NASA Technical Memorandum TM 103820

Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-39

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National Aeronautics and
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DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-39

April 28, 1991

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FOREWORD

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

Shuttle Mission STS-39 was launched at 7:33 a.m. local 4/28/91

1.0 Summary

The first launch attempt of STS-39 was scrubbed on 23 April 1991 due to a failure in the SSME #3 High Pressure Oxidizer Turbo Pump (HPOTP) Secondary Seal Cavity Pressure Sensor. In addition, helium concentrations in the Orbiter aft compartment peaked at 12,000 ppm and stabilized at 9700 ppm during fast fill. The allowable limit is 10,000 ppm with allowable intermittent peaks above this value. Filling the LH2 tank reached 100% (stable replenish) when the scrub was declared. The LO2 tank had been filled to 98% (topping). No Ice Team Inspection was performed. A post-drain walkdown of the SSV and the MLP was performed at Pad-39A on 23 April 1991. There were no significant TPS anomalies and the External Tank was ready for the next launch attempt.

Debris and Photo Analysis Team activities for Mission STS-39 (second launch attempt) began with the pre-launch debris inspection of launch pad 39A/MLP-2 and Shuttle vehicle on 27 April 1991. No major anomalies were observed on OV-103 (12th flight of Discovery), ET-46 (LWT-39), and BI043. Minor facility discrepancies were corrected prior to cryoloading.

The vehicle was cryoloaded for flight on 27 April 1991. A Waiver was taken against icicles that formed on the south GOX vent duct. Winds from the south prevented the icicles from falling near Orbiter tiles. There were no other Launch Commit Criteria or NSTS-08303 violations. There were no ET anomalies. Light condensate, but no ice or frost, was present on the acreage areas of the External Tank. Three Ice/Frost 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 cryo load. 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 39A was performed after launch. No flight hardware or TPS materials were found. Launch damage to the holddown posts was minimal, though the EPON shim material on all south holddown posts was debonded to some degree. No signs indicative of stud hang-up were visible. No fragments from HDP debris containers were found. 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 155 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. SSME ignition vibration/acoustics caused the loss of small pieces of tile surface coating material from tiles on the base heatshield, OMS pod aft face, and aft RCS stingers. Five ordnance fragments fell from the HDP #7 DCS/stud hole just after liftoff. Inspection of the SRB at Hangar AF revealed the

HDP #7 DCS plunger had been obstructed by frangible nut halves. Light-colored particles fell out of the SRB plume just after the roll maneuver and later in flight. Similar particles on previous flights have been attributed to either chunks of SRB propellant/inhibitor or pieces of aft skirt instafoam. Just before SRB separation from 11:35:05.57 through 11:35:05.94 (111 seconds MET), a puff of black smoke, a brightening of the SRB plume (more visible flame), and more puffs of darker smoke were highlighted against the normally lighter SRB plume. This event may be due to burning of inhibitor and/or normal tailoff with better flow visualization for this mission. Post flight inspection inside the SRM revealed no anomalies or causes for the event. No significant discrepancies were discernible in the chamber pressure decay data (via telemetry) during ascent. The event is not considered to be an anomaly. Orbiter performance, landing gear extension, wheel touchdown and vehicle rollout after landing was nominal.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums exhibited no missing TPS, but had a total of 74 debonds over fasteners. The frustum severance rings were missing no pins. EPDM weather seals on RH aft booster factory joints had 5 debonds, the largest of which measured 2"x0.25". Three bolt heads were missing from the RH ETA ring cover near the systems tunnel. HDP #4 DCS plunger was obstructed from seating properly by ordnance fragments. The HDP #7 DCS plunger was obstructed by frangible nut halves. A 4"x0.5" piece of EPON shim material from HDP #3 and two pieces of sidewall shim material (3"x2" and 5"x2") from HDP #4 were missing from the aft skirt prior to water impact.

K5NA was missing from the RH SRB aft booster stiffener ring splice plates (aft ring at 330 degrees, forward ring at 210 degrees). The remaining material was not charred and loss of the K5NA occurred at water impact. Post flight assessment showed failure of the K5NA was caused by an unbond between first and second layers and may be indicative of improper K5NA application (use of the "pancake" method instead of a homogeneous hand-pack). A suspect PR was taken against similar K5NA closeouts on STS-40, 43, and 48. A potential debris hazard exists if the K5NA is lost at liftoff or during ascent. An MRB was approved to use-as-is on STS-40 and accepted the possible improper application of the K5NA. The closeouts on STS-43 and 48 will be addressed after the post flight assessment of STS-40.

The 7th Orbiter landing at the Kennedy Space Center occurred on 6 May 1991. A post landing inspection of OV-103 (Discovery) was conducted on May 6-8, 1991, on Runway 15 and in the Orbiter Processing Facility. The Orbiter TPS sustained a total of 238 hits, of which 16 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 217 hits, of which 14 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of

similar configuration, the number of hits on the lower surface was much greater than average, but the number of hits with a major dimension greater than 1" was less than average. No flight hardware was found on the runway below the ET/Orbiter umbilicals. However, the plunger on the LH2 ET/Orbiter umbilical separation ordnance device (EO-2) was obstructed by an NSI cartridge fragment. Post landing disassembly of the debris container revealed no missing pieces. Obstruction of these plungers by ordnance debris occurs frequently. The EO-1 and EO-3 fitting separation devices appeared to have functioned properly. All tires sustained some degree of damage during rollout. Numerous cuts and nicks were visible on the nose landing gear tires. The RH main landing gear (MLG) lost 3 plies of material from the outboard tire and 1 ply from the inboard tire. One ply of material was lost from the LH MLG inboard tire. No TPS damage was attributed to material from the wheels, tires, or brakes.

Streaks/deposits were present on both wing leading edge RCC panels. Lab analysis revealed the streaks were composed of TPS materials (Orbiter tile), Hypalon paint, BSM/SRB separation products, and foam residue from 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 noted materials have been previously documented in post-landing samples.

A total of 9 Post Launch Anomalies were observed during this mission assessment.

Overall, vehicle TPS subsystem performance and debris issues worked on the STS-39 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 22 April 1991 at 0900 hours with the following key personnel present:

M. Bassignani	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	ET Processing, Ice/Debris
P. Rosado	NASA - KSC	Chief, ET Mechanical Systems
G. Katnik	NASA - KSC	Lead, Ice/Debris/Photo Team
S. Higginbotham	NASA - KSC	STI, Ice/Debris Assessment
B. Davis	NASA - KSC	STI, Ice/Debris Assessment
B. Speece	NASA - KSC	Lead, ET Thermal Protection
B. Bowen	NASA - KSC	ET Processing, Ice/Debris
K. Tenbusch	NASA - KSC	ET Processing, Ice/Debris
J. Rivera	NASA - KSC	Lead, ET Structures
J. Hoffman	LSOC - SPC	Chief, ET Mech/Processing
M. Young	LSOC - SPC	ET Processing, Ice Assess
R. Seale	LSOC - SPC	ET Processing, Ice Assess
J. Blue	LSOC - SPC	ET Processing, Ice Assess
M. Jaime	LSOC - SPC	ET Processing, Ice Assess
W. Richards	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
M. McBain	MMC - MAF	ET TPS Testing/Certif
J. McClymonds	RI - DNY	Debris Assess, LVL II Integ
K. Mayer	RI - LSS	Vehicle Integration
S. Otto	MMC - LSS	ET Processing
G. Witters	USBI - LSS	SRB Processing
W. Nelson	USBI - DAE	SRB Processing
M. Nowling	MTI - LSS	SRM Processing
J. Cook	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-39 had been scheduled for launch in late March, 1991. The discovery of cracks on the ET/ORB umbilical door hinges resulted in a rollback to the VAB on 7 March 1991. After repairs, the SSV was rolled back to the pad on 1 April 1991.

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 22 April 1991 from 1000 - 1130 hours. The detailed walkdown of Launch Pad 39A and MLP-2 also included the primary flight elements OV-103 Discovery (12th flight), ET-46 (LWT-39), and BI043. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

There were no vehicle anomalies.

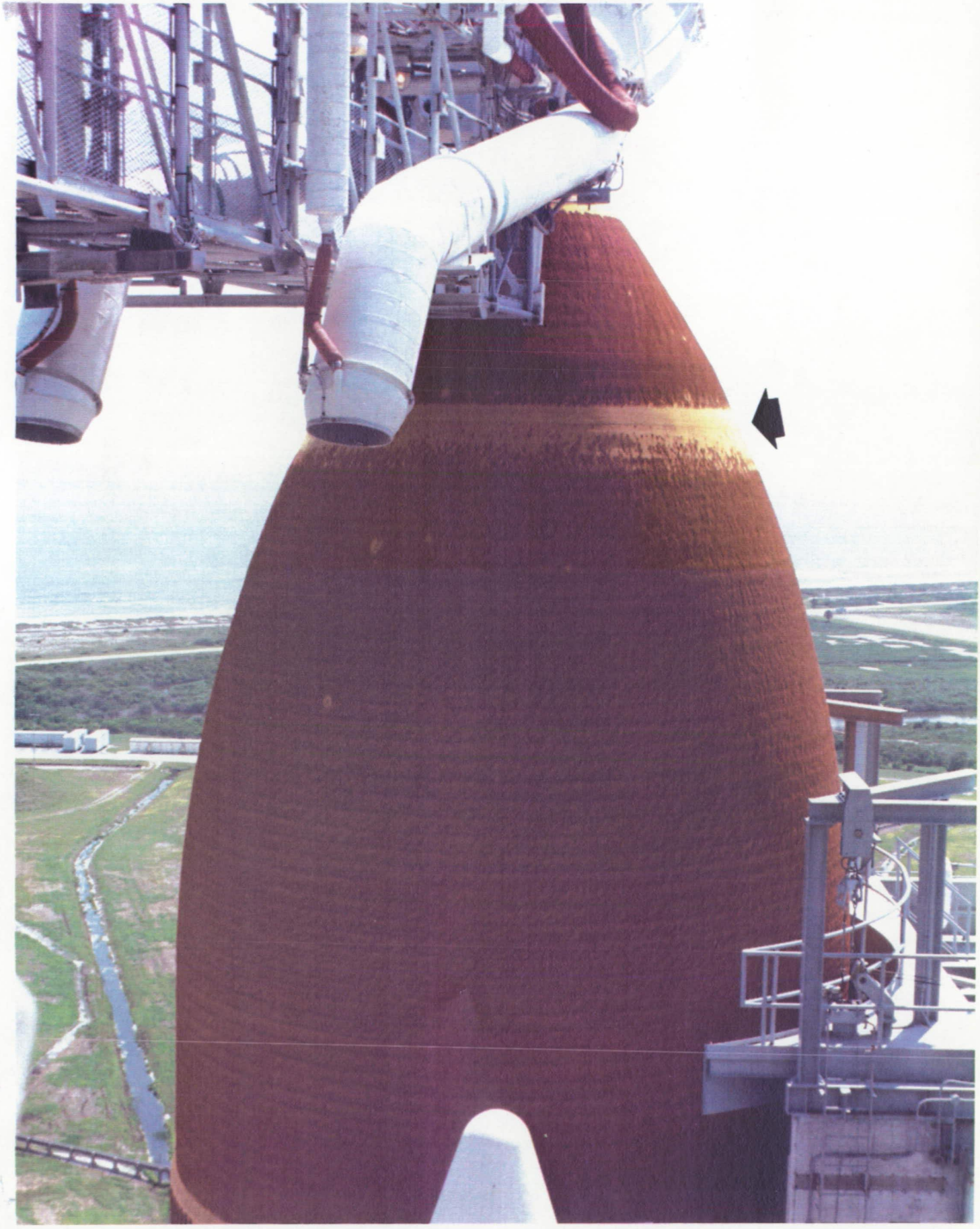
Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload/ launch, temporary hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical until a permanent sensor could be designed and installed. The tygon tubes are intended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

An electrical conduit cap under the sound suppression water pipe west of the RH SRB exhaust hole was loose. A 4'x2' cable tray cover on the FSS 255 foot level was missing.

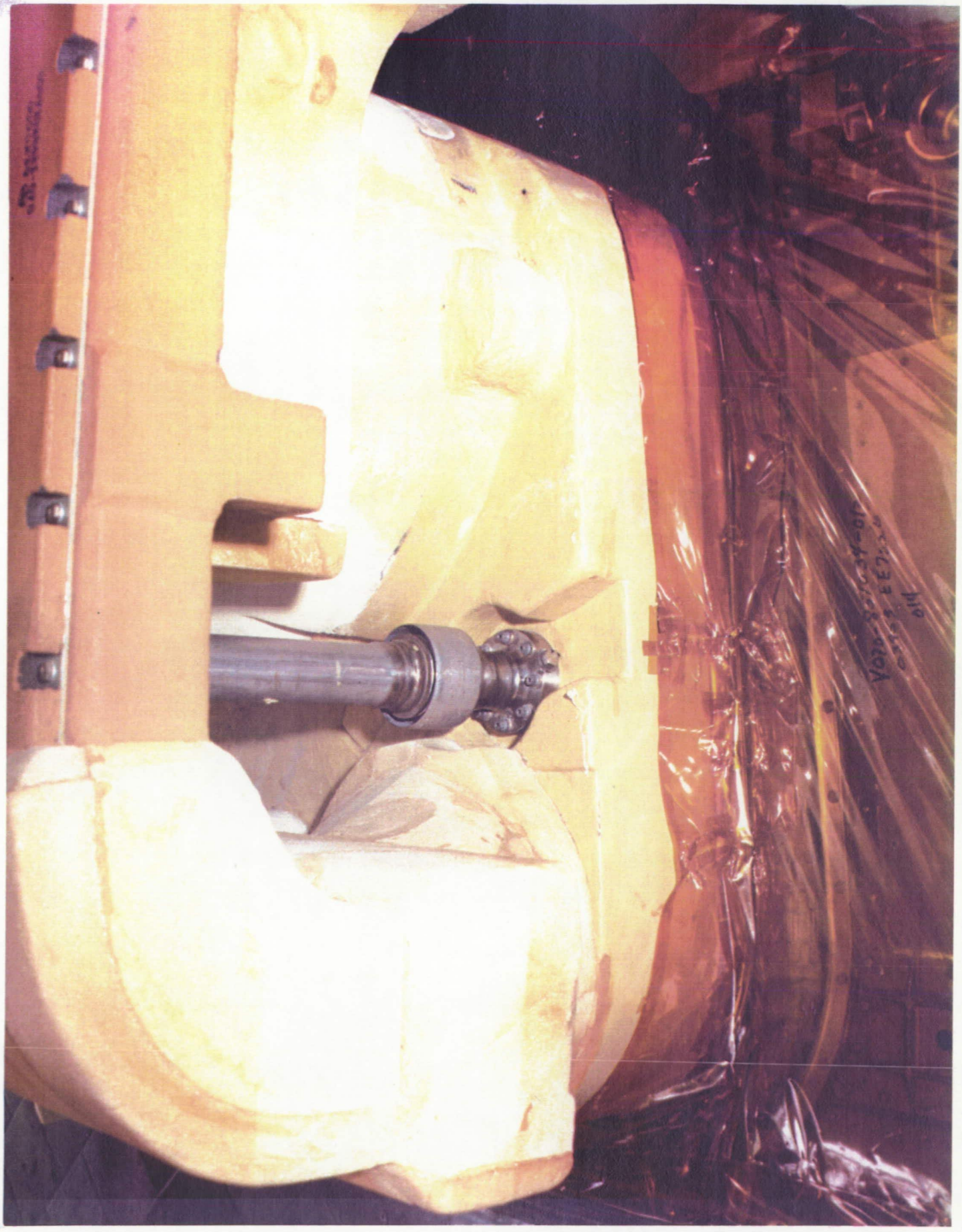
Three tie-wraps had been found attached to the LO2 TSM in the vicinity of the RH aft RCS stinger tiles during the STS-37 Ice Inspection. The LH2 and LO2 TSM's on this MLP were carefully inspected, but no debris discrepancies were noted.

Cleanup of the MLP deck and pad surface was in progress 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.

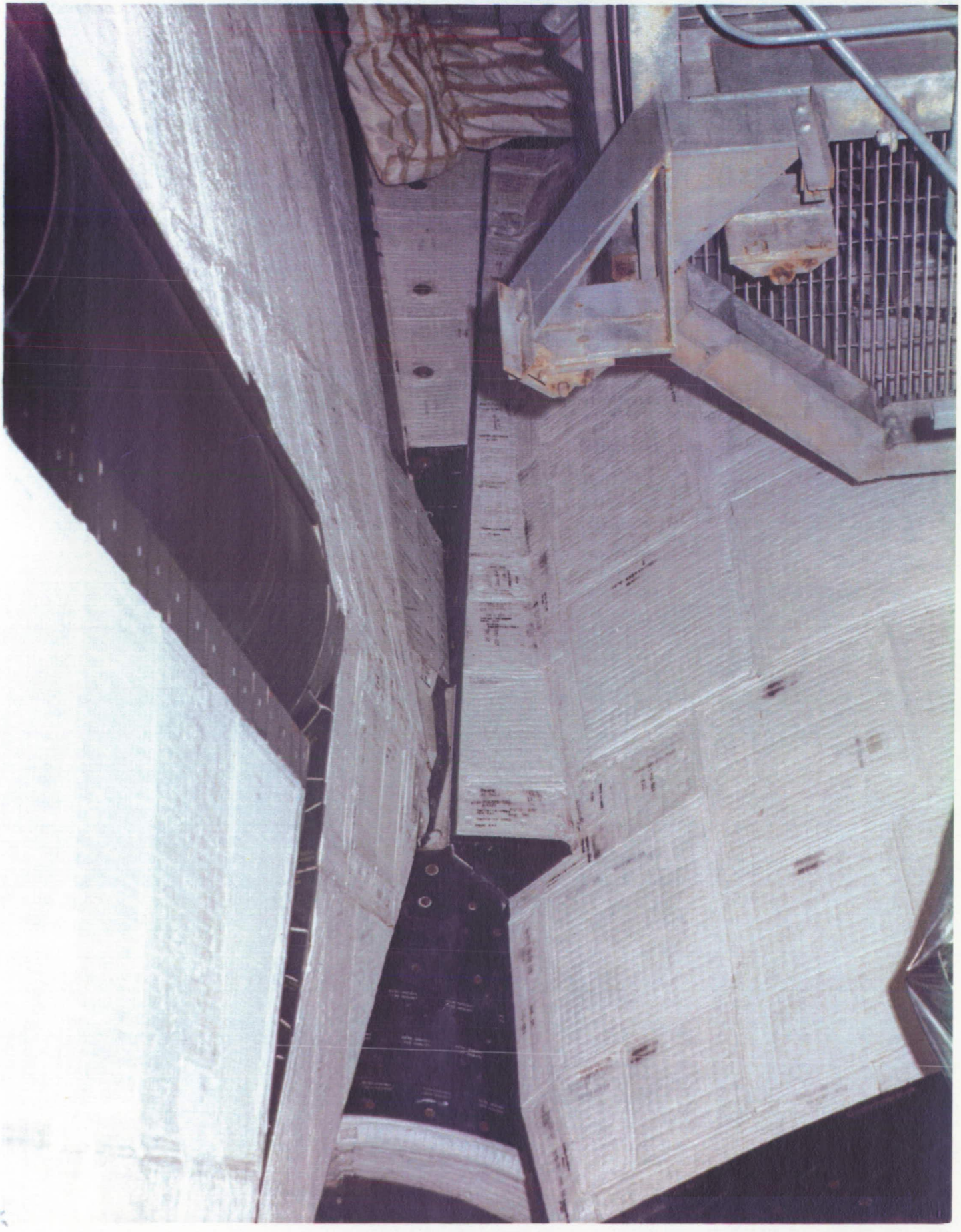
The facility discrepancies were worked real-time or entered into OMI S0007, Appendix K, for resolution prior to vehicle tanking.



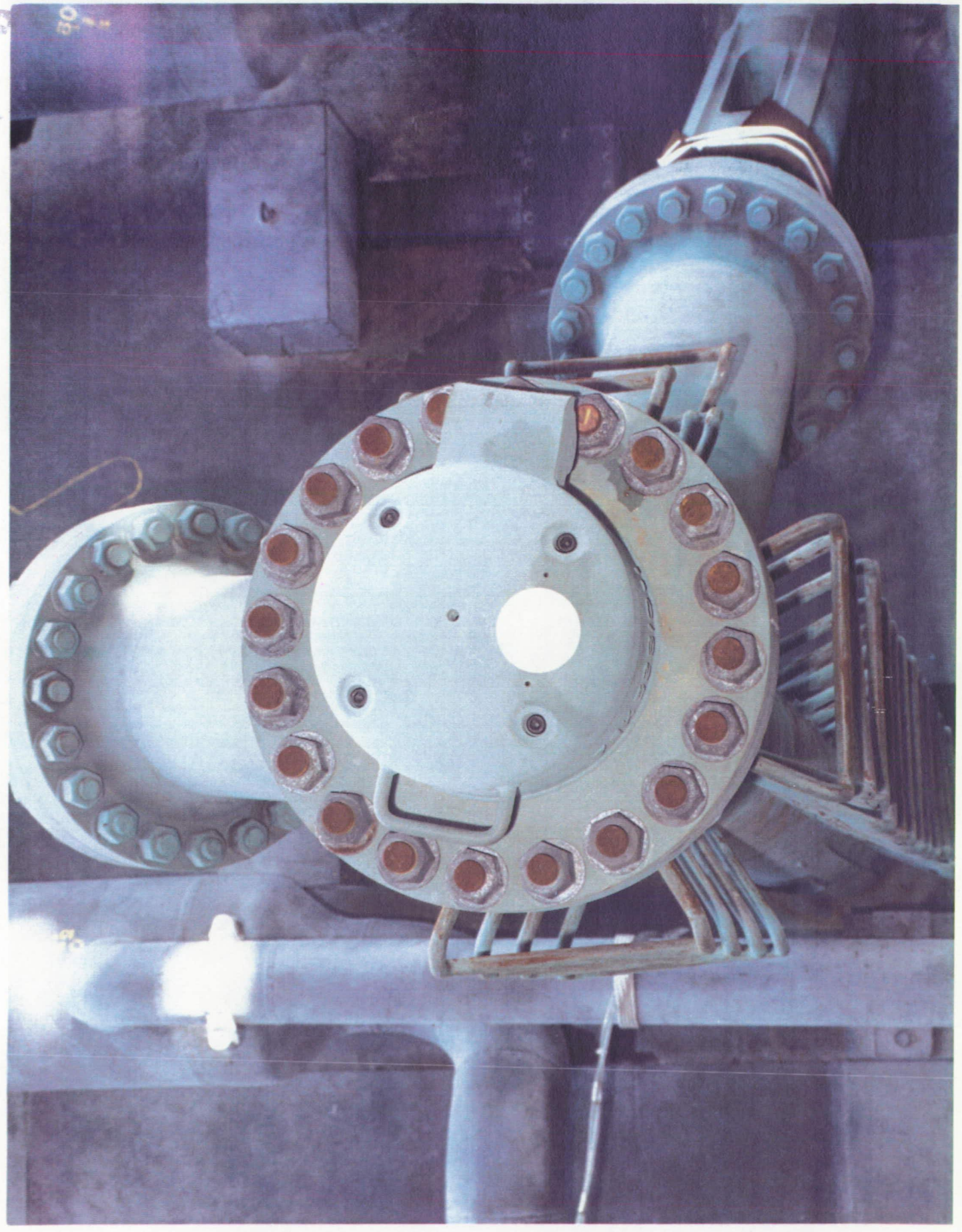
Overall view of ET-46 (LWT 39) LO2 tank. Note SOFI spray interrupt/sanded area on ogive section.



Pre-launch configuration of LH2 ET/ORB umbilical TPS and purge barrier baggie material



Water spray boiler vent ports at base of vertical stabilizer are plugged prior to launch



View looking down on new Hydrogen Dispersal System. White paper cover is positioned over exit nozzle for nitrogen flow.

3.3 POST DRAIN INSPECTION

The STS-39 launch was scrubbed due to a failure in the SSME #3 High Pressure Oxidizer Turbo Pump (HPOTP) Secondary Seal Cavity Pressure Sensor. In addition, helium concentrations in the Orbiter aft compartment peaked at 12,000 ppm and stabilized at 9700 ppm during fast fill. The allowable limit is 10,000 ppm with allowable intermittent peaks above this value. Filling the LH2 tank reached 100% (stable replenish) when the scrub was declared. The LO2 tank had been filled to 98% (topping). No Ice Team Inspection was performed. A post-drain walkdown of the SSV and the MLP was performed at Pad-39A from 0800 to 1015 hours on 23 April 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. The southwest (-Y) nosecone footprint area appeared undamaged and was missing no topcoat. The northeast (+Y) footprint area was not accessible for inspection.

A small void was visible in the LH2 tank-to-intertank flange closeout just aft of the -Y thrust panel (+Z side). An ice/ frost formation with venting vapors occurred at this location during cryogenic loading (ref Anomaly 001).

No ice was present in the LO2 feedline support brackets with the exception of a 1 inch diameter frost ball just aft of the LH2 tank-to-bracket attach pivot (XT-1871). There appeared to be loose foam between the feedline and the support bracket at XT-1871. All other LO2 feedline support brackets did not appear to have damaged/loose foam. A second inspection was performed on 24 April 1991 after RSS access was provided. There was no significant damage to the TPS on the LO2 feedline support brackets.

Small cracks occurred in both +Y and -Y thrust strut-to-longeron interfaces.

The LO2 ET/ORB umbilical had no ice/frost accumulations. A small amount of ice remained on the LH2 ET/ORB umbilical aft pyrotechnic canister purge vent.

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.

The SRB sound suppression water trough were properly configured and filled with water. The tygon tubes for LH2 leak detection system sensors LD 54 and 55 were in the proper positions.

The summary of ice/frost team observation anomalies during the cryoload consists of 6 OTV recorded items:

Anomaly 001 documented an ice/frost formation with venting vapors on the LH2 tank-to-intertank flange closeout between the -Y thrust panel and first stringer valley on the +Z side. Engineering evaluation of an ice formation in this area is required prior to launch.

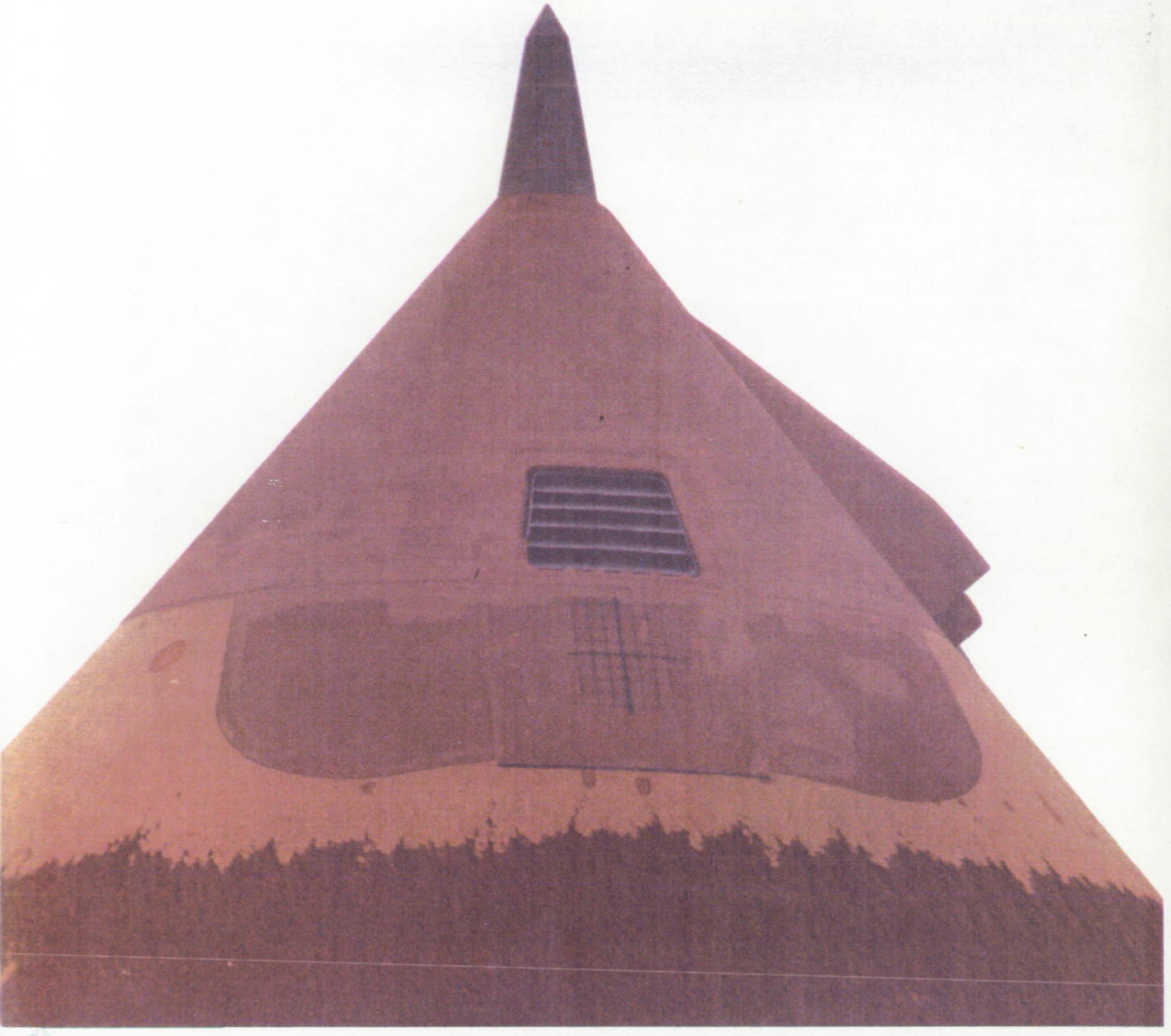
Anomaly 002 recorded ice/frost formations on the bondlines of the pressurization line ramps, PAL ramp, and cable tray support ramps at XT-1270, 1360, 1430, 1657, 1980, 2034. These formations were acceptable per NSTS-08303.

An ice/frost formation in the LH2 feedline bellows (Anomaly 003) was acceptable per NSTS-08303.

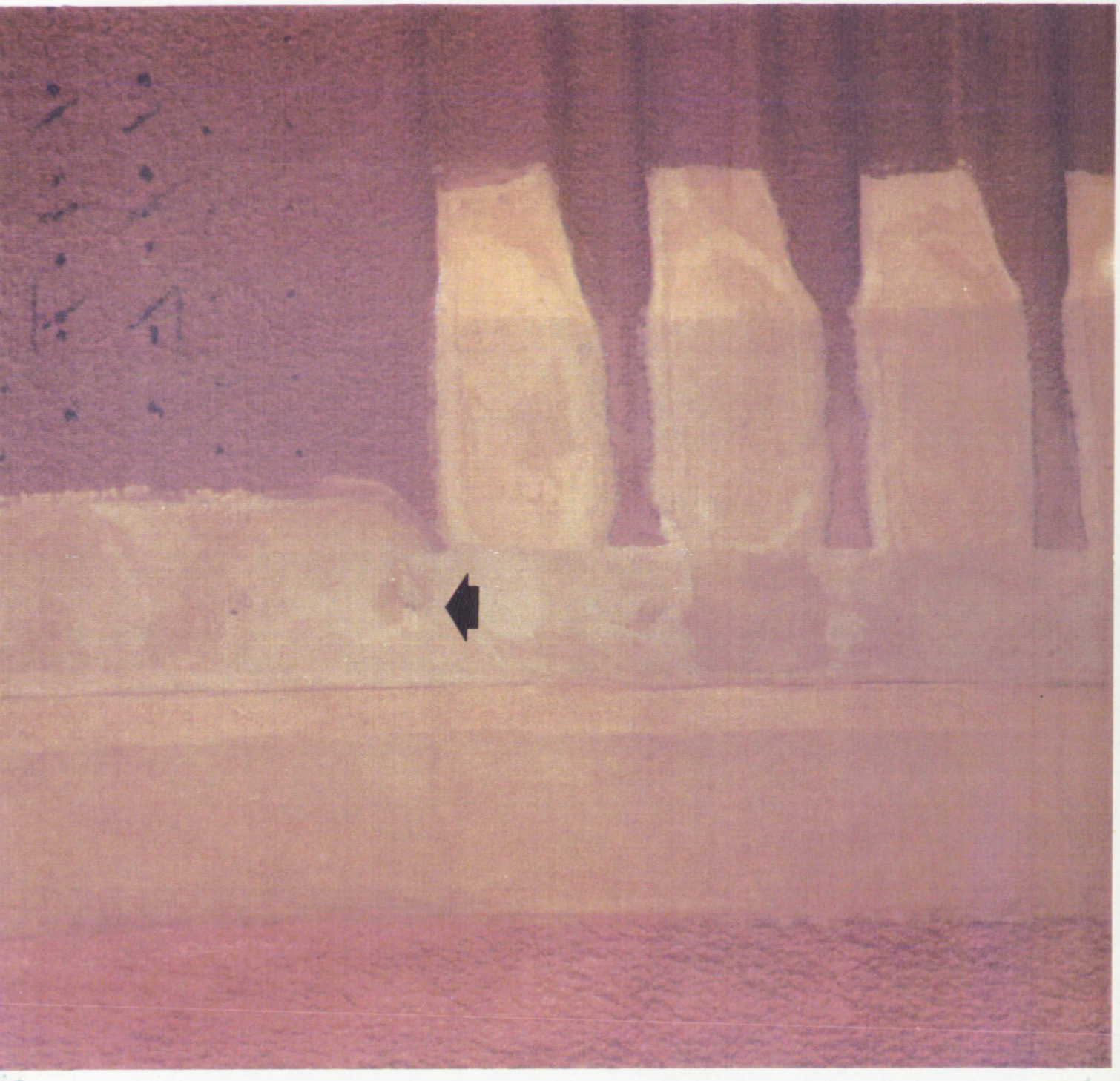
Anomaly 004 documented vapors from the +Y thrust strut-to-longeron interface. A TPS crack in this interface is acceptable per NSTS-08303.

Anomaly 005 recorded vapors from the LH2 recirculation line burst disk area, which was acceptable per NSTS-08303.

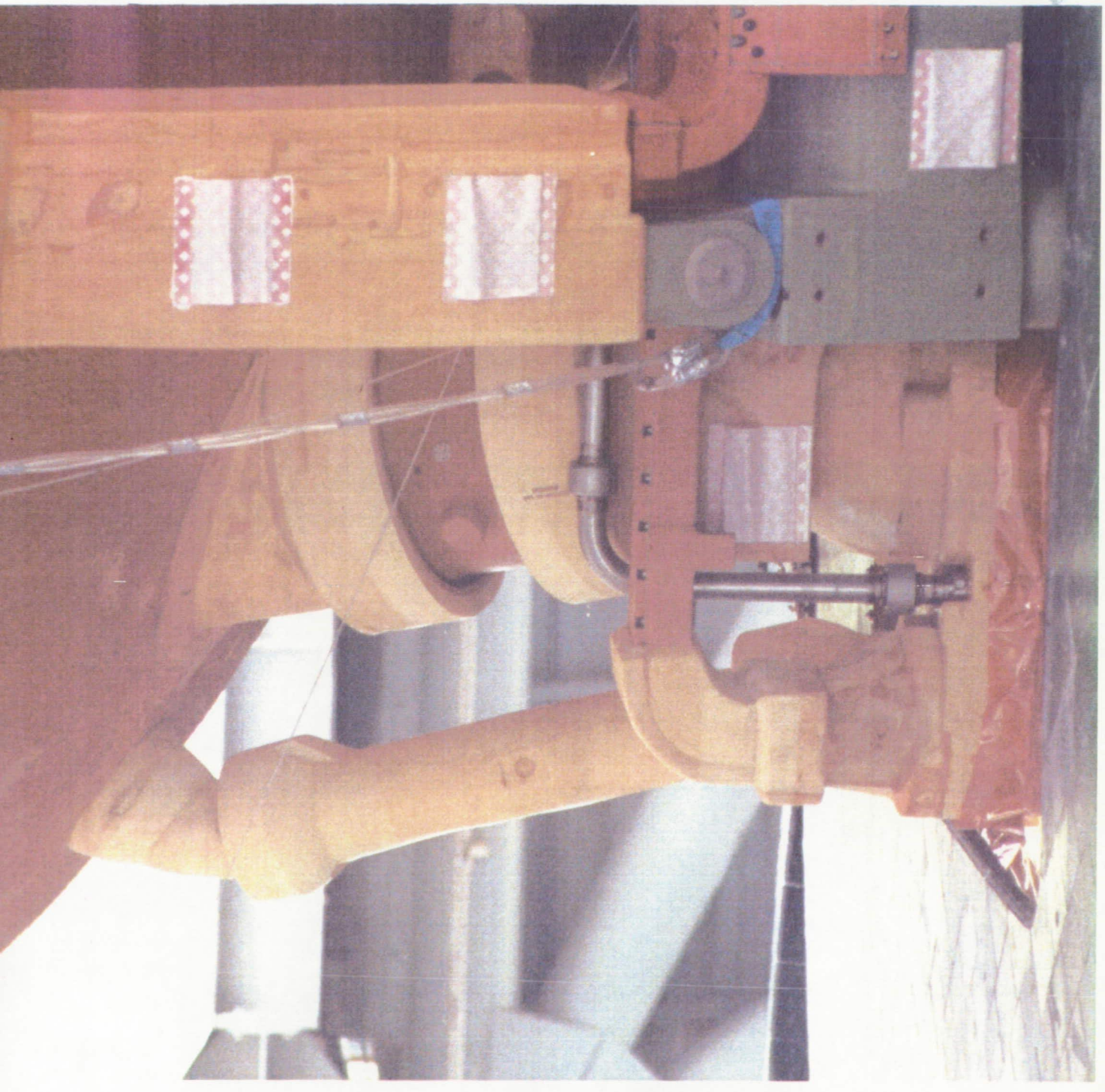
Vapors vented from the LH2 tank aft dome +Z manhole cover TPS closeout on the +Y side at the outer closeout perimeter (Anomaly 006). No TPS defect was visible.



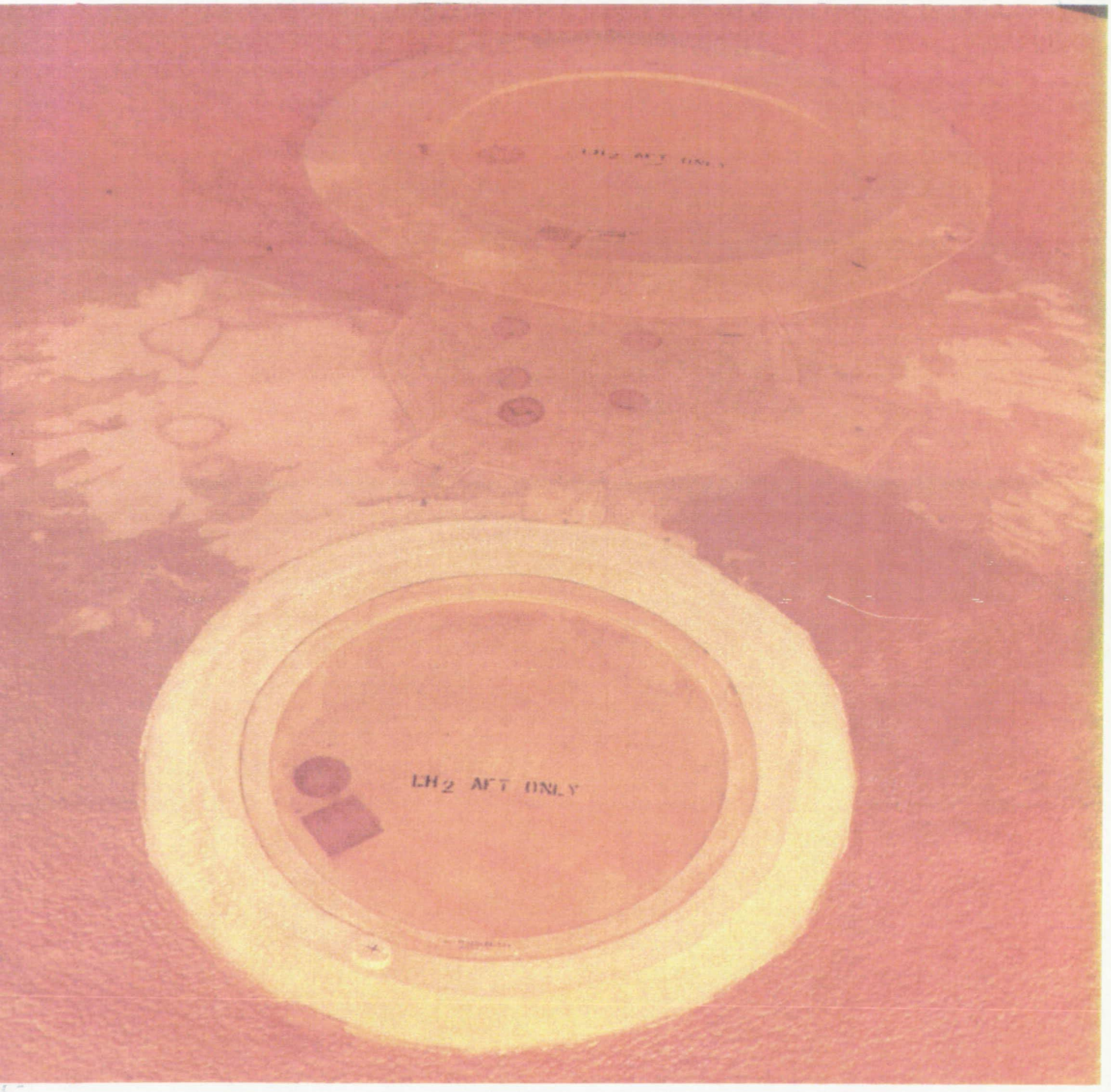
Post drain inspection revealed no damage to the nosecone, southwest louver, footprint, or fairing.



Small void on the LH2 tank-to-intertank flange closeout marked the location where a 1-inch diameter ice/frost ball had formed. The small size of the TPS defect did not require repair prior to the next cryoload.



No anomalies occurred on the LH2 ET/ORB umbilical during cryoload and drain



Vapors vented from the LH2 tank aft dome +Z manhole cover TPS closeout (+Y side) at the outer closeout perimeter during cryoload and drain. No TPS anomaly was visible.

4.0 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A second pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 27 April 1991 from 1000 - 1130 hours. The walkdown of Launch Pad 39A and MLP-2 also included the primary flight elements OV-103 Discovery (12th flight), ET-46 (LWT-39), and BI043. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

There were no vehicle anomalies.

The tygon tubes for hydrogen leak detection sensors LD 54 and 55 were still in the proper configuration from the first launch attempt.

An electrical conduit cap under the sound suppression water pipe near SRB holddown post #1 was loose.

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.

MLP deck cleanliness was good. The only discrepancy consisted of a paper cup near the base of SRB holddown post #1.

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

5.0 LAUNCH

The SSME #3 High Pressure Oxidizer Turbo Pump (HPOTP) Secondary Seal Cavity Pressure Sensor that caused the scrub during the first launch attempt had been replaced. High concentrations of helium in the Orbiter aft compartment had been traced to leakage around the ET/ORB LH2 4-inch recirculation line purge boot. The small leaks were repaired with RTV. STS-39 was launched at 28:11:33:14 GMT on 28 April 1991.

5.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 28 April 1991 from 0205 to 0350 hours during the two hour built-in-hold at T-3 hours in the countdown. A Waiver was taken against icicles that formed on the south GOX vent duct. Winds from the south prevented the icicles from falling near Orbiter tiles. There were no other Launch Commit Criteria or NSTS-08303 violations. Ambient weather conditions at the time of the inspection were:

Temperature:	75.9 F
Relative Humidity:	89.4 %
Wind Speed:	12 Knots
Wind Direction:	174 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.

5.2 ORBITER

No Orbiter tile anomalies were observed. The average Orbiter surface temperature was 77 degrees F. The average surface temperatures of the SSME engine mounted heat shields were measured at 76 degrees F for SSME #1, 76 degrees F for SSME #2, and 74 degrees F for SSME #3. The coldest area on the engine mounted heat shields was 55 degrees F. All of the SSME heat shields were wet with some condensate. Light frost coated the SSME #2 heat shield-to-nozzle interface at the 3-9 o'clock position. No LO2 vapors originated from inside the SSME nozzles. Some condensate was present on base heat shield tiles around SSME #2. 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.

5.3 SOLID ROCKET BOOSTERS

No SRB anomalies or loose ablator/cork were observed. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 76 and 77 degrees F. The Mikron IR gun and the GEI gave measurements of 75 and 80 degrees F, respectively, in comparison. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 72 degrees F, which was within the required range of 44-86 degrees F.

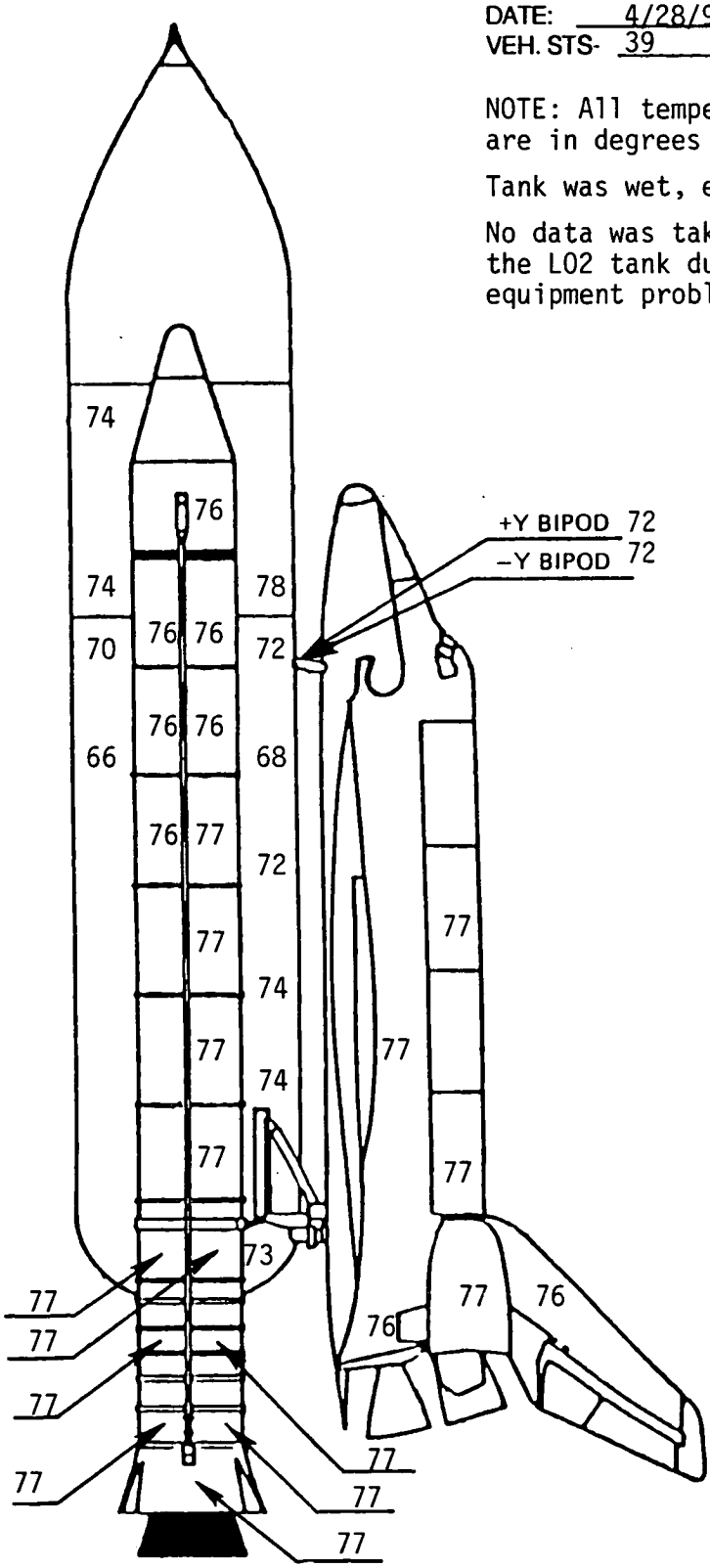
FIGURE 1. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0200 - 0350
DATE: 4/28/91
VEH. STS- 39

NOTE: All temperatures are in degrees F.

Tank was wet, e=0.96

No data was taken on the LO2 tank due to equipment problems.



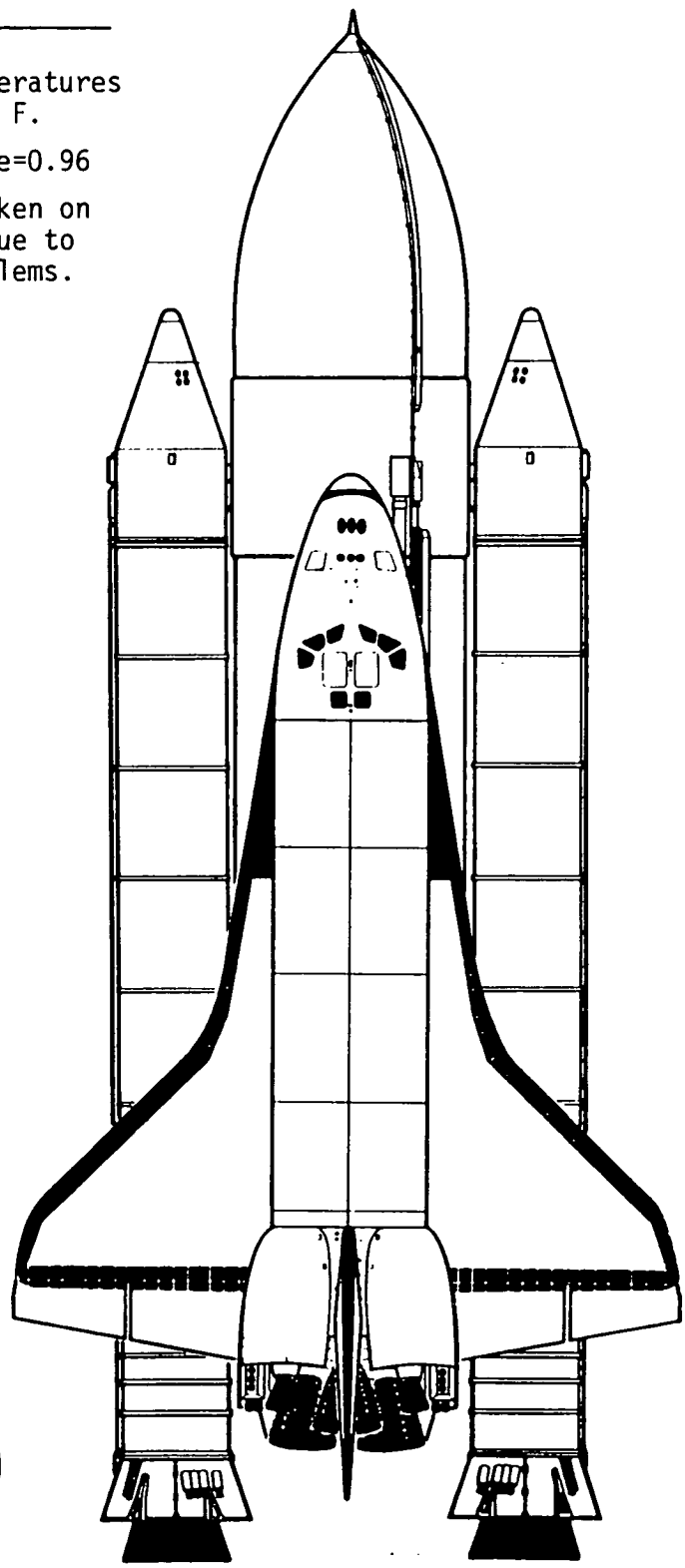


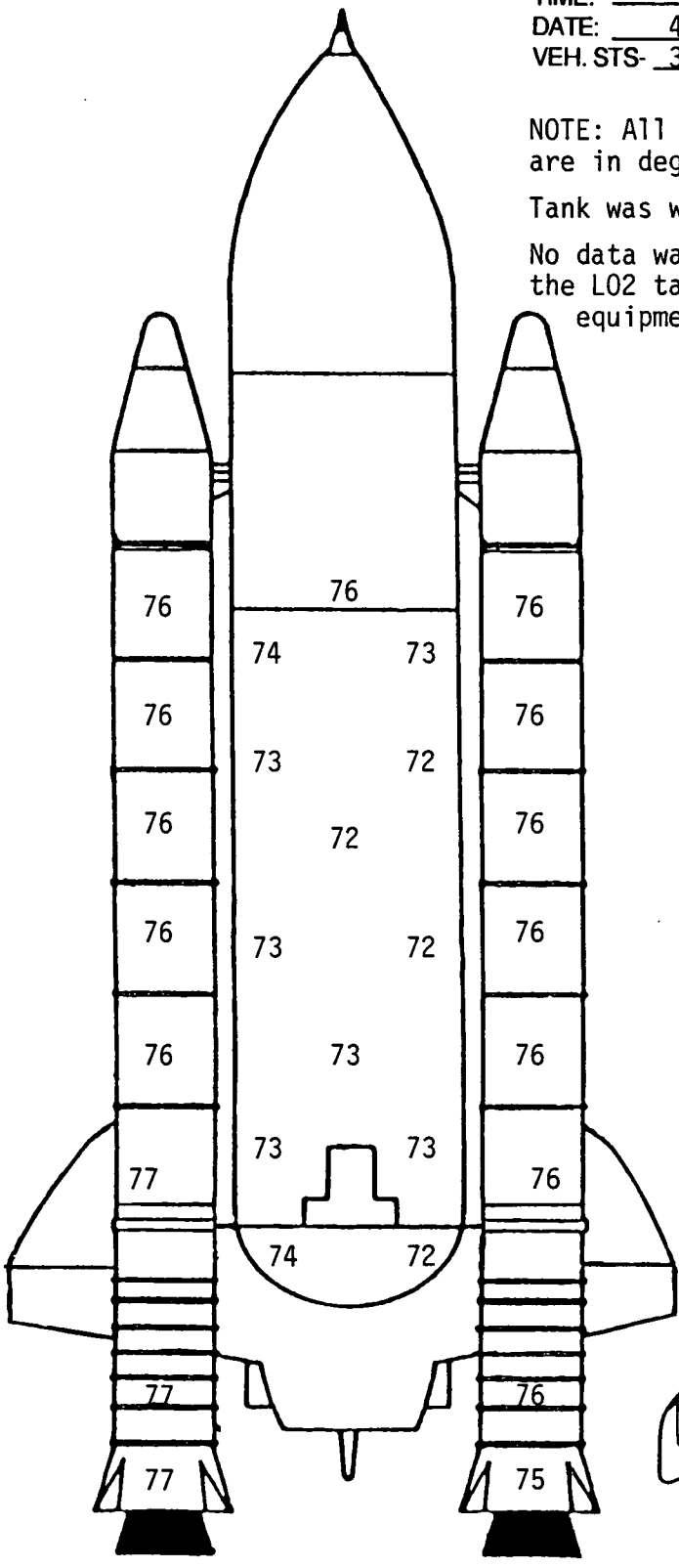
FIGURE 2. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

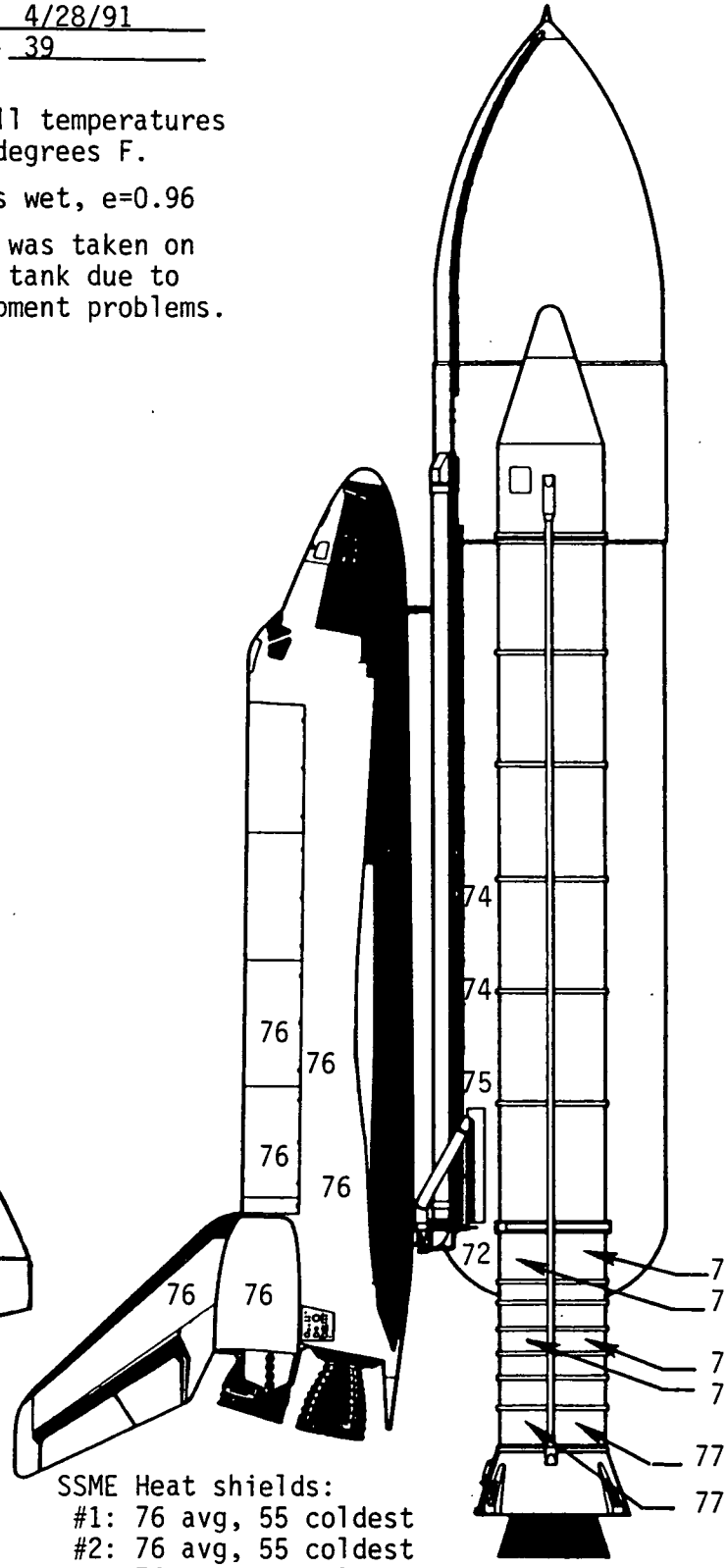
TIME: 0200 - 0350
DATE: 4/28/91
VEH. STS- 39

NOTE: All temperatures are in degrees F.

Tank was wet, e=0.96

No data was taken on the LO2 tank due to equipment problems.





SSME Heat shields:
#1: 76 avg, 55 coldest
#2: 76 avg, 55 coldest
#3: 74 avg, 65 coldest

EGG/V-343C

5.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 2300 to 0715 hours and the results tabulated in Figures 3 and 4. 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 ogive. There were no TPS anomalies. A small piece of ice or white debris, approximately 1/2 inch in diameter, was visible between the southwest (-Y) GOX seal and the nosecone TPS. Retraction of the GOX vent hood revealed no erosion of the TPS. The tumble valve cover was intact. There were no anomalies on the pressurization line and support ramps. SURFICE predicted 69 degrees F on the ogive and 66 degrees F on the barrel section. The Mikron IR gun measured 70 and 68 degrees F, respectively.

The intertank TPS acreage was wet with light run-off condensate. There were no TPS anomalies. No frost spots appeared in the stringer valleys. 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 73 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 68 degrees F on the upper LH2 tank and 73 degrees F on the lower LH2 tank compared to a Mikron IR gun measurements of 66 and 70 degrees F, respectively. SURFICE predicted 63 degrees F on the upper LH2 tank and 62 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, or aft dome apex with the exception of a small frost spot in the +Y thrust strut-to-longeron interface. Froth was visible on the LH2 tank aft dome -Z manhole cover closeout (4 places). 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.

An ice/frost ball, 1-2 inches in diameter, formed on the LH2 tank-to-intertank flange closeout on the +Z side of the tank (between the -Y thrust panel and first stringer valley). The ice/frost ball was venting vapor. Two small frost spots were visible on the flange closeout approximately 6 feet away (in the direction of the bipods) from the ice/frost ball. Ice Team assessment of the condition showed the ice/frost ball would drop vertically to the MLP deck without contacting Orbiter tiles if shaken loose by SSME or SRB (T-0) ignition. In flight, the air flow stream

STS- 39	TEST S0007 LAUNCH																DATE: 27 April 1991					T-0 TIME: 07:33:15 DATE: 4/28/91			NASA KSC Ice/Frost/Debris Team	
ORBITER 102	ET 46	SRB BI-043	MLP 2	PAD A	LO2 CHILLDOWN TIME: 22:57 SLOW FILL TIME: 23:34					FAST FILL TIME: 23:46 REPLENISH TIME: 01:49						LH2 CHILLDOWN TIME: 22:57 SLOW FILL TIME: 23:07					FAST FILL TIME: 23:31 REPLENISH TIME: 01:22					
TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
2300	76.60	89.4	73.40	15	146	II	8.85	70.74	0.0030	-0.3763	II	8.85	68.33	0.0054	-0.3416	II	4.80	63.77	0.0055	-0.1848	II	20.85	71.22	0.0053	-0.7670
2315	76.80	88.6	73.35	14	147	II	8.26	70.56	0.0029	-0.3545	II	8.26	68.01	0.0053	-0.3202	II	4.48	63.25	0.0054	-0.1729	II	19.46	71.04	0.0052	-0.7180
2330	77.20	89.2	73.94	14	156	II	8.26	71.13	0.0030	-0.3619	II	8.26	68.59	0.0054	-0.3273	II	4.48	63.87	0.0055	-0.1773	II	19.46	71.60	0.0054	-0.7329
2345	76.80	88.6	73.35	14	156	II	8.26	70.56	0.0029	-0.3545	II	8.26	68.01	0.0053	-0.3202	II	4.48	63.25	0.0054	-0.1729	II	19.46	71.04	0.0052	-0.7180
0000	76.80	88.4	73.28	17	160	II	10.03	71.06	0.0028	-0.4196	II	10.03	68.90	0.0052	-0.3843	II	7.14	66.60	0.0056	-0.2724	II	6.46	65.95	0.0056	-0.2471
0015	76.80	88.2	73.22	15	157	II	8.85	70.67	0.0029	-0.3752	II	8.85	68.26	0.0052	-0.3406	II	4.80	63.72	0.0054	-0.1843	II	20.85	71.14	0.0050	-0.7646
0030	77.00	87.8	73.29	16	161	II	9.44	70.97	0.0028	-0.3987	II	9.44	68.69	0.0052	-0.3637	II	6.72	66.29	0.0056	-0.2575	II	6.08	65.62	0.0055	-0.2336
0045	76.60	88.2	73.02	18	159	II	10.62	70.95	0.0027	-0.4373	II	10.62	68.89	0.0052	-0.4018	II	7.56	66.68	0.0056	-0.2849	II	6.84	66.05	0.0056	-0.2585
0100	76.80	87.8	73.09	15	158	II	8.85	70.58	0.0028	-0.3739	II	8.85	68.16	0.0052	-0.3393	II	6.30	65.64	0.0055	-0.2397	II	5.70	64.94	0.0055	-0.2174
0115	76.60	88.4	73.08	14	159	II	8.26	70.31	0.0029	-0.3512	II	8.26	67.74	0.0052	-0.3169	II	5.88	65.08	0.0055	-0.2234	II	5.32	64.34	0.0055	-0.2025
0130	76.80	88.8	73.41	16	160	II	9.44	70.99	0.0029	-0.3992	II	9.44	68.72	0.0053	-0.3642	II	6.72	66.31	0.0057	-0.2578	II	6.08	65.64	0.0056	-0.2338
0145	76.60	90.0	73.59	16	163	II	9.44	71.06	0.0031	-0.4003	II	9.44	68.79	0.0054	-0.3652	II	6.72	66.38	0.0058	-0.2585	II	6.08	65.70	0.0057	-0.2345
0200	76.00	89.8	72.93	13	167	II	7.67	69.76	0.0031	-0.3256	II	7.67	67.02	0.0053	-0.2918	II	5.46	64.18	0.0056	-0.2049	II	4.94	63.40	0.0055	-0.1856
0215	76.20	90.4	73.32	9	173	II	5.31	68.79	0.0032	-0.2407	II	5.31	65.08	0.0052	-0.2082	II	3.78	61.46	0.0053	-0.1443	II	3.42	60.50	0.0052	-0.1304
0230	75.80	89.2	72.54	15	172	II	8.85	69.85	0.0030	-0.3642	II	8.85	67.41	0.0053	-0.3298	II	6.30	64.84	0.0056	-0.2324	II	5.70	64.12	0.0055	-0.2106
0245	76.20	89.2	72.94	12	178	II	7.08	69.58	0.0030	-0.3046	II	7.08	66.64	0.0053	-0.2711	II	5.04	63.65	0.0055	-0.1899	II	4.56	62.83	0.0054	-0.1720
0300	76.00	88.8	72.62	12	176	II	7.08	69.27	0.0030	-0.3011	II	7.08	66.32	0.0052	-0.2677	II	5.04	63.32	0.0054	-0.1874	II	4.56	62.50	0.0053	-0.1696
0315	76.00	89.6	72.87	10	180	II	5.90	68.80	0.0031	-0.2593	II	5.90	65.38	0.0052	-0.2266	II	4.20	61.98	0.0053	-0.1575	II	3.80	61.07	0.0052	-0.1424
0330	75.60	88.8	72.22	11	178	II	6.49	68.54	0.0030	-0.2749	II	6.49	65.34	0.0051	-0.2420	II	4.62	62.14	0.0053	-0.1685	II	4.18	61.27	0.0052	-0.1524
0345	75.60	89.2	72.35	13	171	II	7.67	69.20	0.0030	-0.3188	II	7.67	66.43	0.0052	-0.2852	II	5.46	63.57	0.0055	-0.1999	II	4.94	62.79	0.0054	-0.1809
0400	75.60	89.2	72.35	11	172	II	6.49	68.63	0.0030	-0.2759	II	6.49	65.44	0.0052	-0.2430	II	4.62	62.23	0.0053	-0.1692	II	4.18	61.37	0.0052	-0.1530
0415	75.80	89.0	72.48	14	174	II	8.26	69.60	0.0030	-0.3422	II	8.26	67.00	0.0052	-0.3082	II	5.88	64.30	0.0055	-0.2167	II	5.32	63.56	0.0055	-0.1963
0430	75.60	89.4	72.41	13	154	II	7.67	69.24	0.0030	-0.3194	II	7.67	66.48	0.0053	-0.2857	II	4.16	61.37	0.0053	-0.1526	II	18.07	69.76	0.0054	-0.6429
0445	75.60	90.4	72.73	11	153	II	6.49	68.90	0.0031	-0.2788	II	6.49	65.73	0.0053	-0.2457	II	3.52	60.05	0.0051	-0.1301	II	15.29	69.44	0.0058	-0.5520
0500	75.00	90.2	72.07	10	159	II	5.90	67.85	0.0031	-0.2503	II	5.90	64.38	0.0052	-0.2178	II	4.20	60.93	0.0053	-0.1507	II	3.80	60.01	0.0052	-0.1360
0515	75.20	90.2	72.26	12	165	II	7.08	68.73	0.0031	-0.2953	II	7.08	65.76	0.0053	-0.2620	II	5.04	62.72	0.0055	-0.1829	II	4.56	61.89	0.0054	-0.1654
0530	75.00	90.4	72.13	10	177	II	5.90	67.90	0.0031	-0.2507	II	5.90	64.42	0.0052	-0.2182	II	4.20	60.98	0.0053	-0.1510	II	3.80	60.05	0.0052	-0.1363
0545	75.00	90.8	72.25	9	179	II	5.31	67.56	0.0031	-0.2299	II	5.31	63.79	0.0052	-0.1978	II	3.78	60.10	0.0052	-0.1361	II	3.42	59.12	0.0051	-0.1228

FIGURE 3. 'SURFICE' Computer predictions

STS- 39	TEST S0007 LAUNCH				DATE: 27 April 1991	T-0 TIME: 07:33:15 DATE: 4/28/91	NASA KSC Ice/Frost/Debris Team
ORBITER 102	ET 46	SRB BI-043	MLP 2	PAD A	LO2 CHILLDOWN TIME: 22:57 FAST FILL TIME: 23:46 SLOW FILL TIME: 23:34 REPLENISH TIME: 01:49	LH2 CHILLDOWN TIME: 22:57 FAST FILL TIME: 23:31 SLOW FILL TIME: 23:07 REPLENISH TIME: 01:22	

TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0600	74.40	91.0	71.72	8	180	II	4.72	66.44	0.0031	-0.2033	II	4.72	62.25	0.0050	-0.1717	II	3.36	58.26	0.0050	-0.1168	II	3.04	57.21	0.0049	-0.1051
0615	74.40	91.4	71.84	8	177	II	4.72	66.53	0.0031	-0.2040	II	4.72	62.35	0.0051	-0.1724	II	3.36	58.35	0.0050	-0.1173	II	3.04	57.30	0.0049	-0.1056
0630	74.20	91.2	71.58	9	180	II	5.31	66.77	0.0031	-0.2232	II	5.31	62.95	0.0051	-0.1913	II	3.78	59.22	0.0052	-0.1310	II	3.42	58.24	0.0050	-0.1180
0645	74.00	91.0	71.32	6	186	II	3.54	64.59	0.0030	-0.1570	II	3.54	59.35	0.0047	-0.1265	II	2.52	54.64	0.0046	-0.0836	II	2.28	53.49	0.0044	-0.0747
0700	74.00	91.4	71.45	8	184	II	4.72	66.08	0.0031	-0.2005	II	4.72	61.88	0.0050	-0.1691	II	3.36	57.86	0.0050	-0.1147	II	3.04	56.80	0.0049	-0.1031
0715	73.80	91.4	71.25	6	188	II	3.54	64.45	0.0030	-0.1562	II	3.54	59.20	0.0047	-0.1257	II	2.52	54.47	0.0046	-0.0829	II	2.28	53.33	0.0044	-0.0741
AVG	75.78	89.57	72.64	12.2			7.18	69.02				7.18	65.93				4.83	62.40				7.48	63.36		

Period of Ice Team Inspection

FIGURE 4. 'SURFICE' Computer Predictions

lines in the local area would also carry the ice/frost ball aft. The condition posed no significant threat to Orbiter tiles and no IPR was taken.

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 baggie was configured properly and was holding positive purge pressure. A small amount of ice/frost covered the 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 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. The forward and outboard sides of the LH2 ET/ORB umbilical were covered by less than usual ice/frost formations. Ice/frost accumulation on the inboard and aft areas of the baggie was light. Ice/frost fingers 3-8 inches in length had formed on the pyro canister and plate gap purge vents. 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 contact or TPS damage.

The summary of ice/frost team observation anomalies consists of 4 OTV recorded items:

Anomaly 001 documented an ice/frost formation, 1-2 inches in diameter, on the LH2 tank-to-intertank flange closeout. The ice/ frost ball was located near the -Y thrust panel at the first stringer valley and was emitting vapors. Engineering evaluation, required of the ice/frost formation on the Orbiter side of the tank, showed no significant threat to Orbiter tiles.

Anomaly 002 recorded 3"x0.5" icicles on the south GOX vent duct. Icicles are prohibited in this location for launch per NSTS 08303 and IPR 39V-0264 was taken against the condition. Waiver LW-024 accepted the presence of the icicles for launch.

Frost accumulation in the +Y thrust strut-to-longeron interface was acceptable per NSTS-08303.

Two frost spots on the LH2 tank-to-intertank flange closeout approximately 6 feet from the -Y thrust panel were associated with closeout bondlines. The condition was acceptable per NSTS-08303.

5.5 FACILITY

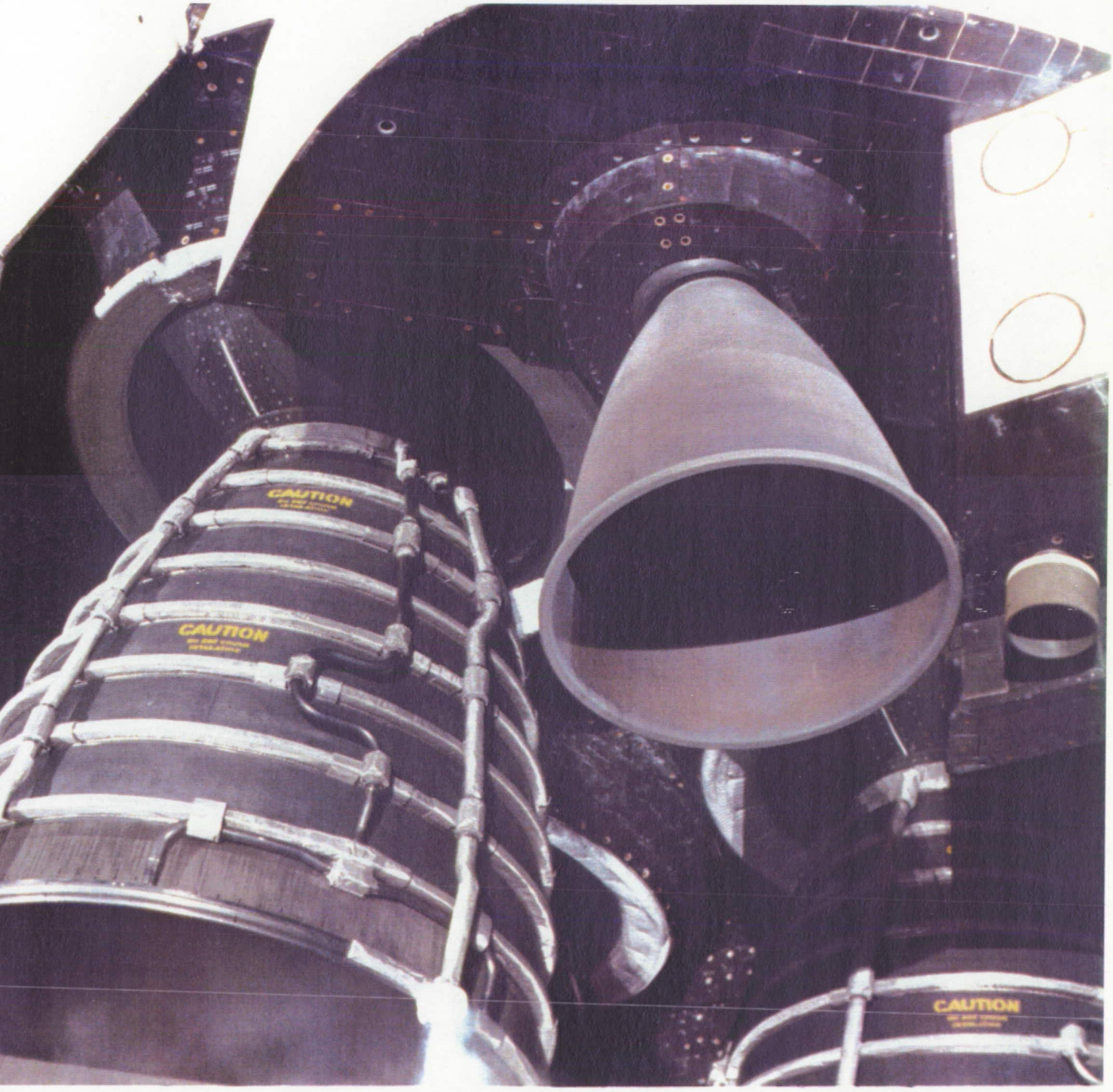
No new debris concerns had been identified during the ice/frost inspection of the vehicle.

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

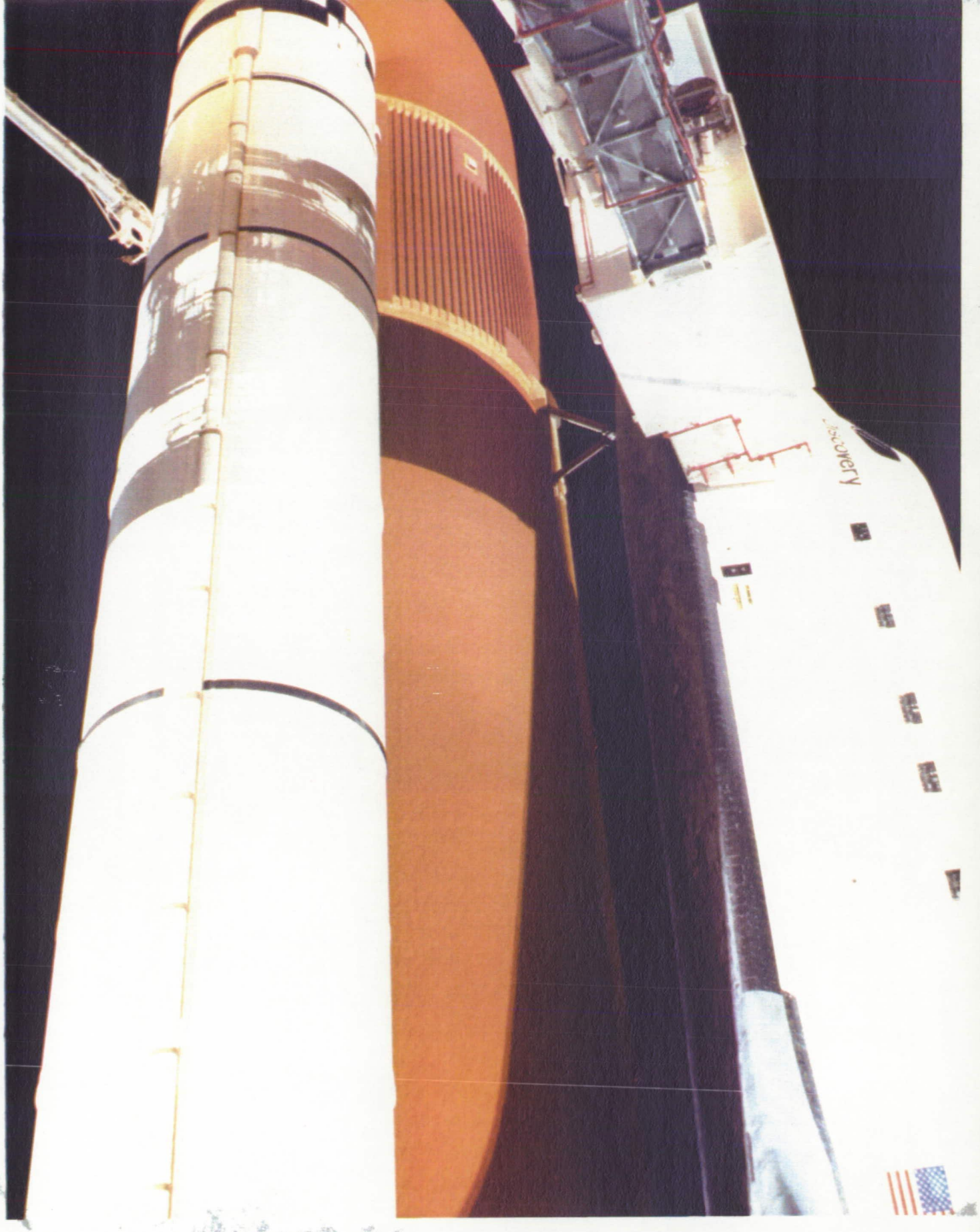
No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, though typical accumulations of ice/frost were present on the cryogenic lines. There was also no apparent leakage anywhere on the GH2 vent line or GUCP. The modification to the GH2 vent line prevented ice from forming but some ice/frost,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

Infrared observations of the ET nosecone showed warm gas leakage (most likely heated GN2 purge) under the southwest (-Y) GOX seal during the first cryo load. Post drain inspection of the seals revealed no anomalies. Visual and infrared observations of the GOX seals confirmed no leakage during the second cryo load. The small piece of ice or white debris between the southwest GOX seal and the ET nosecone was not visible after the GOX vent hood was retracted. There was no ET nosecone/footprint damage.

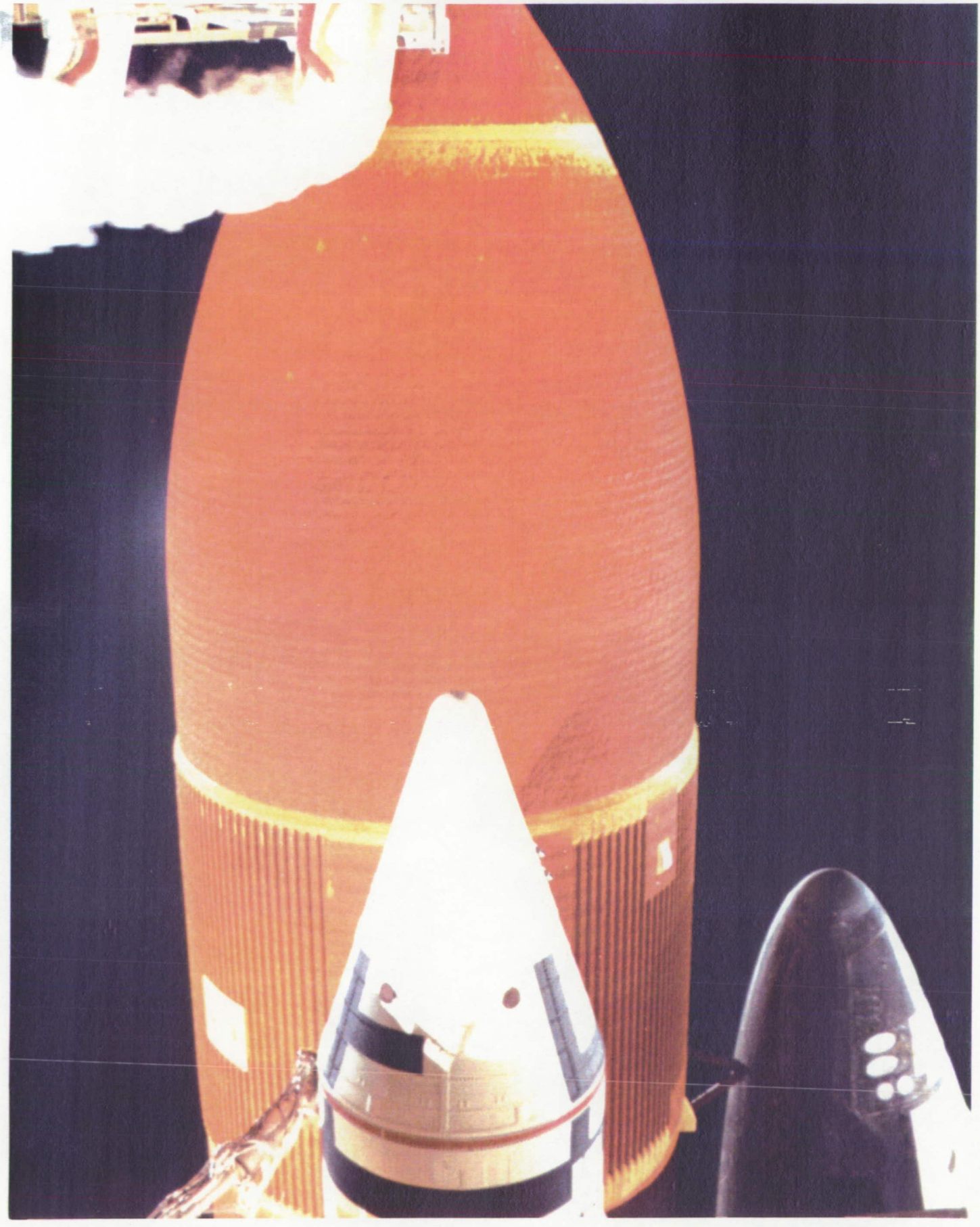
Two icicles, measuring 3"x0.5", had formed on the GOX vent ducts. Although some of the ice had fallen off the duct prior to launch, the remaining ice was prohibited by NSTS-08303. Waiver LW-024 was processed allowing the presence of icicles on the GOX vent duct. Supporting rationale stated the icicles were not directly above any flight element. Winds from the south would tend to blow falling icicles away from the vehicle.



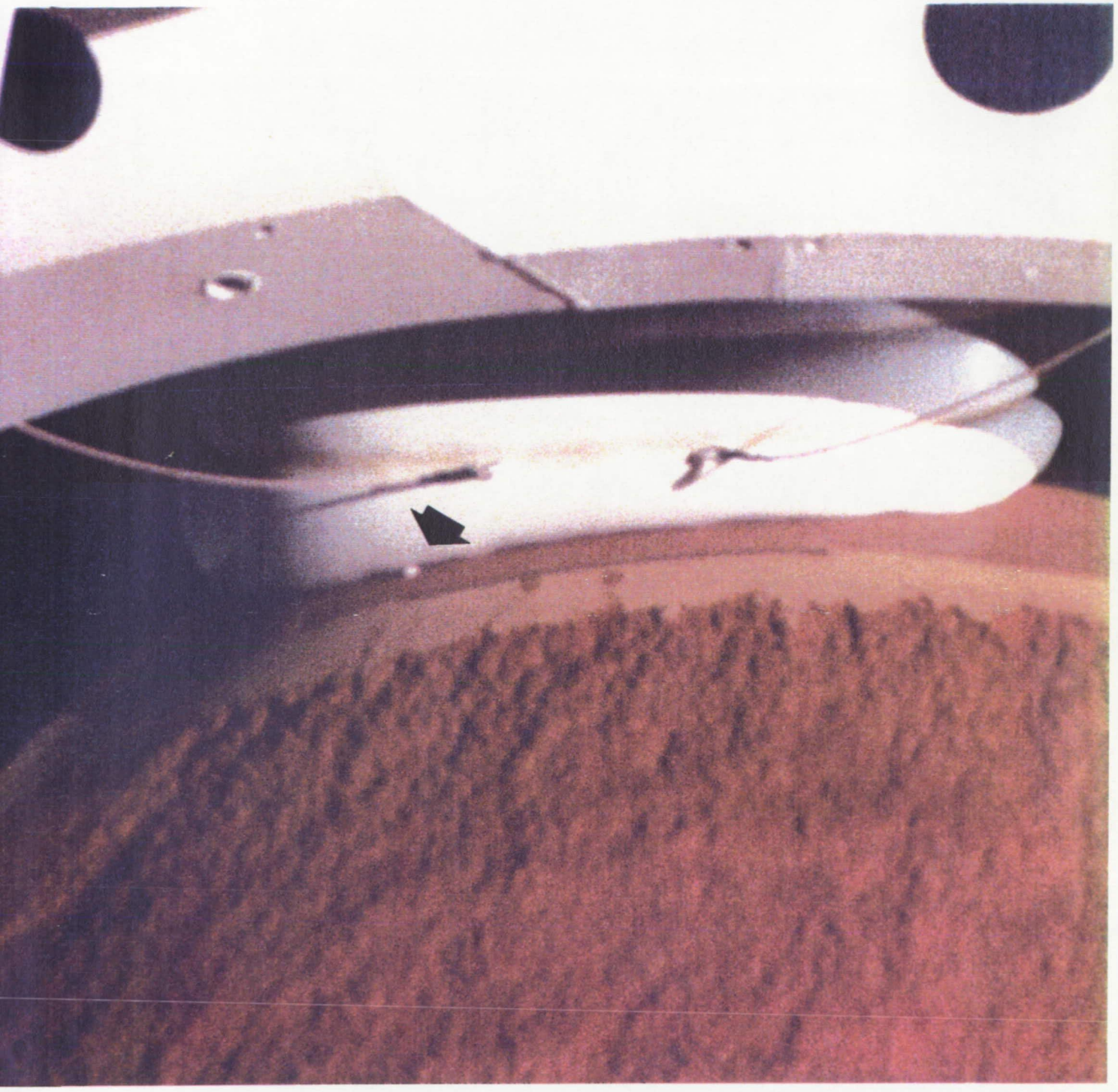
Overall view of OV-103 SSME's. Less than usual ice/frost had formed at the engine heat shield-to-nozzle interface. Some condensate was present on the SSME heatshields.



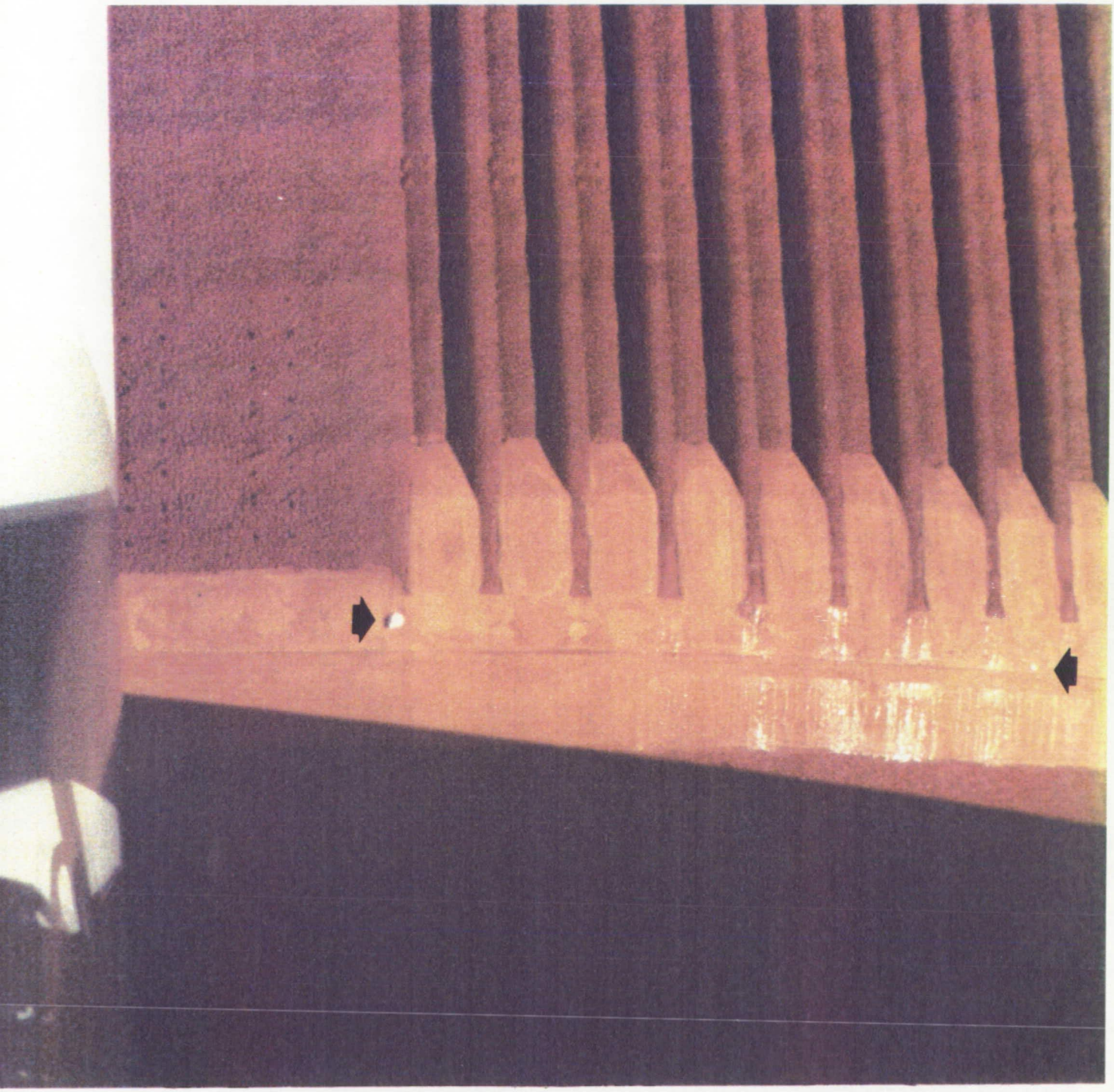
No ice/frost had formed on the LH2 tank acreage TPS. No anomalies occurred on Orbiter and SRB external surfaces.



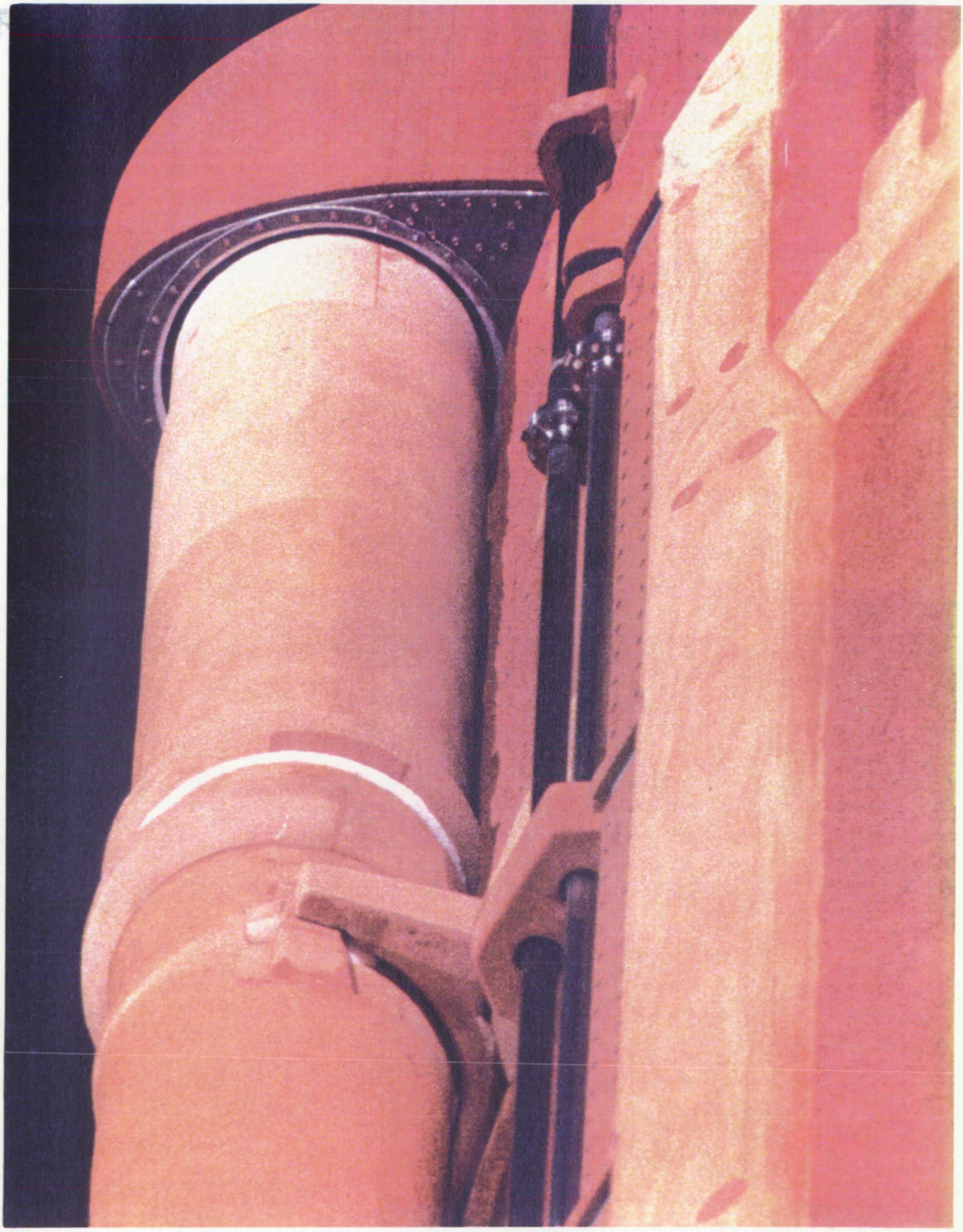
Overall view of ET-46 LO2 tank. No ice/frost had formed on the acreage TPS, though the tank was wet with condensate. Note SOFI spray interrupt/sanded area on ogive section.



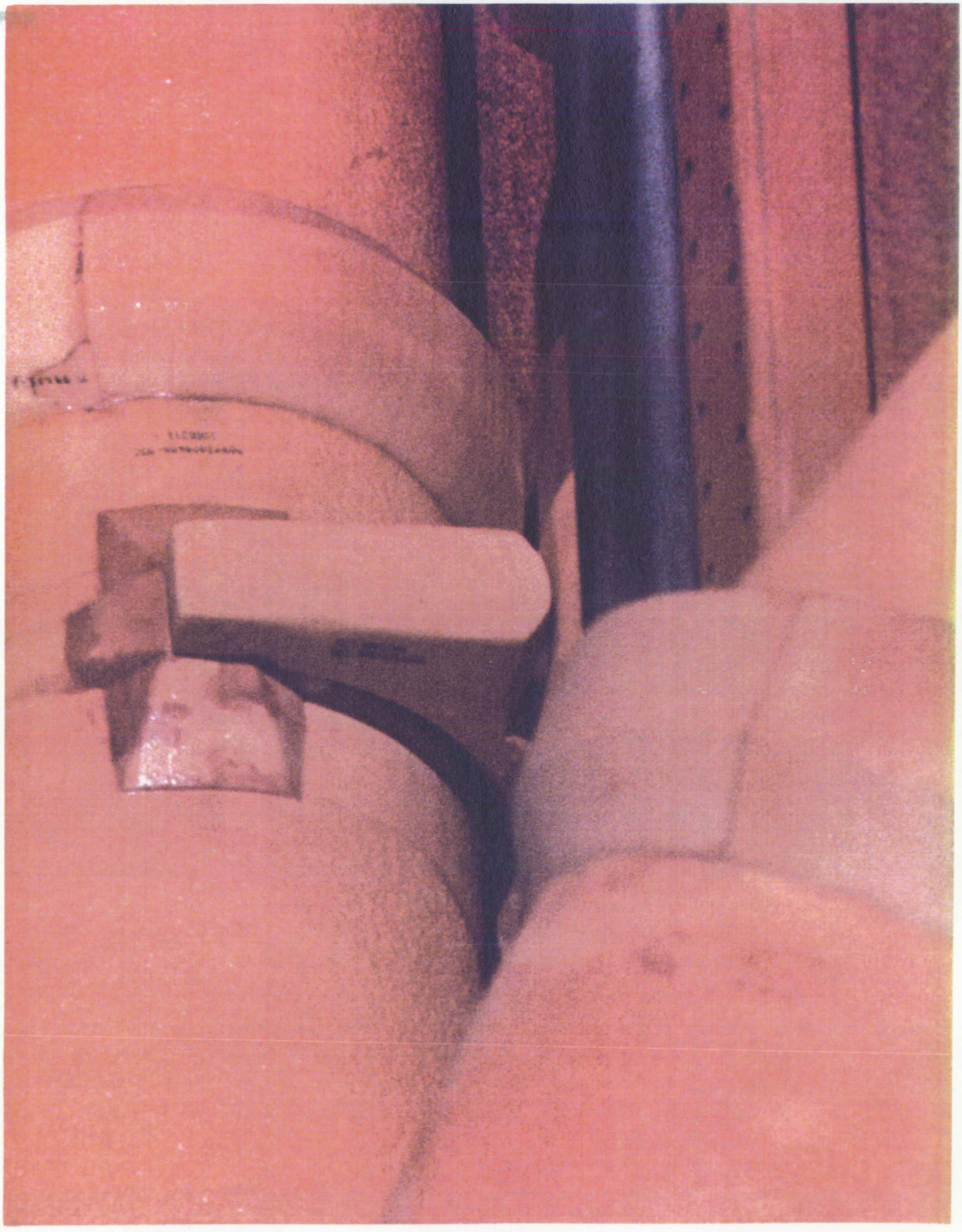
Small white debris particle or ice ball 1/2-inch in diameter was visible between the southwest (-Y) GOX seal and the ET TPS/ footprint. GOX vent hood retraction prior to launch revealed no TPS damage or ice/frost accumulation.



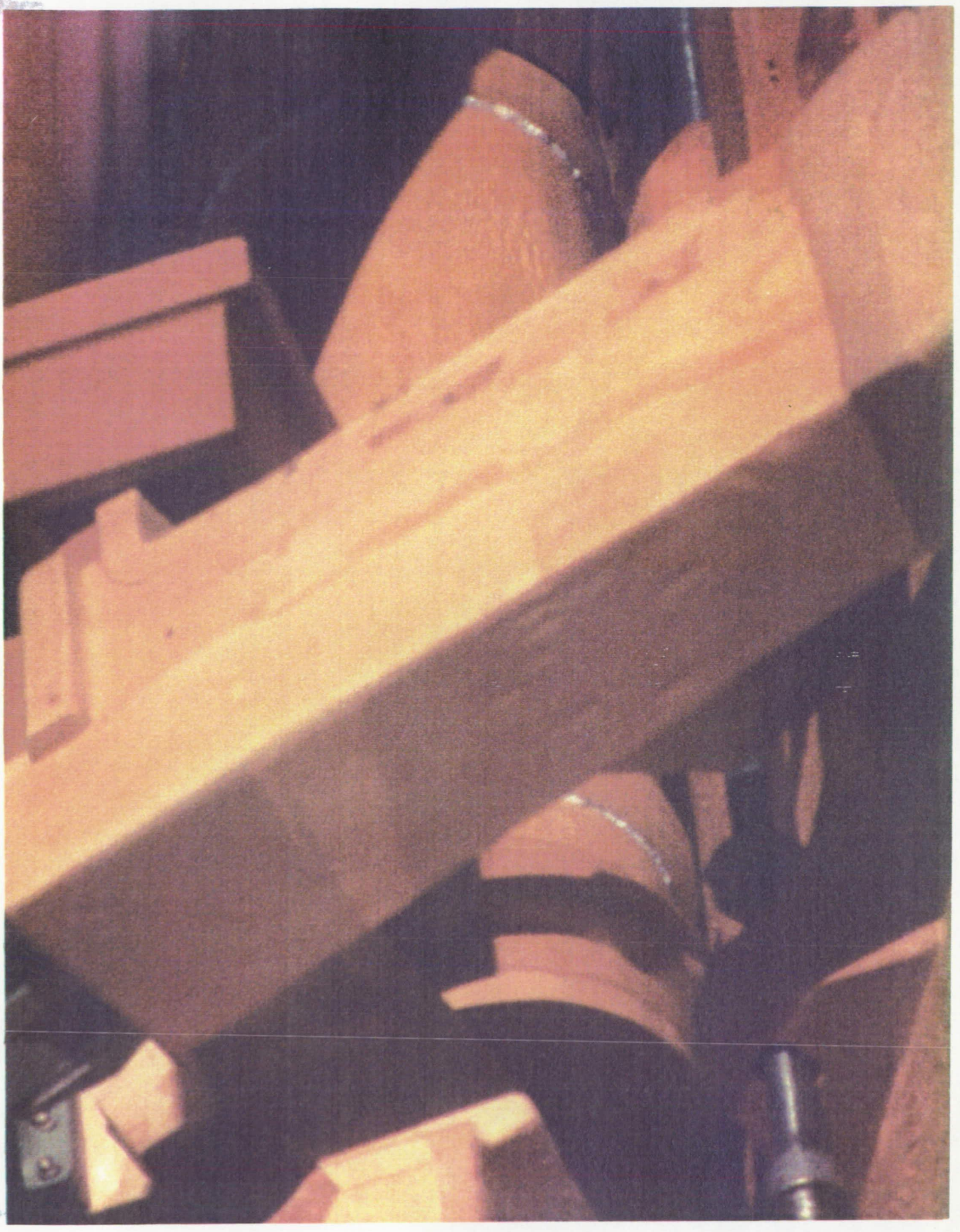
Ice/frost ball, 1-2 inches in diameter, formed on a small void in the LH2 tank-to-intertank flange TPS closeout. Some venting of vapor occurred while the ice/frost accumulated. Engineering evaluation determined this ice/frost condition was acceptable for launch. Two other frost spots also occurred on the flange closeout.



Typical ice/frost accumulation in LO2 feedline upper bellows and support bracket

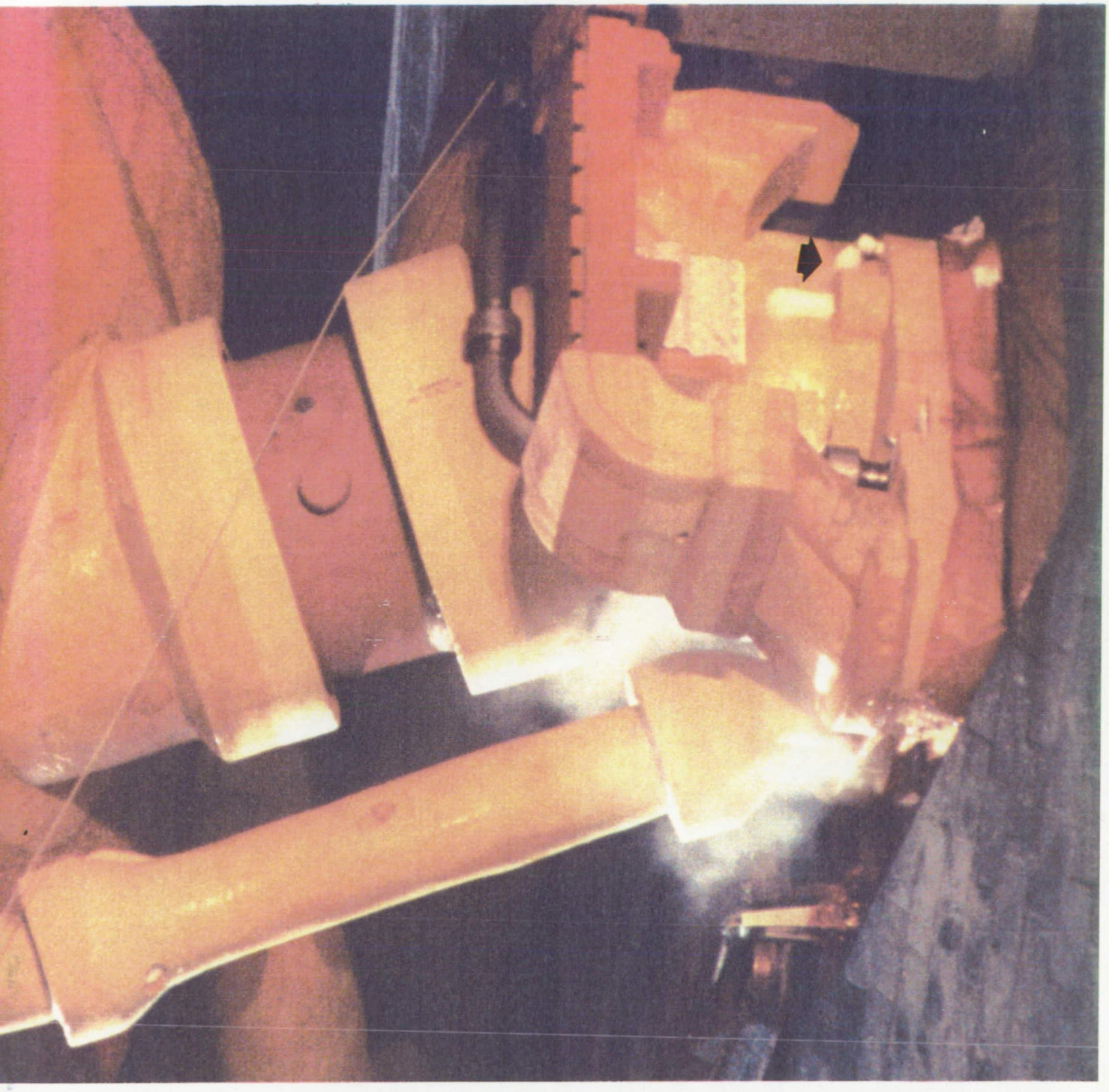


Typical ice/frost accumulation in LO2 feedline support bracket

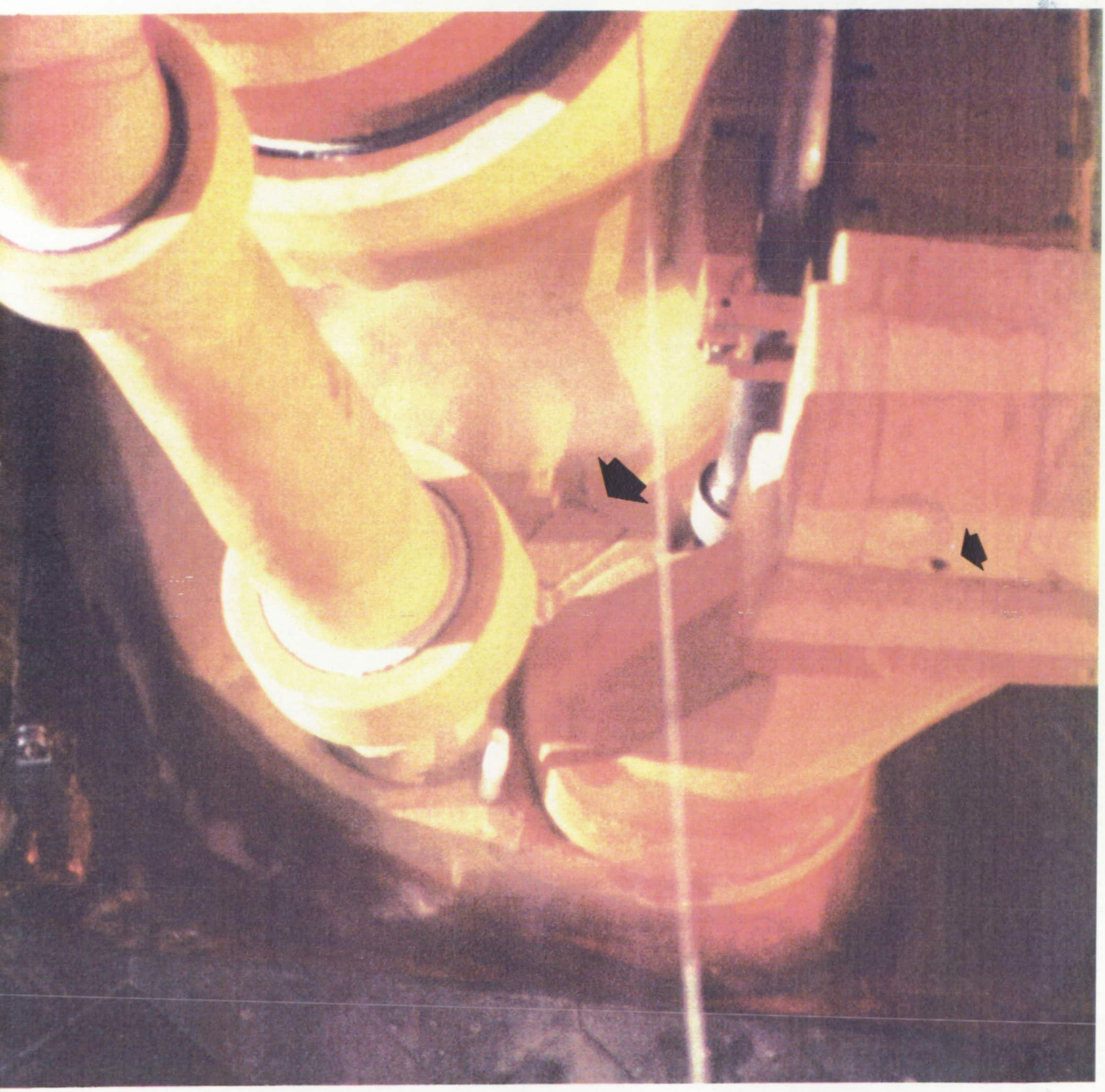


Typical ice/frost accumulation in LO2 feedline lower bellows

Overall view of LO2 ET/ORB umbilical. Ice/frost finger on forward outboard pyrotechnic canister purge vent was typical. No TPS anomalies were visible. White line at LO2 feedline-to-umbilical interface was spackling material, not ice or frost.



Overall view of LH2 ET/ORB umbilical. Ice/frost finger formation on plate gap and pyrotechnic canister purge vents was typical. Small ice/frost ball formed on forward outboard pyro canister TPS closeout bondline (arrow). Venting of vapors was typical and no cryogenic drops were present. Less than usual ice/frost accumulated on the purge barrier baggie material.



Aft view of LH2 ET/ORB umbilical. Ice/frost finger on the aft plate gap purge vent was typical. No ice/frost was present on the cable tray vent hole or the 17-inch flapper valve actuator tool access port foam plug closeout. Typical amounts of ice/ frost accumulated in the LH2 recirculation line bellows.

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 28 April 1991 from Launch + 1 to 3 hours. No flight hardware or TPS materials were found.

South SRB holddown post erosion was typical. EPON shim bottom plate material was intact. Shim sidewall material on south HDP's was intact, but debonded to various degrees. There was no evidence of any stud hang-up. 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. The new electrical cable connector savers on the SRB joint heater T-0 umbilicals were all in place and showed typical plume impingement effects.

The OAA and TSM's showed the usual minor amount of post launch damage. The GOX vent arm was locked in the retracted position and exhibited minor launch damage. The GH2 vent arm appeared to have retracted nominally, was latched on the sixth tooth of the latching mechanism, and had no loose cables. The modification to the static lanyard retract system had been completed on Pad A. The ET intertank access structure sustained typical plume heating effects.

The new Hydrogen Dispersal System structure welded to the MLP deck showed no sign of damage. One MLP electrical box, located at the southeast corner of MLP, was missing a cover. None of the facility cable tray covers were loose or missing.

Damage to the facility was less than usual and included 1) a safety rope/chain storage box found west of the pad apron, 2) a metal sign designating the 175 foot level was detached from and found on the west side of the 175 foot level, and 3) seven pieces of damaged thin metal (less than 1/16 inch in thickness) from the chilled water pipe on the FSS/RSS 107 foot level crossover found on the pad apron and west of the pad apron.

No emergency egress slidewire baskets had released during launch.

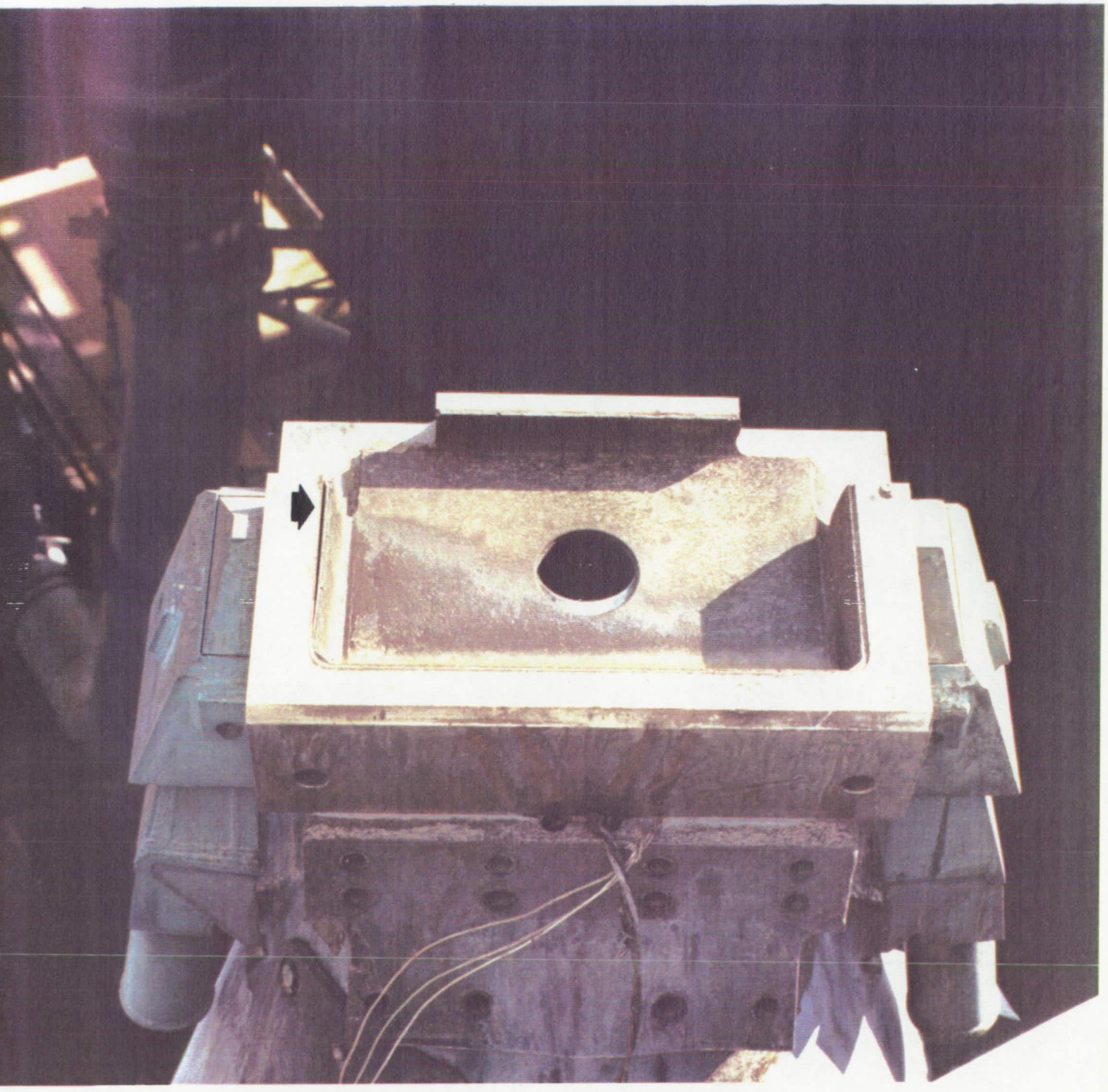
Inspection of the pad perimeter was completed on 29 April 1991 along with the areas outside the pad perimeter, railroad tracks, the beach from UCS-10 to Titan Complex 40, the beach access road, and the ocean areas under the vehicle flight path. Several pieces of Delta and Atlas launch vehicles, but no 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 detec-

table, which generally compares with the types of particles detected on previous Shuttle flights. A total of 55 particles were imaged in the T+139 to 376 second time period, though most of the objects were visible in the T+139 to 240 second time frame. 14 of the particles were imaged by only one radar, 24 particles were imaged by two radars, and 17 particles were imaged by all three radars. There were no particles that stood out by echo amplitude above the others. 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 11.1

All doghouse blast covers on the north holddown posts had closed properly. Plume erosion appeared to be less that usual.



EPON shim material on the south holddown posts was intact but debonded along the sidewalls to various degrees

New SRB T-0 umbilical electrical connector savers (sacrificial pieces) were intact

Electrical box cover was missing at southeast corner of MLP

Post launch debris included pieces of thin sheet metal from a chilled water pipe on the FSS/RSS 107 foot level crossover. No flight hardware was found.

7.0 FILM REVIEW SUMMARY/PROBLEM REPORT DISPOSITION

A total of 155 film and video data items, which included 47 videos, 60 16mm films, 33 35mm films, 5 70mm films, and 10 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.

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 drops during liftoff.

SSME ignition and gimbal profile appeared normal. Free burning hydrogen rose past the vertical stabilizer or was blown under the body flap by south winds (OTV 63, 70, STI C/S-2).

SSME ignition caused numerous pieces of ice to fall from the ET/Orbiter umbilicals. No damage to Orbiter tiles or ET TPS was visible. SSME ignition vibration/acoustics caused a tile on the LH OMS pod aft surface, 3 places on the Orbiter base heat shield, and 2 places on the RH RCS stinger to lose surface coating material (E-18, 19, 20, 23, 24).

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). There was no evidence of the small white particle between the southwest GOX vent seal and the nosecone TPS noted during the Ice Team Inspection.

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 properly. No slack occurred in the static retract lanyard. The modification to the static lanyard retraction system had been completed on Pad 39A prior to this launch (E-33, 42, 50).

Five ordnance fragments, including a piece of NSI cartridge, a 2.5"x0.25" web, and three pieces measuring 2"x1/2", 1-1/4"x3/4", and 1"x3/4", fell from the HDP #7 DCS/stud hole just after liftoff (E-11, 28). Inspection of the SRB at Hangar AF revealed the HDP #7 DCS plunger had been obstructed by frangible nut halves.

One piece of LH SRB aft skirt thermal curtain tape came loose at T-0 (E-4, 16).

Approximately 5 feet of cable on both HDP #6 and #7 remained attached to the LH SRB aft skirt and flew with the vehicle (E-11, 13, 16). The firing cable will usually stretch/break near the DCS.

The ice/frost formation on the LH2 tank-to-intertank flange closeout, reported by the Ice Team during the T-3 Hour Inspection, was still attached to the ET through liftoff/early ascent (OTV 061, 062, E-213).

Numerous particles were ejected out of the SRB exhaust holes after T-0 as the vehicle attained 30 feet altitude. 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.

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, such as RCS paper covers (E-207, 222, 223, 224).

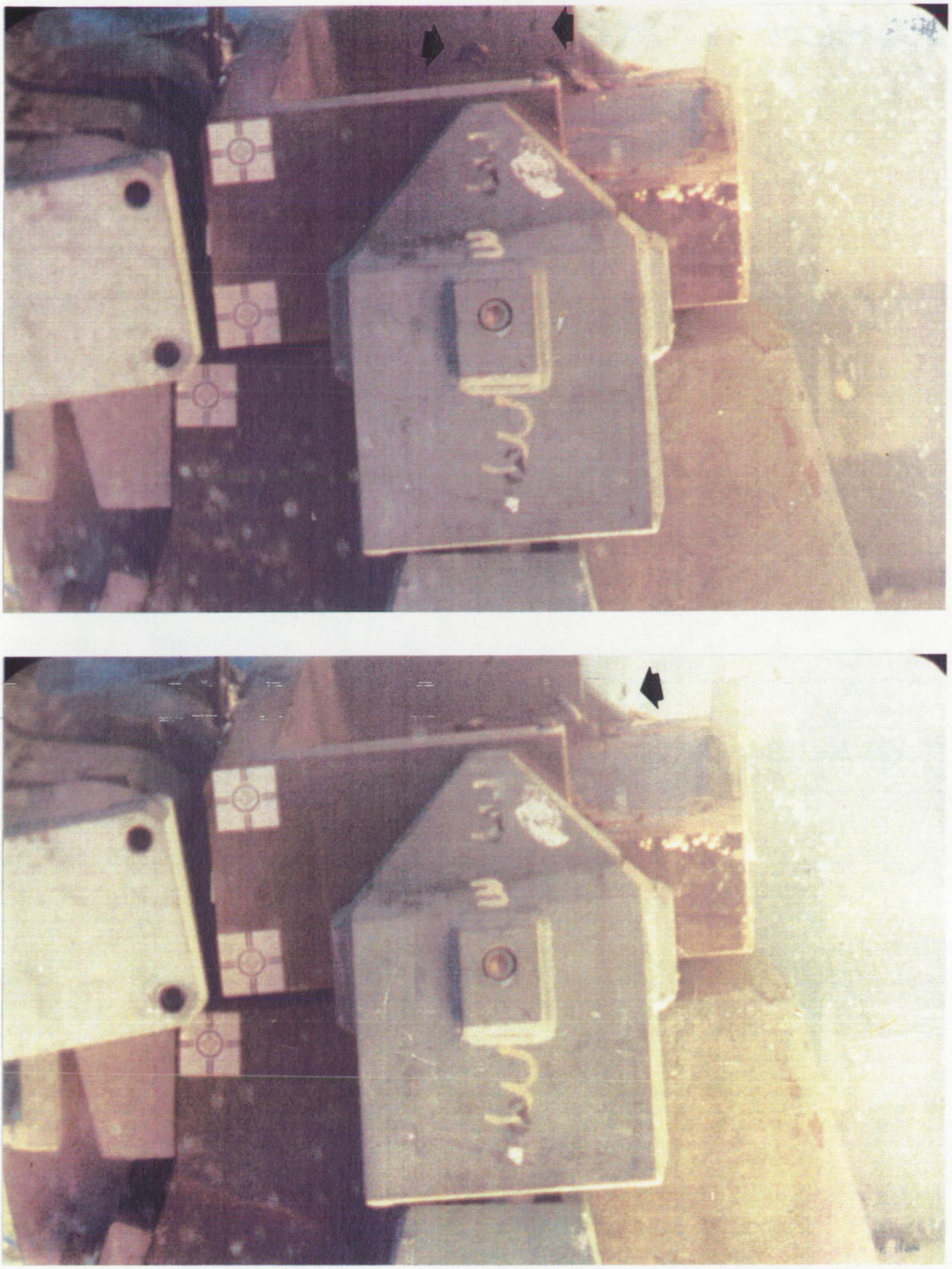
At least 9 light-colored particles dropped out of the SRB plume during ascent in the time frame 61-82 seconds MET (E-208, 212, 218, 223, 224, TV-4A). Similar particles on previous flights have been attributed to either chunks of SRB propellant/inhibitor or pieces of aft skirt instafoam.

Plume recirculation and ET aft dome charring appeared normal.

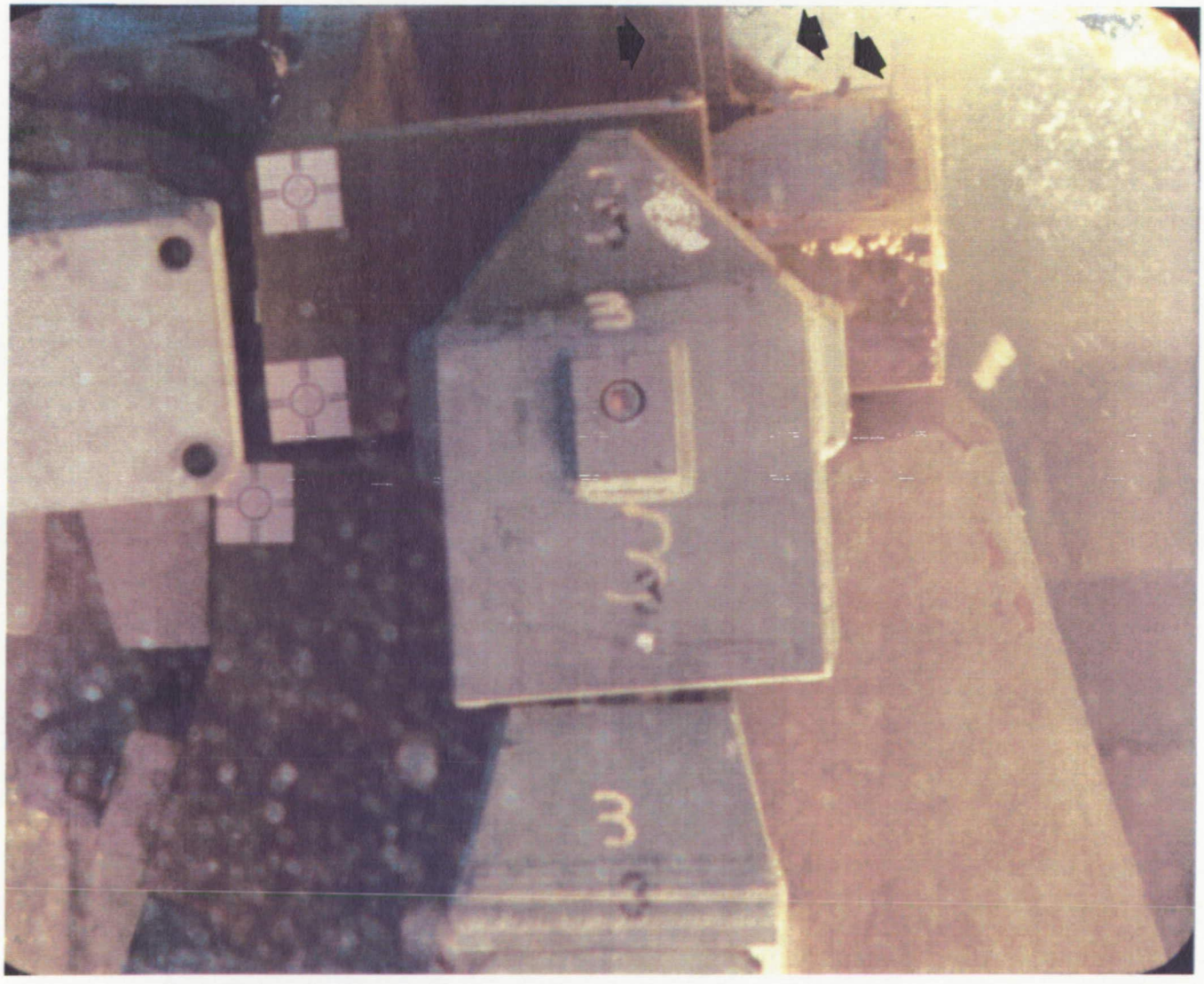
Just before SRB separation from 11:35:05.57 through 11:35:05.94, a puff of dark smoke, a brightening of the SRB plume (more visible flame), and more puffs of darker smoke were highlighted against the normally lighter SRB plume (E-206, 207, 208, 212, 218, 223). This event may be due to burning of inhibitor and/or normal tailoff with better flow visualization for this mission. E-205 provided an almost perpendicular view of the RH SRB plume event at 111 seconds MET. Post flight inspection inside the SRM revealed no anomalies or causes for the event. No significant discrepancies were discernible in the chamber pressure decay data (via telemetry) during ascent. The event is not considered to be an anomaly.

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

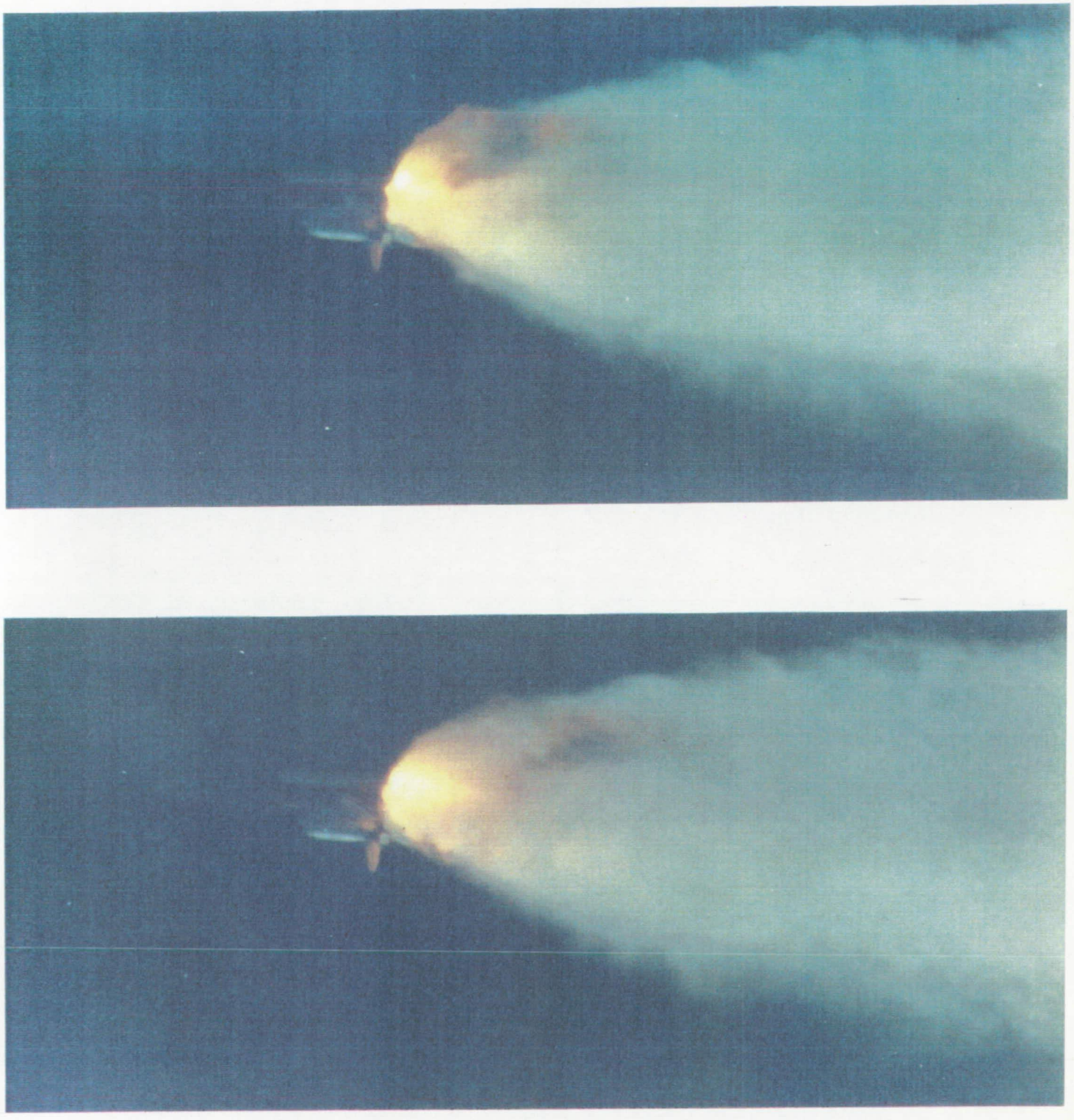
No PR's or IPR's were generated as a result of the film and video data review. Post Launch Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. These anomalies are listed in Section 11.2.



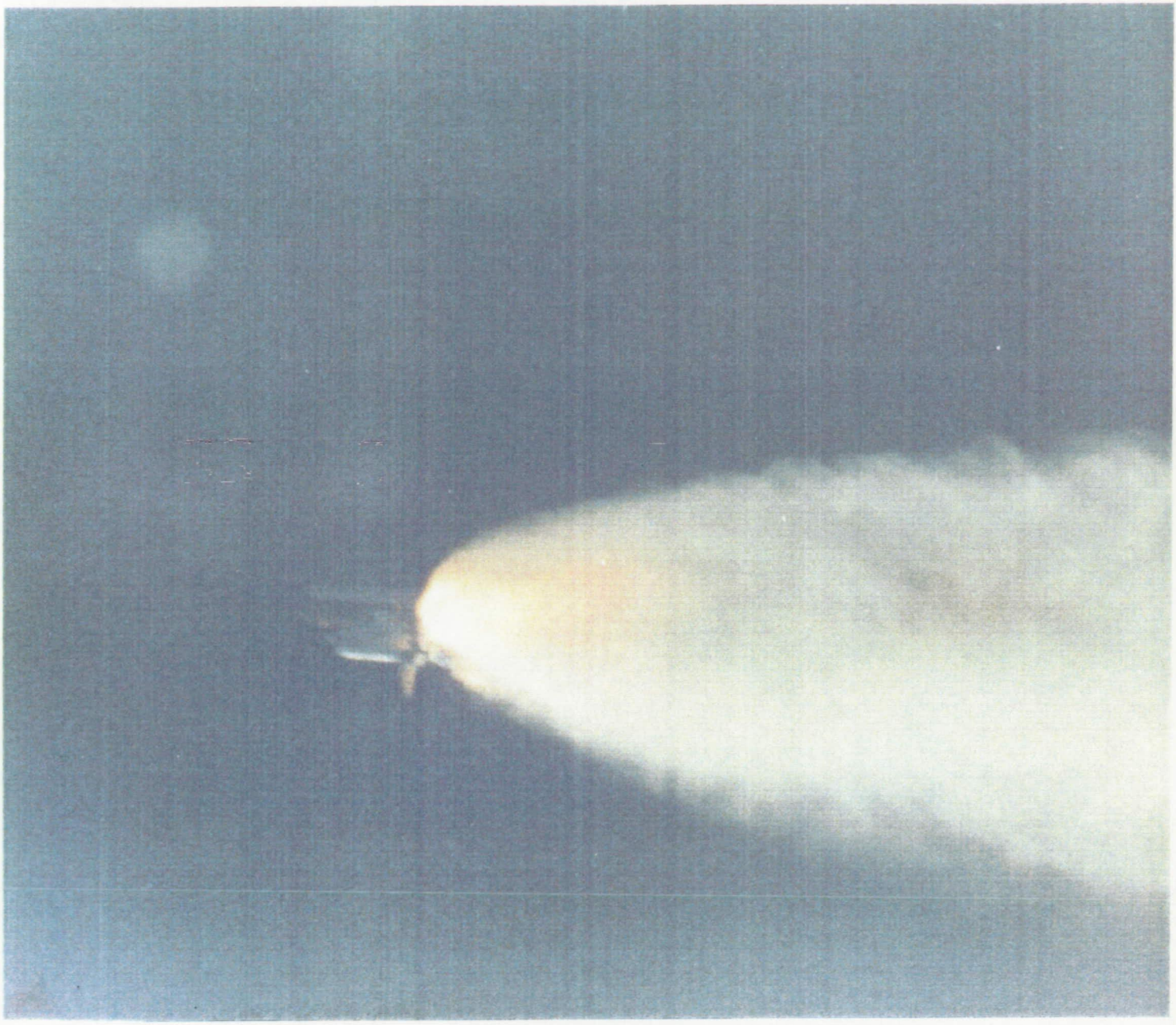
Five ordnance fragments, including the threaded part of an NSI cartridge, fell from the HDP #7 DCS/stud hole



Most of the ordnance fragments from the HDP #7 DCS bounced off of the holddown post shoe and were lost to view



Brightening (more visible flame), along with puffs of darker smoke, occurred in the SRB plume at 111 seconds MET



Typical appearance of SRB plume prior to tailoff

On-orbit view of the External Tank shortly after separation from the Orbiter revealed no major anomalies. BSM burn scar on the LO2 tank is typical. Bright line on the LO2 tank ogive is the SOFI spray interrupt/sanded area - a feature on the tank prior to launch.

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 Heater Umbilical during ignition and liftoff.

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

Comments: HDP shoe shifted (lowered) 1/2-inch after ordnance fired. At T-0 HDP shifted downward and rocked outward. HDP shoe rose approximately 1.5" with SRB foot before settling back down. After separation, black rough object fell from inboard side of shoe. No debris fell from DCS/stud hole. Several particles of SRB throat plug material were visible after liftoff.

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.

Comments: No data. Film started too early and lens fell off.

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.
Exposure: O.K.

Comments: SRB T-0 umbilical separation and retraction was normal. Instafoam trimmings were ejected from between umbilical and SRB aft skirt.

EX4 Camera is located on MLP deck south of LH SRB
400 FPS flame duct and looks north to view LH SRB Heater
16mm Umbilical during ignition and liftoff.

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

Comments: HDP shoe shifted (lowered) 1/2-inch after ordnance fired. At T-0 HDP shifted downward and rocked outward. Black particle in upper RH FOV fell from near base of skirt onto HDP shoe face.

E-1 Camera is located on the NE corner of the MLP deck
400 FPS and views the lower ET, SRB's, and Orbiter.
16mm

Focus : O.K.
F. O. V.: O.K., BUT TIMER PROBLEM CAUSED EARLY START
Exposure: O.K.

Comments: Numerous ice/frost particles fell from ET/Orbiter umbilicals during SSME ignition, but none appeared to contact Orbiter tiles. Free burning hydrogen at SSME ignition drifted between SSME engine nozzles and Orbiter body flap.

E-2 Camera is located on the SE corner of the MLP deck
400 FPS and views Orbiter SSME and OMS engine nozzles.
16mm

Focus : O.K.
F. O. V.: O.K., BUT TIMER PROBLEM CAUSED EARLY START
Exposure: Slightly dark.

Comments: SSME shock diamond formation appeared normal. LH2 TSM door closure was nominal. Residual vapors were visible from LO2 TSM T-0 disconnect. Condensate vaporized on SRB stiffener rings at SSME ignition.

E-3 Camera is located on the SW corner of the MLP deck
400 FPS and views Orbiter SSME and OMS engine nozzles.
16mm

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

Comments: Camera light inside LH2 TSM came on (frame 4603). SSME engine acoustics and plume aspiration tore aft RCS paper covers. A particle, near west side of LH2 TSM, traveled east across FOV and had the appearance of an RCS paper cover. LO2 TSM door was closed as vehicle rose.

E-4 Camera is located on the NW corner of the MLP deck
400 FPS and views lower ET, SRB's, and Orbiter.
16mm

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

Comments: Free burning hydrogen drifted under Orbiter body flap at SSME ignition. Ice/frost particles fell from ET/ORB umbilicals. Condensate vaporized on ET aft dome and SRB stiffener rings during liftoff. LO2 TSM door closure was normal. SRB thermal curtain tape came loose from aft skirt at T-0. SRB sound suppression water trough cords were torn loose by SRB plume.

E-5 Camera is located on the east side of the MLP
400 FPS deck and views the Orbiter RH wing, body flap,
16mm and lower ET/SRB.

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

Comments: Ice/frost particles fell from LO2 ET/ORB umbilical starting at SSME ignition. One large piece fell at T-0, but no Orbiter contact was visible. Residual vapors emanated from LOX T-0 disconnect. At frame 5970, a particle traveled from left to right at SSME ignition and was most likely RCS paper cover material. Three ice particles fell from LOX TSM T-0 disconnect and were visible near upper side of LH wing. Ice frost particles fell from LH2 ET/ORB umbilical inboard side.

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: Underexposed

Comments: Ice/frost particles fell from ET/ORB umbilicals at SSME ignition. Movement of RH outboard elevon during SSME ignition was normal. Residual vapors emanated from LO2 T-0 umbilical. Orange flashes occurred in SSME #3 shock diamond (frame 2916).

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., BUT VIBRATION WAS EXCESSIVE
Exposure: O.K.

Comments: Numerous ice/frost and water deluge particles fell from above SRB aft skirt. Numerous particles of SRB throat plug material and sound suppression water trough material were ejected out of SRB exhaust hole at T-0. SRB doghouse closure was nominal. No debris 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., BUT VIBRATION WAS EXCESSIVE
Exposure: O.K.

Comments: Ice particles fell through FOV with no vehicle contact. SRB aft skirt instafoam outgassed during liftoff. No debris fell from HDP #2 DCS/stud hole.

E-9 Camera is located on the MLP deck and views the
400 FPS RH SRB southwest holddown post (HDP #1).
16mm

Focus : O.K.
F. O. V.: O.K., BUT VIBRATION WAS EXCESSIVE
Exposure: Slightly dark.

Comments: Ice particles fell to MLP deck in camera foreground prior to T-0. Dark debris appeared behind DCS plunger housing. SRB throat plug material was ejected out of SRB exhaust hole at T-0. Ice/frost particles fell from LO2 feedline area onto MLP deck in RH FOV.

E-10 Camera is located on the MLP deck and views the
400 FPS RH SRB northwest holddown post (HDP #3).
16mm

Focus : O.K.
F. O. V.: O.K., BUT STARTED LATE
Exposure: O.K.

Comments: Camera view was obstructed by condensate run-off from ET aft dome. SRB doghouse closure was nominal. HDP shoe rocked during liftoff. MLP debris moved across FOV from left to right with no vehicle contact.

E-11 Camera is located on the MLP deck and views the
400 FPS LH SRB northeast holddown post (HDP #7).
16mm

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

Comments: Ice particle from EB-7 fell onto deck. A piece of sound suppression water trough chord was torn loose and blown upward 6 inches before falling onto MLP deck. Five feet of SRB firing cable remained attached to the aft skirt during liftoff. The firing cable usually stretches/breaks near the DCS. Three ordnance fragments, measuring 1.25"x.75", 1"x.75", and 2"x.5", fell from the HDP #7 DCS/stud hole after liftoff.

E-12
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB southeast holddown post (HDP #5).

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

Comments: Numerous small ice particles from EB-3 and 5 and the LH2 umbilical moved from left to right after SSME ignition. Numerous particles appeared from base of DCS at SSME ignition and T-0. Several pieces of SRB aft skirt instafoam fell from behind HDP #7.

E-13
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB southwest holddown post (HDP #6).

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

Comments: Ice particles fell onto MLP deck from LH2 umbilical during SSME ignition. SRB firing cable elongated before it broke loose leaving 5 feet attached to SRB aft skirt. The firing cable will usually stretch/break near the DCS. SRB aft skirt instafoam outgassed during liftoff. SSME aspiration pulled particles from behind HDP #6 DCS.

E-14
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB northwest holddown post (HDP #8).

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

Comments: SRB aft skirt instafoam outgassed during liftoff. A 3 ft section of SRB thermal curtain tape came loose from aft skirt thermal blanket.

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: Ice/frost particles fell from LO2 ET/ORB umbilical at SSME ignition. Frost particles fell from SSME #3 nozzle. At frame 5170 pieces of SRB throat plug material on east side of SRB moved away from vehicle. No debris fell from HDP DCS/stud holes. Holddown post blast cover closure was nominal.

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: Free burning hydrogen at SSME ignition drifted under the body flap. Ice/frost particles fell from LH2 umbilical after SSME ignition. Firing cable remained attached to HDP #7. Throat plug material appeared near HDP #8. SRB sound suppression water trough material was ejected out of SRB exhaust hole at T-0. SRB thermal curtain tape came loose and dangled from aft skirt during liftoff.

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: Dark

Comments: GOX dump from SSME purge obscured early FOV. Numerous ice particles fell from LOX TSM and T-0 disconnect. Orbiter body flap motion was visible during SSME ignition. Disconnect and retraction of LOX T-0 was normal. No tile chips were visible on Orbiter base heat shield.

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., BUT FILM ENDED PRIOR TO T-0
Exposure: O.K.

Comments: Free burning hydrogen at SSME ignition drifted under the body flap. Ice particles fell from LH2 TSM T-0 disconnect and ET/ORB umbilicals at SSME ignition. Orbiter body flap movement at ignition was normal. SSME ignition acoustics/vibration caused the loss of some tile surface coating material.

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: Dark

Comments: Free burning hydrogen at SSME ignition. SSME ignition and aspiration tore RCS paper covers. Ice/frost particles fell from LOX TSM at T-0. LH2 TSM door closure was nominal. SSME ignition causes tile surface coating material to fall from aft face of RH OMS pod. During SSME ignition, ice fell from LH2 T-0 disconnect and SSME nozzle drain lines.

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., BUT VIBRATION WAS EXCESSIVE
Exposure: O.K.

Comments: SSME ignition acoustics/vibration caused the loss of some tile surface coating material at one location on both the LH stinger and base heat shield. Ice fell from the LO2 T-0 disconnect. Residual vapors emanated from LH2 TSM T-0 disconnect. LO2 TSM door closure was nominal.

E-21 Camera is located inside the LO2 TSM and views
400 FPS the disconnection of the T-0 umbilical.
16mm

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

Comments: Ice/frost fell from T-0 umbilical at SSME ignition. T-0 separation and retraction was nominal. Residual vapors emanated from Orbiter T-0 disconnect. TSM door closed with no rebound. After carrier plate retraction motion stopped, more ice fell from umbilical. Debris fell from inside of door leading edge sill.

E-22 Camera is located inside the LH2 TSM and views
400 FPS the disconnection of the T-0 umbilical.
16mm

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

Comments: Purge barrier was torn loose at SSME ignition. Umbilical separation and retraction was nominal. Residual vapors emanated from Orbiter T-0 disconnect. Ice fell from T-0 umbilical when carrier plate retraction stopped. TSM door closed with no rebound.

E-23 Camera is located on the MLP deck and views the
400 FPS RH OMS engine nozzle.
16mm

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

Comments: Free burning hydrogen occurred at SSME ignition. RCS paper covers were torn loose during ignition. Ice/frost particles fell from LO2 T-0 umbilical. LO2 TSM door closure was nominal. SSME ignition acoustics/vibration caused the loss of tile coating repairs (3 places on the base heat shield and 2 places on the aft face of the RH stinger).

E-24 Camera is located on the MLP deck and views the
400 FPS LH OMS engine nozzle.
16mm

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

Comments: Ice/frost particles fell from LH2 T-0 umbilical during ignition. Residual vapors emanated from LH2 T-0 umbilical after separation. SSME ignition tore RCS paper covers on the aft stinger. SSME acoustics caused 5 tile surface coating repairs to come loose.

E-25 Camera is located on the east side of the MLP and
400 FPS views between Orbiter and ET/SRB during liftoff.
16mm

Focus : O.K., BUT IMAGE WAS SLURRED
F. O. V.: O.K.
Exposure: O.K.

Comments: Ice/frost particles fell from ET/ORB umbilicals during SSME ignition and T-0. No contact with orbiter surfaces. Residual vapors emanated from LOX T-0 disconnect.

E-26 Camera is located on the west side of the MLP and
400 FPS views between Orbiter and ET/SRB during liftoff.
16mm

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

Comments: Ice/frost particles fell from ET/ORB umbilicals at SSME ignition. Condensate vaporized on ET aft dome during lift-off. A particle crossed the side of the TSM and FOV at frame 2885. GH2 vent line retraction appeared normal.

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., BUT VIBRATION WAS EXCESSIVE
Exposure: O.K.

Comments: HDP rocked backward tilting approximately 2 inches. Numerous small foam particles appeared after liftoff. A thin particle fell in upper LH corner FOV at frame 6059.

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., BUT VIBRATION WAS EXCESSIVE
Exposure: O.K.

Comments: HDP rocked backward after liftoff. Foam trimmings were blown around after separation. A piece of SRB aft skirt instafoam was torn loose during liftoff. Five pieces of frangible nut and NSI cartridge fell from DCS/stud hole and landed on HDP shoe face. The three large particles measured 2.5"x.25", .375"x.375", and 1.25" dia. NSI cartridge with thread was visible.

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: Free burning hydrogen at SSME ignition drifted under body flap. Ice/frost particles fell from ET/ORB umbilicals during ignition. SRB thermal blanket tape came loose near HDP #8. Numerous particles of throat plug material and sound suppression water trough were ejected from SRB exhaust hole.

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: Underexposed. Film speed may be incorrect.

Comments: Numerous ice/frost particles fell from LH2 umbilical during SSME ignition. Several particles bounced on umbilical door sill before falling to MLP deck. No tile damage was visible. Ice finger on LO2 cable tray vent hole fell first. Movement of inboard and outboard elevons was typical. Condensate vaporized on ET aft dome and SRB stiffener ring during liftoff.

E-33
200 FPS
16mm

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

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

Comments: FIREX water system was activated on FSS properly. Vapors emanated from GUCP shroud. ET twang was nominal. Ice fell from GUCP prior to T-0 and numerous pieces fell after T-0. Residual vapors were visible in ET T-0 disconnect.

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: Slightly dark.

Comments: Residual vapors emanated from Orbiter LH2 T-0 disconnect. Vapors also appeared in ET -Y vertical strut "doghouse" vent hole. Forward RCS paper covers were intact thru LOV. GH2 vent line disconnect and retraction were nominal. Hydrogen fire detection paper on the ET was intact thru LOV. Numerous debris particles were visible in plume after vehicle cleared FOV.

E-35 Camera is located on the FSS 255 foot level and
300 FPS views the mid-Orbiter/ET/SRB area.
16mm

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

Comments: Free burning hydrogen visible at SSME ignition. Focus too poor for further analysis.

E-36 Camera is located on the FSS 255 foot level and
300 FPS views lower Orbiter, ET, SRB's, and water trough.
16mm

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

Comments: Ice/frost particles fell from ET/ORB umbilical during SSME ignition. LH2 T-0 disconnect appeared normal. No anomalies visible on SRB or Orbiter TPS surfaces.

E-40 Camera is located on the FSS 275 foot level and
300 FPS views the ET ogive, SRB nosecone, and Orbiter
16mm tiled surfaces.

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

Comments: Condensate vaporized on ET aft dome during liftoff. FWD RCS paper covers and Hydrogen Fire Detection paper still intact through liftoff. Numerous facility debris particles were visible after vehicle cleared tower.

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: Shock wave phenomena was visible north of the vehicle (frame 2327). Retraction and latchback of GH2 vent line was normal. No slack was evident in static retract lanyard. Three ice particles were ejected upward from GUCP at T-0 and fell with no vehicle contact. After tower clear, numerous pieces of facility debris were visible near the haunch.

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: Shock wave phenomena was visible north of the vehicle. GUCP retraction and latchback was normal. No slack was visible in the static retract lanyard. GH2 vent line was still venting after latchback. Ice fell from GUCP after retraction. Numerous facility debris particles were visible near the haunch after vehicle had cleared the tower.

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: Residual vapors emanated from LH2 T-0 disconnect. Condensate vaporized on base heat shield during ignition. RCS paper covers were torn loose by SSME acoustics and pulled into SSME plume. After vehicle cleared tower, a particle fell behind LO2 TSM.

E-48 Camera is located on the FSS 215 foot level (ET
300 FPS Intertank access arm structure) and views the GH2
16mm vent line during GUCP disconnection, rotation, and latchback

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

Comments: Ice/frost fell from GUCP legs and arm pivot locations. Three ice pieces were ejected upward after separation. GH2 vent line separation and retraction was normal. Some ice was still attached to EB-7. Condensate vaporized on ET aft dome. Loose thermal curtain tape hung three feet below aft skirt near HDP #8.

E-50 Camera is located at camera site 1 at NE pad
60 FPS perimeter and views entire GH2 vent line and
16mm GUCP during rotation and latchback.

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

Comments: GH2 vent line retraction and latchback was normal. Condensate vaporized on ET aft dome during liftoff. A white particle (ice) was ejected upward from GUCP. A second particle fell from GUCP during retraction.

E-52 Camera is located at camera site 2 on the east pad
96 FPS perimeter. Remote tracking of lower one-third of
35mm launch vehicle from ignition to 1200 feet.

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

Comments: Retraction and latchback of GH2 vent arm appeared normal. A white object appeared in frame 78-03 in upper left of FOV probably close to camera. Condensate on ET aft dome and SRB stiffener rings vaporized during liftoff. Vapor trailed from both RH and LH Orbiter wing tips. White flashes occurred in SSME plume during liftoff. RCS paper covers were torn loose during SSME ignition and pulled into plume.

E-53 Camera is located at camera site 2 on the east pad
96 FPS perimeter. Remote tracking of middle one-third of
35mm launch vehicle from ignition to 1200 feet.

Comments: No data. Film broke.

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: Slightly underexposed.

Comments: Retraction and latchback of GH2 vent arm appeared normal. A white object appeared in frame 78-03 in upper left of FOV probably close to camera. Condensate on ET aft dome and SRB stiffener rings vaporized after liftoff. Vapor trailed from both RH and LH Orbiter wing tips. White flashes occurred in SSME plume during liftoff. RCS paper covers were torn loose during SSME ignition and pulled into plume.

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: Residual vapors emanated from LH2 T-0 disconnect during liftoff. Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff. Vehicle tracking lost early in ascent and reacquired late in flight.

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: Residual vapors emanated from LH2 T-0 disconnect during liftoff. Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff. Vehicle tracking lost early in ascent and reacquired late in flight.

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: Slightly underexposed.

Comments: Residual vapors emanated from LH2 T-0 disconnect during liftoff. Condensate on ET aft dome and in SRB stiffener rings vaporized during liftoff. Vehicle tracking lost early in ascent and reacquired late in flight.

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: GH2 vent line retraction and latchback appeared nominal. Ignition shock condensation was visible above the MLP. 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: Free burning hydrogen drifted from SSME's during ignition. Shock wave phenomenon visible to the north of the vehicle. Condensate on ET aft dome and in SRB stiffener rings vaporized. GH2 vent line retraction and latchback appeared normal. Ice/frost particles fell from ET/ORB umbilicals during liftoff.

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: Free burning hydrogen was visible during SSME ignition. Ice/frost particles fell from LO2 T-0 umbilical during SSME ignition. Condensate vaporized on RH SRB stiffener rings.

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: Free burning hydrogen was visible during SSME ignition. Residual vapors emanated from the LO2 and LH2 T-0 disconnects during liftoff. Condensate vaporized on LH SRB stiffener rings after liftoff. Condensate on the base heat shield created a vapor trail 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: At T-0, shock wave phenomena was visible to the north of the vehicle. Condensate vaporized on ET aft dome and SRB stiffener rings during liftoff.

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 still remained in upper LO2 feedline bellows. Ice particles fell from LH2 feedline during ascent.

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: LO2 T-0 disconnect and retraction was normal. SSME plume dynamics caused LH2 TSM purge barrier to move. Ice and RCS paper covers were pulled into SSME plume. Condensate vaporized on ET aft dome and SRB stiffener rings. A bird flew across FOV prior to T-0.

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: Bright light on Orbiter aft fuselage was caused by the LH2 TSM light. LH2 T-0 disconnect and retraction was normal. Purge barrier on LH2 TSM flapped. Ice and RCS paper covers were pulled into SSME plume. A rectangular, thin object, possibly a gap filler, appeared below (from behind) SSME #2 after the shock diamonds had formed. Condensate vaporized on ET aft dome and SRB stiffener rings.

E-78
400 FPS
16mm

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

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

Comments: Condensate in SRB stiffener rings and on SSME base heat shield vaporized. Residual vapors emanated from LO2 T-0 umbilical. Exhaust smoke was visible from LH SRB HPU. RCS paper covers were torn loose during ignition and pulled into plume.

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 : Poor
F. O. V.: O.K.
Exposure: O.K.

Comments: Residual GO2 vapors emanated from ET louvers. ET twang was a nominal 33 inches. Ice/frost particles fell from umbilicals.

E-201
30 FPS
70mm

UCS-9 IFLOT tracking of launch vehicle from ignition and early flight through LOV.

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

Comments: Shock wave phenomenon is visible at T-0 north of the vehicle. Flashes occurred in the SSME plume during ascent. SRB separation appeared nominal. No vehicle anomalies.

E-202
30 FPS
70mm

U247L116 IFLOT tracking of launch vehicle from ignition and early flight through LOV.

Comments: No data. Camera malfunction.

E-203
30 FPS
70mm

UCS-16 IFLOT tracking of launch vehicle from ignition and early flight through LOV.

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

Comments: Shock wave phenomenon is visible at T-0 north of the vehicle. Flashes occurred in the SSME plume during ascent. SRB separation appeared nominal. No vehicle anomalies.

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

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

Comments: Linear optical distortion occurred twice. Instafoam on SRB stiffener rings outgassed. Plume recirculation near ET aft dome was normal. Black puff of smoke and plume brightening was visible during SRB tailoff.

E-205 Shiloh IFLOT tracking of launch vehicle from
72 FPS acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

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

Comments: SRB stiffener ring Instafoam outgassed. Recirculation and charring on ET aft dome was normal. In frames 381-00 through 383-05, black puffs of smoke and plume brightening occurred in the SRB plume. SRB separation appeared nominal.

E-206 Melbourne Beach ROTI tracking of launch vehicle
72 FPS from acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

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

Comments: Poor details due to atmospheric haze. Recirculation and charring on the ET aft dome were normal. In frames 418-03 through 428-00, black puffs of smoke and plume brightening occurred in SRB plume. SRB separation appeared nominal.

E-207 UCS-10 MIGOR tracking of launch vehicle from
96 FPS acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

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

Comments: Condensate vaporized on ET aft dome during liftoff. Body flap motion was visible shortly after roll maneuver. LH2 aft dome recirculation was normal. Flashes occurred in SSME plume at frame 67-03. Black smoke and plume brightening appeared in SRB plume during tailoff (frame 543-07, 549-04, and 555-02). SRB separation appeared normal. Slag clinkers fell from SRB plume after separation.

E-208 Cocoa Beach DOAMS tracking of launch vehicle
48 FPS from acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

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

Comments: Three particles (frame 152-09) and two particles (frame 147-09) fell from SRB plume. Linear optical distortion was visible in frame 132-00. SRB separation was nominal and numerous slag particles fell from SRB plume after separation.

E-209 SHILOH IFLOT intermediate tracking of
30 FPS launch vehicle from acquisition to LOV.
70mm

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

Comments: Vehicle already in flight when film began. No vehicle anomalies were visible. SRB plume event (brightening with puffs of darker smoke) occurred at 111 seconds MET. SRB separation appeared nominal.

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

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

Comments: Vehicle already in flight when film began. No vehicle anomalies were visible. SRB plume event (brightening with puffs of darker smoke) occurred at 111 seconds MET. SRB separation appeared nominal.

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

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

Comments: SRB stiffener ring Instafoam outgassed after liftoff. Aft dome charring was visible after roll maneuver. Two flashes occurred in SSME plume during ascent. Dark smoke appeared in SRB plume near tailoff. SRB separation appeared nominal.

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: Three pieces of RCS paper cover passed through SSME plume (frame 56-06). SRB stiffener ring Instafoam outgassed after liftoff. Charring was visible on ET aft dome. A particle from the Orbiter upper surface passed by SSME's in frame 78-10. Localized supersonic flow condensation was visible in frame 151-00. A piece of LH SRB thermal curtain tape came loose. Particles dropped out of SRB plume in frames 263-01 and 270-09. Black puff of smoke and brightening occurred in SRB plume during tailoff. SRB separation appeared nominal.

E-213 UCS-12 MOTS tracking of rear portion of launch
96 FPS vehicle from acquisition to LOV.
35mm

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

Comments: Ice/frost ball on LH2/intertank flange closeout was visible after roll maneuver. SRB stiffener ring Instafoam outgassed after liftoff. Forward RCS paper covers came loose shortly after roll maneuver.

E-217 Beach Road IFLOT close-in tracking of launch
30 FPS vehicle during ignition, liftoff, and early
70mm portion of flight through LOV.

Focus : O.K.
F. O. V.: O.K., BUT RUN TIME WAS TOO SHORT
Exposure: O.K.

Comments: Shock wave phenomenon was visible at T-0 north of the vehicle. Some data was lost due to hazy conditions and cloud cover. No vehicle anomalies.

E-218 UCS-26 IFLOT intermediate tracking of
96 FPS launch vehicle from acquisition through LOV.
35mm

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

Comments: Foam outgassed on ET aft dome and SRB stiffener rings. Charring occured on ET aft dome after roll maneuver. Localized supersonic flow condensation was visible. Numerous particles dropped out of SRB plume during ascent. Dark puffs of smoke and brightening appeared in SRB plume during tailoff.

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

Comments: Deleted for STS-39

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

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

Comments: Foam outgassed on ET aft dome and SRB stiffener ring. Charring occurred on ET aft dome. Few engineering details due to atmospheric haze. SRB separation appeared nominal.

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

Focus :
F. O. V.:
Exposure:

Comments: Deleted for STS-39

E-222 Beach Road IFLOT close-in tracking of rear portion
96 FPS of launch vehicle during ignition, liftoff, and
35mm early portion of flight through LOV.

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

Comments: Ice/frost particles and RCS paper covers fell from vehicle during liftoff. Foam on ET aft dome and SRB stiffener rings outgassed. White flashes occurred in SSME plume. Condensate vapor trailed from rudder speed brake. At GMT 11:33:30.827 a large piece of ET umbilical baggie material was torn loose. Two flashes were visible in the SSME plume at GMT 11:33:39. A total of 5 flashes occurred in the time frame 30-50 seconds MET. Two paper particles fell from RH OMS RCS area at GMT 11:33:42.

E-223 UCS-9 IFLOT intermediate tracking of rear portion
96 FPS of launch vehicle during ignition, liftoff, and
35mm early portion of flight through LOV.

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

Comments: LH SRB thermal curtain tape came loose at liftoff. RCS paper covers were torn loose in early ascent and pulled into SSME plume. Body flap motion was visible shortly after roll maneuver. Condensate on ET aft dome and SRB stiffener rings vaporized. Flashes were visible in SSME plume in frames 259-11 and 260-12 (35-40 seconds MET). Particles fell out of SRB exhaust plume in frames 354-08, 375-06, 407-08, 446-09, 453-02, 475-11, and 509-06. (Two of the particles were visible at 28 seconds MET). Dark puffs of smoke appeared in LH and RH SRB plume near aft skirt in frames 706-13, 711-11, and 717-12 with plume brightening occurring at 707-12. SRB separation appeared normal.

E-224 UCS-16 IFLOT close-in tracking of entire launch
100 FPS vehicle during ignition, liftoff, and early flight
35mm through LOV.

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

Comments: A dark particle fell from top of FOV, probably near camera, at GMT 11:33:42.787. Flashes occurred in SSME plume at GMT 11:33:54.912, 11:33:55.083 and 11:33:57.159. At 11:34:09.042, a particle fell out of RH SRB plume. At 11:33:57.905, a particle was visible on -Z side of vehicle and entered plume at 11:33:58.

E-301 RH SRB parachute deployment
200 FPS
16mm

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

Comments: RH frustum separation appeared normal with a straight trajectory. Frustum parachute was fully inflated. Reefing and inflation of the main parachutes was normal with no entanglement of the risers. All main parachutes were fully inflated prior to water impact. The usual amount of debris rose upward after nozzle severance, but no damage to the parachutes was visible.

E-302 LH SRB parachute deployment
200 FPS
16mm

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

Comments: LH frustum separation appeared normal. Frustum parachute was fully inflated. Reefing and inflation of the main parachutes was normal with no entanglement of the risers. All main parachutes were fully inflated prior to water impact. The usual amount of debris rose upward after nozzle severance, but no damage to the parachutes was visible.

VIDEO ITEMS

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

Comments: Water deluge in SSME exhaust hole activated properly. Camera light inside LH2 TSM shined on Orbiter aft fuselage. Disconnect and retraction of the LH2 T-0 umbilical was obscured.

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

Comments: Vehicle twang appeared normal. GUCP disconnect and retraction was nominal. No vehicle anomalies.

OTV 104 Views GH2 vent line and GUCP.
U-Matic

Comments: Ice from GUCP and water on GH2 vent line shook loose during twang. GUCP disconnect and separation appeared nominal. No ET umbilical carrier plate anomalies.

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

Comments: SSME ignition caused pieces of ice to shake loose from LH2 umbilical, but no contact with TPS was visible.

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

Comments: Tumble valve cover was intact. No damage to nosecone, footprint, or fairing. Vehicle twang was normal. No vehicle anomalies.

OTV 133 Views Orbiter and ET TPS (+Y side) and umbilicals.
U-Matic

Comments: Facility water deluge activated properly. Vehicle twang was normal. SRB overpressure shock wave visible at T-0. Condensate on ET aft dome vaporized. No vehicle anomalies.

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

Comments: FSS water activated properly. SSME ignition appeared normal. SRB overpressure shock wave visible at T-0. GH2 vent line appeared to latch properly.

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

Comments: Not available for this mission.

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

Comments: FSS water activated properly. Shock wave phenomenon from SRB ignition was visible north of the MLP. No vehicle anomalies. Water on ET aft dome vaporized after liftoff.

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

Comments: Ice shook loose from LO2 T-0 umbilical. Disconnect and retraction appeared nominal.

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

Comments: Vehicle twang appeared normal. Disconnedt and retraction of the LH2 T-0 umbilical was nominal. No vehicle anomalies.

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

Comments: SSME ignition and gimbal appeared normal. Residual GOX vapors drawn past SSME #3 into plume. Two pieces of dark (or silhouetted) debris passed over camera E-18 after vehicle had risen 15 feet.

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

Comments: SSME ignition shook ice from ET/ORB LO2 umbilical, but no tile damage was visible. Slight movement of elevons during ignition and liftoff. Residual GOX from LO2 T-0 was drawn past SSME #3 into plume.

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

Comments: SSME ignition and gimbal profile appeared normal. Ice fell from both LH2 and LO2 ET/ORB umbilicals. No vehicle anomalies. No facility or hydrogen dispersal system anomalies.

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

Comments: SSME ignition and gimbal profile appeared normal. Ice fell from both LH2 and LO2 ET/ORB umbilicals. Ice also fell from LO2 T-0 umbilical cryogenic lines. No vehicle anomalies. No facility or hydrogen dispersal system anomalies.

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

Comments: Vehicle twang appeared normal. Water on ET aft dome vaporized. No vehicle anomalies.

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

Comments: Light coating of frost on louver. No nosecone footprint or fairing damage. Twang looked normal. Ice/frost ball on LH2 tank-to-intertank still present until out of FOV. No vehicle anomalies.

OTV 162 Views -Y side of vehicle.
U-Matic

Comments: Vehicle twang was normal. Ice/frost ball on LH2 tank-to-intertank still attached until out of FOV.

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

Comments: SSME ignition shook ice from umbilicals, no tile damage visible. Free burning hydrogen blown under body flap by south winds. Slight movement of elevons. Vapor emanated from ET/SRB cable tray vent hole.

OTV 164 Views LH2 ET/ORB umbilical.
U-Matic

Comments: SSME ignition shook ice loose from LH2 umbilical, no tile damage.

OTV 165 Views +Y-Z side of overall vehicle
U-Matic

Comments: Vehicle twang was normal. SRB overpressure shock wave at T-0. GH2 vent line did rebound. No vehicle or facility anomalies.

OTV 166 Views +Y+Z side of overall vehicle
U-Matic

Comments: T-0 at 11:33:14.02. Vehicle twang was normal. Forward RCS paper covers intact while in FOV. No vehicle anomalies.

OTV 167 Views -Y-Z side of overall vehicle.
U-Matic

Comments: Facility water activated properly. Vehicle twang was normal. SRB overpressure shock wave was visible at T-0. No vehicle anomalies.

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

Comments: Free burning hydrogen rose past SSME #1 nozzle. SSME ignition appeared normal. Recirculation of RCS paper covers were drawn into plume.

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

Comments: SSME ignition and SRB T-0 appeared normal. SRB over-pressure shock waves visible at T-0. GH2 vent line did not rebound. No vehicle or facility anomalies.

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

Comments: No anomalies. SSME ignition appeared normal. Free burning hydrogen was blown under body flap near SSME #3 and rose past vertical stabilizer near SSME #1. Shock diamonds visible is SSME plume during liftoff.

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

Comments: Not available for this launch.

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

Comments: Too distant for detail. No vehicle anomalies.

TV-4A Views Pad A launch from Beach Road IFLOT site
Color M-II north of complex 41.

Comments: SSME and SRB ignition appeared nominal. Multiple over-pressure shock waves after T-0. Roll maneuver looked normal. Four light colored particles dropped out of SRB plumes at T+61,68,69 and 82 seconds MET. Local supersonic flow condensation visible near mad Q. SRB separation appeared nominal.

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

Comments: Too distant and too much camera shake for detail. SRB separation appeared normal.

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

Comments: Vehicle twang looked normal. Forward RH RCS paper covers intact. No vehicle anomalies.

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

Comments: Numerous SRB shock waves in rapid succession after T-0. Too distant for detail. No vehicle anomalies. Very little plume disturbance at altitude.

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

Comments: Local supersonic flow condensation normal. Some charring on ET aft dome during early ascent. Six optical linear distortion events occurred at altitude. Vapor trailed past vehicle aft end. SRB separation looked normal. Not many pieces of SRB slag appeared in plume.

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

Comments: Not available for this launch.

TV-21A Views Pad A launch from UCS-15.
Color M-II

Comments: SSME ignition appeared normal. Liftoff obscured by SSME plume. GH2 vent line did not rebound. Local supersonic flow condensation near max Q was normal.

OTV 160 Views launch on Pad A from Pad B.
Color M-II

Comments: Facility water deluge activated properly. Shock wave phenomenon was visible north of the vehicle. No vehicle anomalies

OTV 170 Views launch on Pad A from Pad B.
Color M-II

Comments: Facility water deluge activated properly. Shock wave phenomenon was visible north of the vehicle. No vehicle anomalies

OTV 171 Views launch on Pad A from Pad B.
Color M-II

Comments: Facility water deluge activated properly. Shock wave phenomenon was visible north of the vehicle. No vehicle anomalies

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

Comments: Tracking problems in early flight. Vehicle details obscured due to atmospheric haze. SRB separation appeared normal.

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

Comments: Recirculation on ET aft dome was typical. Vehicle details obscured due to atmospheric haze. SRB separation appeared normal. LH SRB tracked after separation. SRB tumbled with no anomalies noted.

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

Comments: Localized supersonic flow condensation visible around entire vehicle. Recirculation on ET aft dome was typical. Near tailoff, a brightening of SRB plume occurred at 11:35:05.981 GMT. SRB separation appeared normal.

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

Comments: Localized supersonic flow condensation visible around entire vehicle. Condensate on ET aft dome vaporized. Brightening of SRB plume occurred during tailoff. After separation, slag clinkers fell out of LH SRB plume.

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

Comments: Localized supersonic flow condensation visible around entire vehicle. Four light-colored particles dropped out of the SRB plume during ascent. Plume brightening occurred in SRB plume at approximately 111 seconds MET. SRB separation appeared normal.

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

Comments: Condensate on ET aft dome vaporized. Tracking lost in clouds.

7.2 ON-ORBIT FILM DATA REVIEW

Ten 70mm frames were taken of the External Tank on-orbit after separation from the Orbiter.

No Orbiter attitude change had been performed to obtain the views and the External Tank was already too distant for detail. No major anomalies were visible.

7.3 LANDING FILM AND DATA REVIEW

E-702 KSC Tracking Site B IFLOT close-in tracking of
35mm Orbiter from final flare through rollout.

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

Comments: Landing gear extension was normal. Touchdown occurred near the runway threshold. Orbiter right bank caused RH main landing gear to contact runway first. LH main landing gear contacted runway a couple hundred feet beyond the RH MLG touchdown point and bounced once. No unusual control surface deflections occurred. Nose landing gear touchdown was nominal. Piece of LH MLG door corner tile was missing as Orbiter rolled by. Tire material came of RH MLG near wheel stop position.

E-703 KSC Tracking Site C tracking of Orbiter from final
35mm flare through rollout.

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

Comments: Orbiter right bank caused RH main landing gear to contact runway first. LH main landing gear contacted runway a couple hundred feet beyond the RH MLG touchdown point and bounced once. No unusual control surface deflections occurred. Nose landing gear touchdown was nominal. No significant tile damage was visible during rollout.

E-706 KSC Tracking Site B tracking of Orbiter from final
16mm flare through rollout.

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

Comments: Landing gear extension was normal. Touchdown occurred near the runway threshold (just past the white markings). Orbiter right bank caused RH main landing gear to contact runway first. LH main landing gear contacted runway a couple hundred feet beyond the RH MLG touchdown point and bounced once. No unusual control surface deflections occurred. Nose landing gear touchdown was nominal. No significant tile damage was visible during rollout.

E-707
16mm

Camera is located on runway centerline. View looks south to record Orbiter landing gear, speed brake extension, and control surface deflections.

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

Comments: Orbiter banked right causing RH main landing gear to contact runway first. Left MLG contacted runway a couple hundred feet after the right MLG and bounced once. Speed brake opened fully after touchdown. Elevons moved upward as nose landing gear contacted runway, then moved back to the neutral position. Orbiter appeared to move right of centerline during rollout. Frayed closeout blankets were visible on the SSME's.

E-708
16mm

Camera is located on runway centerline. View looks north to record Orbiter landing gear, speed brake extension, and control surface deflections.

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

Comments: Orbiter was already on runway and rolling out when film started. Heat waves softened detail on the vehicle. No anomalies were visible.

E-709
35mm

Camera is located on runway centerline. View looks north to record approach/landing gear deployment.

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

Comments: Short run of data due to low approach angle of Orbiter. No anomalies were visible as Orbiter passed overhead.

C-2

E-712 KSC Tracking Site B IFLOT close-in tracking of
16mm Orbiter from final flare through rollout.

Focus : O.K.
F. O. V.: O.K., EXCEPT FOR NUMEROUS SCRATCHES ON THE FILM
Exposure: O.K.

Comments: Orbiter right bank caused RH main landing gear to contact runway first. LH main landing gear contacted runway a couple hundred feet beyond the RH MLG touchdown point and bounced once. No unusual control surface deflections occurred. Nose landing gear touchdown was nominal. No significant tile damage was visible during rollout.

E-713 KSC Tracking Site C tracking of Orbiter from final
16mm flare through rollout.

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

Comments: Orbiter right bank caused RH main landing gear to contact runway first. LH main landing gear contacted runway a couple hundred feet beyond the RH MLG touchdown point and bounced once. No unusual control surface deflections occurred. Nose landing gear touchdown was nominal. No significant tile damage was visible during rollout.

E-716 KSC Tracking Site F tracking of Orbiter from final
16mm flare through rollout.

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

Comments: Landing gear extension was normal. Touchdown occurred near the runway threshold (just past the white markings). Orbiter right bank caused RH main landing gear to contact runway first. LH main landing gear contacted runway a couple hundred feet beyond the RH MLG touchdown point and bounced once. No unusual control surface deflections occurred. Nose landing gear touchdown was nominal. No significant tile damage was visible during rollout.

TV-2 View from convoy position at SLF midfield.
Video

Comments: Landing gear deployment appeared nominal. Left main landing gear touched down first just ahead of RH MLG. Nose landing gear touchdown was smooth. No anomalies during rollout. Wheel stop was normal.

TV-5 View from VAB roof.
Video

Comments: Orbiter touchdown occurred near runway threshold. Rollout looked normal. View was too distant for detail.

TV-6 View from top of Mate Demate Device at SLF.
Video

Comments: View was too distant for detail.

TV-11 View from Shuttle Landing Facility TV Tower #1
Video east of the runway.

Comments: Landing gear extension appeared normal. Right main landing gear contacted runway first. Nose landing gear touchdown was nominal. No anomalies were visible during rollout.

TV-15 View from Shuttle Landing Facility TV Tower #2
Video west of the runway.

Comments: Right main landing gear contacted runway first near the runway threshold. Nose landing gear touchdown was nominal. No anomalies were visible during rollout.

TV-33 View from SLF midfield.
Video

Comments: Landing gear extension appeared normal. Right main landing gear contacted runway first. Nose landing gear touchdown was nominal. No anomalies were visible during rollout.

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 30 April 1991 from 0830 to 1130 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 had no areas of missing TPS but had 52 MSA-2 debonds over fasteners (Figure 5). Blistering of Hypalon paint was insignificant. All BSM covers had opened properly, though the lower right BSM cover had been bent by parachute riser entanglement.

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

The Field Joint Protection System (FJPS) closeouts were generally in good condition. A small area of K5NA was spongy at the forward joint 180-190 degree location and one place on the center field joint. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris hits from severance of the nozzle extension. A 2.4"X0.25" debond occurred on the aft center segment GEI cork run (XB-1411 station, 200 degrees). The substrate was lightly sooted, but there was no missing material.

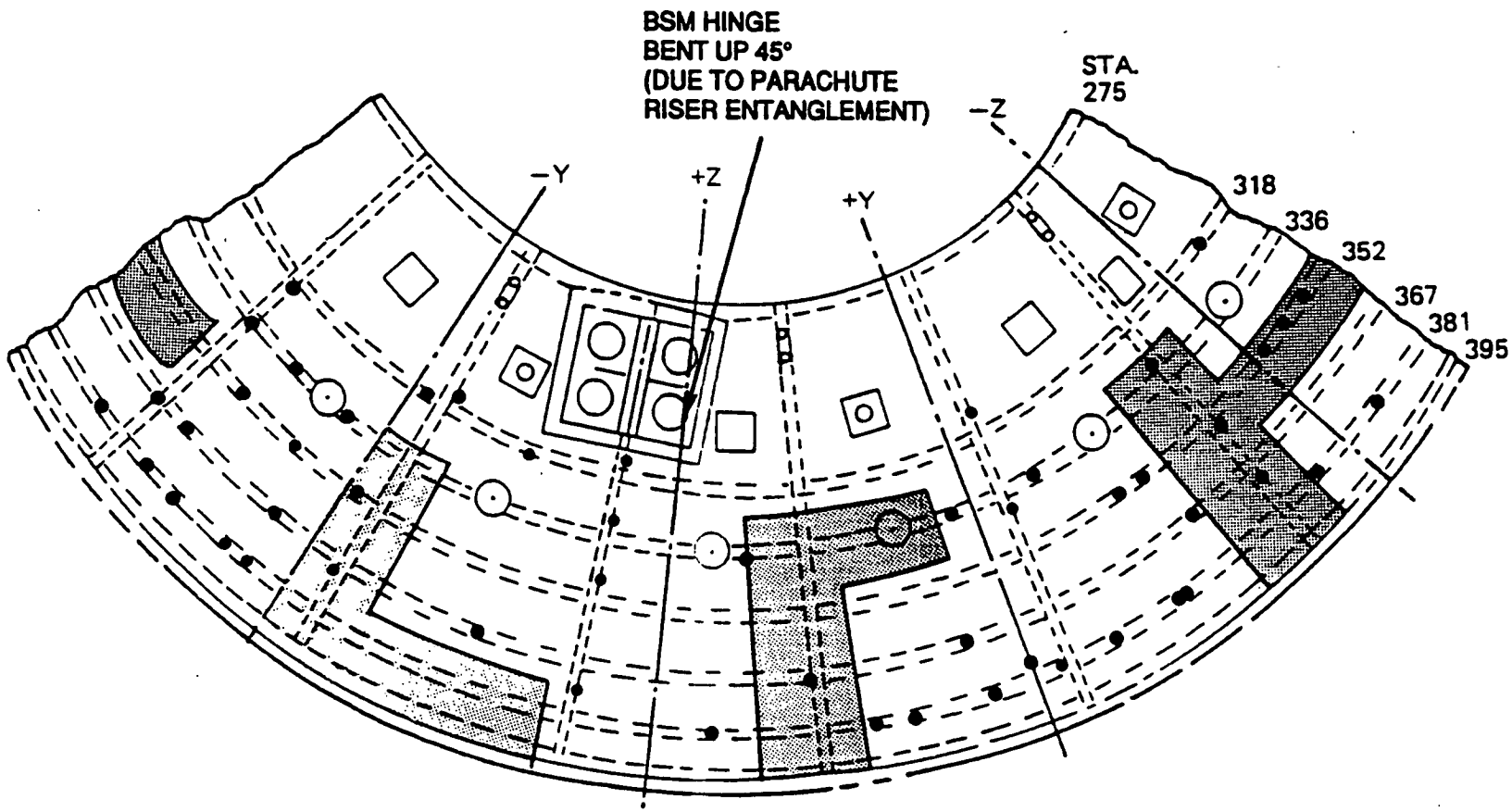
Separation of the aft ET/SRB struts appeared nominal. The ET/SRB aft struts, ETA ring, and IEA sustained minimal damage. K5NA closeouts on the IEA covers were intact. Three bolt heads were missing from ETA ring cover fasteners near the systems tunnel. K5NA was cracked on the aft booster stiffener rings. EPDM weather seals on aft booster factory joints had 5 debonds, the largest of which measured 2"x0.25".

The phenolic material on the kick ring delaminated in only a few locations. None of the K5NA protective domes were lost from bolt heads on the aft side of the phenolic kick ring during ascent.

The aft skirt TPS acreage was in generally good condition. K5NA was missing from all aft BSM nozzles (Figure 7). Instafoam was missing from the aft ring around the aft skirt feet, the HPU exhaust horns, and the SRB T-0 umbilical.

Debris Containment System (DCS) plungers were properly seated except for HDP #4, which was obstructed by ordnance fragments. A 4"x0.5" piece of EPON shim material from HDP #3 and two pieces of sidewall shim material (3"x2" and 5"x2") from HDP #4 were missing from the aft skirt prior to water impact.

FIGURE 5. **RIGHT SRB FRUSTUM**



MISSING TPS

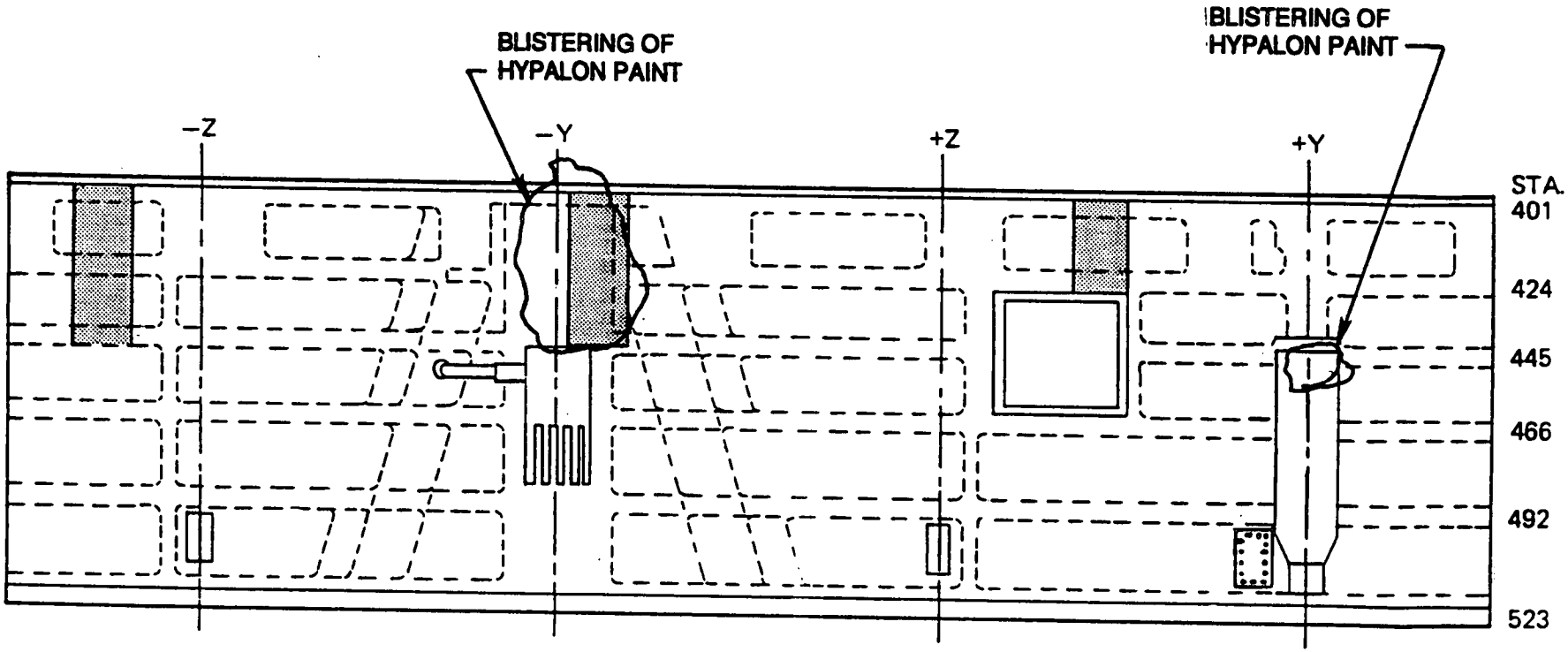
NONE

DEBONDS

- 52 DEBONDS OVER FASTENERS

EGG/V-326

FIGURE 6. **RIGHT SRB FWD SKIRT**



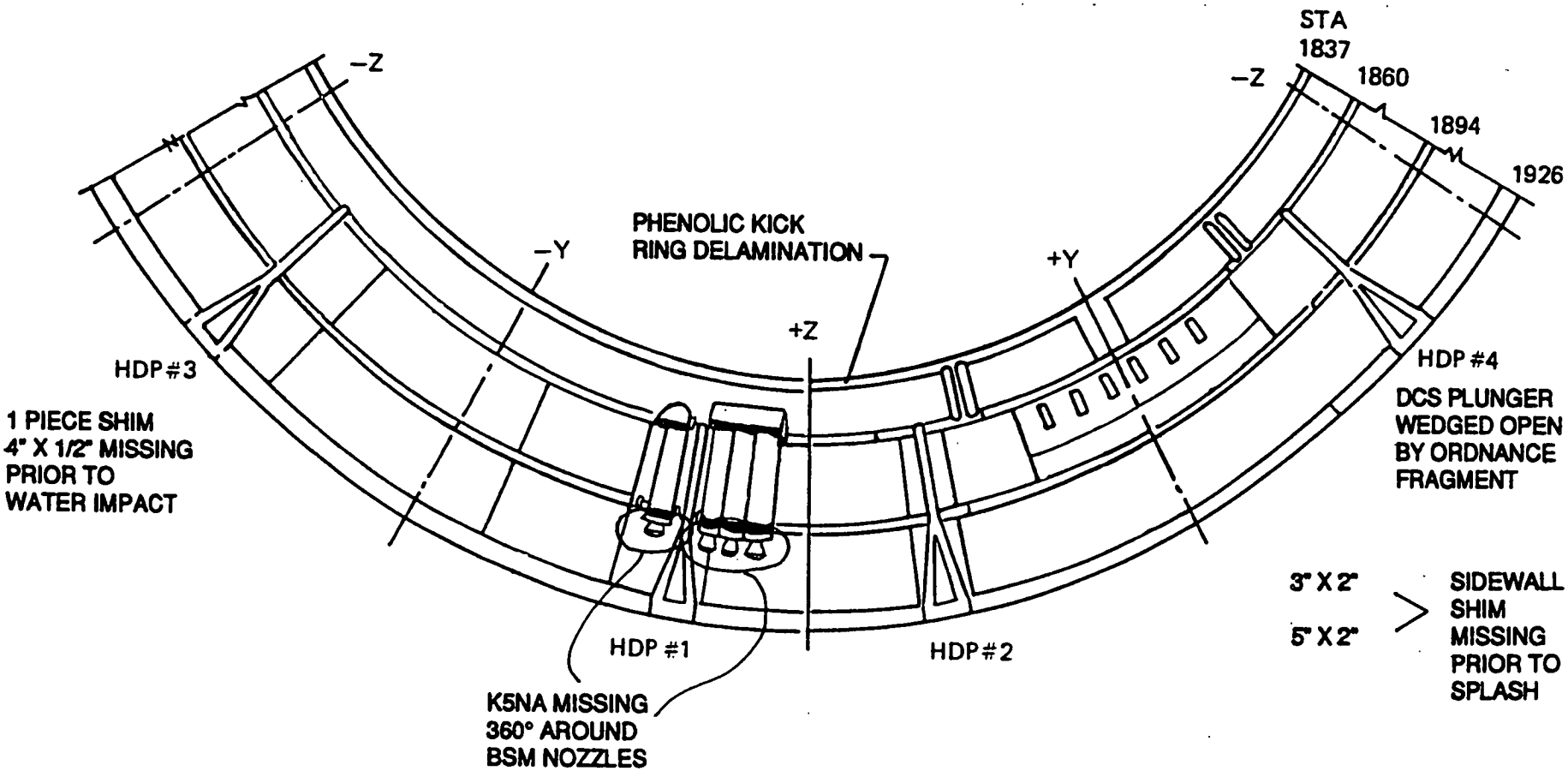
TPS MISSING

NONE

DEBONDS

NONE

FIGURE 7. RIGHT SRB AFT SKIRT EXTERIOR TPS



EGG/V 326C

8.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nosecap was not recovered. The LH frustum exhibited no missing TPS but had 22 MSA-2 debonds over fasteners. The Hypalon paint had blistered at 28 locations, primarily along the 395 ring (Figure 8). All BSM covers were locked in the fully opened position.

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

The Field Joint Protection System (FJPS) closeouts were in good condition. The K5NA was cracked on the aft field joint at the 30 degree trunnion location. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris hits from severance of the nozzle extension.

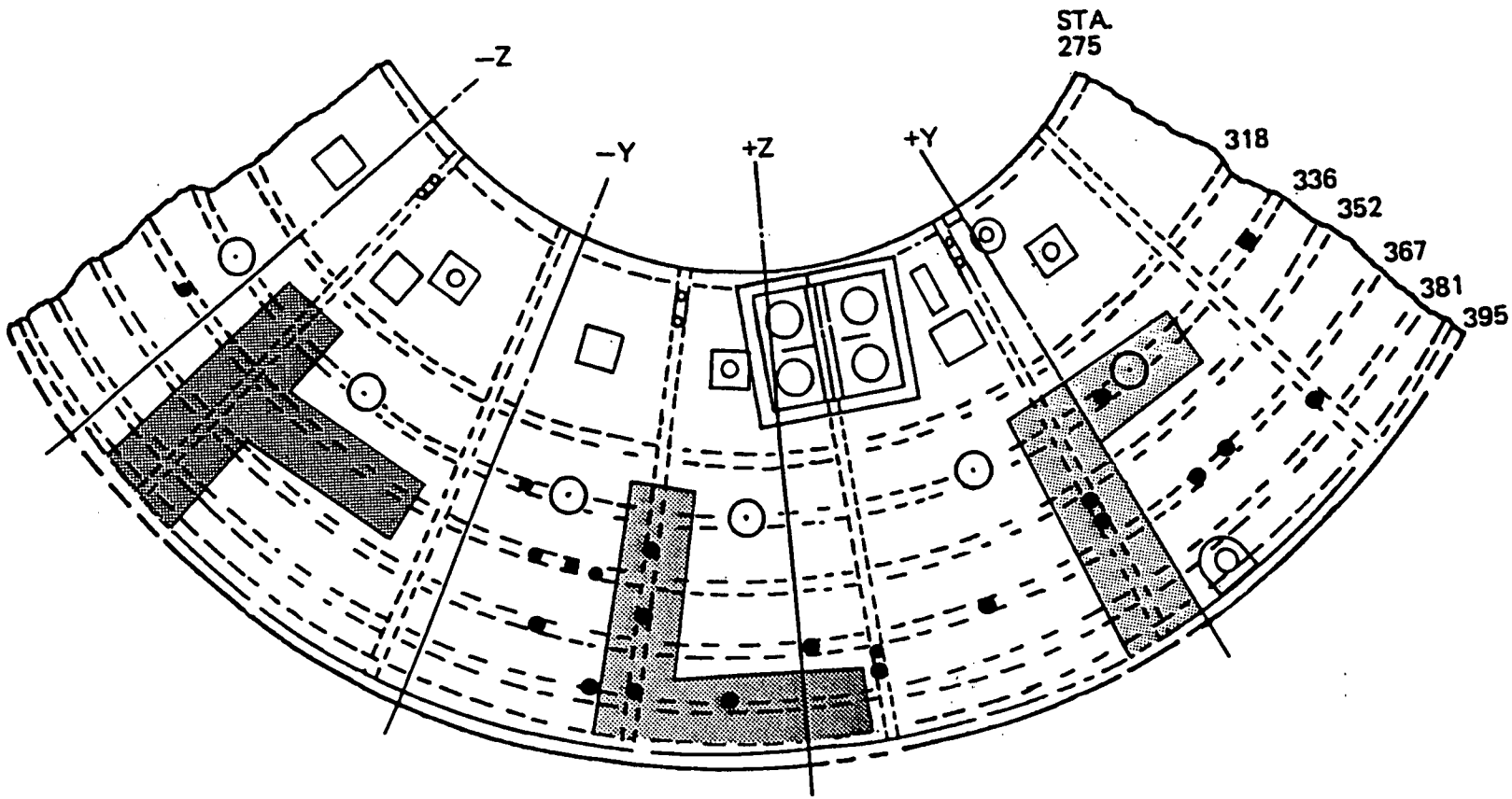
Separation of the aft ET/SRB struts appeared nominal. The ET/SRB aft struts, ETA ring, and IEA sustained minimal damage. K5NA closeouts on the IEA covers were intact. All three aft booster stiffener rings were damaged by water impact and several bolts were protruding/missing.

The phenolic material on the kick ring delaminated in only a few locations. One K5NA protective dome was lost from a bolt head on the phenolic kick ring prior to water impact.

The aft skirt TPS acreage was in generally good condition. K5NA was missing from all aft BSM nozzles (Figure 10). Instafoam was missing from the aft ring around the aft skirt feet, the HPU exhaust horns, and the SRB T-0 umbilical.

Debris Containment System (DCS) plungers were properly seated except for HDP #7, which was obstructed by frangible nut halves. None of the EPON shim material on the LH aft skirt was missing prior to water impact.

FIGURE 8. LEFT SRB FRUSTUM



MISSING TPS

NONE

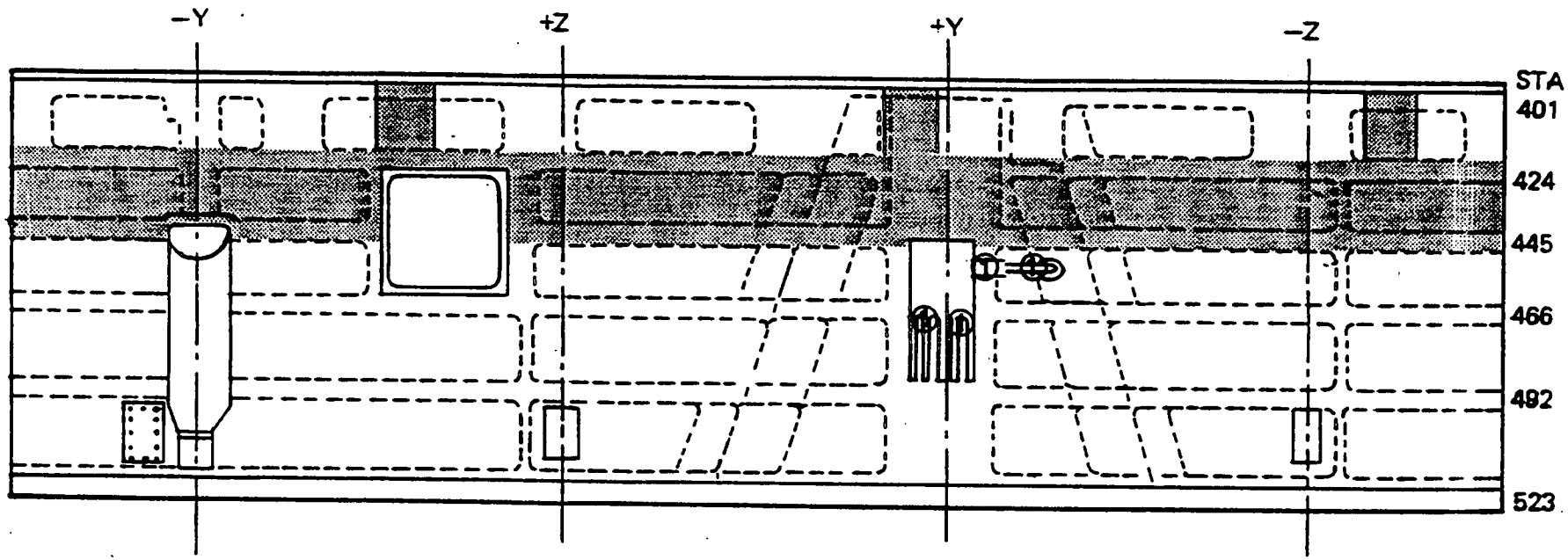
DEBONDS

- 22 DEBONDS OVER FASTENERS

NOTES:
OPEN HYPALON PAINT BLISTERS ALONG 395 RING

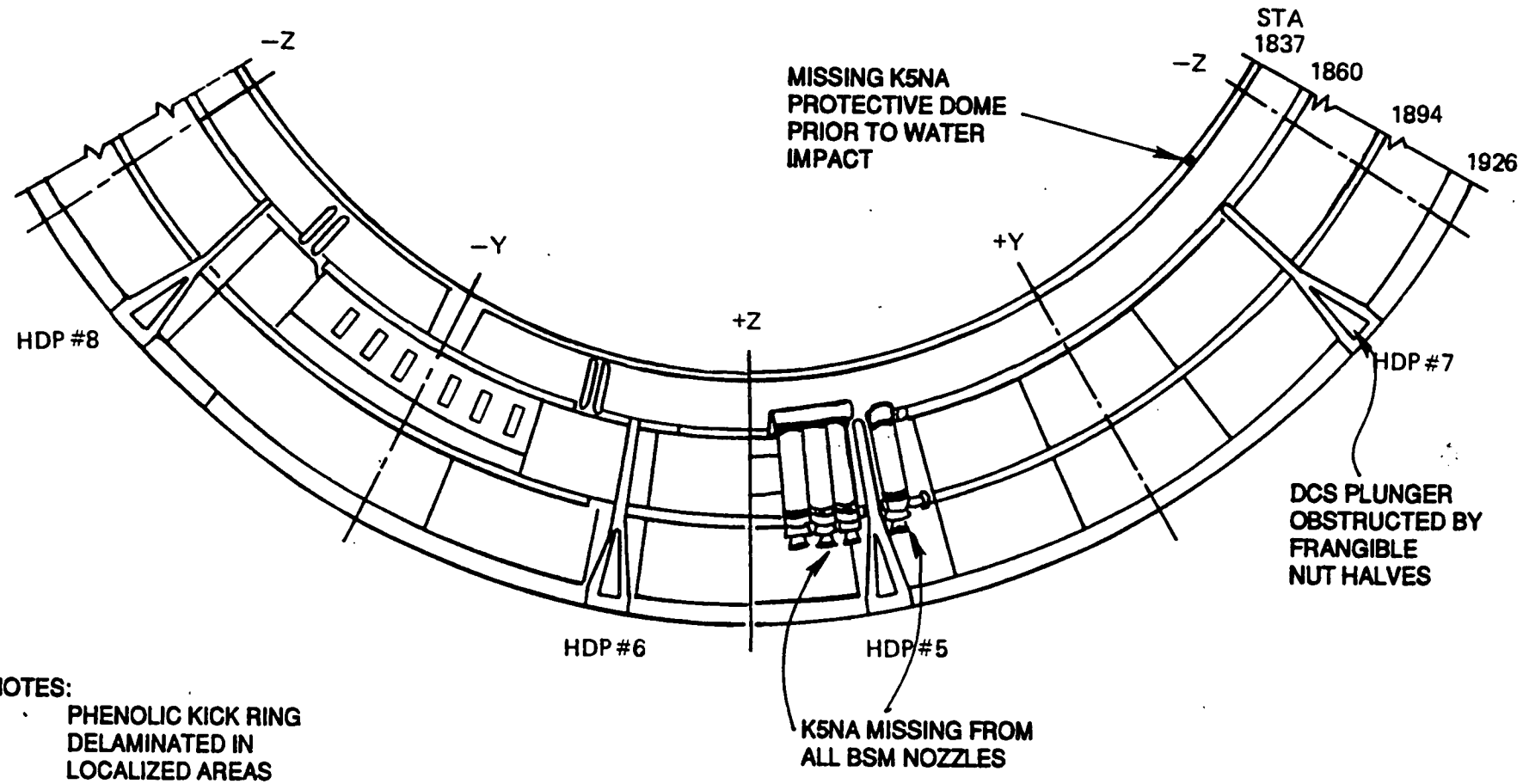
EGG/V-326E

FIGURE 9. **LEFT SRB FWD SKIRT**



TPS MISSING	DEBONDS
① HYPALON PAINT OPEN BLISTERS (SOOTING)	NONE

FIGURE 10. LEFT SRB AFT SKIRT EXTERIOR TPS



NOTES:

- PHENOLIC KICK RING DELAMINATED IN LOCALIZED AREAS

EGG/V-326F

8.3 RECOVERED SRB DISASSEMBLY FINDINGS

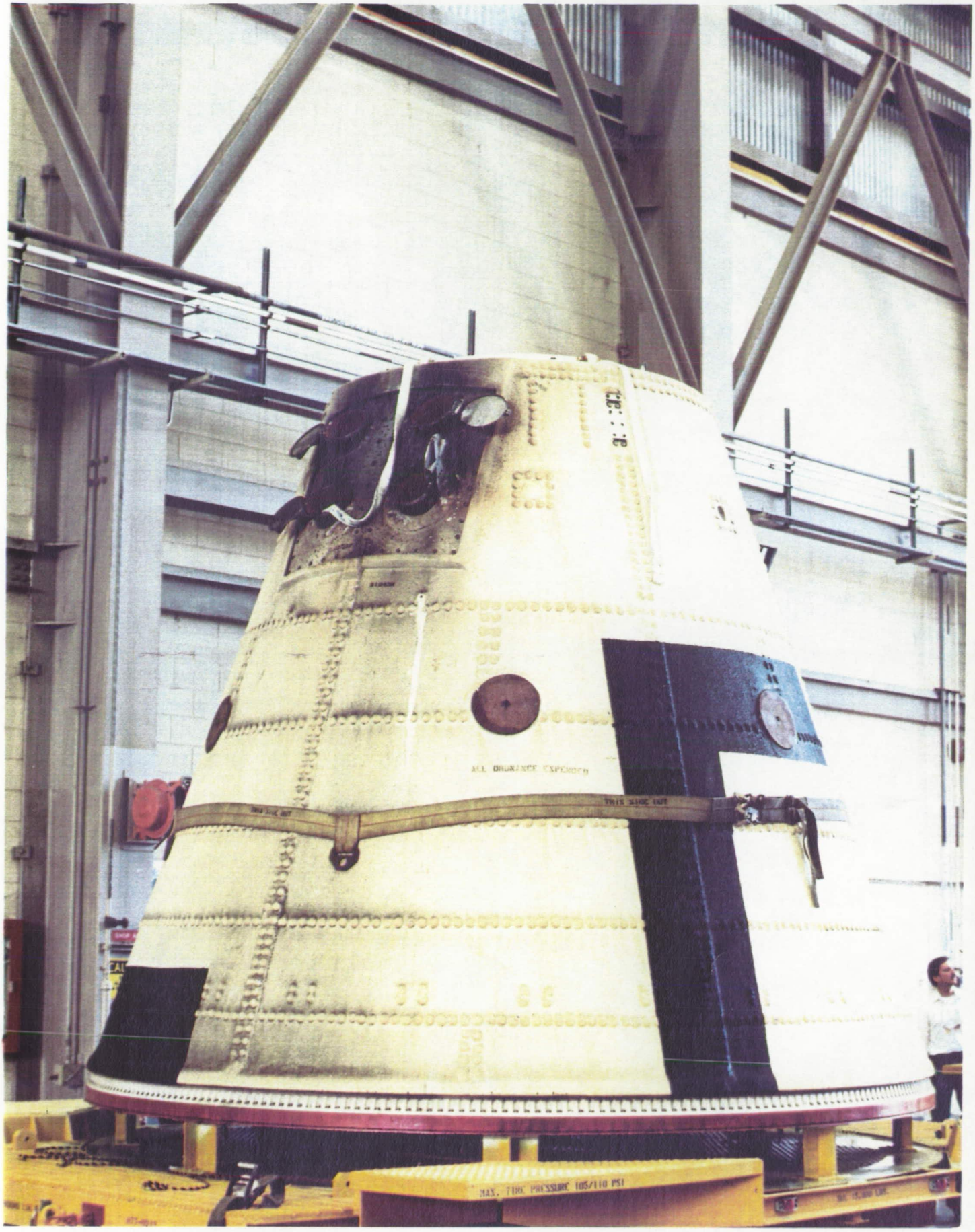
Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 91 percent and individual holddown post retention percentages as listed:

HDP #	Overall %	% of Nut without 2 large halves	% of Ordnance
1	99	99	94
2	99	99	96
3	96	98	93
4	98	99	93
5	99	99	93
6	99	99	94
7	38	38	39
8	99	99	93

The minimum allowable retention per NSTS-07700 is 90 percent. A PR was taken against the retention performance of the Debris Containment System on HDP #7.

K5NA was missing from the RH SRB aft booster stiffener ring splice plates (aft ring at 330 degrees, forward ring at 210 degrees). The remaining material was not charred and loss of the K5NA occurred at water impact. Post flight assessment showed failure of the K5NA was caused by an unbond between the first and second layers and may be indicative of improper K5NA application (use of the "pancake" method instead of a homogeneous hand-pack). A suspect PR was taken against similar K5NA closeouts on STS-40, 43, and 48. A potential debris hazard exists if the K5NA is lost at liftoff or during ascent.

SRB Post Launch Anomalies are listed in Section 11.3.



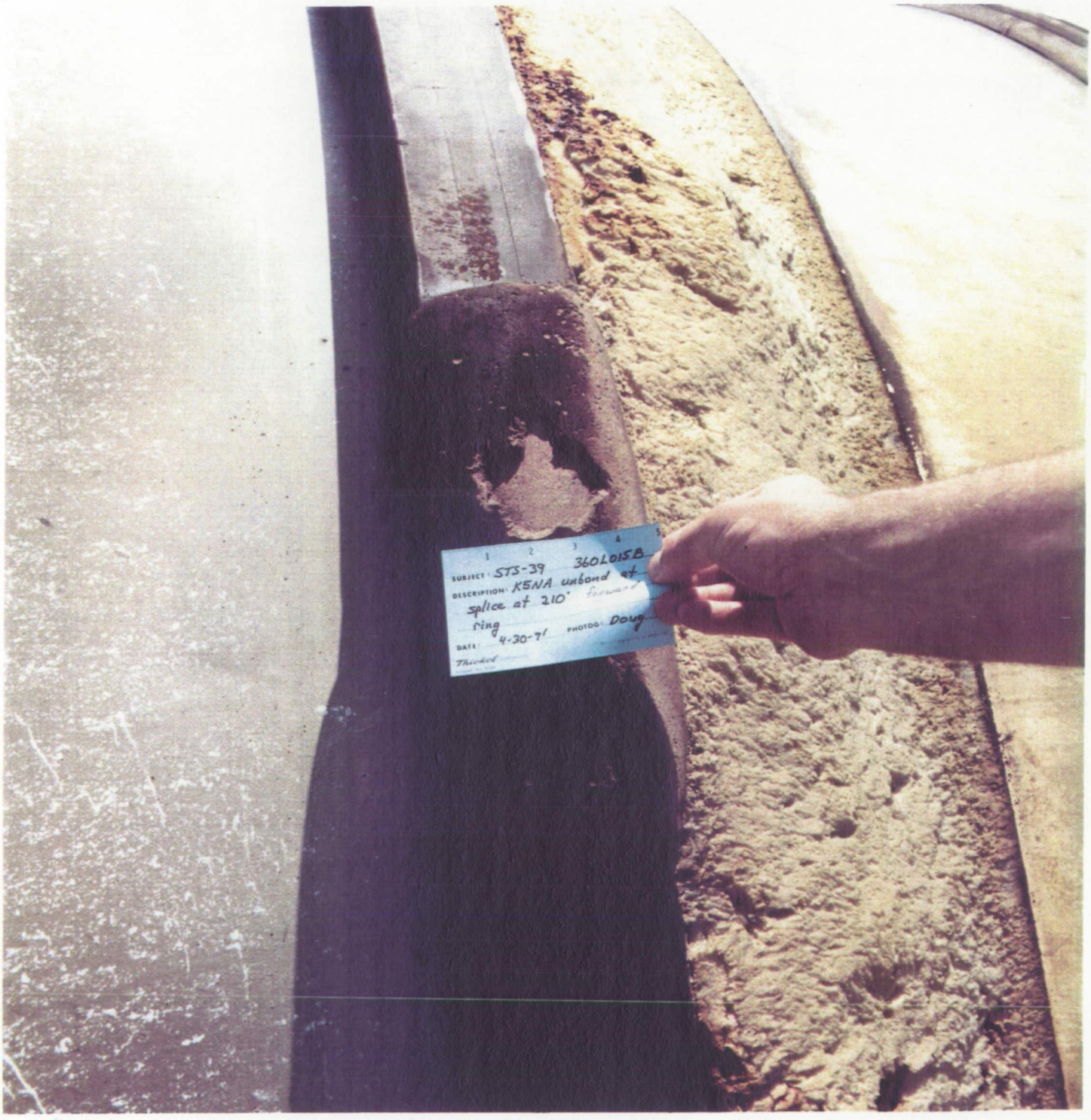
Post flight condition of the RH frustum. There were 52 MSA-2 debonds over fasteners, but no areas of missing TPS.

Post flight condition of the RH forward skirt. There were no significant TPS or structural anomalies.

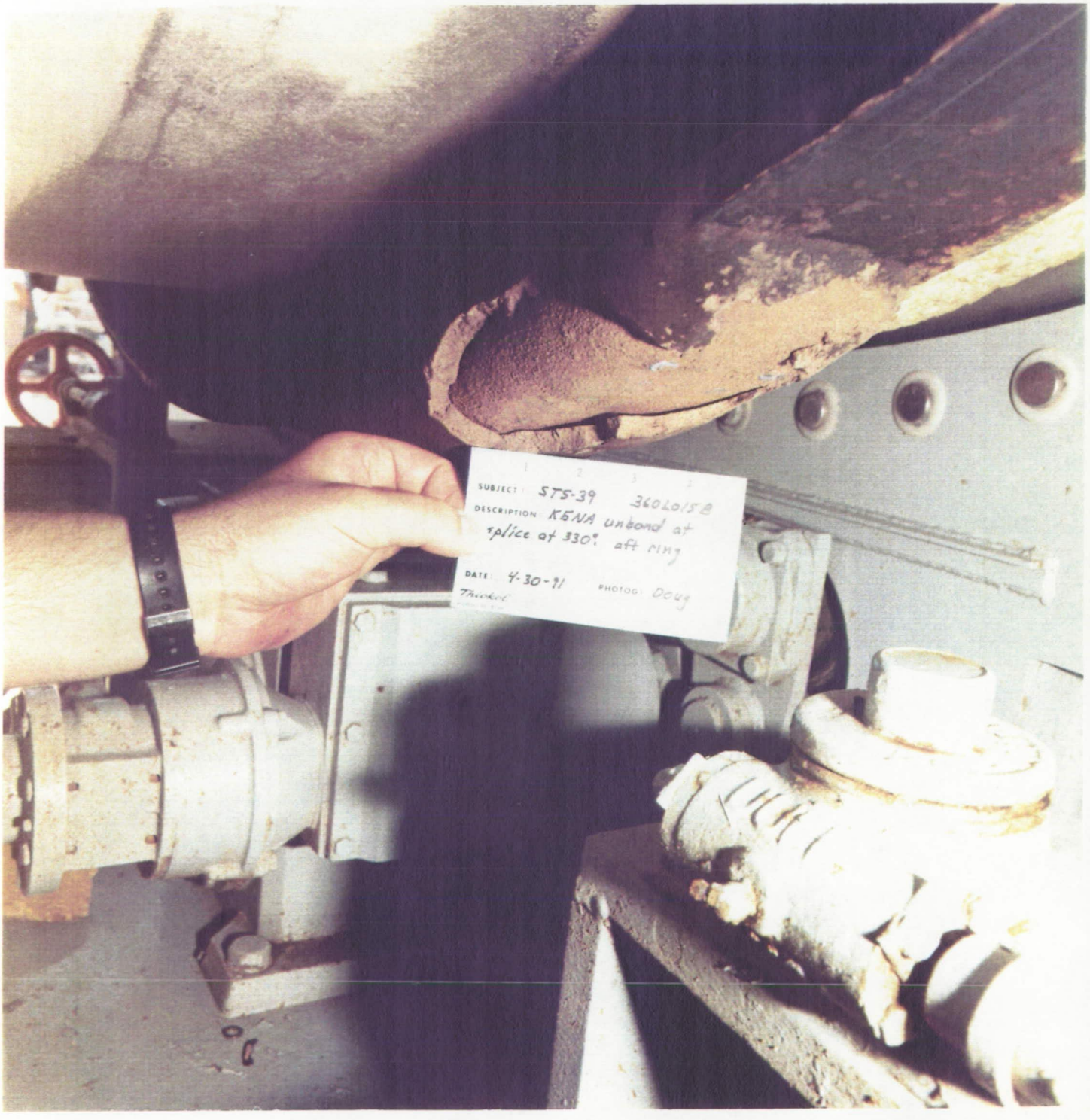
Post flight condition of the RH aft booster

Three bolt heads were missing from ETA ring cover fasteners

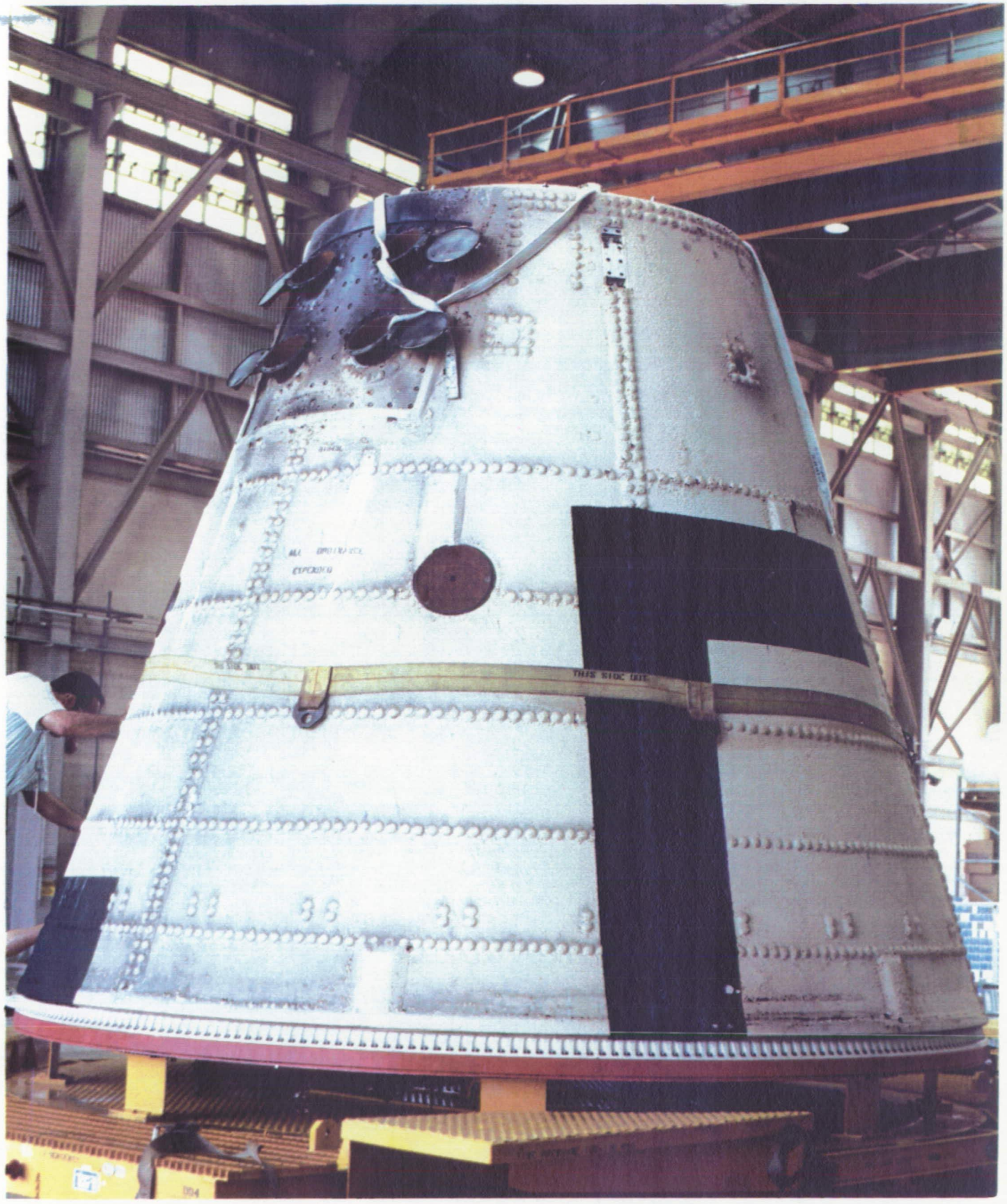
EPDM weather seals on the RH aft booster factory joint closeouts had 5 debonds, the largest of which measured 2"x0.25"



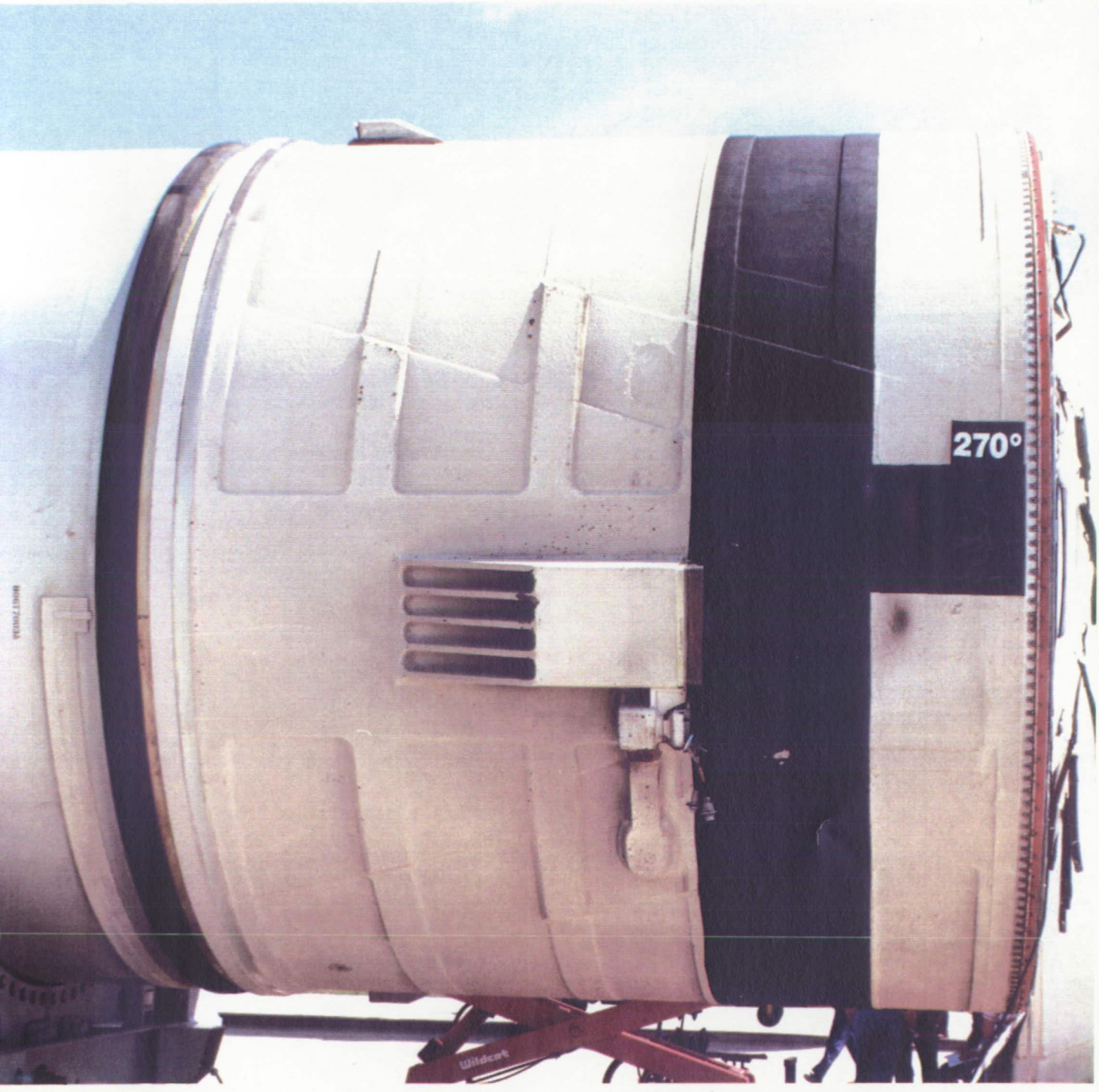
K5NA was missing from the RH aft booster stiffener ring splice plates (aft ring at 330 degrees, forward ring at 210 degrees). The substrate was not charred and loss of the material occurred at water impact.



Post flight assessment showed failure of the K5NA was caused by an unbond at the substrate. Loss of this closeout at T-0 or during ascent could be a potential debris hazard.

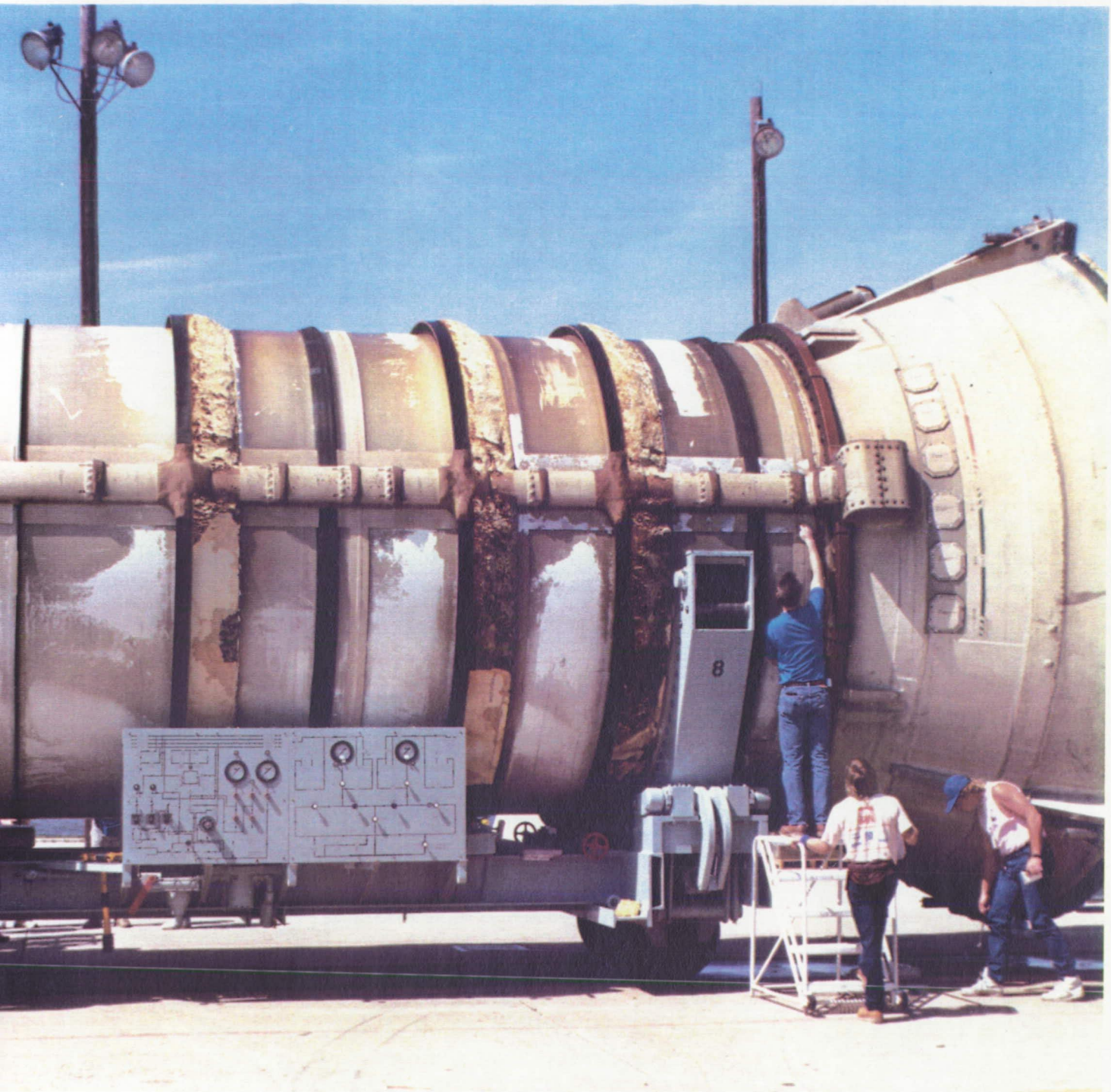


Post flight condition of the LH frustum. There were 22 MSA-2 debonds over fasteners, but no missing TPS.

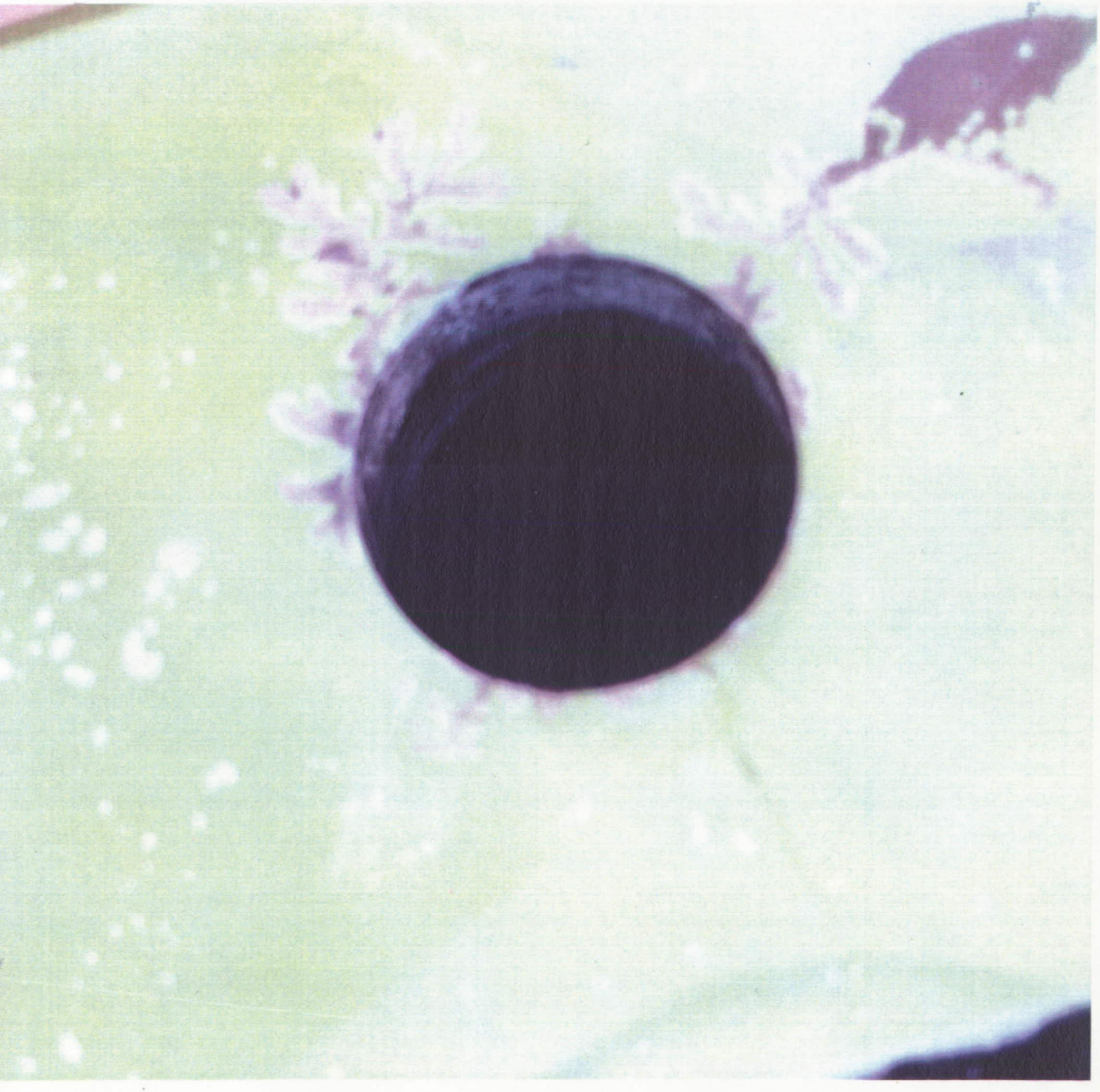


Post flight condition of the LH forward skirt. There were no significant TPS or structural anomalies.

Post flight condition of LH SRM segment cases. The field joint protection system closeouts were generally in good condition.



Post flight condition of the LH aft booster. All three stiffener rings were damaged by water impact.



Holddown post #7 Debris Containment System (DCS) plunger was obstructed by frangible nut halves. Five ordnance fragments had fallen from the DCS/stud hole shortly after liftoff.

9.0 ORBITER POST LANDING DEBRIS ASSESSMENT

The 7th Orbiter landing at the Kennedy Space Center occurred on 6 May 1991. A detailed post landing inspection of OV-103 (Discovery) was conducted on May 6-8, 1991, on Runway 15 and in the Orbiter Processing Facility (OPF) to identify debris impact damage, and if possible, debris sources. The Orbiter TPS sustained a total of 238 hits, of which 16 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield, which are attributed to SSME vibration/acoustics and plume recirculation.

The Orbiter lower surface had a total of 217 hits of which 14 had a major dimension of one inch or greater. A comparison of these numbers to statistics from 26 previous missions of similar configuration (excluding missions STS-24, 25, 26, 26R, 27R, and 30R which had damage from known debris sources), indicates the total number of hits on the lower surface was much greater than average, but the number of hits with a major dimension greater than 1" was less than average. Figures 11 through 14 show the TPS debris damage assessment for STS-39. Figure 15 indicates the sites where samples were taken for laboratory chemical analysis.

A cluster of 141 hits (with 11 larger than one inch) occurred in an area aft and inboard of the LH2 ET/Orbiter umbilical cavity. Similar clusters of hits have been observed in this area on previous flights but have not included such a large quantity of damage sites. These hits are attributed to ice/debris impacts during ET separation and/or damage from purge barrier baggie and ice during ascent. A cluster of 14 hits (none larger than one inch) occurred just forward of the LO2 ET/Orbiter umbilical cavity. This cluster may also be attributable to ice/debris impacts during ET separation.

No flight hardware was found on the runway below the ET/Orbiter umbilicals. However, the plunger on the LH2 ET/Orbiter umbilical separation ordnance device (EO-2) was obstructed by an NSI cartridge fragment. Post landing disassembly of the debris container revealed no missing pieces. The EO-1 and EO-3 separation ordnance devices appeared to have operated properly.

The lightning protection contacts on both ET/Orbiter umbilicals were intact. No lightning protection contacts from the ET half of the umbilical were present. However, a 2-inch long section of the purge barrier seal, which should have remained with the ET, adhered to the LH2 disconnect interface plate.

All tires sustained some degree of damage during rollout. Numerous cuts and nicks were visible on the nose landing gear tires. The RH main landing gear (MLG) lost 3 plies of material from the outboard tire and 1 ply from the inboard tire. One ply of material was lost from the LH MLG inboard tire. No TPS damage was attributed to material from the wheels, tires, or brakes.

FIGURE 11
STS-39

DEBRIS DAMAGE LOCATIONS

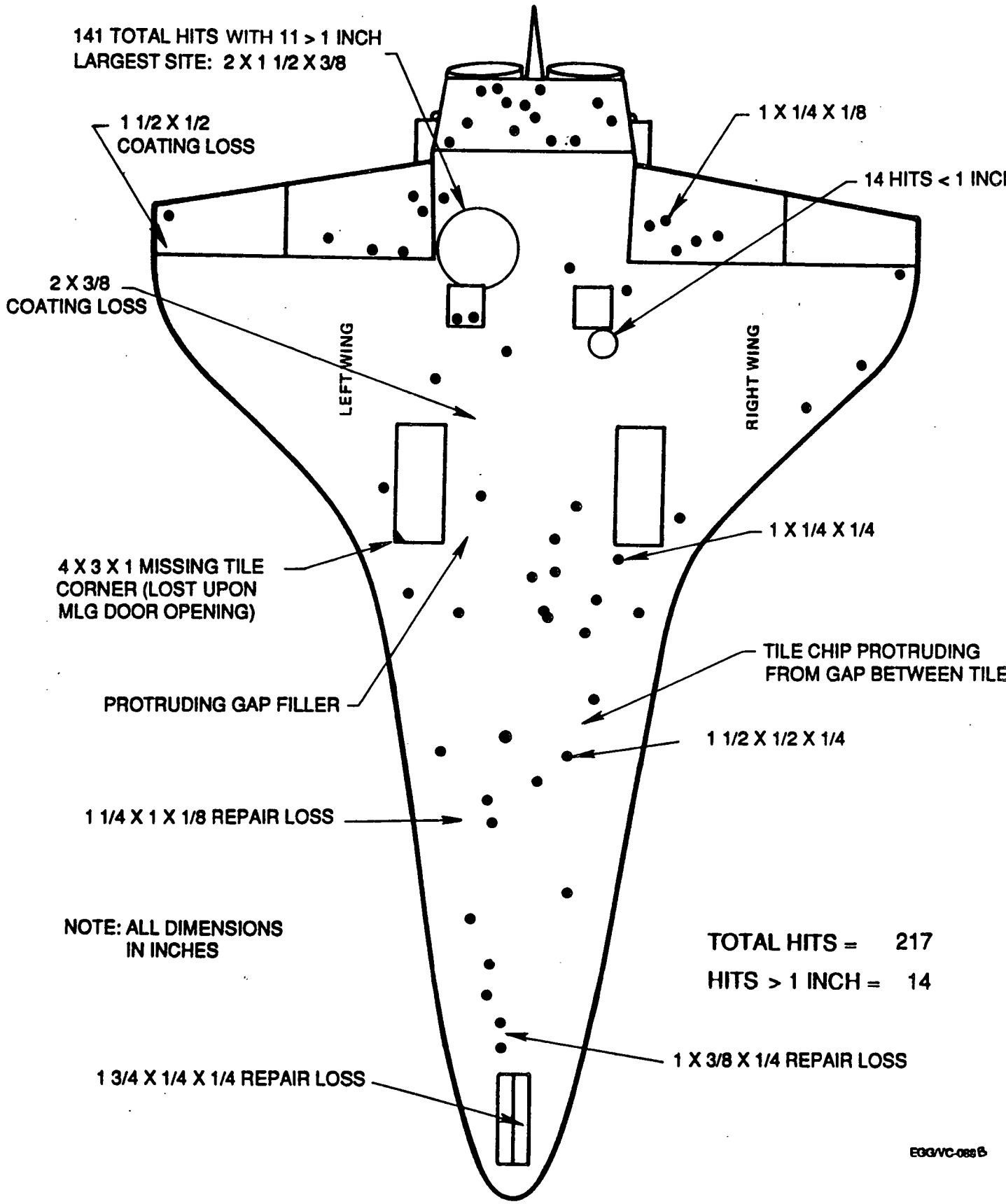
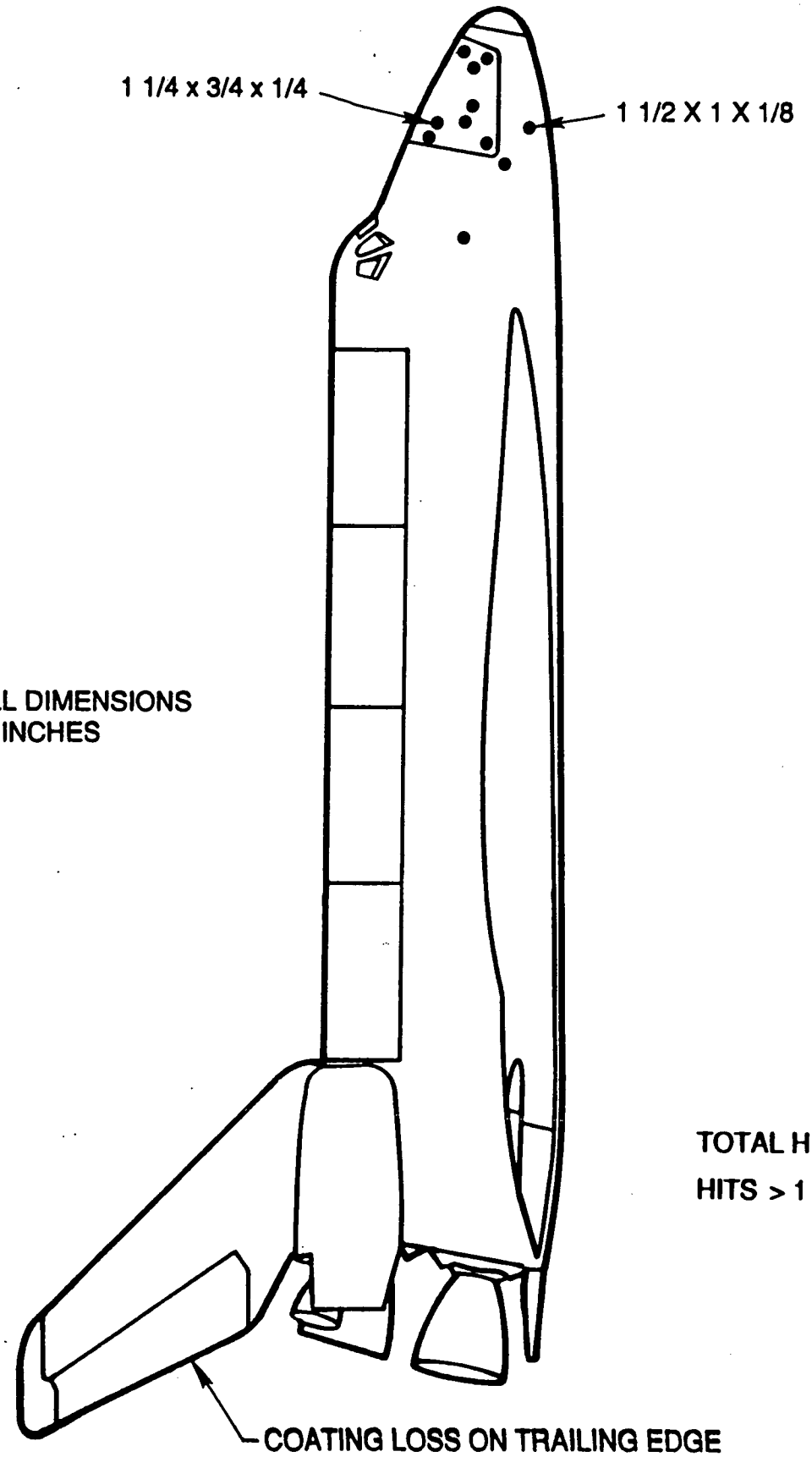


FIGURE 12. **DEBRIS DAMAGE LOCATIONS**



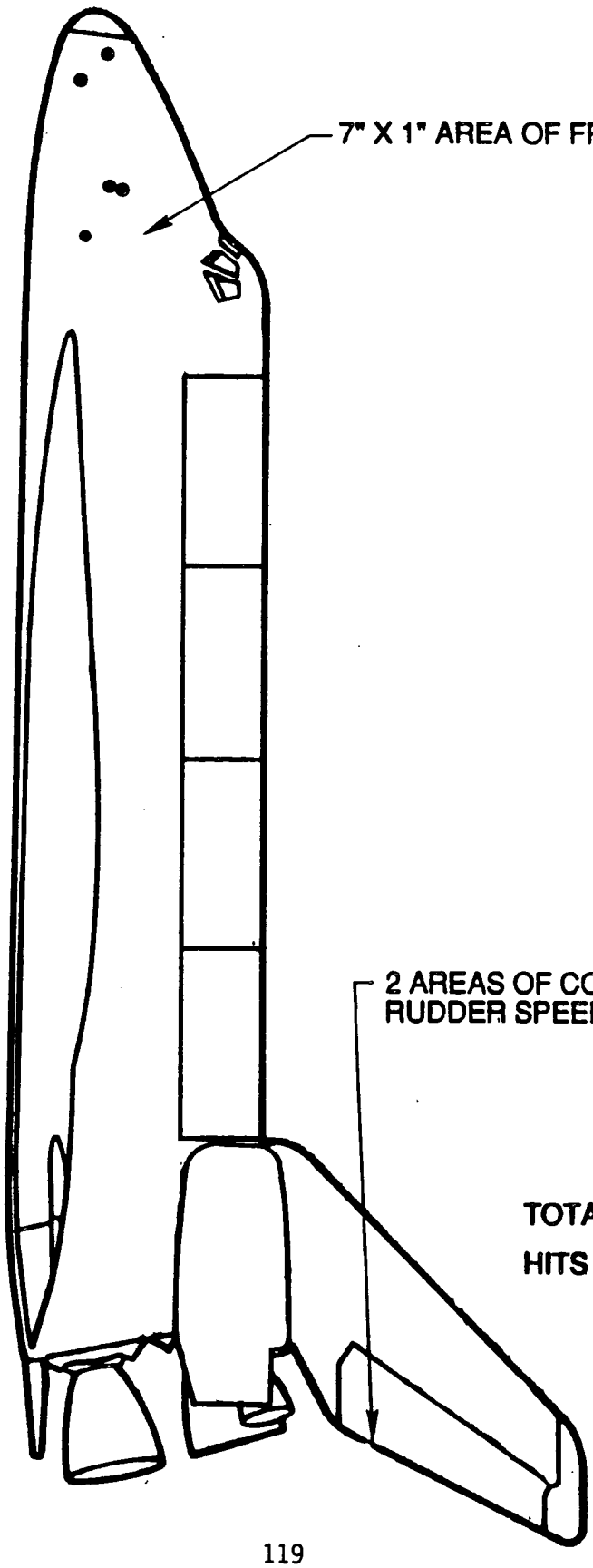
NOTE: ALL DIMENSIONS
IN INCHES

TOTAL HITS = 11

HITS > 1 INCH = 2

EGG/VC-088A

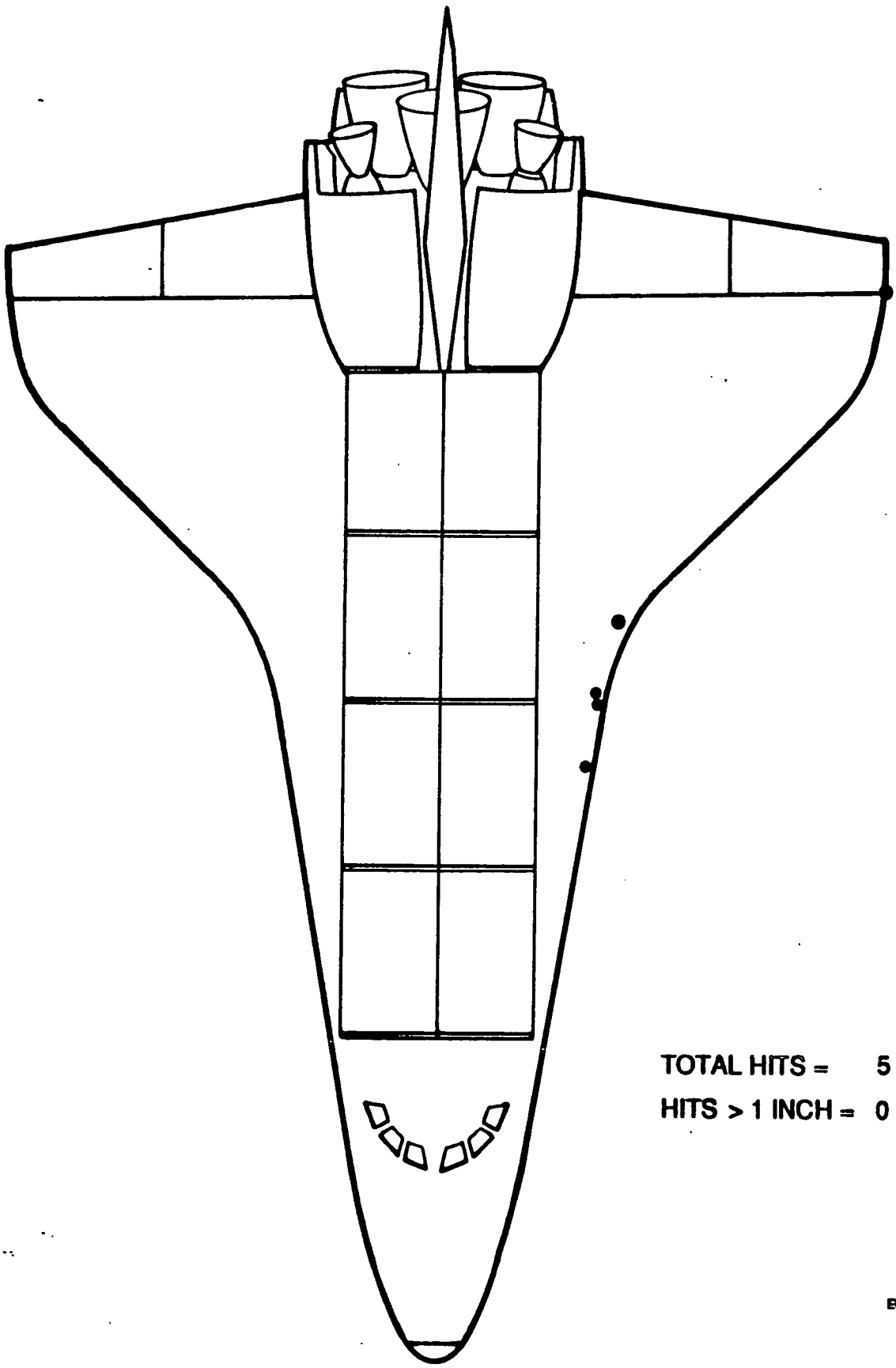
FIGURE 13
STS-39
DEBRIS DAMAGE LOCATIONS



EGG/VC-089

FIGURE 14
STS-39

DEBRIS DAMAGE LOCATIONS



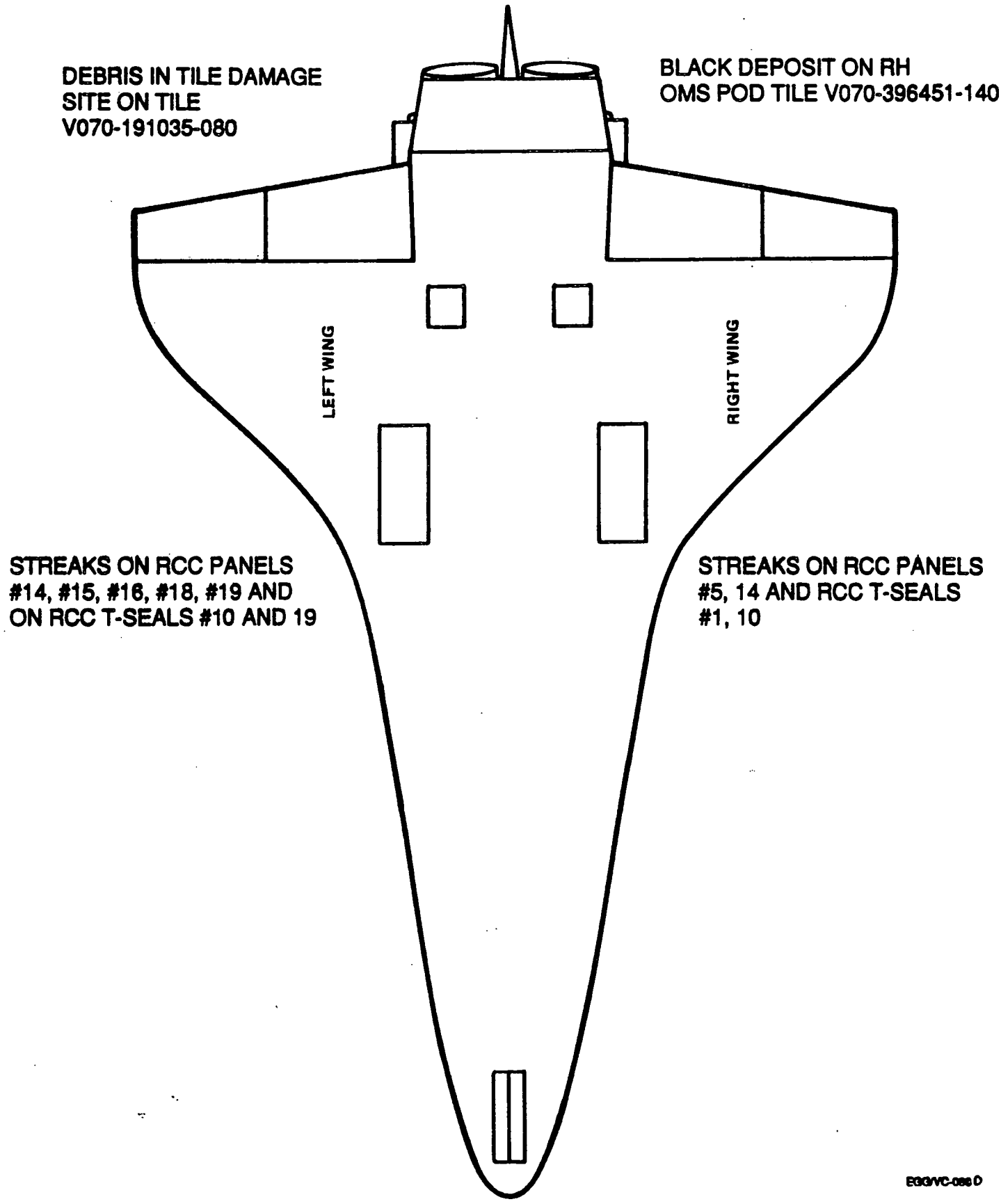
TOTAL HITS = 5

HITS > 1 INCH = 0

EGG/VC-088C

FIGURE 15
STS-39

CHEMICAL SAMPLE LOCATIONS



Damage to the base heat shield tiles was less than average. The main engine #3 closeout blanket had an area of frayed material from 9:00 to 10:00 o'clock, the SSME #2 blanket was frayed at the 3:00 o'clock position, and the SSME #1 blanket was frayed at the 6:00 o'clock position. Tile surface coating material was missing from three places (one on the right side, 2 on the left side) on the trailing edge of the rudder speed brake. Damage in this area is usually caused by vibration/acoustics during ascent.

Several small pieces of gap filler sleeving material were protruding slightly on the leading edges of the RH OMS pod with no detectable damage to adjacent tiles. The overall condition of the TPS on the OMS pods was good.

Only a few small white streaks were present on the wing leading edge RCC panels. Samples of selected streaks were taken for laboratory analysis (Figure 15).

Orbiter windows #3 and #4 were moderately hazed with a few small streaks. Windows #2 and #5 were lightly hazed.

The KSC Shuttle Thermal Imager (STI) was used to measure the surface temperatures of several areas. Fourteen minutes after landing, the Orbiter nosecap RCC was 140 degrees F. Twenty-six minutes after landing the RH wing leading edge RCC panel #9 was 105 degrees F and the RH wing panel #17 was 103 degrees F (Figure 16).

Runway 15 had been inspected and swept by SLF Operations personnel prior to Orbiter landing. The runway was found to be in acceptable condition.

The post landing inspection of Runway 15 was performed approximately 1/2 hour after landing. Small pieces of tire ply material lost from the main landing gear tires lay on the runway within 1000 feet of the Orbiter stop position. No other flight hardware was found on the runway or overrun.

In summary, although the total number of Orbiter TPS debris hits was greater then average, the number of hits larger than one inch was less than average when compared to previous flights as shown in the comparison chart (Figure 17-19). If the hits from the area aft and inboard of the LH2 umbilical are discounted, the number of total hits is slightly less than average and the number of hits greater than one inch is much less than average. The distribution of the remaining 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 11.4.

FIGURE 16

STS-39

TEMPERATURE MEASUREMENTS

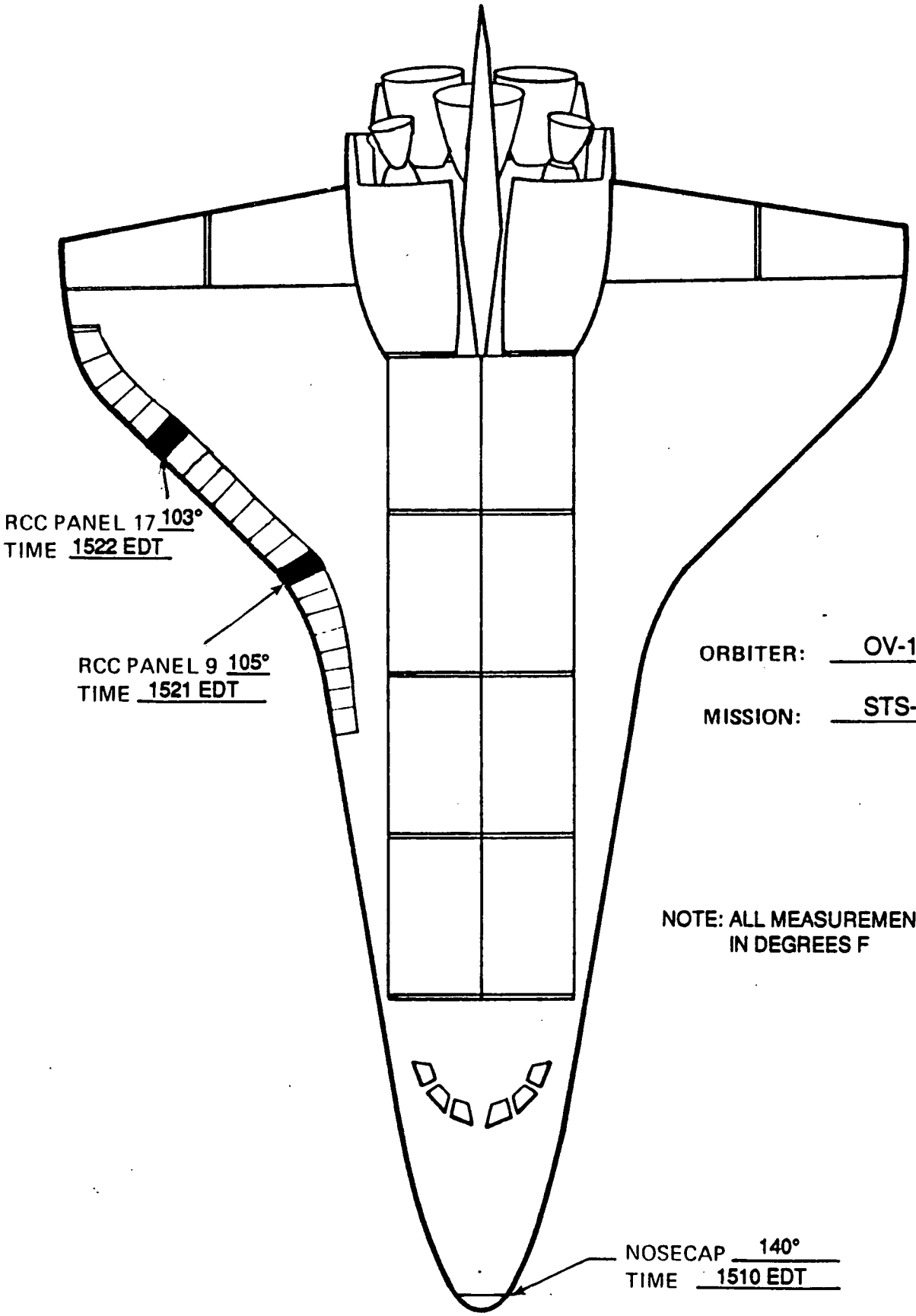


FIGURE 17. STS-35 DEBRIS DAMAGE ASSESSMENT SUMMARY

	Hits > or = 1"	Total Hits
Lower Surface	14	217
Upper Surface	0	5
Right Side	2	11
Left Side	0	5
Right OMS Pod	0	0
Left OMS Pod	0	0
TOTALS	16	238

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

FIGURE 18. # COMPARISON TABLE

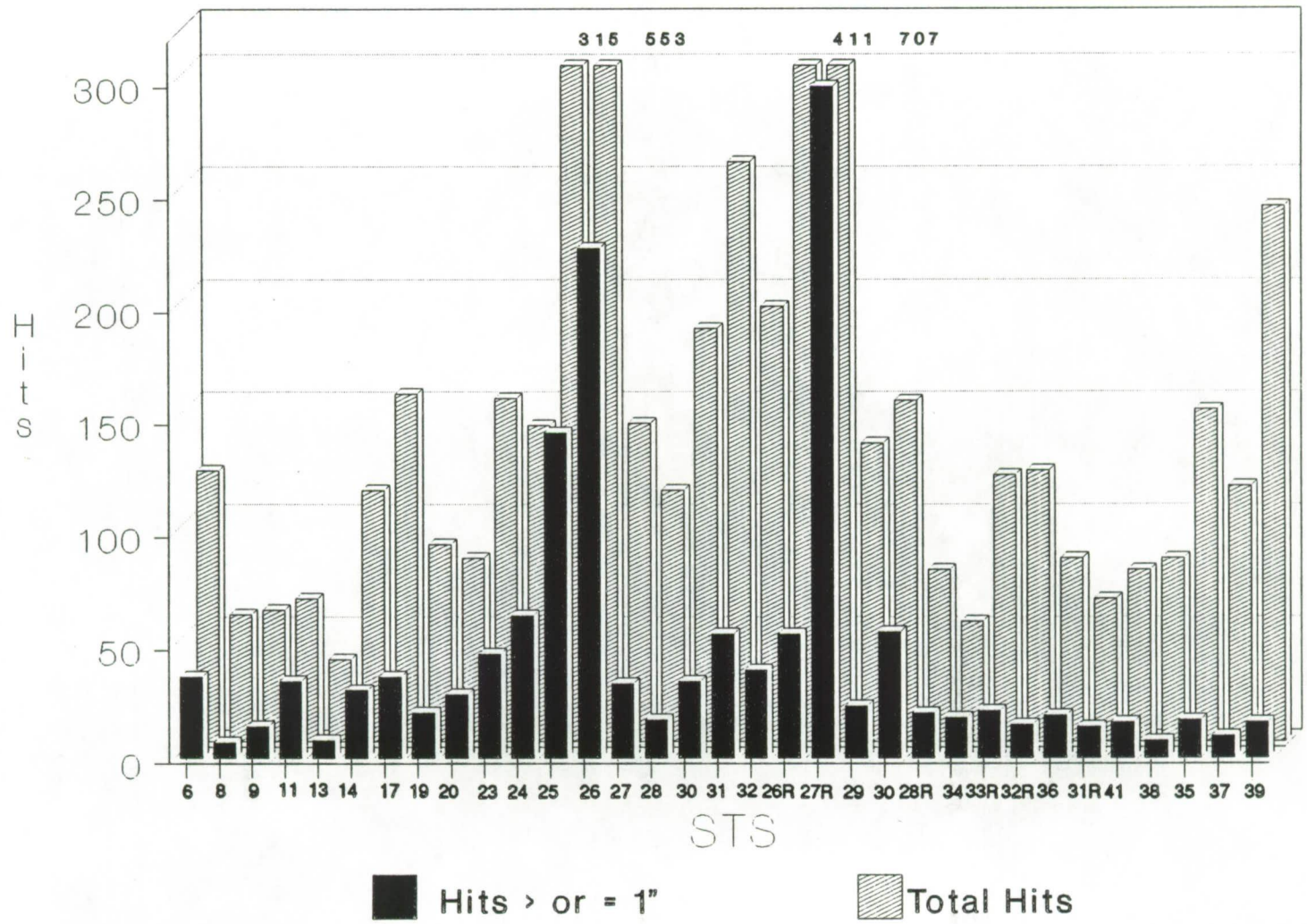
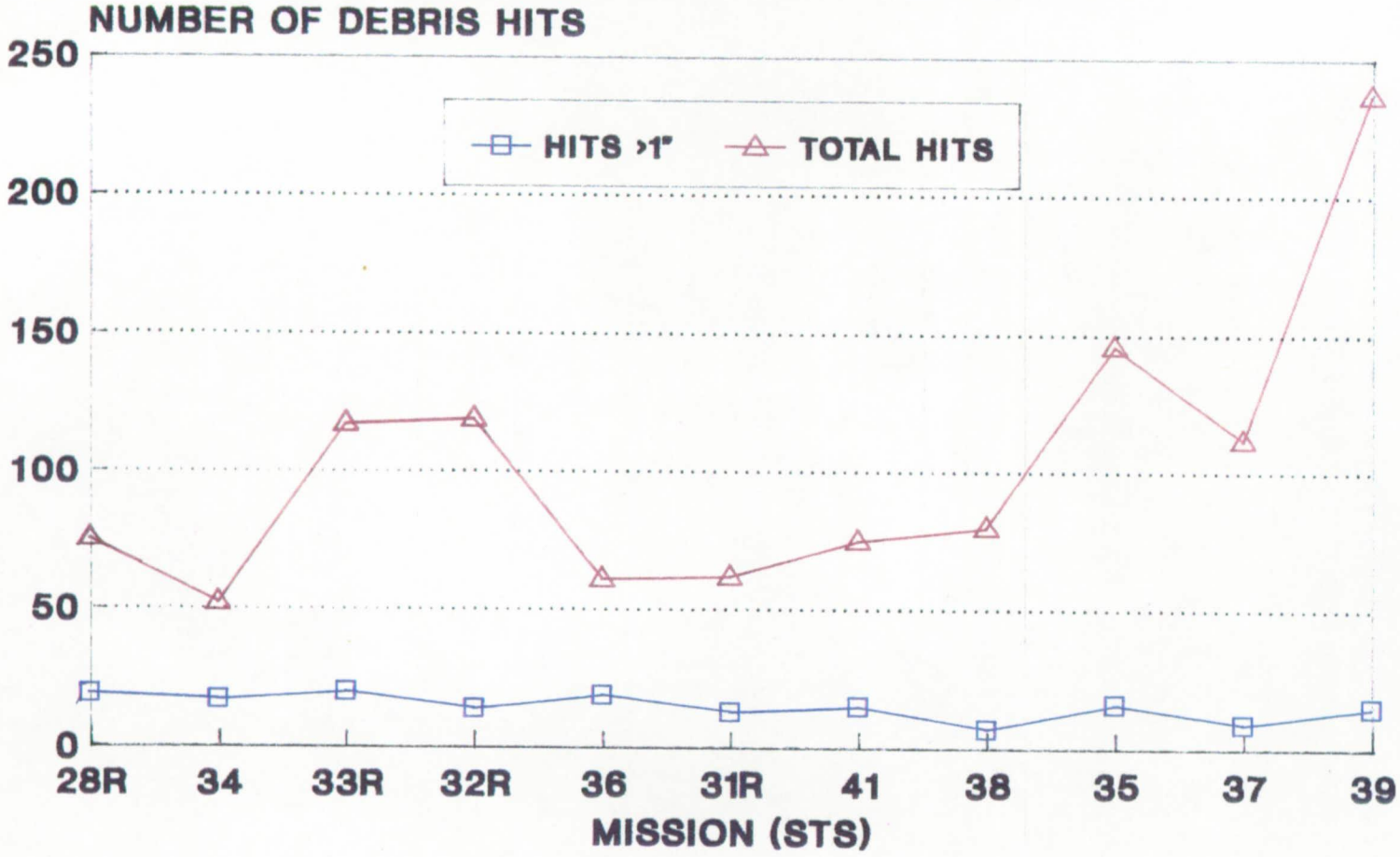
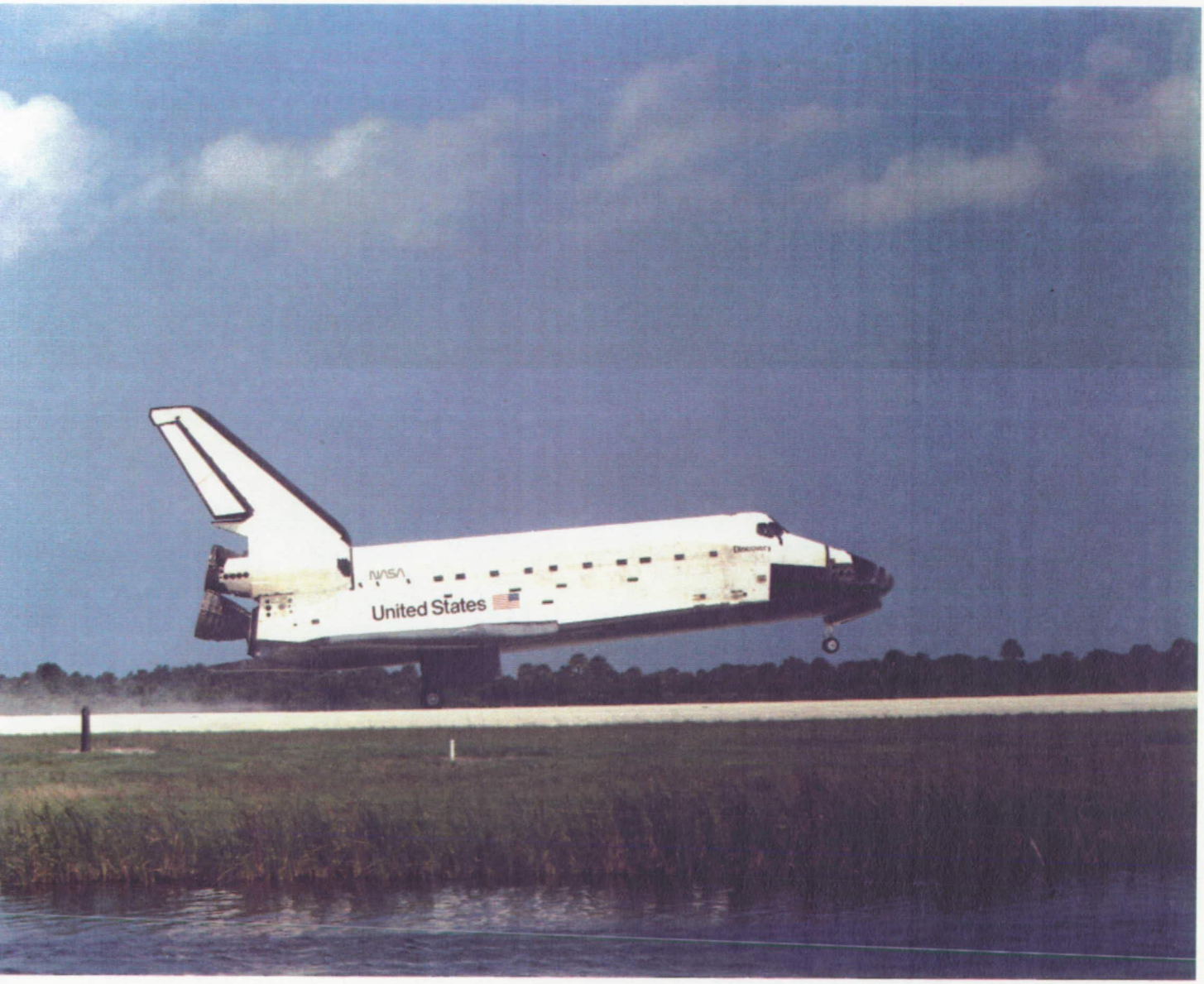


FIGURE 19.

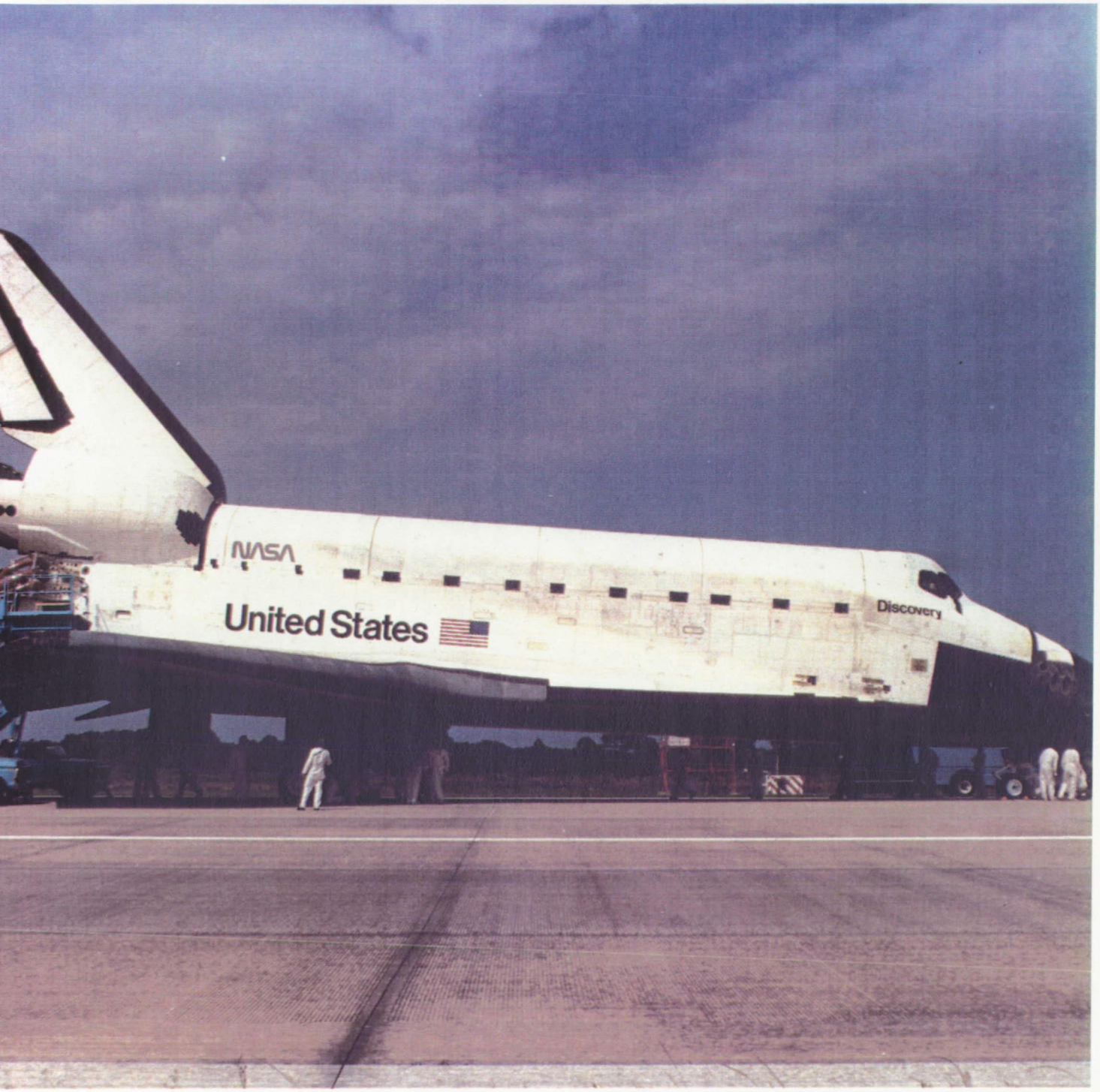
ORBITER TPS DEBRIS DAMAGE
STS-28R THROUGH STS-39



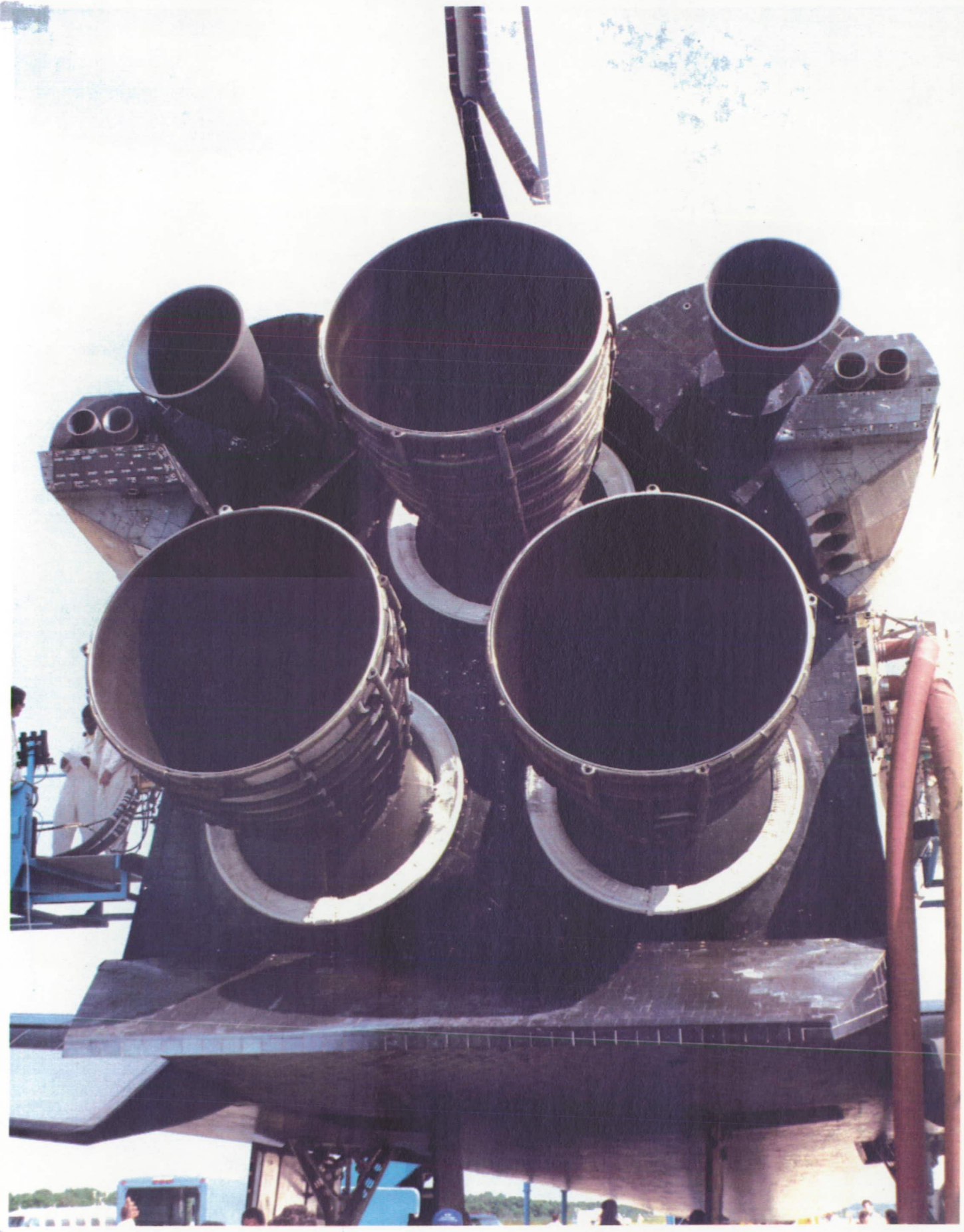


OV-103 made the 7th landing at KSC on 6 May 1991 due to high winds at Edwards AFB/ADFRF

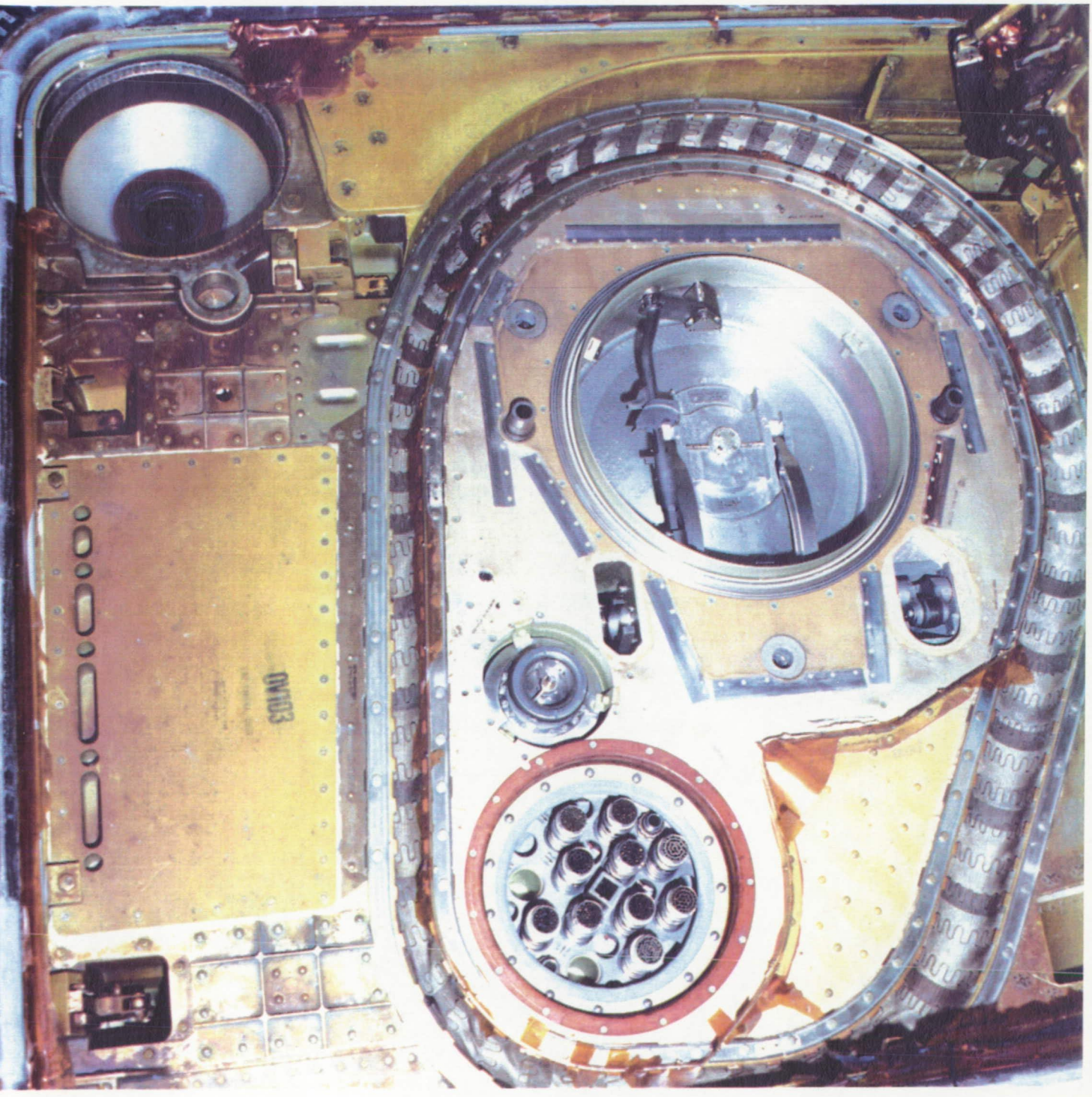
Overall view of OV-103 left side



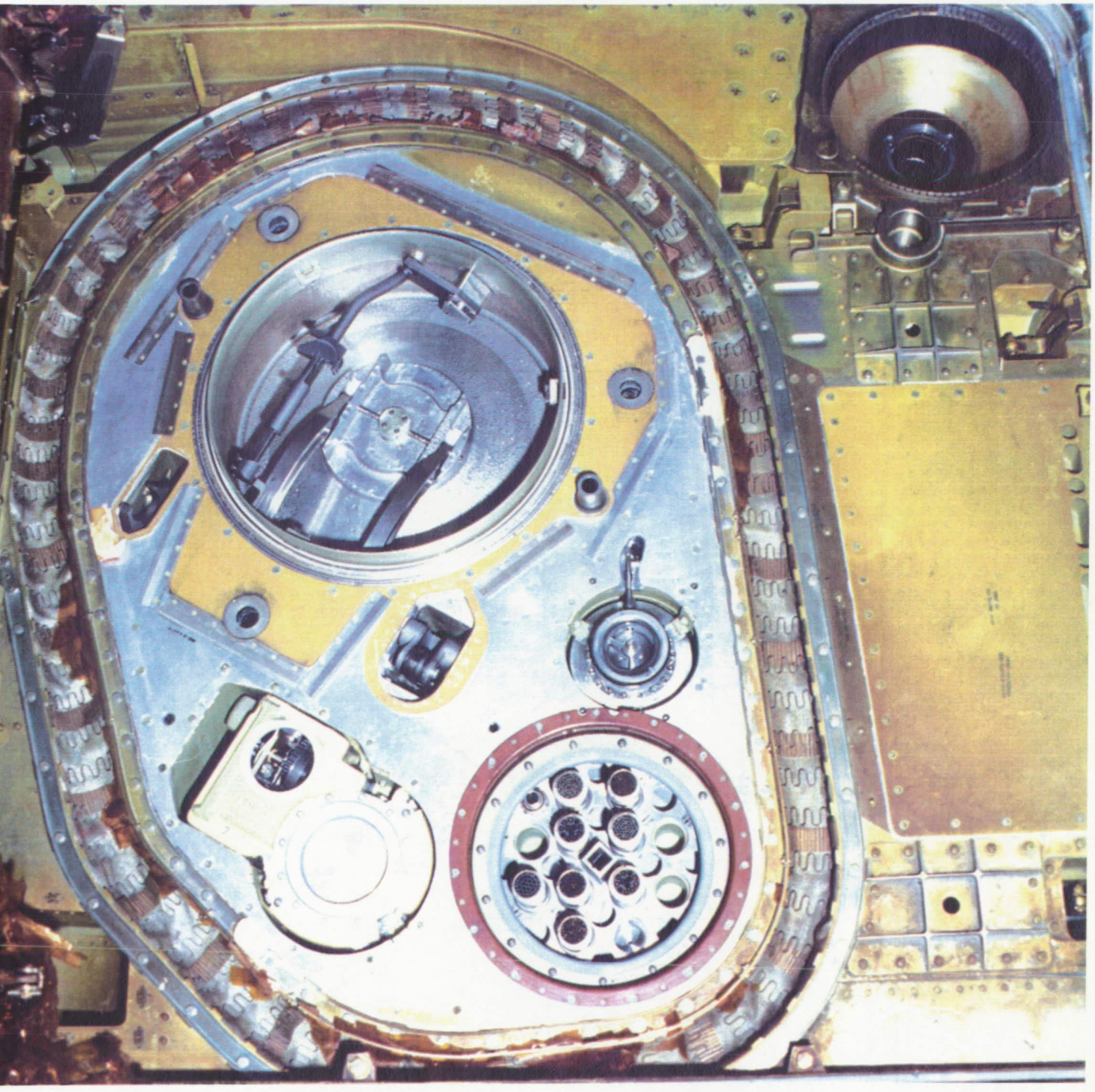
Overall view of OV-103 right side



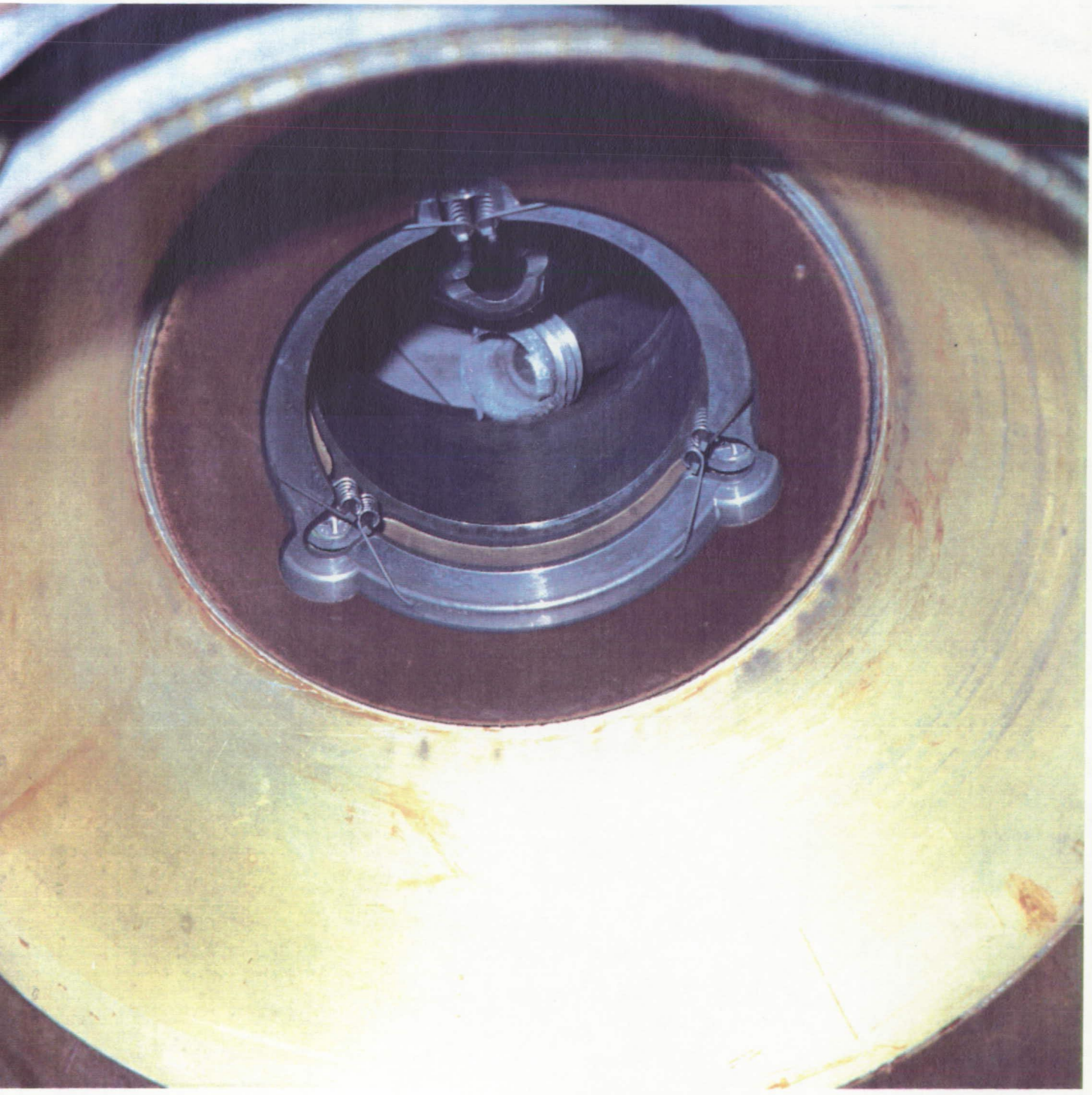
Overall view of SSME's and base heat shield area



Post flight condition of the LO2 ET/ORB umbilical

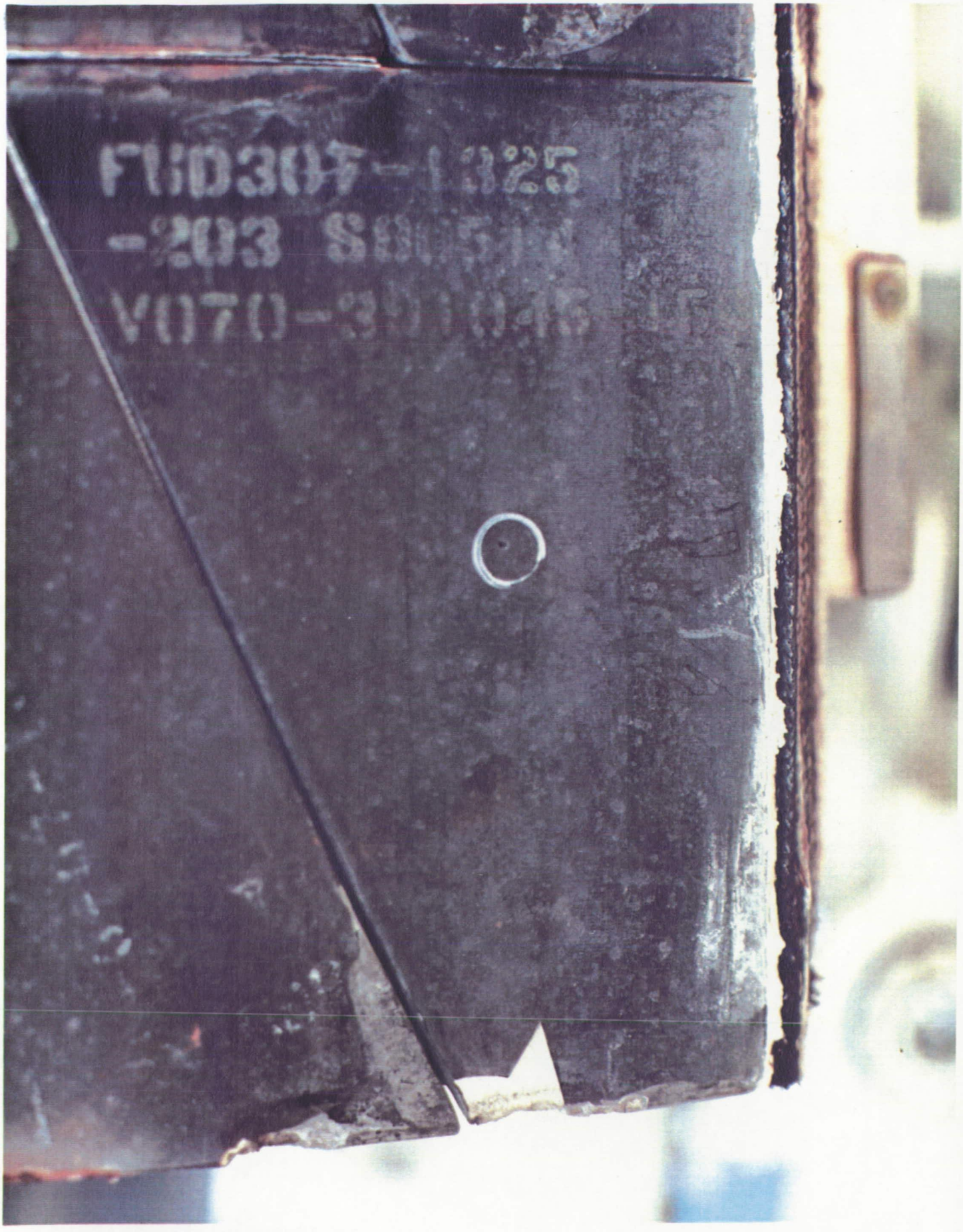


Post flight condition of the LH2 ET/ORB umbilical

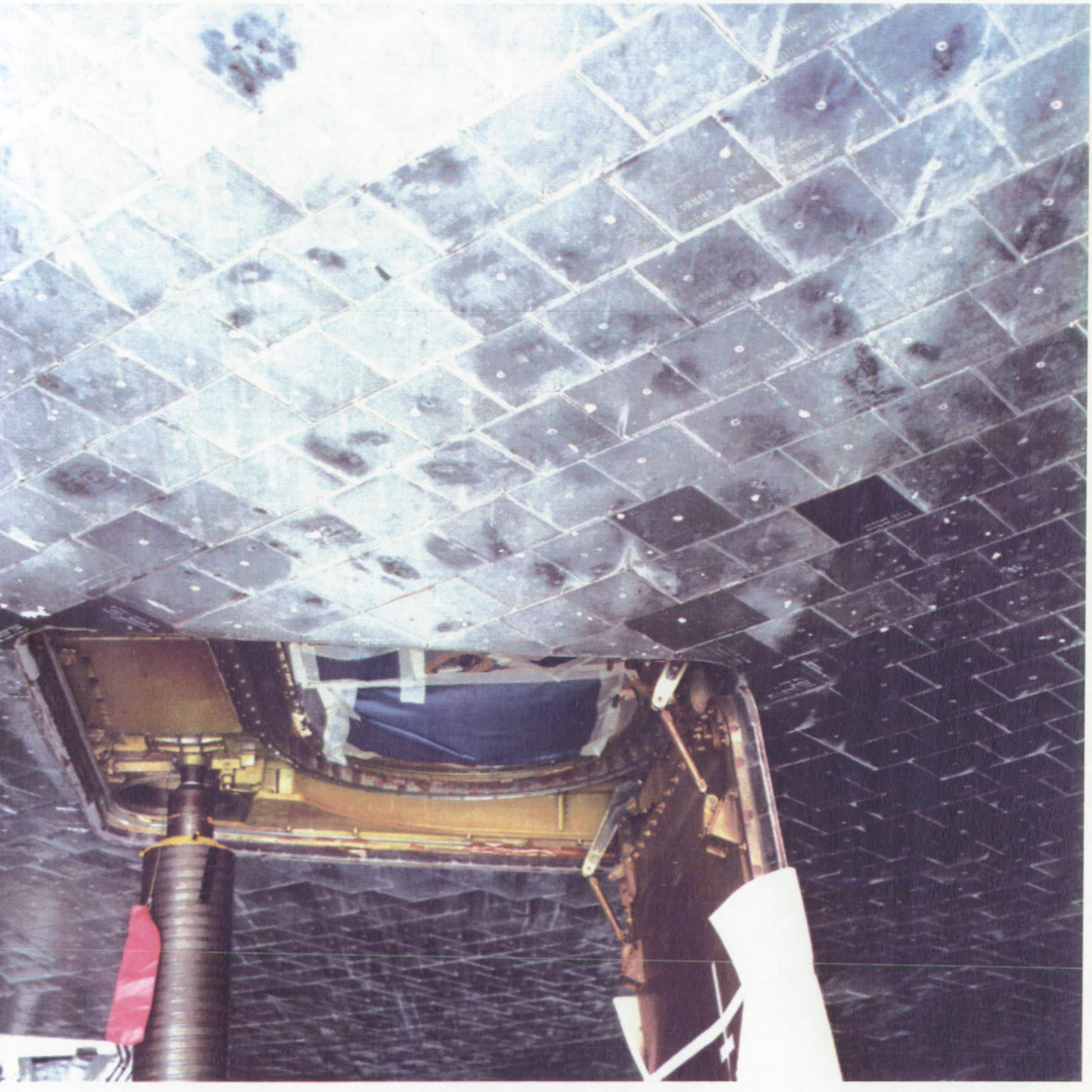


EO-3 debris plunger was obstructed by an NSI cartridge fragment

2-inch piece of umbilical purge seal, which should have remained attached to the External Tank, adhered to the Orbiter side of the LH2 ET/ORB umbilical plate



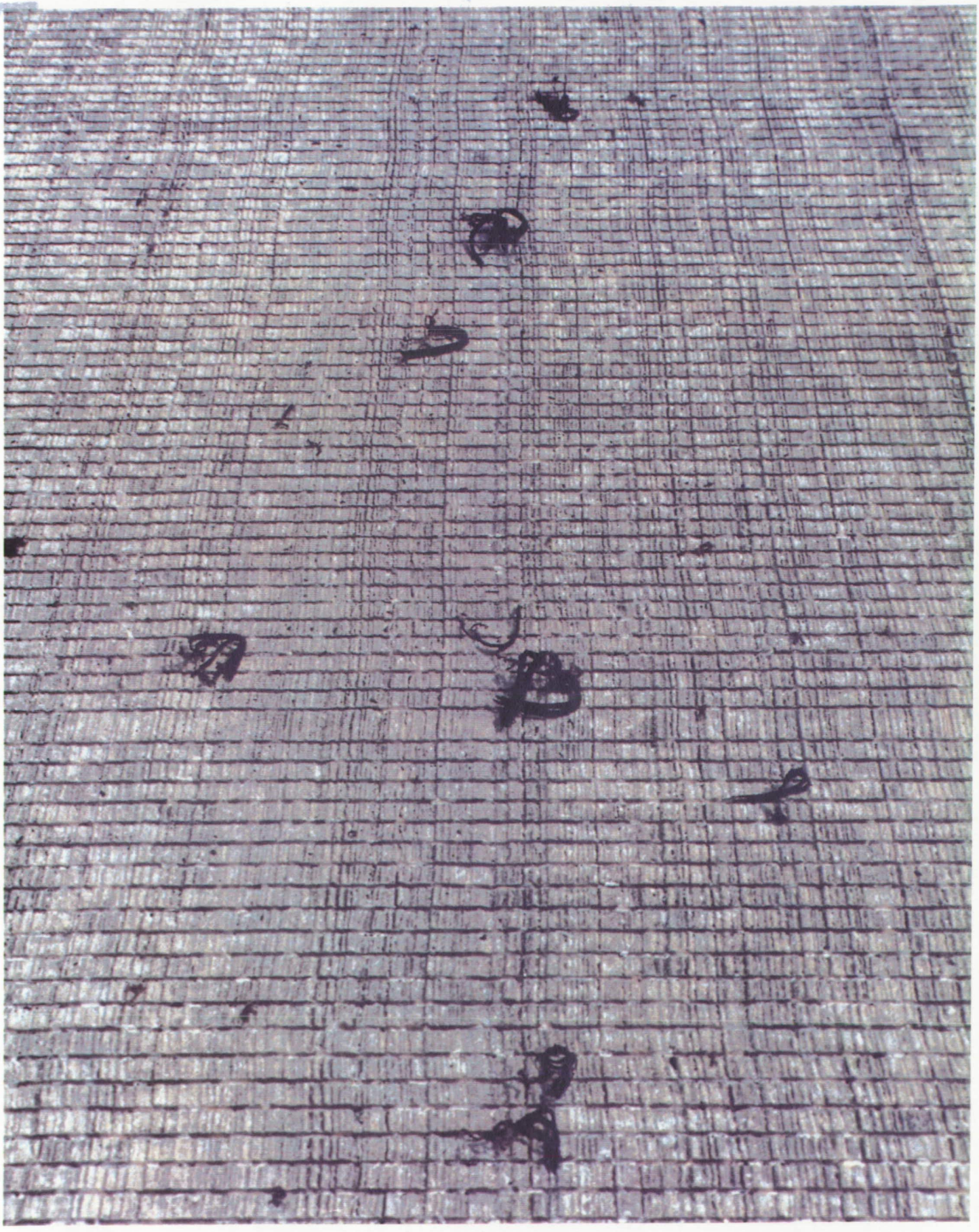
Tile damage on trailing edge of RH nose landing gear door



Cluster of hits on the tiles aft of the LH2 ET/ORB umbilical is typically caused by ice impacts during ascent and separation

No tile damage was attributed to the loss of tire material from the main landing gear wheels

Material from the RH main landing gear tires lay on the runway within 1000 feet of the Orbiter stop point. There was no tire material at the touchdown point.



Three plies of material were lost from the RH outboard tire
and 1 ply was lost from the RH inboard tire

10.0 DEBRIS SAMPLE LAB REPORTS

A total of 12 samples were obtained from Orbiter OV-103 during the STS-39 post landing debris assessment at Kennedy Space Center, Florida (Figure 15). The 12 submitted samples consisted of 10 wing leading edge RCC samples (6RH, 4LH) and 2 tile residue samples. 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 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. Hypalon paint
6. Rust and paint
7. Organics

Debris analysis provides the following correlations:

1. Metallic particles (aluminum and carbon steel) 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 glass are Orbiter TPS materials.

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

5. Hypalon paint is a topcoat on SRB thermal protection system (TPS) surfaces.

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 type, with possible origin of adhesive or proteinaceous (food/insect) materials. Some Cellulosic (sample cloth) fibers were also present.

Orbiter Tile

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

1. Black and white silicon-rich tile and insulation glass
2. Organic fiber (trace)

Debris analysis provides the following correlations:

1. Black and white silicon-rich tile and insulation glass fibers originate from the Orbiter thermal protection system (TPS).
2. Organic fiber (Cellulosic) originates from sample cloth material.

Conclusions

The STS-39 mission sustained Orbiter tile TPS damage to a greater than average degree. The chemical analysis results of post flight samples did not provide data that points to a single source of damaging debris.

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, Hypalon paint, 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.

11.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 9 Post Launch Anomalies were observed for STS-35. This list contains one IFA candidate.

11.1 LAUNCH PAD/FACILITY

1. Shim sidewall material on the south holddown posts was intact, but debonded to various degrees. Shim material should remain bonded to the HDP shoes. (KSC processing item)

2. An electrical box on the southeast corner of the MLP was missing a cover. (KSC processing item)

11.2 EXTERNAL TANK

1. No items.

11.3 SOLID ROCKET BOOSTERS

1. The RH frustum had no areas of missing TPS but had 52 MSA-2 debonds over fasteners. The LH frustum had no areas of missing TPS but had 22 MSA-2 debonds over fasteners. (SRB Project item)

2. GEI cork closeout on the RH aft center segment exhibited a 1.5"x0.5" debond at 180 degrees. EPDM weather seals on the LH aft booster factory joints had 5 debonds, the largest of which measured 2.0"x0.25". (SRB Project item)

3. Three bolt heads were missing from the ETA ring cover near the systems tunnel. (SRB Project item)

4. HDP #4 DCS plunger was obstructed by ordnance fragments. HDP #7 DCS plunger was obstructed by frangible nut halves. Five ordnance fragments, including a piece of NSI cartridge and web, fell from the HDP #7 DCS/stud hole after liftoff in film items E-11 and 28. (SRB Project item)

5. A 4"x0.5" piece of EPON shim material from HDP #3 and two pieces of sidewall shim material (3"x2" and 5"x2") from HDP #4 were missing from the aft skirt prior to water impact. (SRB Project item)

11.4 ORBITER

1. SSME ignition vibration/acoustics caused the loss of tile surface coating material from 3 places on base heat shield and 2 places on RH RCS stinger. (Orbiter Project item)

2. The plunger in the EO-2 (LH2) separation fitting debris container was obstructed by an NSI cartridge and failed to seat properly. (IFA candidate)

APPENDIX A.
MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
MAY 29, 1991

SUBJECT: Orbiter Debris/ Residue Samples From STS-39 Landing

LABORATORY REQUEST NO: MCB-0363-91

RELATED DOCUMENTATION: Intercenter Debris Team Requirements

1.0 FOREWORD:

1.1 REQUESTER: R. F. Speece/TV-MSD-22/1-2946

1.2 REQUESTER'S SAMPLE DESCRIPTION: The samples were from OV-103, STS-39 landing, KSC and were identified as follows:

I. R/H Wing RCC
1. #10T.
2. #14/15.
3. #16.
4. #18.
5. #19T.
6. #19

II. L/H Wing RCC
7. #1T.
8. #5.
9. #10T.
10. #14.

III. Tile Residue
11. V070-396451-140, CW5569, RH OMS.
12. Debris in tile 191035-080.

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

1.4 ADDITIONAL ANALYSTS: M. Williams.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

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

2.2 Results:

2.2.1 The particulates from each sample 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,Al	
2.Blk mtls	Fe,Si,Cl,S,Ca,Al,K	Cr,Cu,Mg,
3.Wht mtls	Ca,P,Si,Ti,Mg,Al,Cl	K,S,Fe,P
4.Red mtls	Fe,Si	
5.Glass fiber	Si,Al	
6.Organics	polyamide	
7.Organic fiber	cellulose	

*: 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 # / Components	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
1.Metallics	T	x	x	x	x	x	x	T	x	T	x	x
2.Blk mtls	5	30	70	40	37	30	25	T	2	3	25	10
3.Wht mtls	40	60	28	60	60	70	30	95	98	95	75	90
4.Red mtls	T	x	x	x	x	x	T	x	x	x	x	x
5.Glass fiber	x	x	x	x	x	x	x	x	T	x	T	T
6.Organics	50	10	2	T	1	T	42	5	T	T	x	T
7.Organic fiber	5	T	T	T	2	T	3	T	T	2	T	T
Particle size in um	1-200	1-800	1-250	1-110	1-250	1-300	1-350	1-130	1-450	1-150	1-400	1-900

5: Estimated Volume Percent.
x: Not Detected.
T: Trace Amounts.

2.2.3 Figures 1 and 2 are EDS spectra of Elephant-hide standard "as received" and "heated to 2600F for 1 hr," respectively.

2.2.4 Figures 3 and 4 are EDS spectra of Hypalon paint standards "as received" and "heated to 2600F for 1 hr," respectively.

2.2.5 Figures 5 and 6 are EDS spectra of white materials from sample numbers 4 and 6 to show elemental distribution.

3.0 CONCLUSIONS:

3.1 All samples contained trace amounts of particulates and the particulates were composed of metallics, black materials, white materials, red materials, glass fibers, organics, and organic fibers.

3.2 The sample numbers 1, 8, and 10 contained metallics and metallics were composed of Al-alloy and carbon steel.

3.3 All samples contained black materials, and black materials were composed of a combination of tile materials, rust, paints, Si-Ca-Ti-S-Cl rich materials, and Cr-Si-K-Al rich materials.

3.4 All samples contained white materials, and white materials were composed of as follows:

#1: Ca-P rich materials.
#2: Si rich tile.
#3: Si-Zn rich materials.
#4: Si-Zn rich materials and heated elephant-hide.
#5: Si-rich tile.
#6: Tile and heated elephant-hide.
#7: Si-rich tile and Ca-Si rich materials.
#8: Si-rich tile and Mg-Si-P rich materials.
#9: Si-rich tile.
#10: Si rich tile and heated elephant-hide.
#11 and #12: Si-rich tile.

3.5 The sample numbers 4, 6, and 10 appeared to be contained elephant-hide which might have been heated to high temperature (compare Figures 1, 2, 3, 4, 5, and 6) during reentry.

3.6 The sample number 1 contained red RTV and sample number contained red rust particles.

3.7 The samples 9, 11, and 12 contained Si-Al rich high temperature insulation glass.

3.8 The organics were identified to be of the polyamide class, and might have an origin of either adhesives or proteinaceous materials. There was also some cellulosic material present.

3.9 The organic fibers were identified to be cellulosic types.

3.10 The particle sizes estimated to be in the range of 1 to 1500 micrometers.

INVESTIGATOR: H. S. Kim
H. S. KIM

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

Figure 1. ELEPHANT,STD,AS RECEIVED

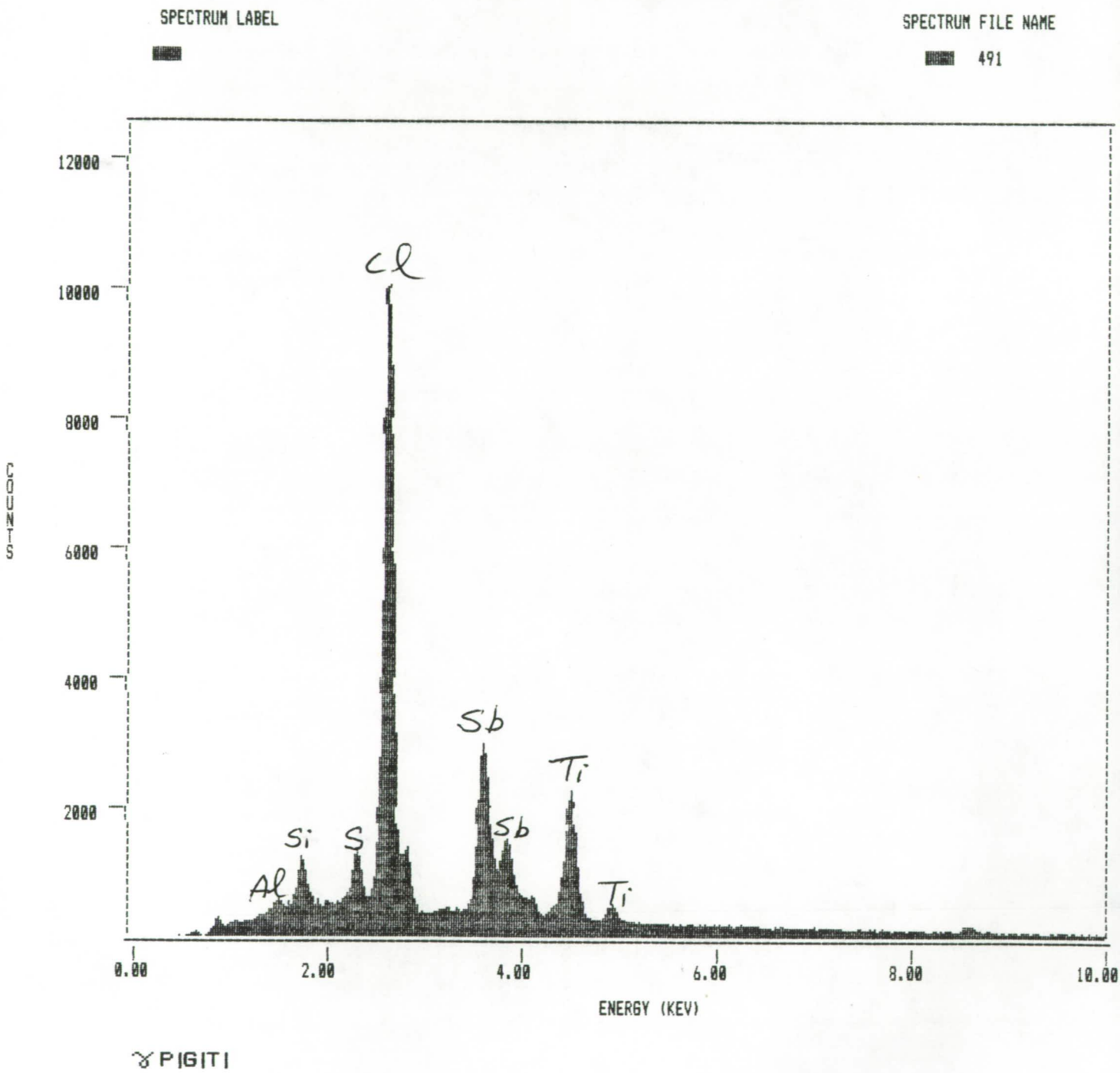


Figure 2. ELEPH,STD,2600F

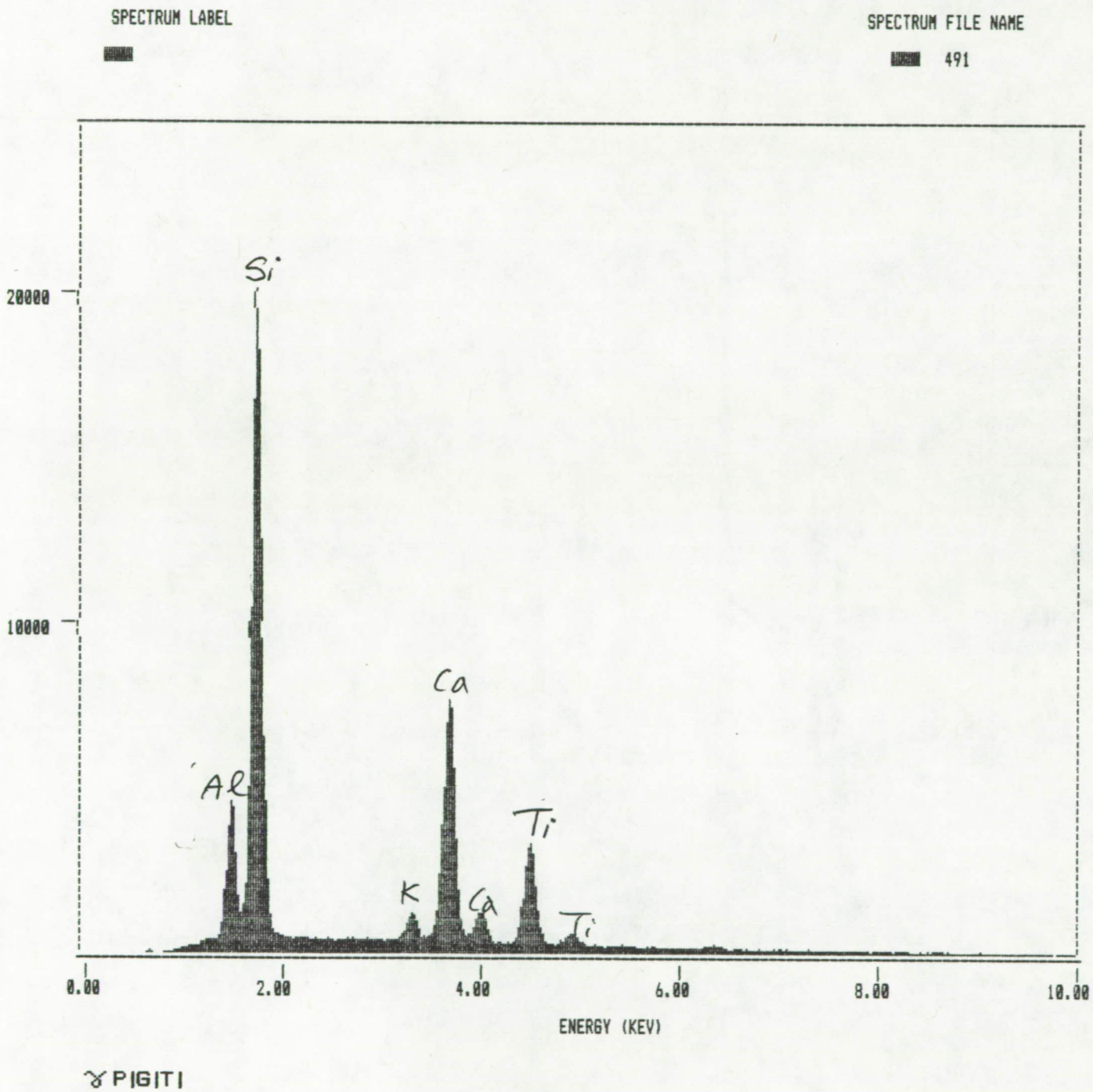


Figure 3. HYPALON PAINT.STD,AS RECEIVED

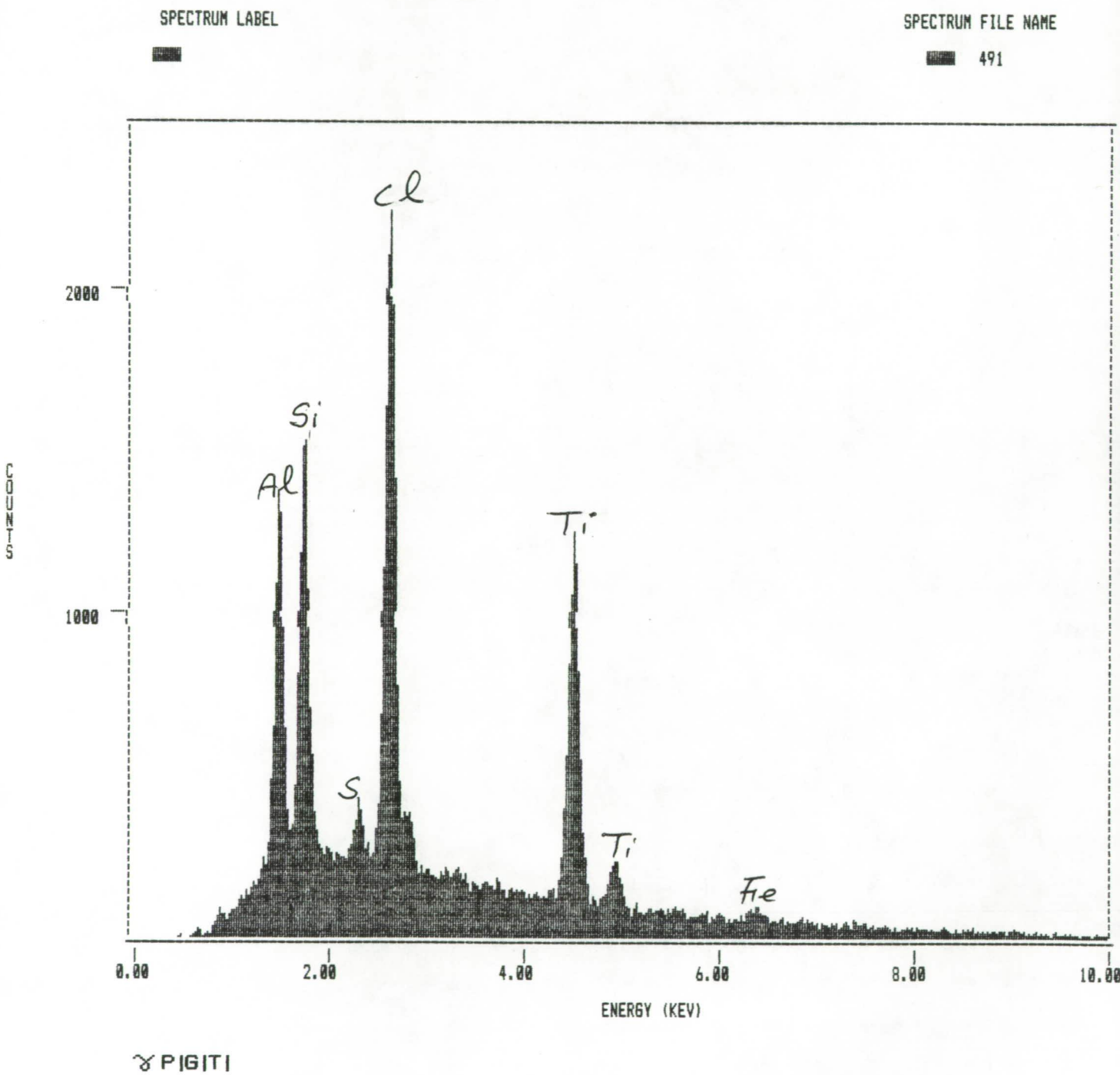


Figure 4. HYPALON,STD,2600F

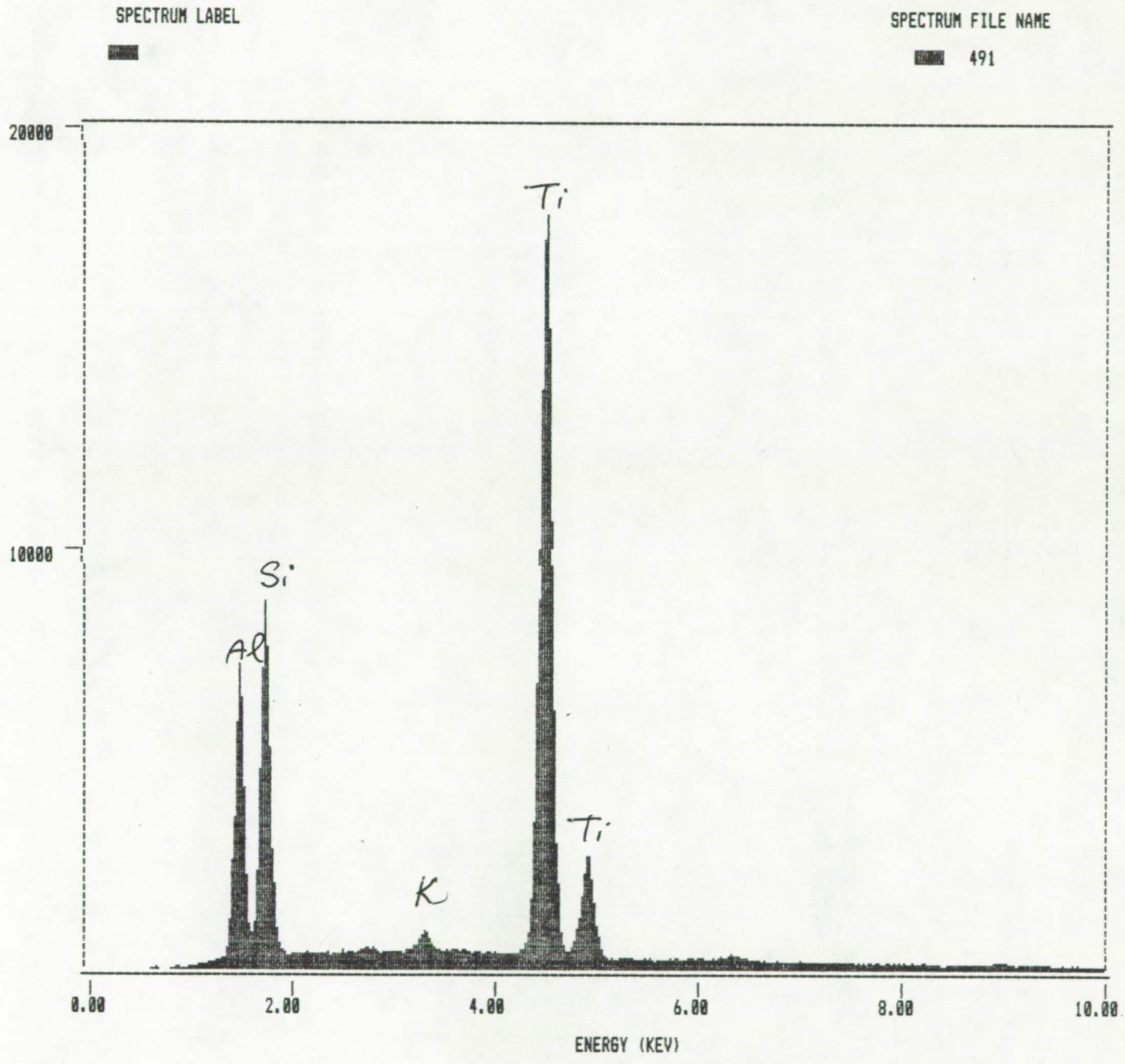
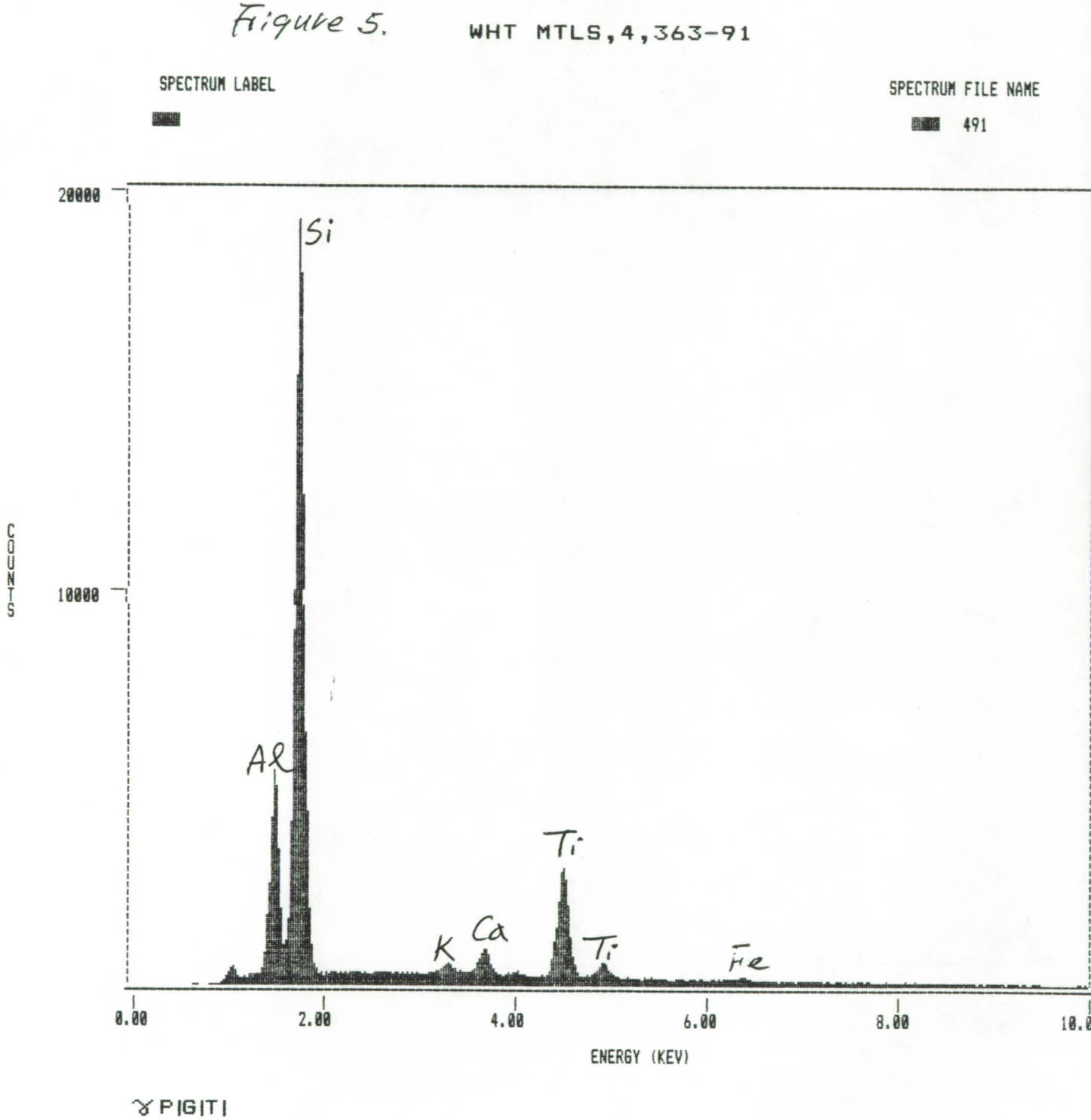


Figure 5.


WHT MTLS,4,363-91
SPECTRUM LABEL
SPECTRUM FILE NAME
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20000
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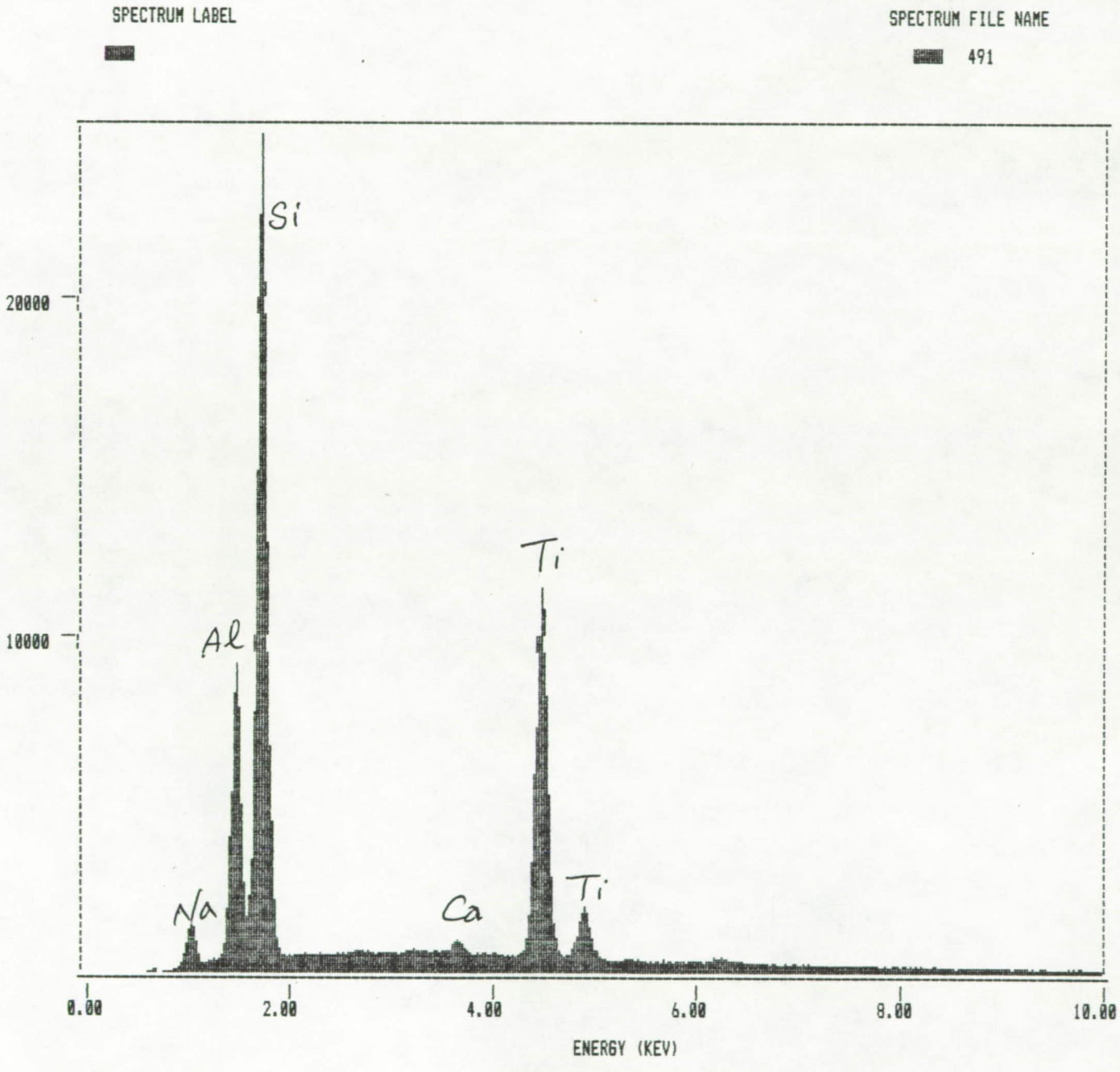
COUNTS
Si
Al
K
Ca
Ti
Ti
Fe
0.00
2.00
4.00
6.00
8.00
ENERGY (KEV)
PIGIT

Figure 6. WHT MTSL,6,363-91



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Kennedy Space Center, Florida 32899

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15. Supplementary Notes

16. Abstract

A Debris/Ice/TPS assessment and photographic analysis was conducted for Space Shuttle Mission STS-39. 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 of launch was analyzed 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-39, and their overall effect on the Space Shuttle Program.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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