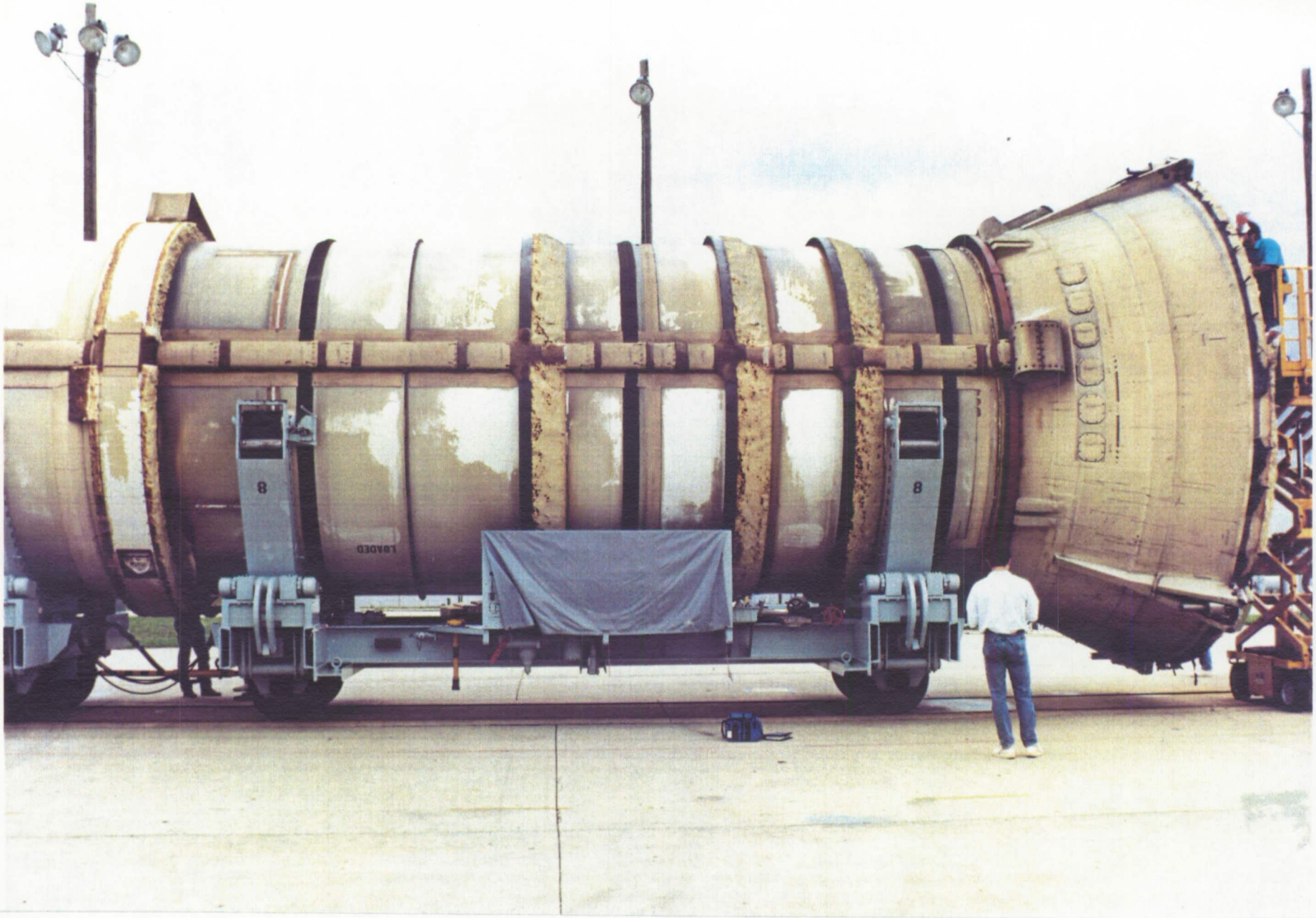

Post flight condition of the LH aft booster and aft skirt

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Three IEA cover bolts near the lower ET/SRB strut were bottomed out and the washers under the bolt heads could be rotated

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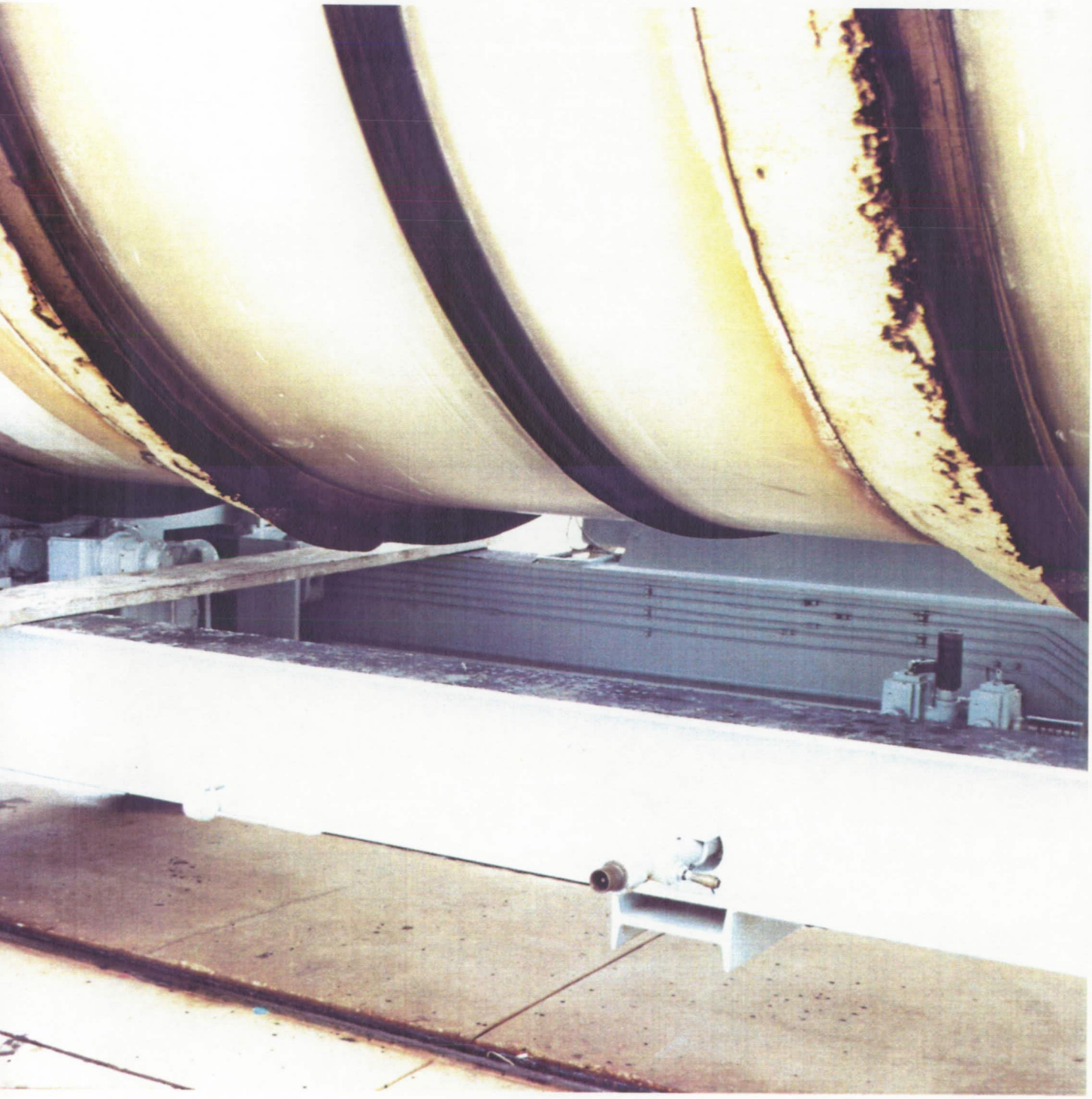

The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing

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Post flight condition of the LH aft skirt where hydraulic fluid had dripped from a leak at the GOX vent arm hinge before launch

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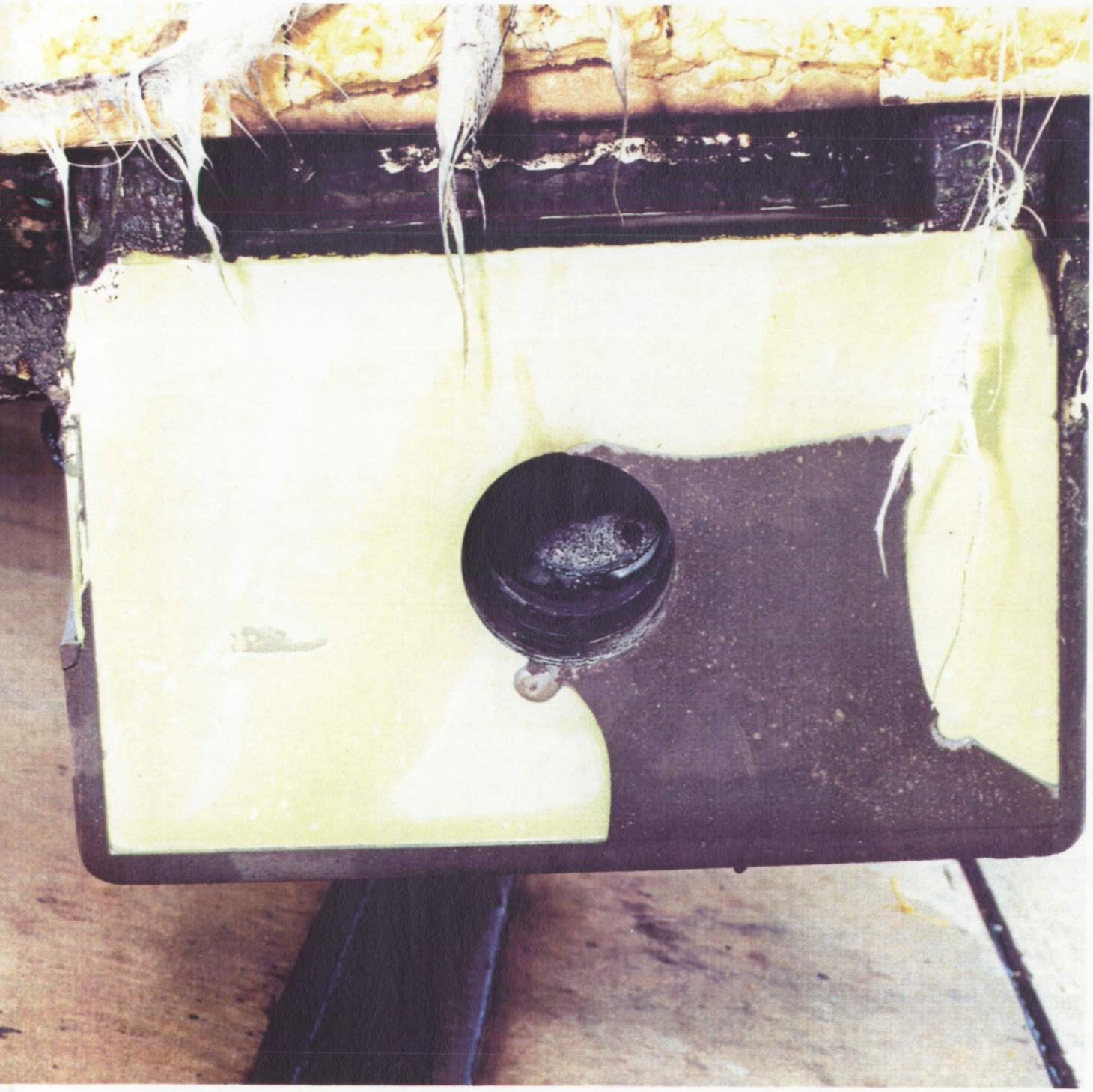

The HDP #7 DCS plunger was obstructed by frangible nut halves

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9.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A detailed post landing inspection of OV-102 (Columbia) was conducted on June 14-15, 1991, at Ames-Dryden (EAFB) on Runway 22 and in the Mate-Demate Device (MDD) to identify debris impact damage, and if possible, debris sources. The Orbiter TPS sustained a total of 197 hits, of which 25 had a major dimension of one inch or greater. This total does not include the numerous damage sites (over 100) on the base heat shield, which are attributed to SSME vibration/acoustics and plume recirculation.

The Orbiter lower surface had a total of 153 hits of which 23 had a major dimension of one inch or greater. A comparison of these numbers to statistics from 27 previous missions of similar configuration (excluding missions STS-24, 25, 26, 26R, 27R, and 30R which had damage from known debris sources), indicates both the total number of hits and the number of hits with a major dimension of 1 inch or larger on the lower surface was greater than average. Figures 15-18 show the TPS debris damage assessment for STS-40. Figure 19 indicates the sites where samples were taken for laboratory chemical analysis.

The largest single damage site on the Orbiter lower surface occurred on the RH inboard elevon and measured approximately 7-3/4"x1-1/8"x1/2". This hit may have been the result of ice from the ET LO2 feedline bellows or support brackets.

A cluster of 30 hits (with 2 larger than one inch) occurred just aft of the LH2 ET/Orbiter umbilical cavity. Similar clusters of hits have been observed in this area on previous flights and are attributed to ice/debris impacts during ET separation and/or damage from purge barrier baggie and ice during ascent.

Two chips (2-1/2"x1"x3/4" and 1"x1"x5/8") occurred in the LH ET/Orbiter umbilical door leading edge tiles. The RH ET/Orbiter (LO2) umbilical door centerline forward outboard latch fitting and adjacent tile sustained hot gas intrusion and exhibited significant melting/erosion due to the lack of or degradation of the RTV seal. This event was not considered to be a debris issue.

No flight hardware was found on the runway below the ET/Orbiter umbilicals. The ET/ORB separation ordnance device plungers were seated and appeared to have functioned properly. Post landing disassembly of the EO-2 and EO-3 debris containers revealed no missing pieces. The EO-1 separation ordnance device operated properly though the contact surface of the LH stop bolt was slightly deformed.

The lightning protection contacts on both ET/Orbiter umbilicals were intact. No lightning protection contacts from the ET half of the umbilical were present.

FIGURE 15. **STS-40**

DEBRIS DAMAGE LOCATIONS

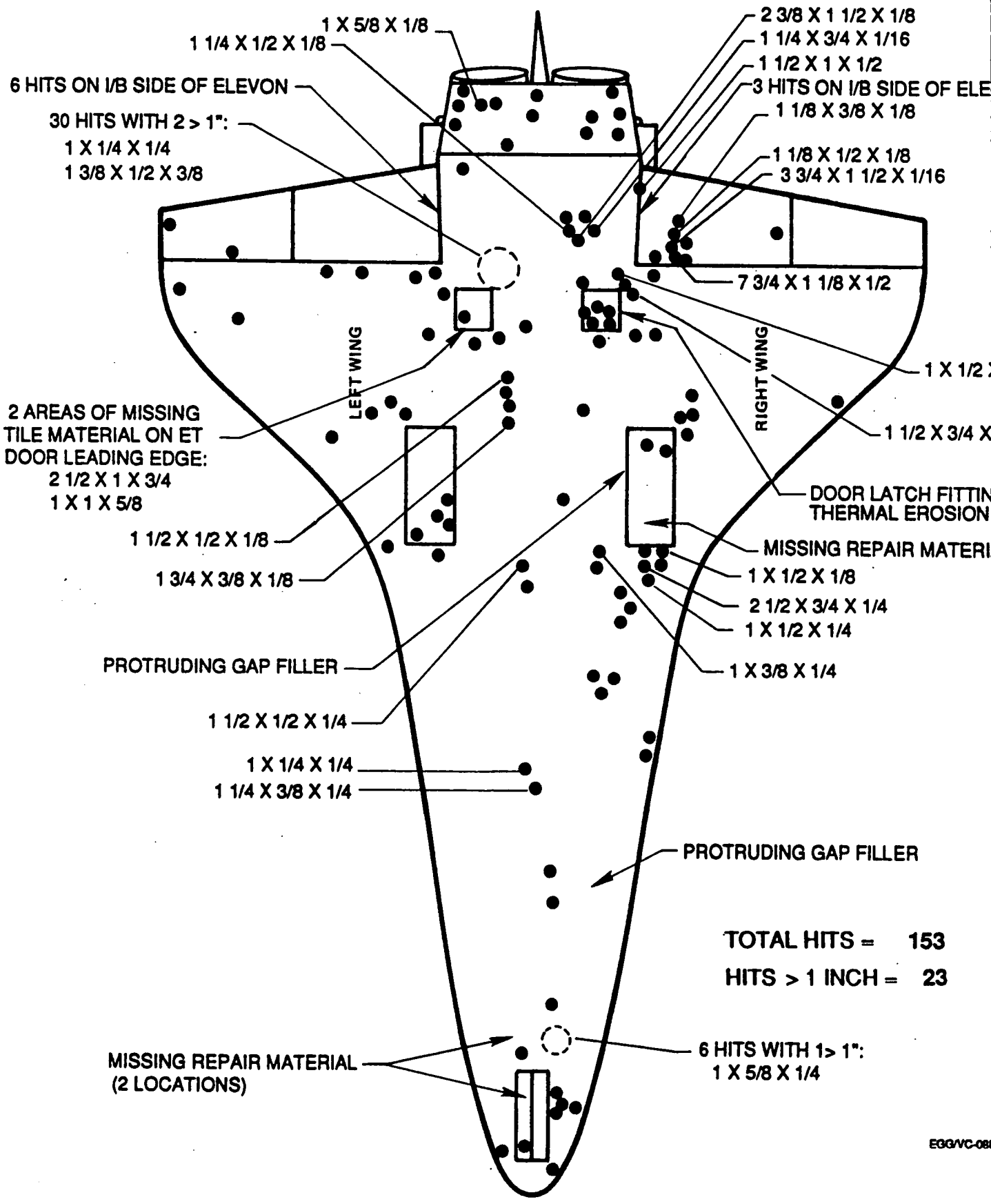


FIGURE 16. **STS-40**
DEBRIS DAMAGE LOCATIONS

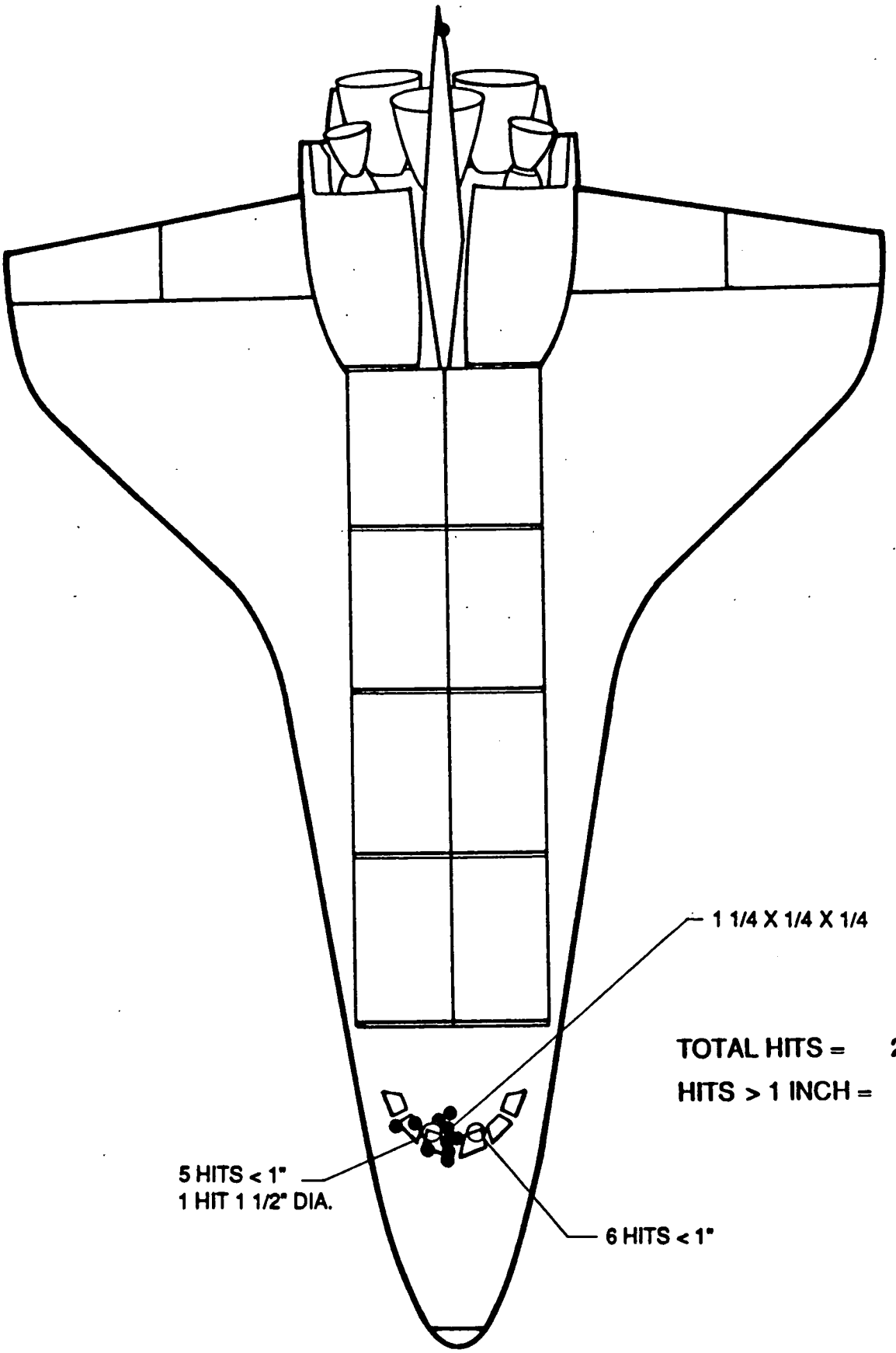
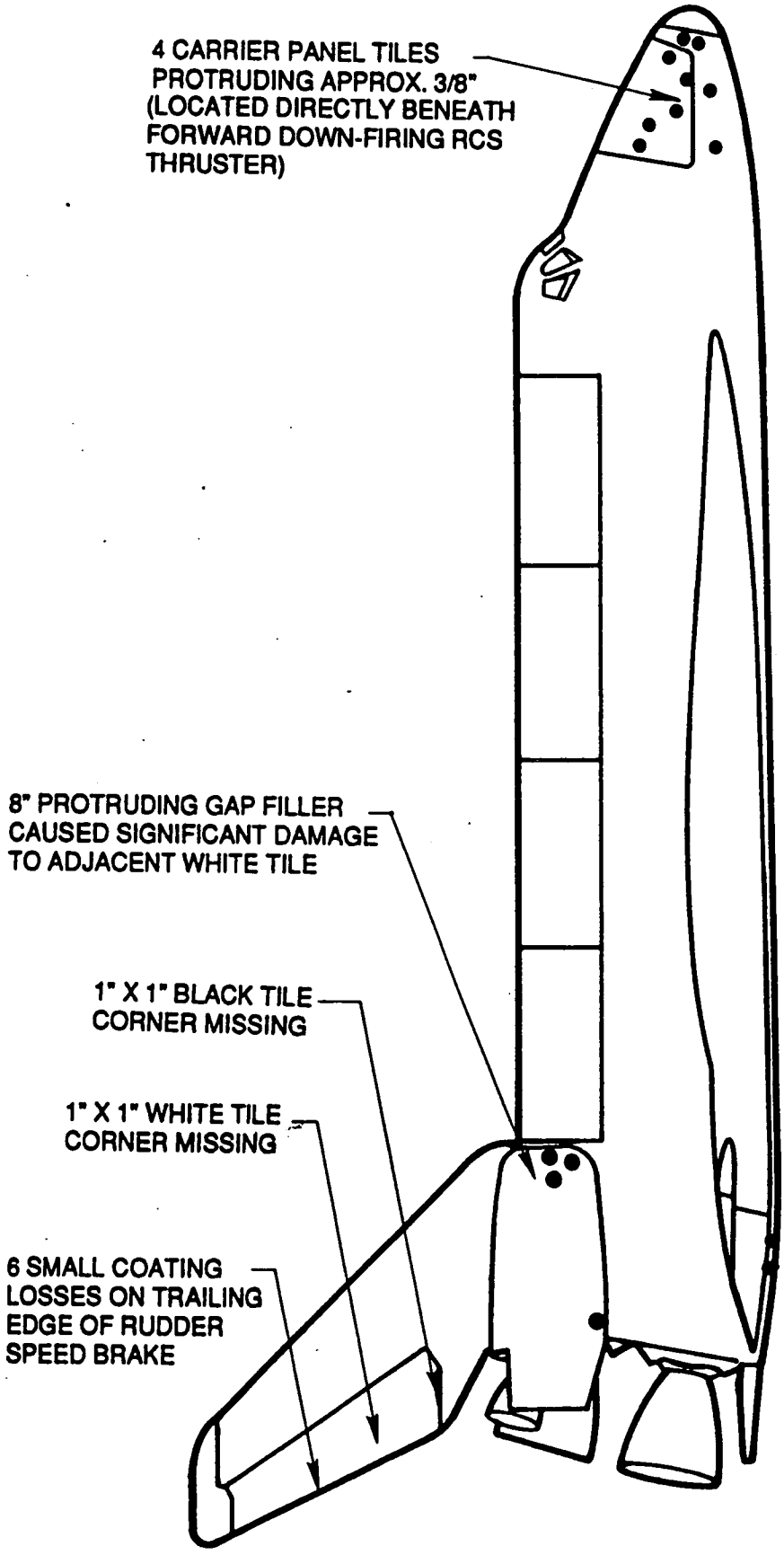


FIGURE 17. **STS-40**
DEBRIS DAMAGE LOCATIONS



TOTAL HITS = 15

HITS > 1 INCH = 0

EGG/VC-

FIGURE 18. **STS-40**

DEBRIS DAMAGE LOCATIONS

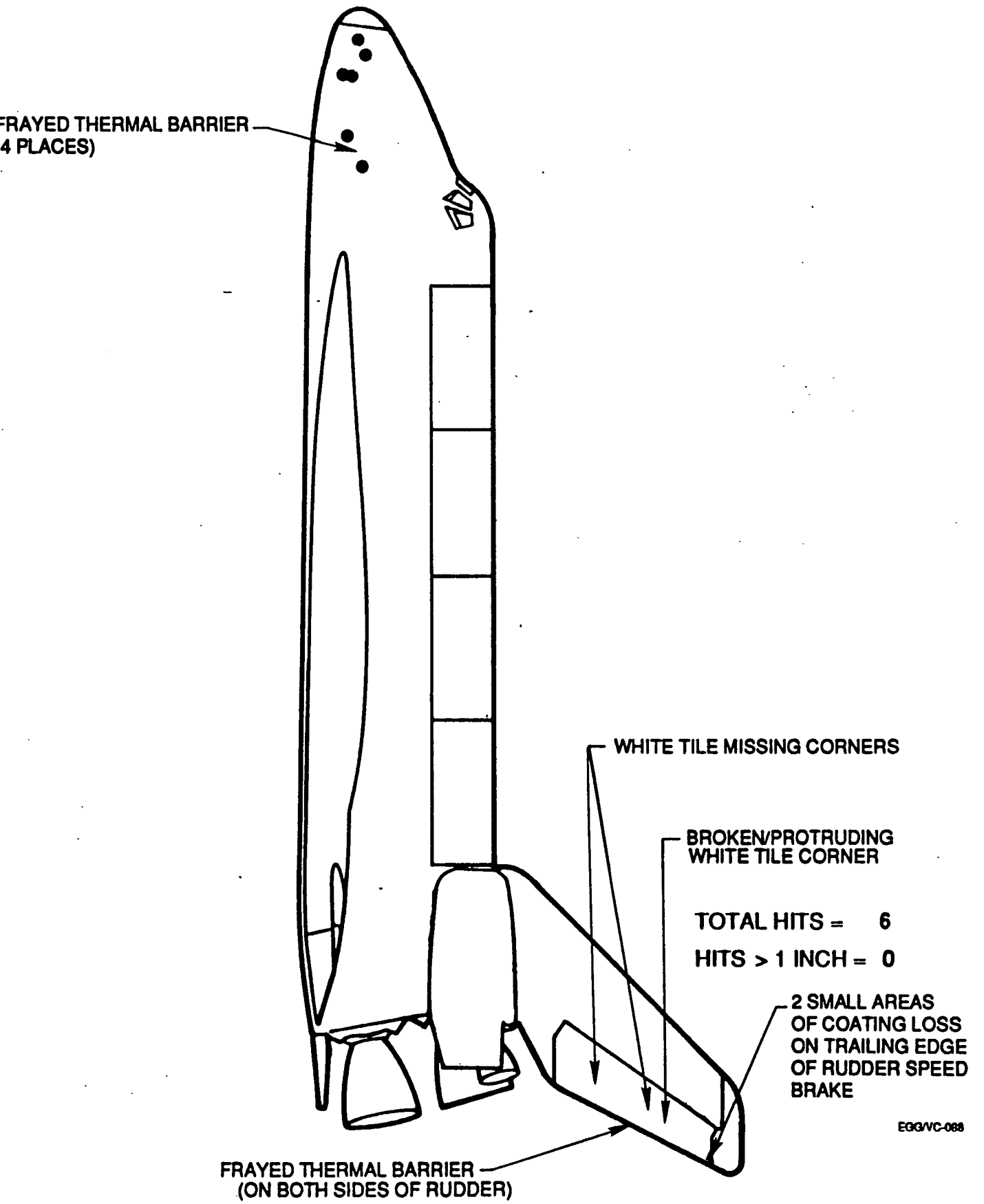
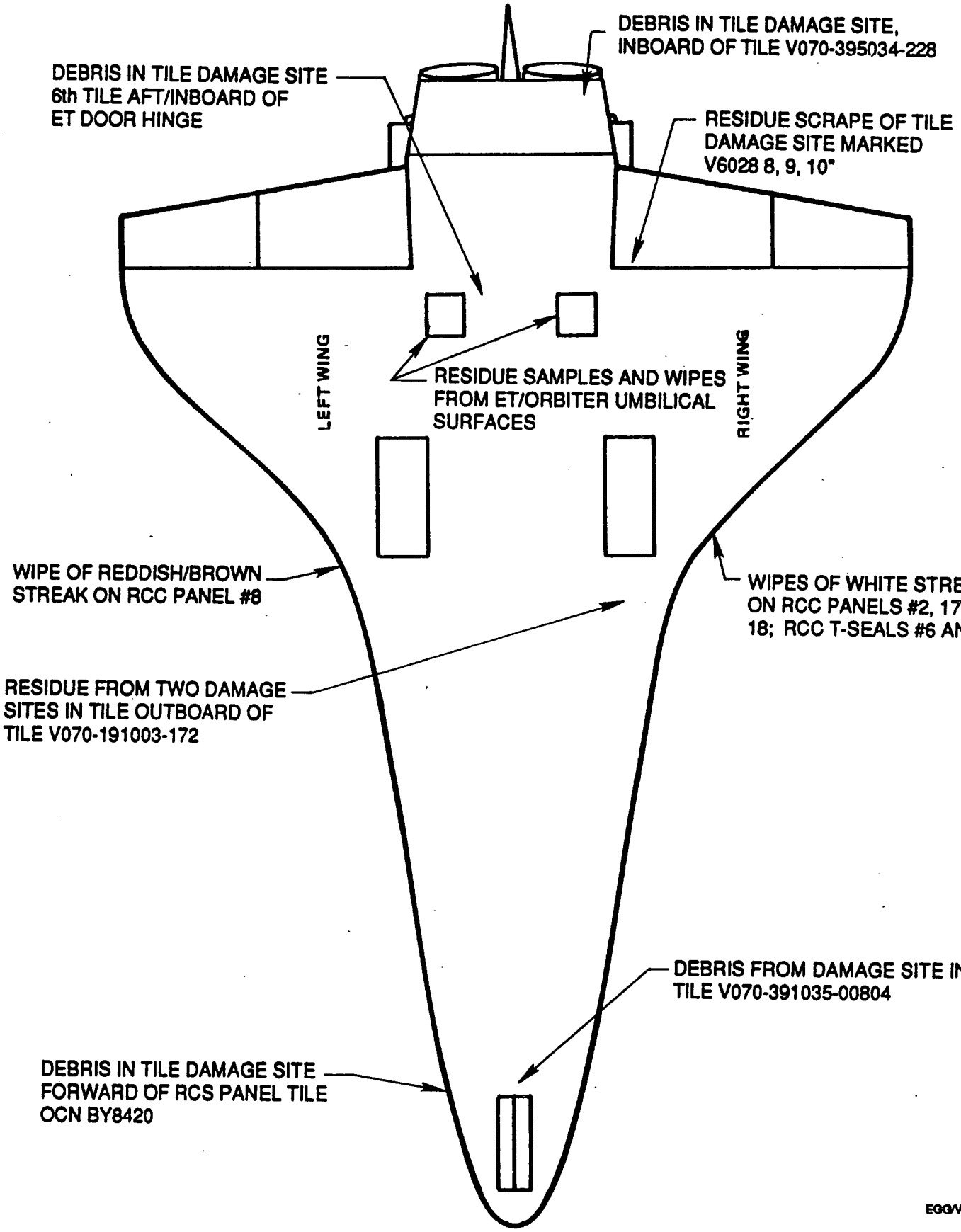


FIGURE 19. **STS-40**

CHEMICAL SAMPLE LOCATIONS



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

Damage to the base heat shield tiles was less than average. The outer layer of SSME #3 closeout blanket was peeled back from 1:30 to 2:00 o'clock (approximately 16 inches in length), SSME #1 blanket showed minor fraying from 4:30 to 6:00 o'clock, and the outer layer of SSME #2 blanket was missing from 2:30 to 3:30 o'clock (approximately 30 inches).

The Orbiter upper surface white tiles exhibited typical degradation. Four white tiles on the vertical stabilizer had broken corners, three of which were missing.

A piece of gap filler sleeving material approximately 8 inches in length was loose and protruding from the RH OMS pod leading edge and caused significant damage to two adjacent white tiles. In addition, several small pieces of gap filler sleeving material were protruding slightly on the leading edges of both OMS pods with no detectable damage to adjacent tiles. The overall condition of the TPS on the OMS pods was good.

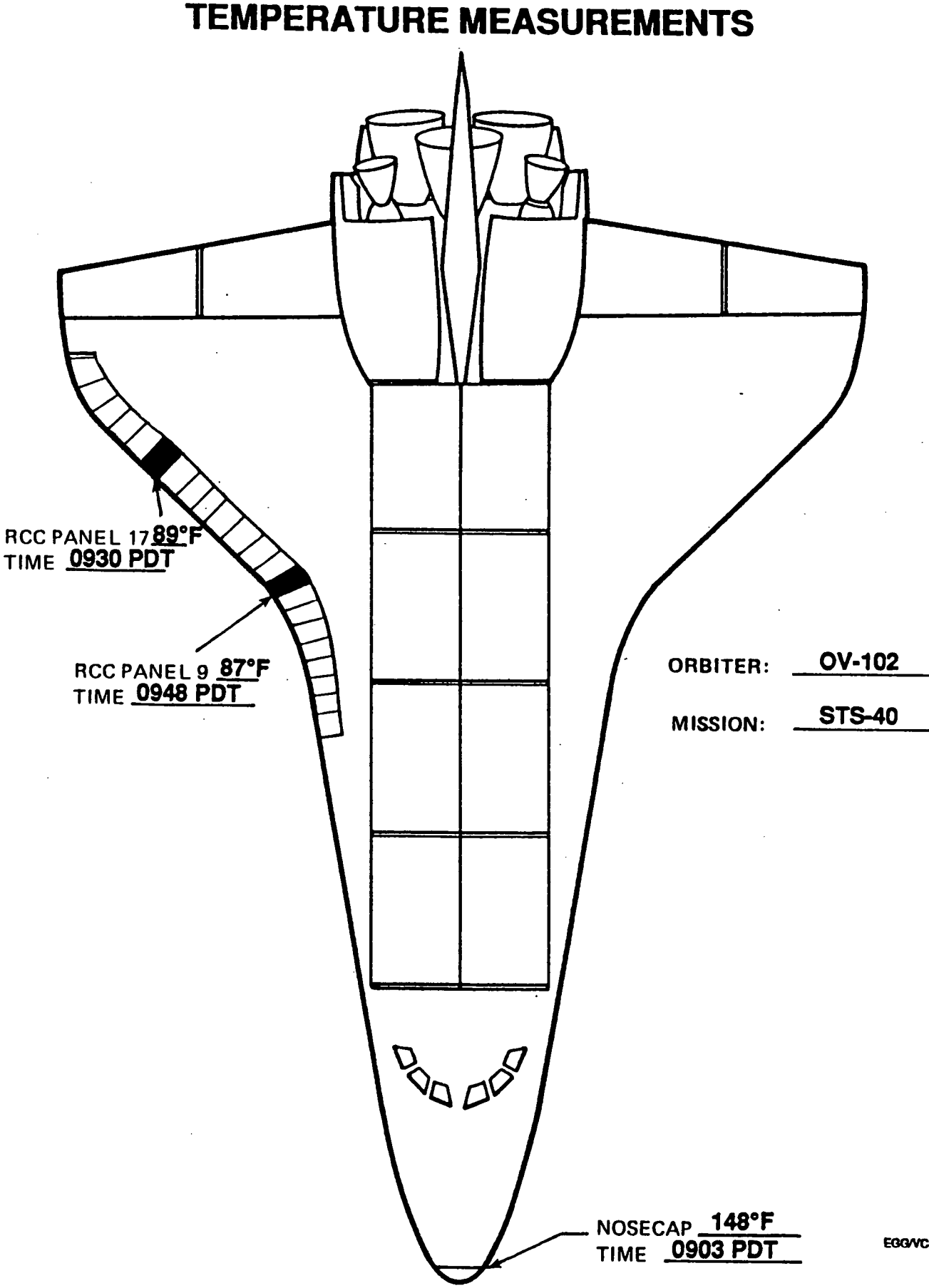
There were no external visible indications associated with the payload bay door environmental seal anomaly. This seal had debonded at the splice point and protruded from the retainer while on-orbit. The door was successfully closed prior to re-entry when the seal was compressed between the guide hook on the LH aft bulkhead roller assembly housing #4 and the fore-aft PLBD load roller. The LH aft bulkhead latching mechanism was then able to cycle. The seal anomaly may be the result of airflow intrusion during ascent or vehicle flexure due to payload weight.

White streaks were present on the RH wing leading edge RCC panels #2, 17, and 18; and T-seals #6 and 11. A reddish-brown streak was present on the LH wing leading edge RCC panel #8. Samples of selected streaks were taken for laboratory analysis (Figure 19).

Orbiter windows #3 and #4 exhibited moderate to heavy hazing with a few small streaks. Windows #2 and #5 had light to moderate hazing with several small streaks. Laboratory analysis was performed on samples taken from all windows.

The KSC Shuttle Thermal Imager (STI) was used to measure the surface temperatures of several areas. Twenty-four minutes after landing, the Orbiter nosecap RCC was 148 degrees F. The RH wing leading edge RCC panel #9 was 87 degrees F sixty-nine minutes after landing. Fifty-one minutes after landing the RH wing panel #17 was 89 degrees F (Figure 20).

FIGURE 20. **STS-40 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**



Runway 15 was inspected by the Debris Team on June 13, 1991, and potentially damaging debris was removed. Runway 22 was inspected and swept by Air Force personnel. Both runways were found to be in acceptable condition.

The post landing inspection of Runway 22 was performed approximately 1/2 hour after landing. No flight hardware was found on the runway or overrun.

In summary, while the total number of Orbiter TPS debris hits was greater than average, the number of hits with a major dimension of one inch or larger was near average when compared to previous flights as shown in the comparison charts (Figures 21-23). 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 11.

FIGURE 21. STS-40 DEBRIS DAMAGE ASSESSMENT SUMMARY

	Hits > or = 1"	Total Hits
Lower Surface	23	153
Upper Surface	2	23
Right Side	0	11
Left Side	0	6
Right OMS Pod	0	4
Left OMS Pod	0	0
TOTALS	25	197

COMPARISON TABLE

STS-6	36	120
STS-7	48	253
STS-8	7	56
STS-9 (41-A)	14	58
STS-11 (41-B)	34	63
STS-13 (41-C)	8	36
STS-14 (41-D)	30	111
STS-17 (41-G)	36	154
STS-19 (51-A)	20	87
STS-20 (51-C)	28	81
STS-23 (51-D)	46	152
STS-24 (51-B)	63	140
STS-25 (51-G)	144	315
STS-26 (51-F)	226	553
STS-27 (51-I)	33	141
STS-28 (51-J)	17	111
STS-30 (61-A)	34	183
STS-31 (61-B)	55	257
STS-32 (61-C)	39	193
STS-26R	55	411
STS-27R	298	707
STS-29R	23	132
STS-30R	56	151
STS-28R	20	76
STS-34	18	53
STS-33R	21	118
STS-32R	15	120
STS-36	20	62
STS-31R	14	63
STS-41	16	76
STS-38	8	81
STS-35	17	147
STS-37	10	113
STS-39	16	238
STS-40	25	197

FIGURE 22. COMPARISON TABLE

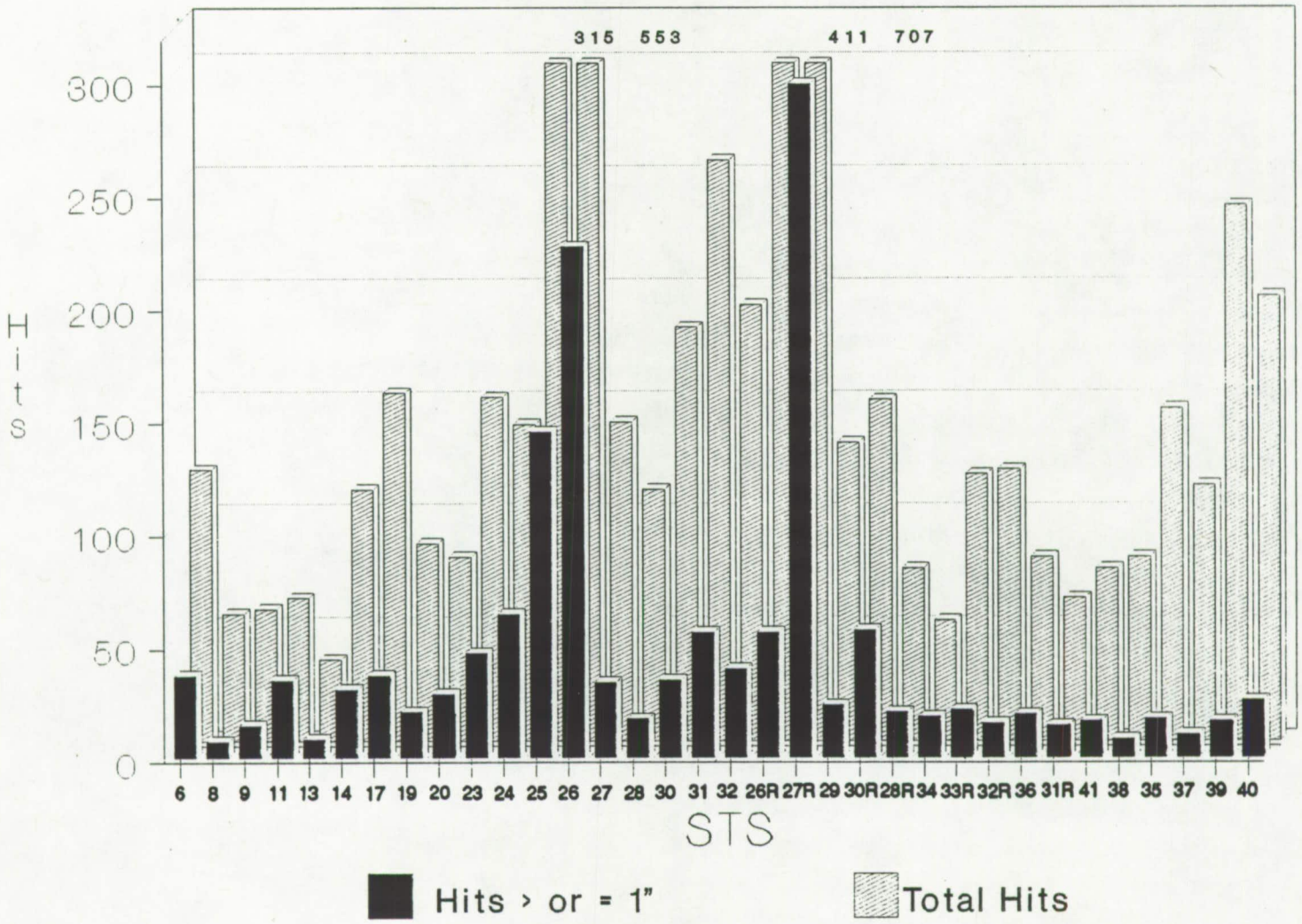
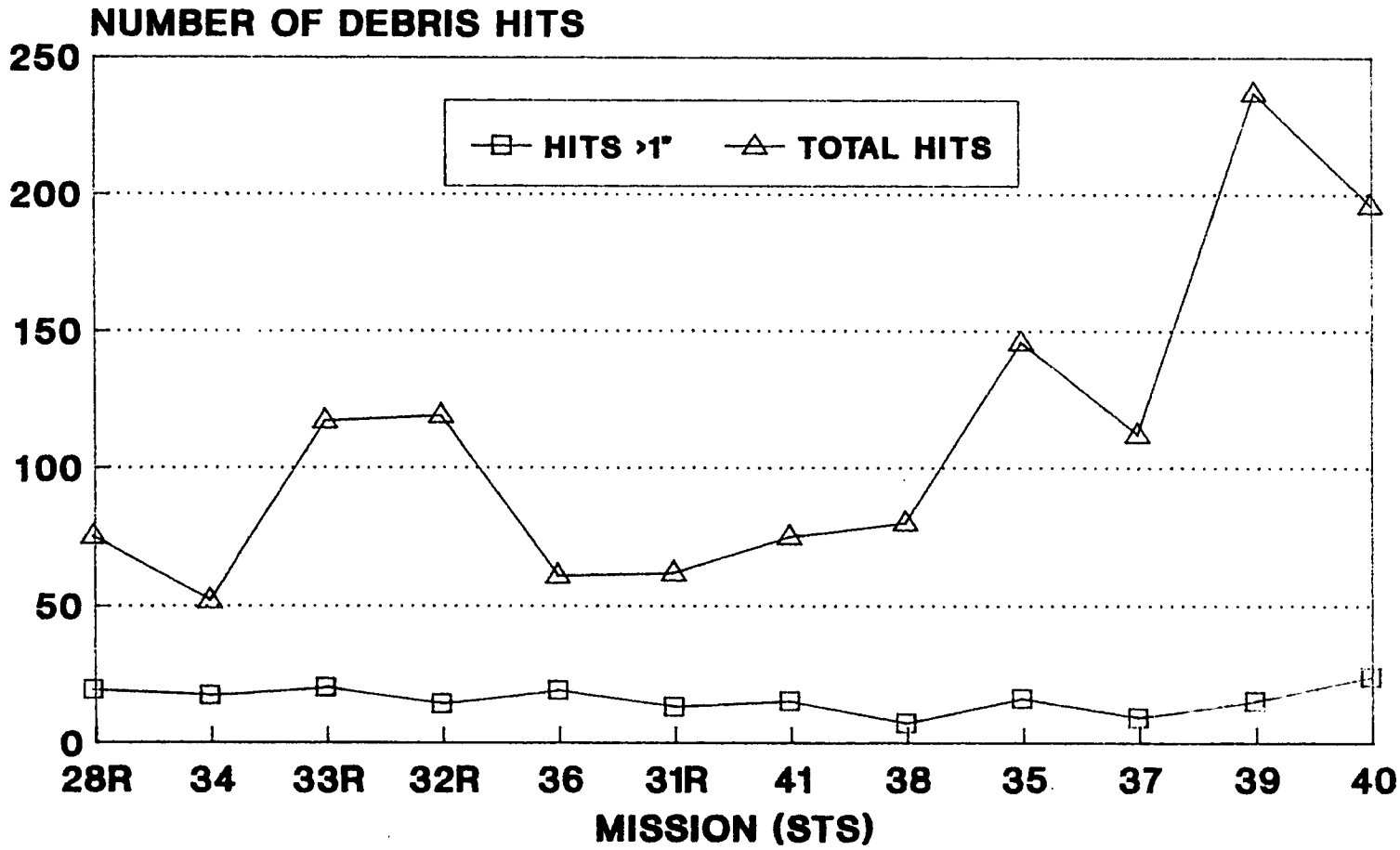
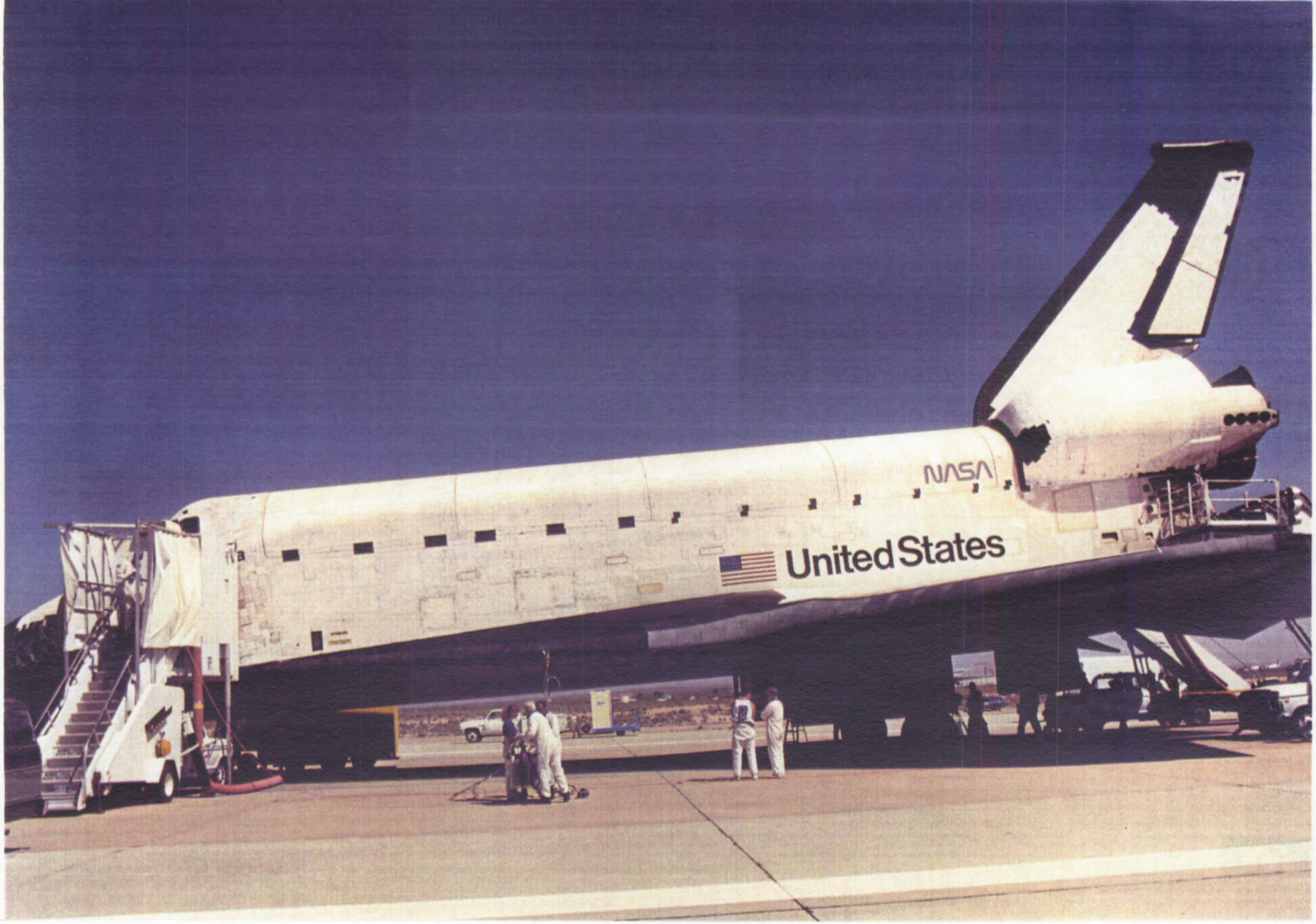


FIGURE 23. ORBITER TPS DEBRIS DAMAGE
STS-28R THROUGH STS-40





Overall view of OV-102 left side

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Overall view of OV-102 right side

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Front view of OV-102 during tow operations

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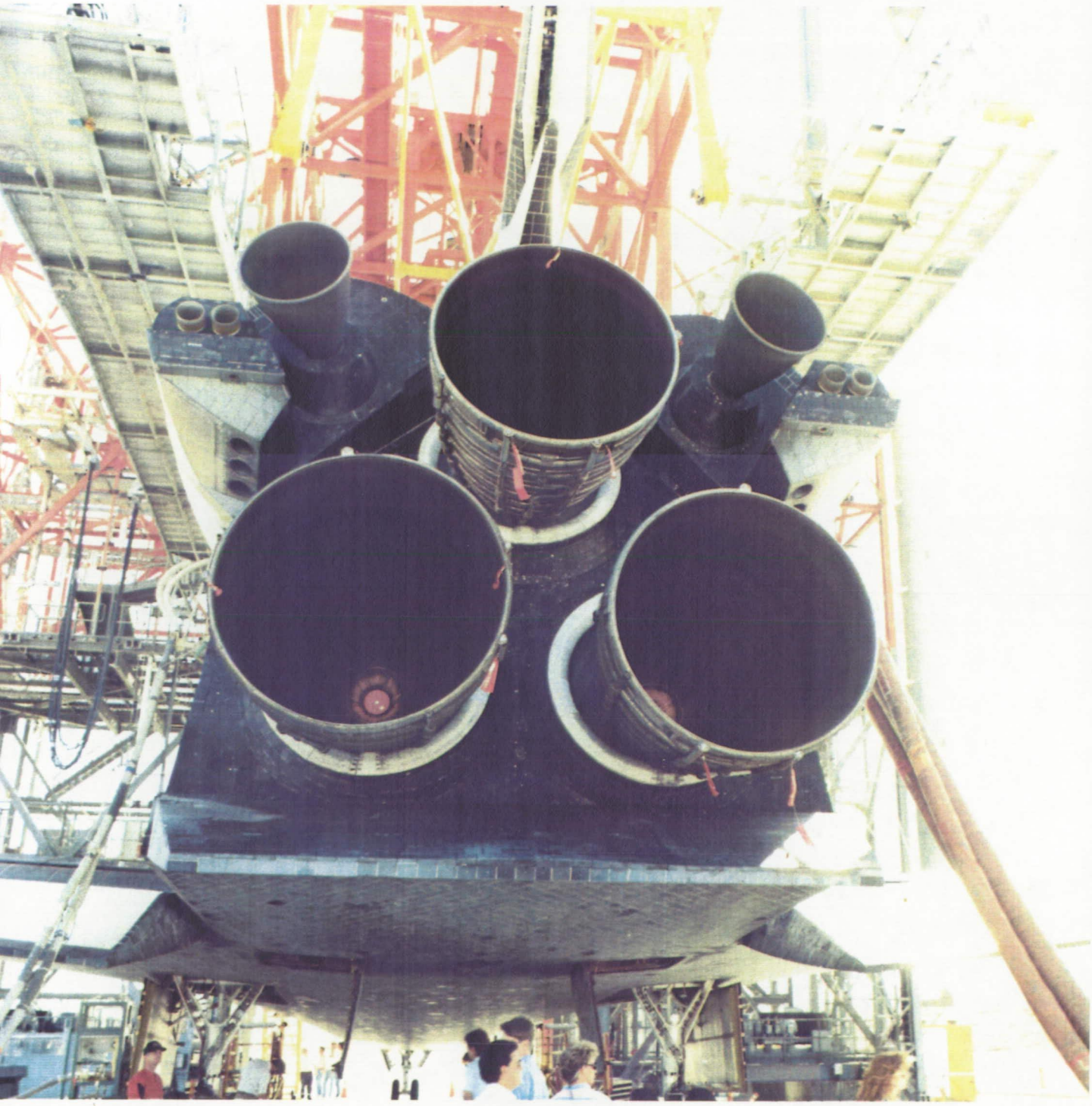

Overall view of SSME's, base heat shield, and body flap

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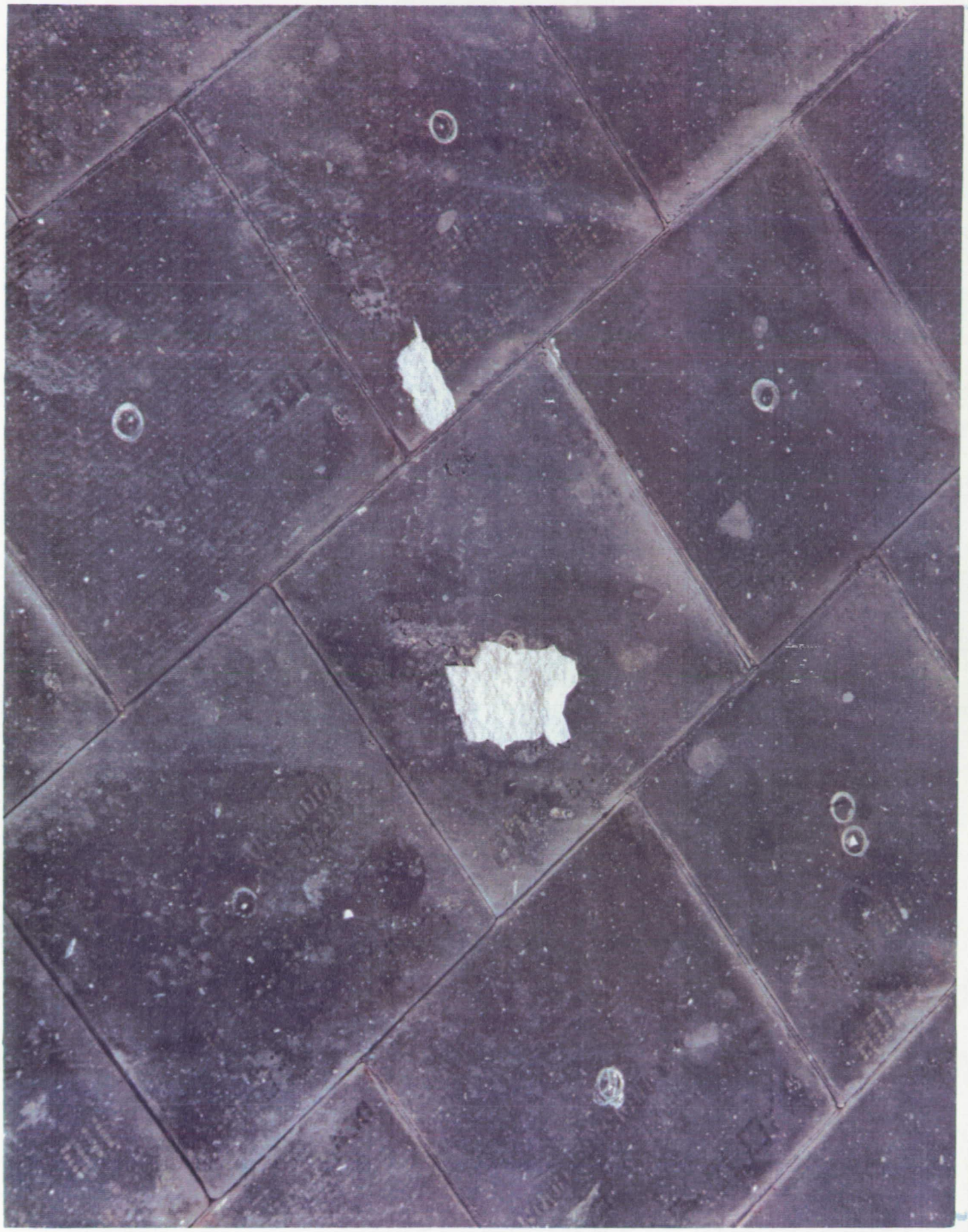

Typical tile debris impact damage on the lower surface

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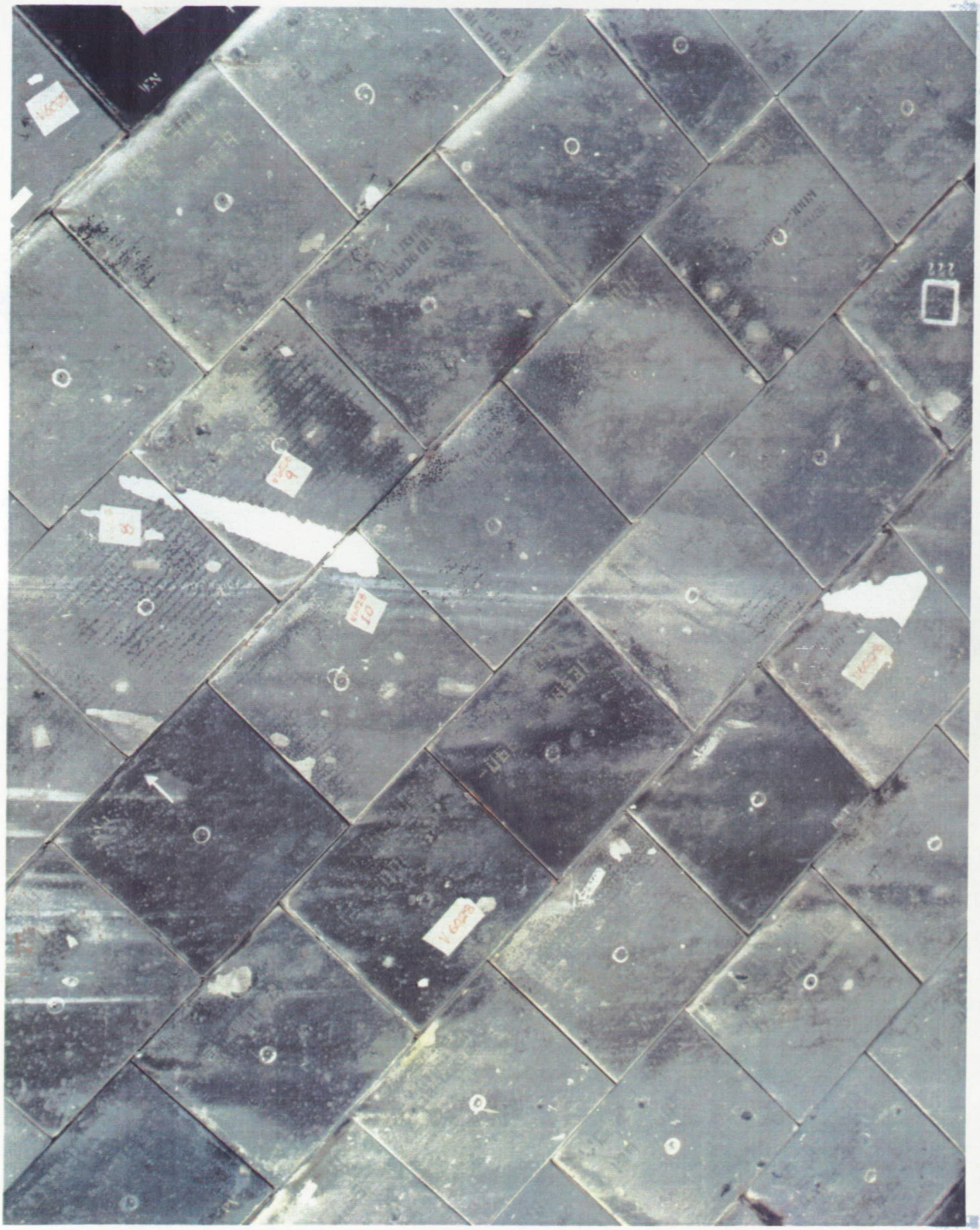

Typical tile debris impact damage on the lower surface

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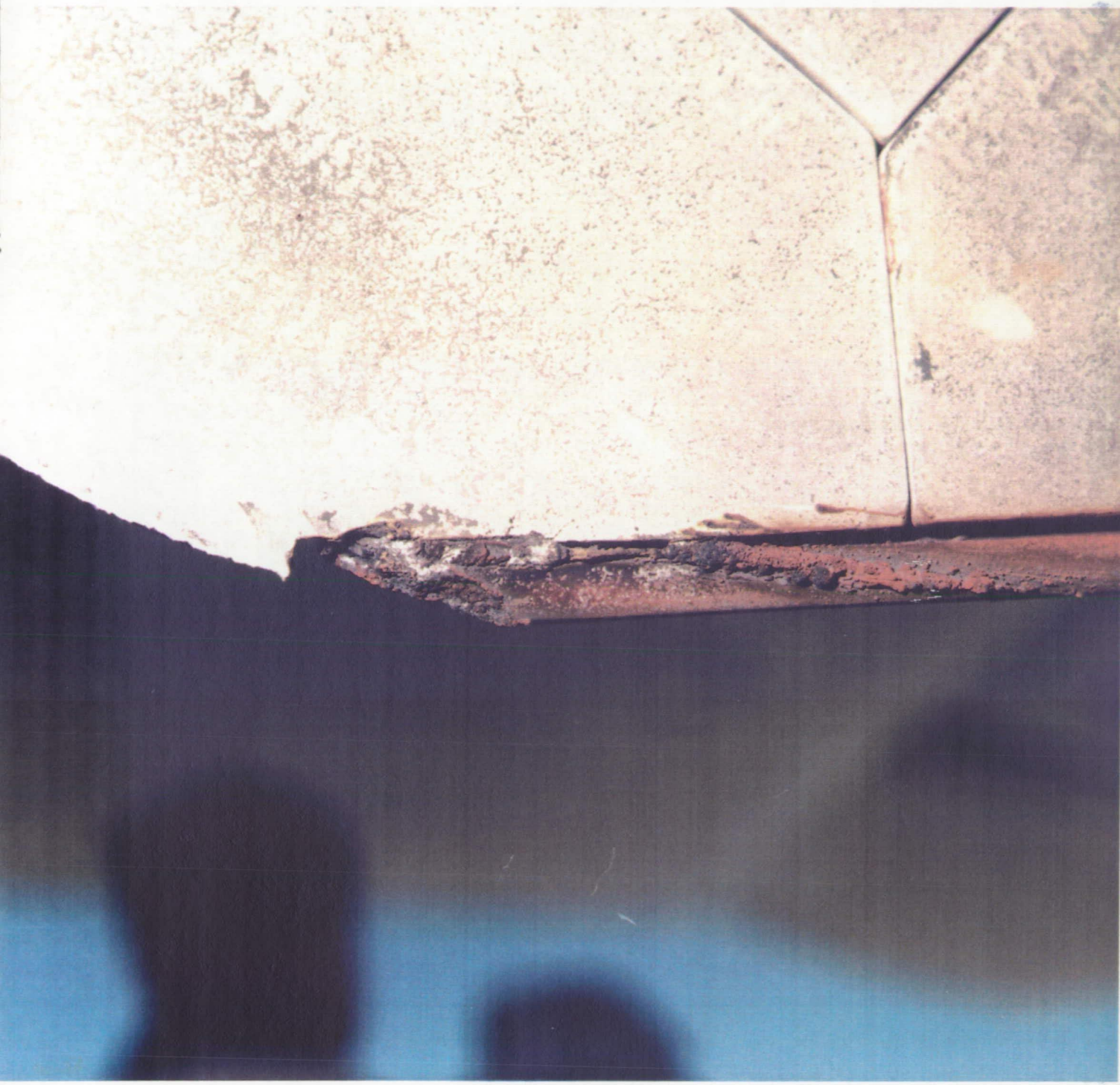

The RH ET/Orbiter (LO2) umbilical door centerline forward outboard latch fitting and adjacent tile sustained hot gas intrusion and exhibited significant melting/erosion due to the lack of or degradation of the RTV seal.

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Overall view of the LO2 ET/ORB umbilical cavity. No hardware was found on the runway or missing from the umbilical.

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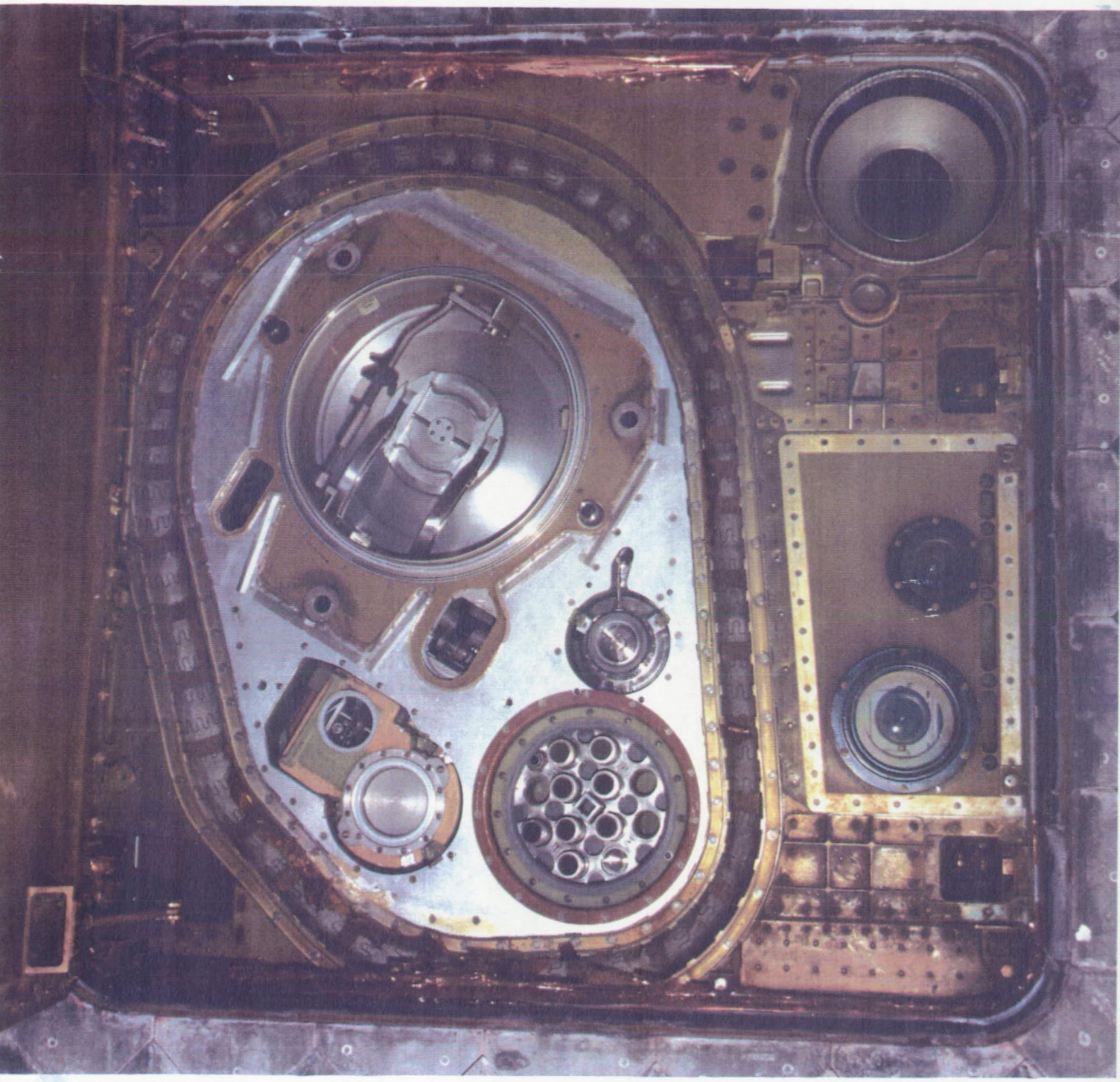

Overall view of the LH2 ET/ORB umbilical cavity. No hardware was missing. There was no galling or raised metal on the shear pins that could be associated with the loss of the LH2 ET/ORB shear pin bushing during ET separation.

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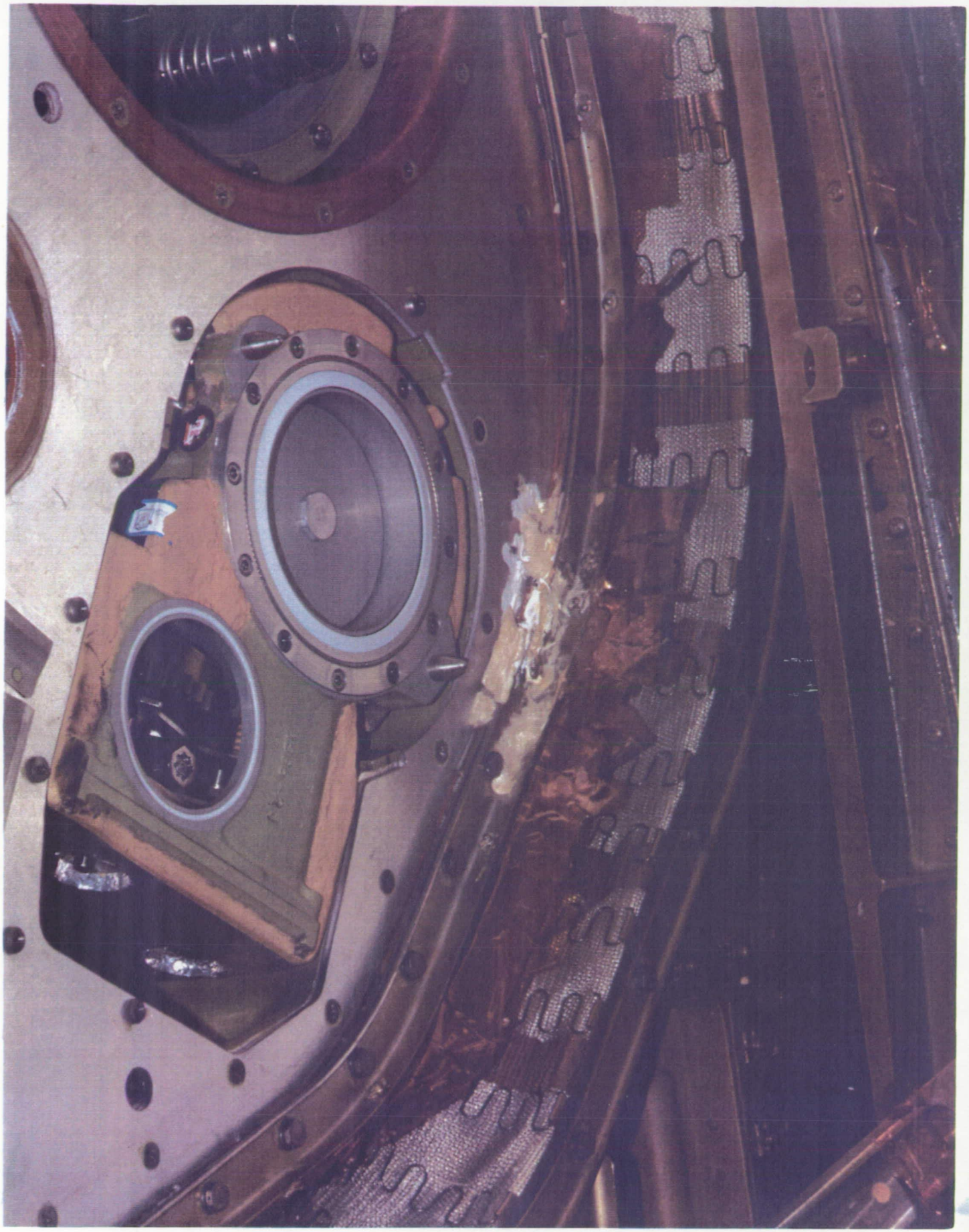

Closeout foam intrusion along the purge barrier seal

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COLOR PHOTOGRAPH

Typical damage to the outer layer of the SSME closeout blanket

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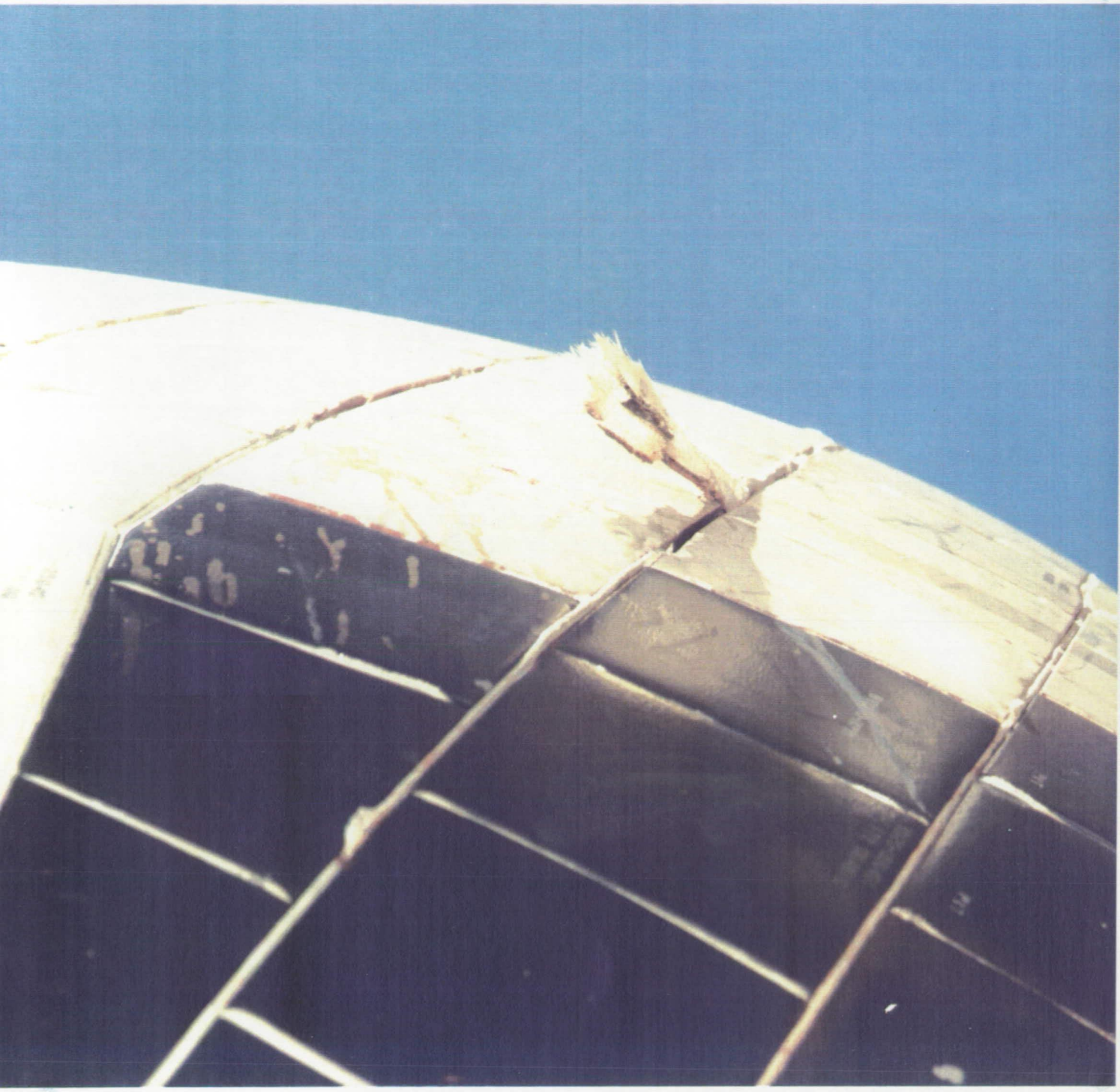
COLOR PHOTOGRAPH



Eight inch long piece of gap filler sleeving material protruded from the RH OMS pod leading edge and caused significant damage to two adjacent white tiles

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COLOR PHOTOGRAPH

The payload bay door environmental seal debonded at the splice point and protruded from the retainer while on-orbit. The door was successfully closed prior to re-entry when the seal was compressed between the guide hook on the LH aft bulkhead roller assembly housing #4 and the fore-aft PLBD load roller. The LH aft bulkhead latching mechanism was then able to cycle.

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COLOR PHOTOGRAPH

Orbiter RTV caused a reddish-brown streak on the LH wing leading edge RCC panel #8

ORIGINAL PAGE
COLOR PHOTOGRAPH

10.0 DEBRIS SAMPLE LAB REPORTS

A total of 24 samples were obtained from Orbiter OV-102 during the STS-40 post landing debris assessment at Ames-Dryden Flight Research Facility (ADFRF), California (Figure 19). The 24 submitted samples consisted of 8 Orbiter window wipes (W 1-8), 6 wing leading edge RCC samples (5RH, 1LH), 7 tile residue samples, and 3 ET-ORB umbilical wipes (1LH2,2LO2). The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. The specific elemental analysis is shown in the appended MAB report. 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. Metallics
2. RTV, glass fibers, insulation
3. Cerium-rich materials
4. Dust, rust and salt
5. Organics and paint
6. Earth compounds

Debris analysis provides the following correlations:

1. Metallic particles (aluminum, stainless and carbon steel, and 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. RTV, glass fibers, and insulation originate from Orbiter TPS (thermal protection system).

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

4. Dust and salt are naturally-occurring landing site products, rust is an SRB/BSM exhaust residue.

5. Organics were found to be polyamide, ester, and carbohydrate (adhesive/proteinaceous origin); polysulfide (SRB closeout origin); and polystyrene, polyethylene, and cellulose fibers (sample bag/cloth origin). Paint is of flight hardware/facility/GSE origin.

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

Orbiter Wing RCC Panels

Results of the wing leading edge RCC samples indicated the presence of the following materials:

1. Metallic particles
2. Black and white silicon-rich materials
3. RTV, Black and white tile, and insulation glass
4. "Elephant hide"-ensolite foam
5. Dust and salt
6. Rust and paint
7. Organics and Organic fiber

Debris analysis provides the following correlations:

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

2. Black and white silicon-rich particles originate from Orbiter thermal protection system (TPS).

3. RTV, black and white tile, and insulation are Orbiter TPS materials.

4. "Elephant hide"-ensolite foam is used as a padding/ liner for RCC protective covers.

5. Dust and salt are landing site materials.

6. Rust is common to SRB/BSM exhaust residue. Paint is used on flight element, ground support equipment (GSE), and facility as a coating material.

7. Organics were polyamide, ester, and carbohydrate (adhesive/proteinaceous origin); polysulfide (SRB closeout origin); and polystyrene, polyethylene, and cellulose fibers (sample bag/cloth origin).

Orbiter Tile

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

RTV, Black and white silicon-rich tile.

Debris analysis provides the following correlations:

RTV, Black and white silicon-rich tile originate from the Orbiter thermal protection system (TPS).

Orbiter/ET Umbilical

Results of the Orbiter/ET umbilical samples revealed the presence of the following materials:

1. Metallics
2. RTV, tile, insulation, glass fibers
3. Dust, rust and salt
4. Organics and paint

Debris analysis provides the following correlations:

1. Metallic particles (Aluminum, Titanium, Carbon, and Stainless steel alloys are common to SRB/BSM residue, but are not considered a debris concern in this quantity (micrometer) and have not generated a known debris effect.

2. RTV, tile, insulation, and glass fibers are used in Orbiter thermal protection system (TPS).

3. Rust if common to SRB/BSM exhaust, dust and salt are natural environment products.

4. Organics from the umbilicals were found to contain closeout materials of this area; other organics were of sampling origin (cloth/bag); paint is used on flight element, facility, and ground support equipment.

Conclusions

The STS-40 mission sustained Orbiter tile TPS damage to a greater than average degree. 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, landing site products, organics, and paint. Also noted was the presence of SRB closeout material (polysulfide).

Samples from the Orbiter wing RCC panels were found to contain SRB/BSM exhaust residuals, Orbiter thermal protection system (TPS) materials, "elephant-hide" foam from RCC protective covers, and organic materials. These types of materials have been noted in previous mission's sample analyses and do not provide a single source debris anomaly.

The Orbiter tile sample results provided indications of thermal protection system (TPS) only. The absence of non-TPS material suggests the damaging debris was either not retained in the damage site or was TPS material.

The Orbiter/ET umbilical samples were found to contain 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. All of these materials are within the established data base and do not provide indications of material or process problems.

11.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 9 Post Launch Anomalies, including two IFA candidates, were observed on the STS-40 mission.

11.1 LAUNCH PAD/FACILITY

1. HDP #6 shim sidewall material was intact, but debonded. Sidewall material should remain bonded to the HDP shoe. (KSC processing item).

2. Damage to the facility, which was less than usual, included 1) a phone box cover on the RSS 207 foot level torn from its hinges, 2) an OIS box on the access platform for the LH SRB forward skirt detached from its mount and hanging by a cable, 3) a section of cable tray, approximately 100 feet long, on the east pad apron torn from its mounting, 4) a 4"x7" metal placard from an unknown origin found on the MLP deck southwest of the LH2 TSM, 5) a light fixture from the 135 foot level of the -Y Orbiter weather protection structure found on the FSS 115 foot level. These items will be repaired during the Pad B refurbishment period. (KSC pad turnaround item).

11.2 EXTERNAL TANK

1. Shortly after ET separation, on-orbit photography showed a metallic cylinder drifting past the LH2 ET/ORB camera and moving away from the Orbiter. Inspection of OV-102 ET/ORB umbilicals after landing revealed no missing hardware. KSC identified the object as the outboard shear pin bushing from the ET half of the LH2 ET/ORB umbilical. The bushing measures 1.75 inches in diameter by 1.432 inches in height with 0.2 inch wall thickness. On-orbit umbilical photography confirmed the inboard bushing on the LH2 umbilical and the two bushings on the LO2 umbilical were still in place after ET separation. No hardware should be lost from ET during separation. (IFA candidate).

2. On-orbit photography showed three TPS divots on the LH2 tank-to-intertank flange closeout. Two divots, approximately 8-10 inches in diameter, were located below the intertank access door and GH2 vent line QD, and the third divot, 6-8 inches in diameter, was located below the +Y ET/SRB forward attach point. A fourth divot occurred on the -Z side of the tank in the aft hardpoint closeout. The ET should not lose TPS during ascent. (ET Project Item).

11.3 SOLID ROCKET BOOSTERS

1. Three frangible nut fragments and an NSI cartridge fell from the HDP #5 DCS/stud hole shortly after liftoff. One fragment was found in the HDP #5 holddown post. A 3.25" x 1" x 0.5" frangible nut fragment lay on the MLP deck under the sound suppression pipe just east of HDP #5. A frangible nut web piece 2 inches long fell from the HDP #3 DCS/stud hole after the vehicle had gained 6-8 feet altitude. These fragments were observed in the post launch film review. SRB post flight assessment revealed the HDP #7 DCS plunger was obstructed by frangible nut halves. Large debris fragments should be contained by the DCS. (SRB project item).

2. The RH frustum had no areas of missing TPS but had 32 MSA-2 debonds over fasteners. The LH frustum exhibited no missing TPS but had 30 MSA-2 debonds over fasteners. MSA-2 debonds can potentially lead to loss of material during ascent (SRB project item)

3. Three LH IEA cover bolts near the lower ET/SRB strut were bottomed out and the washers under the bolt heads could be rotated. (SRB project item).

11.4 ORBITER

1. Tile surface coating material was lost from the base heat shield at one location outboard of SSME #3 and at 3 locations outboard of SSME #2. Surface coating material was also lost from tiles on the upper surface of the RH outboard elevon. (Orbiter project item).

2. 35mm camera in the LO2 ET/ORB umbilical failed and provided no data on ET separation. 16mm camera with 5mm lens in the LH2 ET/ORB umbilical failed and provided no data on SRB and ET separation. Suspect problems were internal to cameras. (IFA candidate).

APPENDIX A.

FLIGHT PROBLEM REPORT
OV-102 FLIGHT 11

NO. STS-40-V-16
Page 1 of 3

Statement Of Problem:
LH2 Umbilical Guide Pin Bushing Dislodged

Discussion:
A postflight review of film from the 16 mm camera located in the LH2 ET umbilical well, revealed a cylindrical object drifting past the camera and moving away from the Orbiter. The object entered the field of view approximately 44 seconds after separation and was visible for about 2.5 seconds. The object appeared to be metallic and hollow with an approximate length/diameter ratio of 1.2. Inspection of the OV-102 Orbiter umbilicals after landing showed no missing hardware. Further review of the ET separation sequence films indicated that the inconel-718 bushing was apparently missing from the outboard LH2 ET umbilical guide pin hole. This determination was based on the lack of sheen around the bushing hole (i.e. the shiny bushing was missing) and the calculated hole diameter at the bushing site was nearer to the inner diameter of the bore rather than the inner diameter of the bushing. The bushing sheen was visible at the LH2 inboard and both LO2 ET bushing locations.

(Continued on next page)

Conclusions:
The LH2 outboard ET umbilical guide pin bushing became dislodged from the ET umbilical plate during ET/Orbiter separation due to unknown reasons. The bushing translated away from the Orbiter and had no effect on the mission.

Corrective Action:
For STS-43, the bushings were verified during mating to be at least finger tight. Several inspection techniques for ET bushing installations have been discussed, but the issue is not as yet settled. Additionally, several tests are being considered to determine the actual pin bushing side load required to dislodge a bushing. Also, testing is being considered to define the distinguishing marks associated with forces necessary to dislodge the bushing.

Effects On Subsequent Missions: None.

Criticality: CAR No: 40RF13 IPR/PR No: None

Resolution: Closed.

Concur

7/12/91 — R.C. Cota/EP2/39033, Subsystem Manager

7/12/91 — for C.S. McMillan/VP3/35913, Evaluation Manager

G.A. Fiedler/NA/33126, SR&QA Manager

Approval:

D.M. Germany (Date)
Manager, Orbiter and GPE Projects

PRCBD No: _____ (Date)

Discussion: (Continued)

Each ET umbilical has two guide pin bushings. Their purpose is to accept the guide pins located on the Orbiter umbilical that provide alignment control during umbilical mating as well as during umbilical separation after MECO. The bushing has a stepped outer diameter of 1.750 and 1.648 inches, an inner diameter of 1.250 inches, and a length of 1.432 inches.

they align pins Shea

The bushing is designed to remain within the ET during separation. The main concern with this bushing becoming dislodged during separation is that it may migrate into the Orbiter's ET umbilical door closure mechanism, causing a failure of the door to close. However, this is unlikely since the relative motion of the debris is away from the Orbiter and several translation maneuvers are performed prior to umbilical door closure that tend to further move the vehicle away from the debris. Therefore, the likelihood of the bushing finding its way into critical parts of the mechanism is small; and if it did, the umbilical door could be recycled in an attempt to remove the bushing. It can still have caused damage

An investigation into why the bushing became dislodged has, thus far, been unable to determine the reason. These bushings are retained in the body by a shrink fit interference that by blueprint is between 0.0005 to 0.0015 inch at ambient temperatures. This interference increases by an additional 0.0027 inch at LH2 temperature because of differential contraction of the aluminum body/inconel-718 bushing. The combined minimum interference should require an axial load of about 8100 pounds to dislodge the bushing. The mating Orbiter pin has two diameters that provide a minimum diametrical clearance of 0.011 inch for the first 0.36 inch of separation travel, then 0.014 inch of diametrical clearance for the remaining 1.2 inches of pin-to-bushing travel. This allows for up to 3 degrees of "angular" misalignment.

A review of the build documentation on this disconnect failed to provide an explanation into the apparent missing bushing. Recorded measurements of the bore actual diameter showed it provided an interference of 0.0004 inch above the minimum required. Bushing dimensions were not recorded, but it was from a lot where all dimensions were noted as being within requirements. This indicates that the dislodging forces should have been in the 8000 pounds range. ET separation dynamics were nominal. A postflight review of umbilical plate retractors showed no evidence of binding or cocking of the umbilical plate. An inspection of the OV-102 pins revealed a number of light burnish marks on the outboard guide pin. However, all burnish marks were visible on preflight photographs except for a linear burnish mark noted at the 11:00 position (12:00 being toward the nose) and extending from the beginning of the tapered section to the end of the pin. A similar mark was also noted on the LH2 inboard guide pin, as well as on all four pins on OV-103.

A review of prior OV-102 ET separation photographs suggests that the same location may be missing its bushing on STS-5 and STS-28. The film of STS-3 shows that the bushing is definitely in place. Other mission films are either too dark and/or the location is too obscured by H_2 ice to determine the bushing status. STS-40 was the second flight for this umbilical (installed from OV-105 following the STS-35 mission scrub for LH2 leakage), but first flight film is not available because STS-35 separation occurred in darkness.

(Continued on next page)

Discussion: (Continued)

Possible causes of the bushing removal include a manufacturing and/or inspection problem that resulted in improper bushing-to-ET umbilical plate fit or a cracked ET umbilical plate around the bushing that reduced the bushing-to-body interference fit. Also, excessive side and/or angular forces (from an undetermined source) could result in high axial friction forces that could pull the bushing during separation and hydraulic retraction of the Orbiter umbilical plate.

APPENDIX B.

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
JULY 18, 1991

SUBJECT: Orbiter Debris/Residue Samples From STS-40 Landing

LABORATORY REQUEST NO: MCB-0461-91

RELATED DOCUMENTATION: INTERCENTER DEBRIS TEAM REQUIREMENT

1.0 FOREWORD:

1.1 REQUESTER: R. F. Speece/TV-MSD-22/1-3637

1.2 REQUESTER'S SAMPLE DESCRIPTION: The samples were from OV-102, STS-40 landing DFRF, and were identified as:

I. Window wipe
1. window #1
2. window #2
3. window #3
4. window #4
5. window #5
6. window #6
7. window #7
8. window #8

II. RCC wings
9. RH wing RCC "streaks"-6'T'
10. RH wing RCC 11'T'
11. RH wing RCC panel,#18
12. LH wing RCC panel "streak" -8

III. Tile debris
13. Debris in tile hit adjacent to 395034-228
14. Tile hit AFT/INBD of LH umbilical
15. 6-15, residue in damage site 193001-008
16. Debris in tile hits, tile OTBD of 191003-172
17. 6-15, sample V070391035-008084
18. 6-14, sample V070391035-008084
19. Tile hit LFRCS, OCN BY8420

VI. ET umbilical surfaces
20. LH2 ET umbilical surfaces
21. LOX ET umbilical surfaces
22. LOX ET umbilical wipe, outboard

1.3 REQUESTED: Perform material analysis and compare results to known STS materials.

1.4 ADDITIONAL ANALYSTS: William Carman.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

The sample was analyzed by means of optical microscopy (OM), infrared spectrometer (IRS), and electron microprobe with energy dispersive spectrometry (EDS).

2.2 Results:

2.2.1 The particulates were classified into components on the basis of color and texture by OM. The classified components from each sample are listed in Table 1 with elemental analysis.

Table 1

Component ID	Elemental Analysis by EDS*	
	Major	Minor
1.Metallics	Fe,Cr,Cd,Al,Cu,Sn,Pb,Ni,	Ti
2.Red rubbery mtl	Fe,Si	
3.Red mtls	Fe,Cl,Ca,Ti,K,Ce,Si	P,S,Zn,Pb,Al
4.Blk mtls	Si,Fe,S,Cl,Ca,Al,Ti,K	Mg,Cr,Sb,Ce
5.Blk dense tile	Si	
6.Lgt grey mtls	Fe,Ca,Si,Cl,Cu,Zn,Al	K,S,Ti
7.Amber mtls	Fe,K,Si,Al	Ti,Mg
8.yellow mtls	Pb,Ti,Cr	Si,Mg
9.Wht mtls	Si,Ca,Al,S,P,Cl,K,Ti	Ce,Fe
10.Wht clear mtls	Si	
11.Wht fiber tile	Si	
12.Glass fibers	Si,Al	Ca
13.Organics	cellulose,phenolic resin, polyurethane, epoxy,protein,polyamide,polystyrene,carbo-hydrate,ester,polyethylene	
14.Organic fibers	cellulose fibers	

*: O, C, H, and B are not detectable by using this technique.

2.2.2 Table 2 lists estimated amounts of each component versus sample number.

Table 2

Sample No Components	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1.Metallics	T	1	T	T	T	3	1	T	2	5	3
2.Red rubbery mtl	T	T	x	T	T	x	x	x	x	x	x
3.Red mtl	13	10	5	7	10	6	6	5	x	x	x
4.Blk mtl	8	12	6	10	15	10	12	9	36	x	x
5.Blk dense tile	x	x	x	x	x	x	x	x	x	x	x
6.Lgt grey mtl	T	4	2	3	5	1	T	T	x	50	47
7.Amber mtl	22	15	40	28	20	15	29	22	x	x	x
8.Yellow mtl	x	x	x	x	x	x	T	x	x	x	x
9.Wht mtl	20	20	23	30	28	23	20	20	x	5	10
10.Wht clr mtl	2	3	1	2	2	2	2	1	x	x	x
11.Wht fiber tile	x	x	x	x	x	x	x	x	x	x	x
12.Glass fibers	1	5	3	T	T	T	2	3	x	x	x
13.Organics	25	30	20	20	20	40	22	40	60	40	40
14.Organic fibers	T	T	1	T	T	T	T	T	2	T	T
Particle sizes in um	1-250	1-300	1-360	1-350	1-350	1-170	1-300	1-250	1-350	1-250	1-250

Table 2 continue

Sample No Components	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
1.Metallics	13	x	x	x	x	x	x	x	T	T	T
2.Red rubbery mtl	40	x	x	x	x	T	x	T	x	x	x
3.Red mtl	x	x	x	x	x	x	x	x	18	2	1
4.Blk mtl	x	x	x	x	x	x	x	x	13	88	3
5.Blk dense mtl	x	50	2	3	4	5	15	40	x	x	x
6.Lgt grey mtl	7	x	x	x	x	x	x	x	22	x	x
7.Amber mtl	x	x	x	x	x	x	x	x	x	x	x
8.Yellow mtl	x	x	x	x	x	x	x	x	x	x	x
9.Wht mtl	5	x	x	x	x	x	x	x	15	T	x
10.Wht clear mtl	x	x	x	x	x	x	x	x	x	x	x
11.Wht fiber mtl	x	50	98	97	96	95	85	60	x	x	93
12.glass fibers	x	x	x	x	x	x	x	x	T	T	2
13.Organics	35	x	x	x	x	x	x	x	40	10	1
14.Organic fibers	T	x	x	x	x	x	x	x	T	T	T
Particle sizes in um	1-210	1-L	1-L	1-L	1-L	1-L	1-L	1-L	1-380	1-400	1-260

5: Estimated Volume Percent. T: Trace.
x: Not Detected. L: 500 - 5000 micrometer.

3.0 CONCLUSIONS:

3.1 All samples contained trace to small amounts of particulates. The particulates were composed of a combination of metallics, red rubbery materials, red materials, black materials, black dense tile, light grey materials, amber materials, yellow materials, white materials, white clear materials, white fibrous tile, glass fibers, organics, and organic fibers.

3.2 The following samples contained metallics:

1. 300 series stainless steel
2. carbon steel, Cd-alloy, and Al-alloy
3. 300 series stainless steel, Cd-alloy, Cu-alloy
4. Cd-alloy, Sn-Pb alloy
5. Cd-alloy
6. carbon steel
7. Cd-alloy, carbon steel
8. Cd-alloy, carbon steel
9. Al-alloy, carbon steel
10. Al-alloy, carbon steel
11. Al-alloy
12. Al-alloy, carbon steel
20. Al-Fe alloy, carbon steel, 400 series stainless steel
21. Al-alloy, carbon steel, Ti-alloy
22. 300 series stainless steel.

3.3 The sample numbers 1, 2, 4, 5, 12, 20, 21, and 22 contained red rubbery RTV.

3.4 The particulates from window wipe (1 through 8) and ET umbilical (20, 21, 22) contained red materials. The red materials were composed of rust, paints, Ce-Si rich materials (3, 4,) & Fe-Ce rich materials, and Sb-Si-Cl rich materials (21 and 22).

3.5 The samples 1 through 9, 20, and 21 contained black materials. The black materials were composed of dust, rust, salt, Ce-Sb-Fe rich materials (3), and paints.

3.6 The samples 13 through 19 were composed of black dense tile materials.

3.7 The sample numbers 1 through 8, 10, 11, 12, and 22 contained light grey materials. The light grey materials were composed of Si-Al rich powdery materials which could be a part of high temperature insulation.

3.8 The window wipe samples (1 through 8) contained muscovite [$KAl_2(AlSi_3O_{10})(OH)_2$].

3.9 The sample 7 contained trace amounts of yellow paint particles.

3.10 The white materials from the window wipes (1 through 8) were composed mainly of Si-Al-Ca rich materials, Si-rich materials, Ca-Si-S-P rich materials, salt, calcite ($CaCO_3$), alpha-quartz (alpha-SiO_2), albite ($NaAlSi_3O_8$), and paints. Some of samples from the RCC wings (~~13~~ 9 through 1~~9~~8) appeared to contain elephant-hide which might have been heated to high temperature during reentry.

3.11 The window wipes (1 through 8) contained white clear colored alpha-quartz (alpha-SiO_2).

3.12 The samples 13 through 19 and 22 contained white fibrous tile materials.

3.13 The samples 1 through 8 and 20 through 22 contained glass fibers. The glass fibers were composed of Si-Al rich high temperature insulation, Si-rich glass fibers, and Si-Ca-Al rich glass fibers.

3.14 The samples 1 through 12 contained organics and organic fibers. They were identified as cellulose fibers, polyamide, polysulfide, polystyrene, carbohydrate, ester, and polyethylene. The samples 20 through 22 also contained organics and organic fibers. They were identified to be polyurethane, epoxy with nitrate, and epoxy resin binders.

3.15 The particle sizes from samples 1 through 12 were estimated to be 1 to 350 micrometers, while those of samples 13 through 22 were ranged from 1 to 5000 micrometer.

CHEMIST H. S. Kim
H. S. Kim

APPROVED: J. F. Jones
J. F. Jones

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
JULY 19, 1991

SUBJECT: Orbiter Residue Samples From STS-40 Landing

LABORATORY REQUEST NO: MCB-0519-91

RELATED DOCUMENTATION: Intercenter Debris Team Requirements

1.0 FOREWORD:

1.1 REQUESTER: R. F. Speece/TV-MSD-22/1-3637

1.2 REQUESTER'S SAMPLE DESCRIPTION: The samples were from orbiter wing leading edge RCC panel, OV-102, STS-40 and were identified as:

1. R/H #2
2. R/H #17

1.3 REQUESTED: Perform chemical analysis and compare results to known STS materials.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

The sample was analyzed by means of optical microscopy (OM) and electron microprobe with energy dispersive spectrometry (EDS).

2.2 Results:

The particulates were classified into components on the basis of color and texture by OM and the analytical results are listed in Table 1.

Table 1

Component ID	Elemental Analysis by EDS*		Part Size um
	Major	Minor	
1.R/H.#17			
a.Blk mtls(2)	Si,Cl,S	K,Fe	1-110
b.Wht mtls (30)	Si	Ca,Ti,Al,Fe,Zn	1-120
c.Organics(65)	ND		1-210
d.Organic fiber(3)	ND		10
2.R/H.#2			
a.Blk mtl(1)	Ca,Si,Cl,Fe	K,S,Al	1-150
b.Wht mtl(34)	Si	Ca,Ti,Fe,Al	1-60
c.Organics(65)	ND		1-180
d.Organic fiber(T)	ND		10

(2): Estimated Volume Percent.
T: Trace Amount.
ND: Not Determined.
*: O, C, H, and B are not detectable by using this technique.

3.0 CONCLUSIONS:

3.1 Both samples contained small amounts of particulates and the particulates were composed of black materials, white materials, organics, and organic fibers.

3.2 The black materials appeared to be composed of a combination of rust, dust, salt, and carbon fibers.

3.3 The white materials were composed of Si-rich materials and elephant-hide which might have been heated to high temperature during reentry.

3.4 The organics and organic fibers were not analyzed at this time due to small amounts of samples.

3.5 The particle sizes were estimated to be in the range of 1 to 210 micrometers.

CHEMIST: H. S. Kim
H. S. Kim

APPROVED: J. F. Jones
J. F. Jones

NASA
National Aeronautics and Space Administration

Report Documentation Page

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16. Abstract

A Debris/Ice/TPS assessment and photographic analysis was conducted for Space Shuttle Mission STS-40. 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-40, and their overall effect on the Space Shuttle Program.

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