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# Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-37

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# Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-37

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April 1991

National Aeronautics and
Space Administration

John F. Kennedy Space Center

KSC FORM 16-12 (REV. 8/76)

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

# DEBRIS/ICE/TPS ASSESSMENT AND PHOTOGRAPHIC ANALYSIS OF SHUTTLE MISSION STS-37

April 5, 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-37 was launched at 9:22 a.m. local 4/5/91



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## 1.0 Summary

Debris and Photo Analysis Team activities for Mission STS-37 began with the pre-launch debris inspection of the launch pad and Shuttle vehicle on 4 April 1991. No major anomalies were observed on OV-104 Atlantis, ET-37 (LWT-30), and BI042. Minor facility discrepancies were corrected prior to cryoloading the vehicle.

The vehicle was cryoloaded for flight on 5 April 1991. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. A facility IPR was taken against tie-wraps attached to the LO2 TSM near the Orbiter RH aft RCS stinger. (The tie-wraps remained attached to the TSM during launch). There were no ET anomalies. The ET TPS was wet from rainfall, but there was no ice/frost on the acreage. Seven 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. At launch, the ET ice condition was well within the data base for ice formation.

A debris inspection of Pad 39B was performed after launch. No significant flight hardware or TPS material was found with the exception of one Orbiter base heat shield Q-felt plug just west of the crawlerway. Launch damage to the holddown posts was minimal. EPON shim material on south holddown posts was intact, but debonded to various degrees. A small amount of sidewall shim material was missing from HDP #6. A small piece of NSI cartridge was wedged between the HDP #6 stud and bolt hole. No signs indicative of stud hang-up were visible. The GH2 vent line had latched properly. Damage to the facility included 1 loose and 4 missing cable tray covers from the FSS. Two of the missing cable tray covers were found west of the pad apron. The modification program to replace old cable tray cover fasteners with new trapeze fasteners is still in work at Pad 39B. The new Hydrogen Dispersal System structure welded to the MLP deck showed no sign of damage.

A total of 147 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 success of the mission. SSME ignition vibration/acoustics caused ice to shake loose from the LO2 T-0 carrier plate/cryogenic lines. Some of the ice was drawn to and impacted SSME #3 nozzle by aspiration. No damage to the nozzle was visible. SSME ignition vibration/ acoustics also caused the loss of tile surface coating material on the OMS nozzle heat shields, aft RCS stingers, and Orbiter base heatshield. Two small ordnance fragments fell from the HDP #6 DCS/stud hole during liftoff. Just after initiation of the roll maneuver, the F2U FWD RCS paper cover detached from the thruster and fell aft. Coincident with this event, a puff of reddish/brown vapor, most likely oxidizer, exited the nozzle at 14:22:57.7. There was no further leakage after the initial puff. This thruster

had been leaking slightly during ground operations. The presence of the vapor was expected and not considered a mission anomaly.

Twelve frames were taken of the External Tank shortly after separation from the Orbiter. There were no anomalies that would have affected the mission or safety-of-flight. Six TPS divots occurred in the LH2 tank-to-intertank flange (-Y side) closeout during ascent. Two of the divots were in the -Y+Z quadrant.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums exhibited a total of 67 debonds over fasteners and two areas of missing TPS. No frustum severance ring pins were missing. A 12-inch debond occurred in the aft edge of the LH aft center factory joint adjacent to the systems tunnel. HDP #6 Debris Containment System (DCS) plunger was obstructed by a frangible nut half. All other DCS plungers were seated properly. Post flight disassembly revealed 7 of 8 DCS's had retained greater than 90 percent of the ordnance debris. A 4"x1" piece of HDP #6 sidewall shim, which should have remained attached to the HDP shoe, was found attached to the side of the aft skirt foot after retrieval. A 10"x1.5" piece of EPON shim material was missing from HDP #4 prior to water impact.

The LH SRB forward skirt sustained damage in the area of the system tunnel. TPS (K5NA and MSA) was cracked and the metal substrate was buckled on both sides of the systems tunnel. Some of the Hypalon topcoat was missing. Debris Team assessment indicates the forward skirt damage was not a source of debris nor was caused by a debris problem. The most likely causes, according to MSFC, were unusual loads induced by water slapdown or parachute deployment.

A post landing inspection of OV-104 was performed at EAFB on Runway 33. The Orbiter TPS sustained a total of 113 hits, of which 10 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 91 hits, of which 7 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of hits on the lower surface was greater than average, but the number of hits with a major dimension of 1" or larger was less than average. All ET/Orbiter separation ordnance device plungers appeared to have functioned properly. The stop bolts on the EO-1 separation assembly device did not sustain any damage/bending.

A lightning protection contact fell onto the runway when the LH2 ET/Orbiter umbilical door was opened. This contact, which is approximately 17.5" long by 2.5" wide, is normally bonded to the ET half of the LH2 umbilical and should have stayed with the ET after separation. Subsequent laboratory analysis revealed adhesive failure with very little adhesive present on the inner surface (bonding side of the part to the umbilical). There was no evidence of foam material or contaminants. The

polyurethane adhesive had been poorly cured. The cause of the bonding problem is unknown, but the use of self tapping screws to secure the lightning contact is under review. The new 14 inch disconnects were designed with fastened lightning protection contacts.

Streaks/deposits were present on both wing leading edge RCC panels. Lab analysis revealed the streaks were caused by TPS materials, SRB separation products, and landing site products. The lower surface tile samples indicated localized heating from re-entry, but the only materials recovered from the damage sites were tile TPS elements.

The post-landing chemical sampling results continue to provide indications of Shuttle and environmental deposits. Due to the success of debris control as evidenced by fewer damage sites, these results are now scientific data populous. The presence of
polyamide (Orbiter/ET umbilical purge barrier material) has been noted on previous missions' umbilical sampling and complements the film review observations. The special heat testing of Hypalon paint and "Elephant hide" material at 2600 F provided data for correlation in RCC sampling debris analyses.

A total of 13 Post Launch Anomalies were observed during this mission assessment.

## 2.0 KSC ICE/FROST/DEBRIS TEAM ACTIVITIES

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

Team Activities:

1) Prelaunch Pad Debris Inspection

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

2) Launch Countdown Firing Room 2

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

3) Ice/Frost TPS and Debris Inspection

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

4) Post Launch Pad Debris Inspection

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

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

5) Launch Data Review

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

6) SRB Post Flight/Retrieval Inspection

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

7) Orbiter Post Landing Debris Damage Assessment

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

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

8) Level II report

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

## 3.0 PRE-TEST BRIEFING

The Ice/Debris/Photo Analysis Team briefing for the STS-37 mission was conducted on 4 April 1991 at 0830 hours with the following key personnel present:

| | | |
|---|---|---|
| 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 |
| A. Oliu | NASA - KSC | ET Processing, Ice/Debris |
| 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 |
| M. Bassignani | NASA - KSC | ET Processing, Debris Assess |
| A. Biamonte | NASA - KSC | ET Processing, Debris Assess |
| J. Hoffman | LSOC - SPC | ET Processing, Ice Assess |
| M. Young | LSOC - SPC | ET Processing, Ice Assess |
| R. Seale | LSOC - SPC | ET Processing, Ice Assess |
| D. Jenkins | LSOC - SPC | ET Processing, Ice Assess |
| J. Blue | LSOC - SPC | ET Processing, Ice Assess |
| Z. Byrns | NASA - JSC | Level II Integration |
| C. Gray | MMC - MAF | ET TPS & Materials Design |
| S. Copsey | MMC - MAF | ET TPS Testing/Certif |
| J. McClymonds | RI - DNY | Debris Assess, LVL II Integ |
| K. Mayer | RI - LSS | Vehicle Integration |
| T. Thorson | RI - LSS | Vehicle Integration |
| S. Otto | MMC - LSS | ET Processing |
| M. Nowling | MTI - LSS | SRM Processing |
| J. Cook | MTI - LSS | SRM Processing |
| W. Nelson | USBI - EI | SRB Processing, Hangar AF |
| D. Denaburg | USBI - LSS | SRB Processing |
| C. Laster | LSOC - SPC | Safety |

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

## 3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 4 April 1991 from 0930 - 1100 hours. The detailed walkdown of Launch Pad 39B and MLP-1 also included the primary flight elements OV-104 Atlantis (8th flight), ET-37 (LWT-30), and BI042. 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 can be designed and installed. The tygon tubes are intended to remain in place during cryo loading and be removed by the Ice Inspection Team during the T-3 hour hold.

A recurring problem is loose MLP deck bolts. This inspection revealed two loose bolts on the northeast deck plate and two loose bolts on the Portable Purge Unit receptacle cover.

Miscellaneous debris items consisted of a plastic bag in one of the sound suppression water troughs, a handrail clip with a pip pin lay on the deck, a tie-wrap in the southeast haunch pedestal area, and debris items (foam trimmings, plastic pieces, corroded nut) in the LH SRB south holddown post haunches.

A cable tray cover was loose on the RSS 207 foot level adjacent to the FSS crossover. An adjacent cable tray cover exhibited loose flanges due to broken spot welds.

Cleanup of the MLP deck and pad surface to remove foam and debris particles was still required at the time of the inspection. The facility discrepancies were reported to the pad leader/facility coordinator and worked real-time. The SRB sound suppression water troughs were topped off prior to cryogenic loading.

Foam, in the liquid state, dripped from the LH2 ET/ORB umbilical onto body flap tiles during closeout operations



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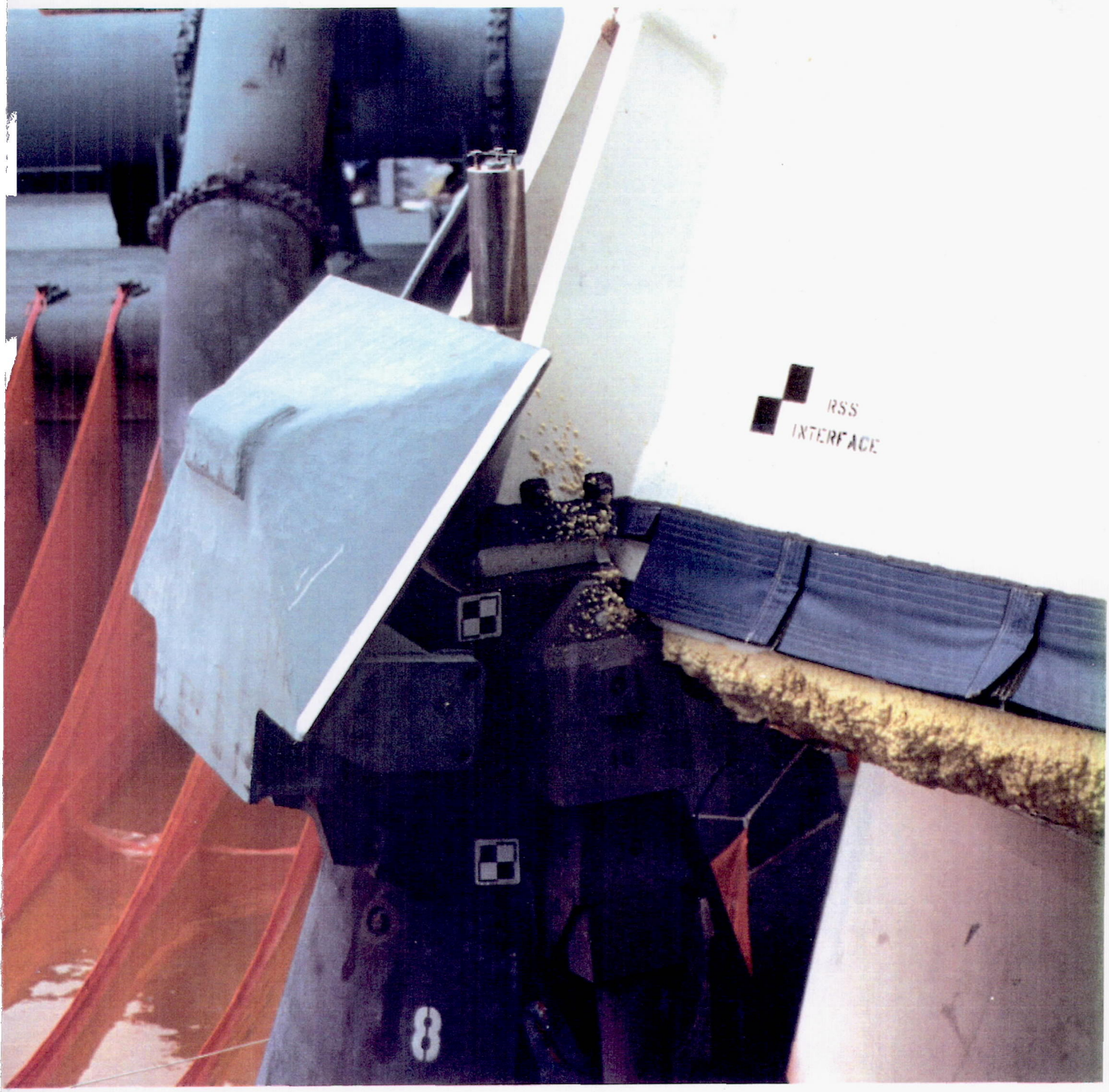


Instafoam overspray adhered to the aft skirt foot and holddown post. Note two optical targets for measuring HDP shoe rotation.



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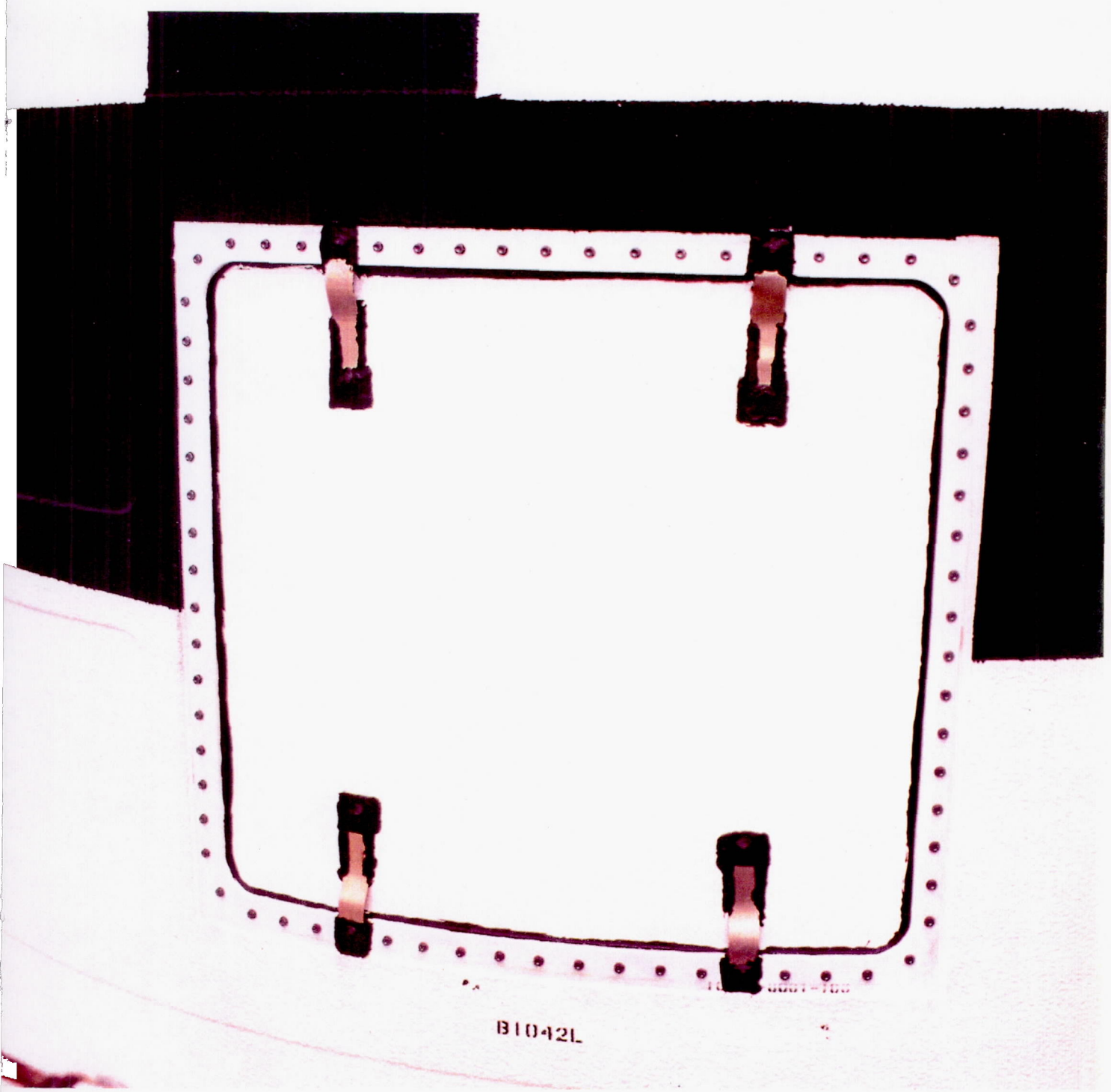


First flight with new grounding straps attached to SRB forward skirt flight door



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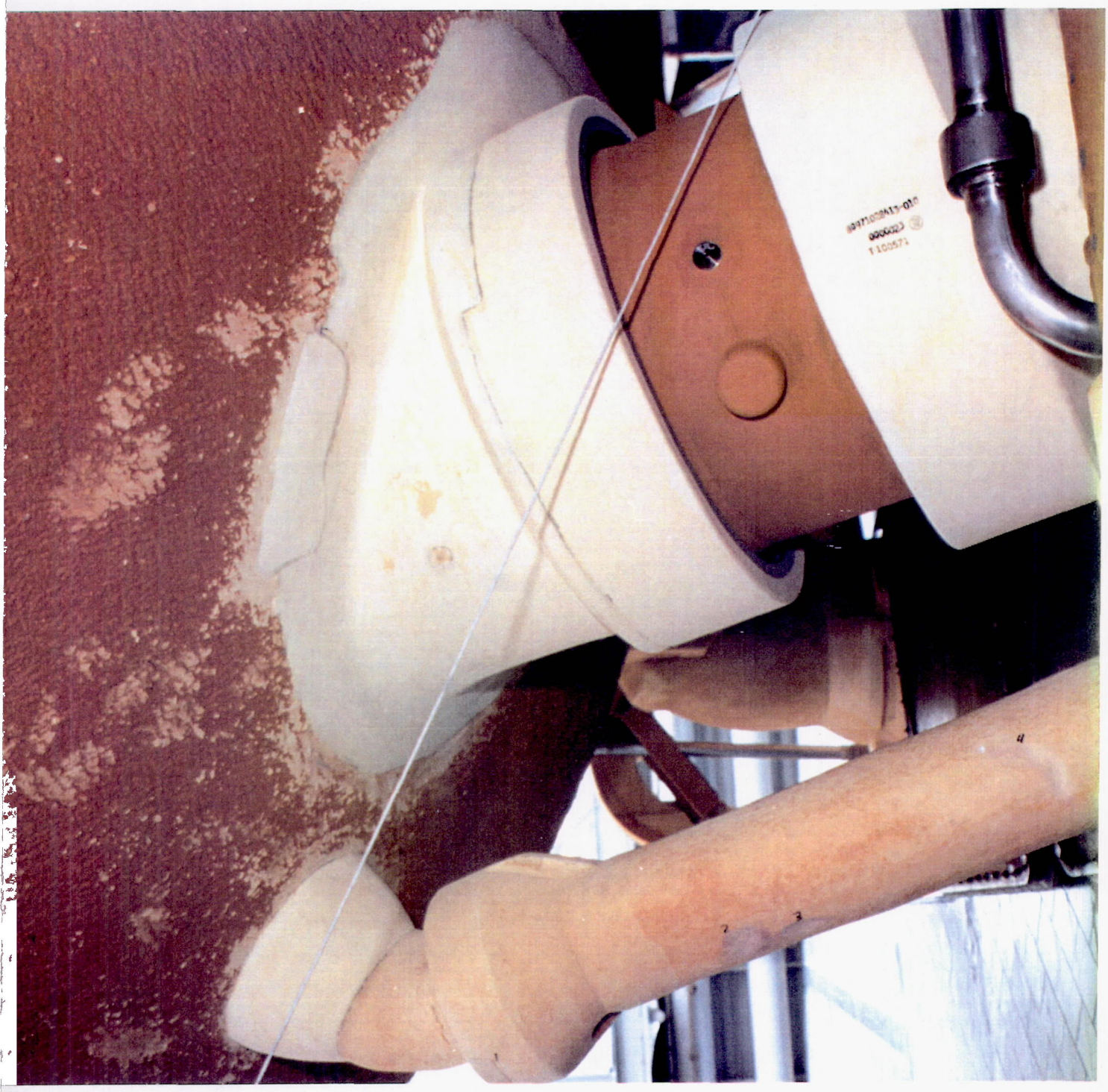

Pre-cryo load condition of foam repairs on the LH2 feedline and recirculation line-to-tank interfaces



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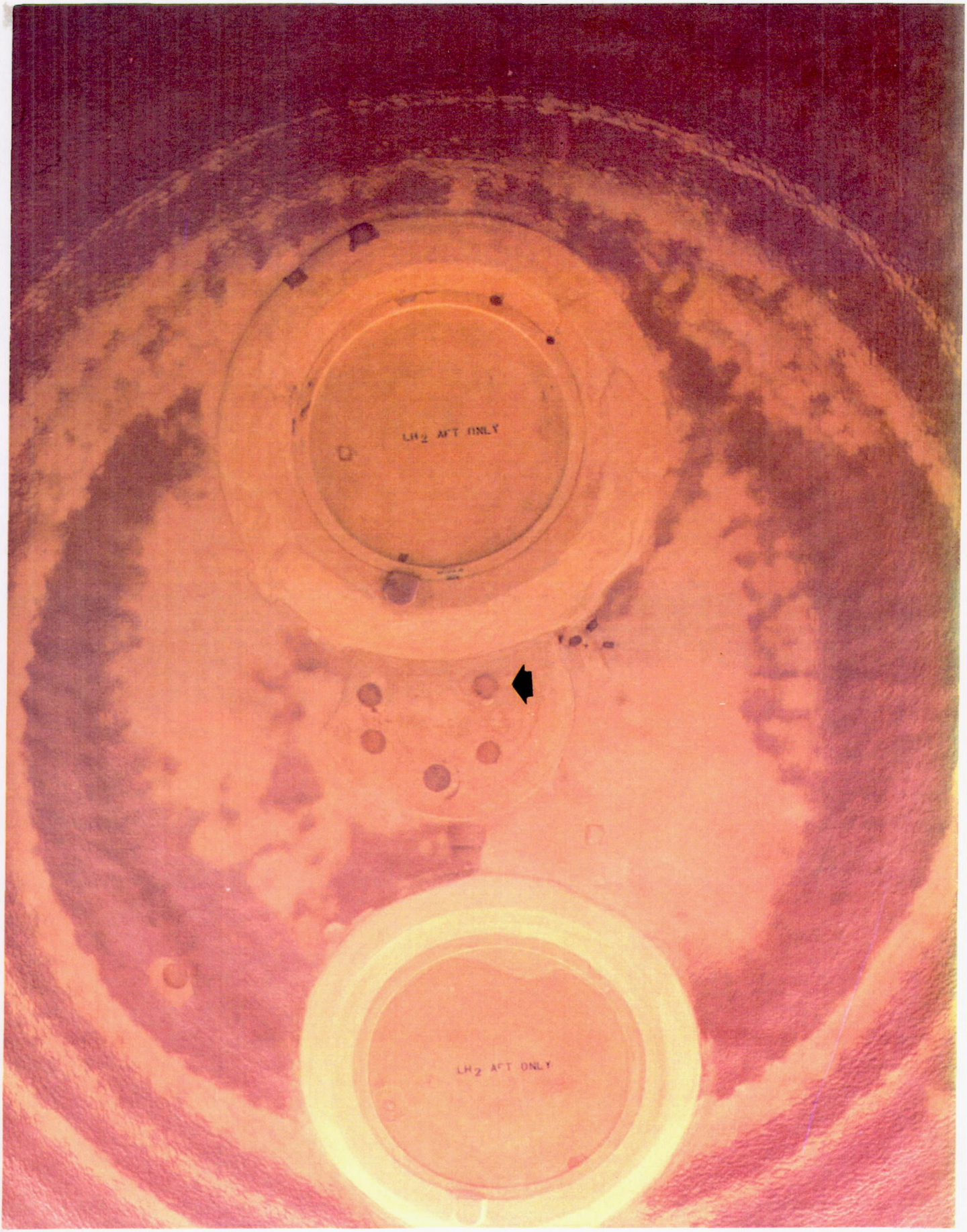


Top right plug repair on the LH2 tank aft dome apex protruded 1/4-inch after the tank was loaded with cryogenic propellant



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## 4.0 LAUNCH

STS-37 was launched at 14:22:45 GMT on 5 April 1991.

## 4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 5 April 1991 from 0410 - 0605 hours local time during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria or NSTS-08303 violations. A facility IPR was taken against tie-wraps attached to the LO2 TSM near the Orbiter RH aft RCS stinger. Ambient weather conditions at the time of the inspection were:

| | |
|---|---|
| Temperature: | 69.6 F |
| Relative Humidity: | 90.6 % |
| Wind Speed: | 11 Knots |
| Wind Direction: | 98 Degrees |

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

## 4.2 ORBITER OBSERVATIONS

No Orbiter tile anomalies were observed. The average Orbiter surface temperature was 69 degrees F. The average surface temperatures of the SSME engine mounted heat shields were measured at 66 degrees F for SSME #1, 67 degrees F for SSME #2, and 67 degrees F for SSME #3. The coldest spot on the engine mounted heat shields was 44 degrees F. A small frost spot was present on the SSME #1 engine mounted heat shield. A small amount of clear ice mixed with condensate was visible at the 6 o'clock position on SSME #2 engine mounted heat shield. SSME #1 and #2 heat shields exhibited some condensate. The SSME #3 heat shield was dry. No LO2 vapors originated from inside the SSME nozzles. Condensate was present on the base heat shield tiles around SSME #2 and in the areas between the SSME's. RCS paper covers were wet, most likely from the rainfall, but were intact with no liquid line visible: L1L, R2R, R3R, F2U, F3U, F2R, and F4R. The aft edges of F2D and F4D were curled.

## 4.3 SRB OBSERVATIONS

No SRB anomalies or loose ablator/cork were observed. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 68 and 69 degrees F. The GEI gave measurements of 70 to 71 degrees F in comparison. The Mikron IR gun measured the case surface temperatures between 74 to 76 degrees F. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 69 degrees F, which was within the required range of 44-86 degrees F.

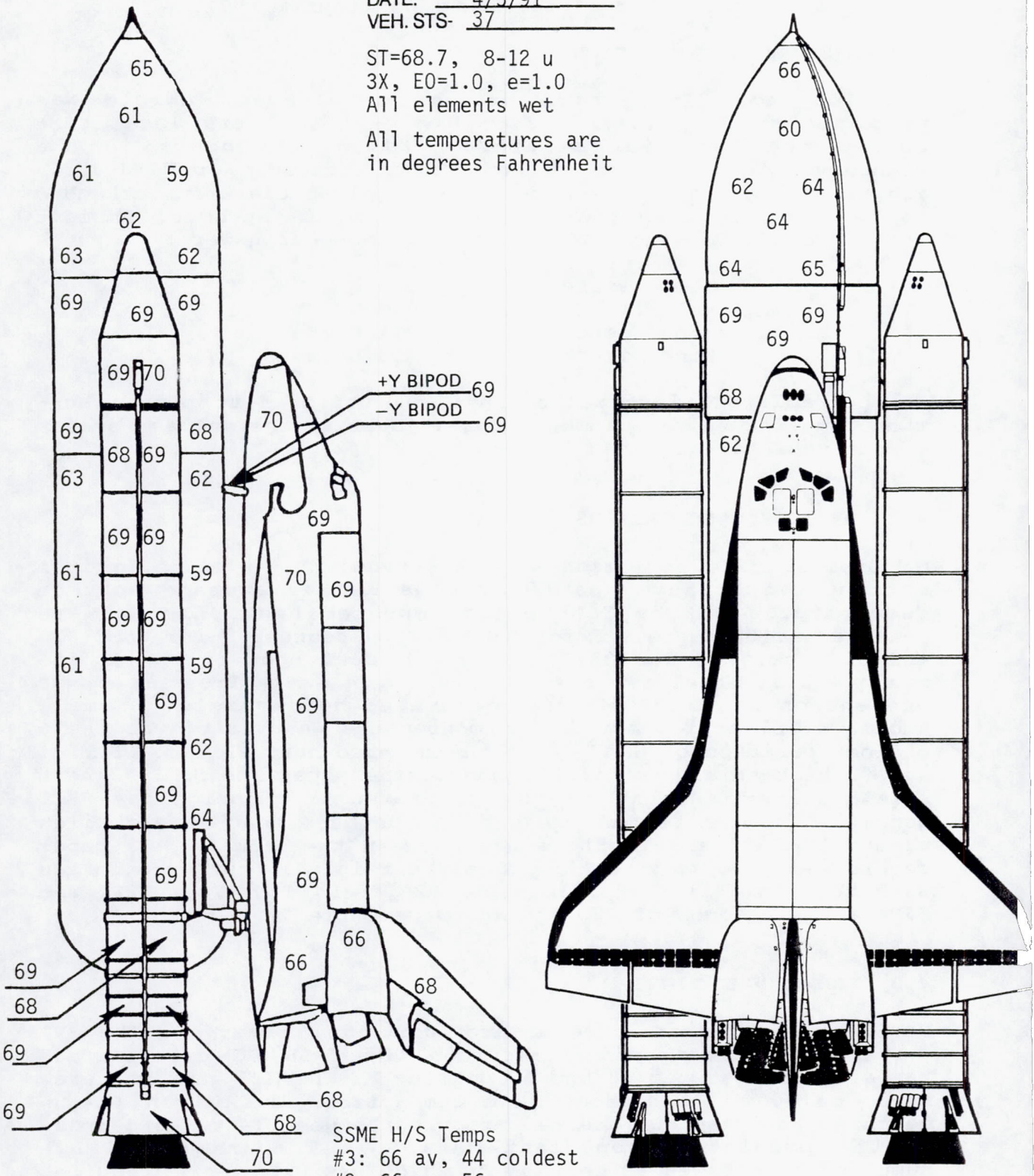
FIGURE 1.

# SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA

TIME: 0415 - 0600
DATE: 4/5/91
VEH. STS- 37

ST=68.7, 8-12 u
3X, EO=1.0, e=1.0
All elements wet

All temperatures are in degrees Fahrenheit




SSME H/S Temps
#3: 66 av, 44 coldest
#2: 66 av, 56
#1: 67 av, 52



EGG/V–343D

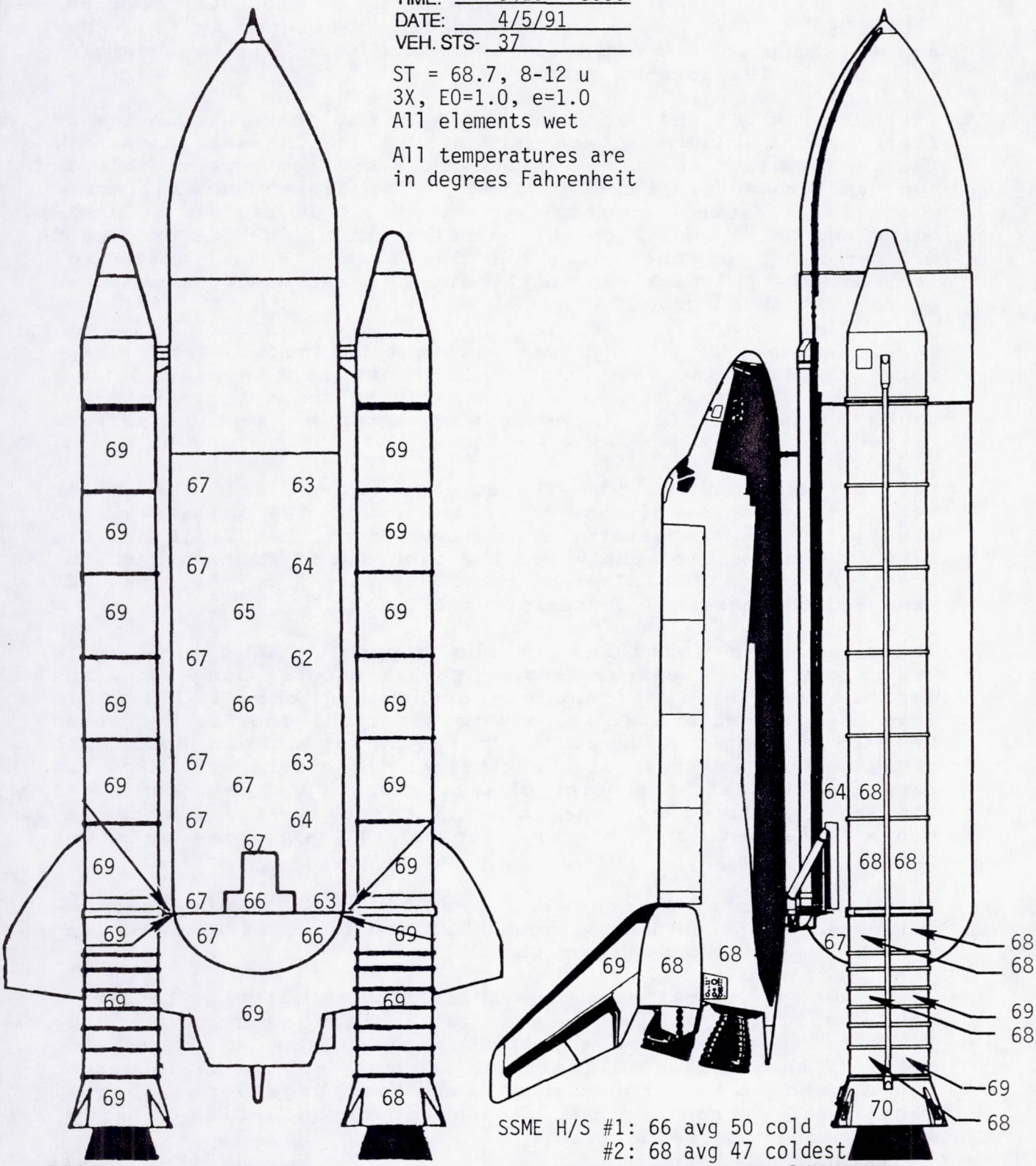
FIGURE 2.

# SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA

TIME: 0415 - 0600
DATE: 4/5/91
VEH. STS- 37

ST = 68.7, 8-12 u
3X, EO=1.0, e=1.0
All elements wet

All temperatures are in degrees Fahrenheit




SSME H/S #1: 66 avg 50 cold
#2: 68 avg 47 coldest
#3: 68 avg 56 coldest



EGG/V–343C

## 4.4 EXTERNAL TANK OBSERVATIONS

The ice/frost prediction computer program 'SURFICE' was run from 1745 to 0149 hours and the results tabulated in Figures 3 and 4. The program predicted condensate with no ice accumulation on all TPS acreage surfaces.

The LO2 tank TPS was wet from rainfall, but there was no ice or frost on the acreage. There were no TPS or GOX seal anomalies. The tumble valve cover was intact. No anomalies were visible on the LO2 pressurization line/ramps. The STI infrared scanner measured an average surface temperature of 65 degrees F on the ogive and 63 degrees F on the barrel section. SURFICE predicted 62 degrees F on the ogive and 59 degrees F on the barrel section. The LO2 tank was in the mid-60's degrees F as measured by the Mikron IR gun.

The intertank TPS acreage was wet from the recent rain. There were no TPS anomalies. One small frost spot appeared in a stringer valley in the -Y-Z quadrant near the intertank-to-LO2 tank flange. The STI IR scanner measured an average surface temperature of 69 degrees F.

The LH2 tank and aft dome TPS acreage was wet from the recent rain. There was no acreage ice/frost and no TPS anomalies. The average surface temperatures as measured by the STI IR scanner were 60 degrees F on the upper LH2 tank and 65 degrees F on the lower LH2 tank. SURFICE predicted 53 degrees F on the upper LH2 tank and 60 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, longerons, and manhole covers. 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. The repair on the aft hardpoint closeout, which had debonded after the last tanking test, was intact with no ice/frost accumulations. One 2-inch diameter plug on the aft dome apex was protruding 1/4 inch.

Typical amounts of ice were present in all LO2 feedline bellows. Less than usual amounts of ice/frost were present in the LO2 feedline support brackets.

There were no anomalies on the LO2 ET/ORB umbilical. The baggie was configured properly and was holding positive purge pressure. There was no ice/frost accumulation on the acreage areas of the umbilical. Ice/frost fingers 4-5 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.

| STS- 37 | TEST S0007 LAUNCH | DATE: 5 April 1991 | T–0 TIME: 09:22:45 DATE: 4/5/91 | NASA KSC Ice/Frost/Debris Team |
|---|---|---|---|---|

| ORBITER | ET | SRB | MLP | PAD | LO2 | LH2 |
|---|---|---|---|---|---|---|
| 104 | 37 | BI–042 | 1 | B | CHILLDOWN TIME: 01:19 FAST FILL TIME: 01:56 SLOW FILL TIME: 01:40 REPLENISH TIME: 03:58 | CHILLDOWN TIME: 01:04 FAST FILL TIME: 01:38 SLOW FILL TIME: 01:12 REPLENISH TIME: 03:51 |

| 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 |
| 0115 | 70.40 | 84.0 | 65.49 | 16 | 71 | II | 9.44 | 63.20 | 0.0021 | –0.2950 | II | 9.44 | 60.65 | 0.0042 | –0.2627 | II | 8.80 | 59.74 | 0.0046 | –0.2393 | II | 19.52 | 63.36 | 0.0038 | –0.5328 |
| 0130 | 70.40 | 83.6 | 65.36 | 13 | 84 | II | 7.67 | 62.42 | 0.0022 | –0.2438 | II | 7.67 | 59.37 | 0.0042 | –0.2123 | II | 7.15 | 58.30 | 0.0046 | –0.1921 | II | 15.86 | 62.53 | 0.0041 | –0.4318 |
| 0145 | 70.40 | 82.6 | 65.02 | 14 | 90 | II | 8.26 | 62.45 | 0.0021 | –0.2581 | II | 8.26 | 59.58 | 0.0041 | –0.2264 | II | 7.70 | 58.57 | 0.0045 | –0.2053 | II | 17.08 | 62.58 | 0.0038 | –0.4602 |
| 0200 | 70.40 | 82.4 | 64.95 | 14 | 90 | II | 8.26 | 62.41 | 0.0021 | –0.2576 | II | 8.26 | 59.54 | 0.0041 | –0.2259 | II | 7.70 | 58.53 | 0.0045 | –0.2049 | II | 17.08 | 62.53 | 0.0037 | –0.4593 |
| 0215 | 70.20 | 83.8 | 65.23 | 12 | 83 | II | 7.08 | 61.96 | 0.0023 | –0.2254 | II | 7.08 | 58.70 | 0.0042 | –0.1942 | II | 6.60 | 57.55 | 0.0046 | –0.1751 | II | 14.64 | 62.05 | 0.0042 | –0.3959 |
| 0230 | 68.40 | 86.2 | 64.23 | 15 | 96 | II | 8.85 | 61.38 | 0.0024 | –0.2600 | II | 8.85 | 58.63 | 0.0044 | –0.2284 | II | 8.25 | 57.64 | 0.0047 | –0.2069 | II | 18.30 | 61.56 | 0.0043 | –0.4675 |
| 0245 | 66.80 | 89.4 | 63.66 | 18 | 88 | II | 10.62 | 60.96 | 0.0026 | –0.2943 | II | 10.62 | 58.58 | 0.0046 | –0.2623 | II | 9.90 | 57.71 | 0.0050 | –0.2385 | II | 21.96 | 61.20 | 0.0046 | –0.5382 |
| 0300 | 67.00 | 90.6 | 64.23 | 15 | 82 | II | 8.85 | 60.82 | 0.0028 | –0.2540 | II | 8.85 | 58.05 | 0.0048 | –0.2225 | II | 8.25 | 57.05 | 0.0051 | –0.2013 | II | 18.30 | 61.05 | 0.0050 | –0.4576 |
| 0315 | 67.80 | 91.8 | 65.40 | 15 | 78 | II | 8.85 | 61.92 | 0.0030 | –0.2665 | II | 8.85 | 59.19 | 0.0050 | –0.2346 | II | 8.25 | 58.20 | 0.0053 | –0.2127 | II | 18.30 | 62.15 | 0.0053 | –0.4801 |
| 0330 | 68.00 | 93.0 | 65.96 | 13 | 90 | II | 7.67 | 61.87 | 0.0031 | –0.2387 | II | 7.67 | 58.81 | 0.0051 | –0.2072 | II | 7.15 | 57.69 | 0.0054 | –0.1871 | II | 15.86 | 62.08 | 0.0056 | –0.4245 |
| 0345 | 70.80 | 91.0 | 68.14 | 15 | 84 | II | 8.85 | 64.95 | 0.0030 | –0.3020 | II | 8.85 | 62.33 | 0.0051 | –0.2692 | II | 8.25 | 61.38 | 0.0055 | –0.2453 | II | 18.30 | 65.14 | 0.0054 | –0.5434 |
| 0400 | 68.20 | 90.0 | 65.24 | 19 | 74 | II | 11.21 | 62.71 | 0.0027 | –0.3313 | II | 11.21 | 60.49 | 0.0048 | –0.2986 | II | 10.45 | 59.68 | 0.0052 | –0.2726 | II | 23.18 | 62.94 | 0.0047 | –0.6081 |
| 0415 | 67.80 | 90.4 | 64.97 | 17 | 74 | II | 10.03 | 62.04 | 0.0028 | –0.2950 | II | 10.03 | 59.58 | 0.0048 | –0.2628 | II | 9.35 | 58.69 | 0.0052 | –0.2390 | II | 20.74 | 62.27 | 0.0049 | –0.5369 |
| 0430 | 68.60 | 89.8 | 65.58 | 13 | 78 | II | 7.67 | 61.85 | 0.0028 | –0.2383 | II | 7.67 | 58.79 | 0.0048 | –0.2069 | II | 7.15 | 57.68 | 0.0051 | –0.1868 | II | 15.86 | 62.03 | 0.0051 | –0.4233 |
| 0500 | 72.00 | 89.8 | 68.96 | 10 | 102 | II | 5.90 | 64.50 | 0.0030 | –0.2197 | II | 5.90 | 60.86 | 0.0049 | –0.1882 | II | 5.50 | 59.59 | 0.0052 | –0.1696 | II | 12.20 | 64.54 | 0.0055 | –0.3792 |
| 0500 | 72.00 | 89.8 | 68.96 | 10 | 96 | II | 5.90 | 64.50 | 0.0030 | –0.2197 | II | 5.90 | 60.86 | 0.0049 | –0.1882 | II | 5.50 | 59.59 | 0.0052 | –0.1696 | II | 12.20 | 64.54 | 0.0055 | –0.3792 |
| 0515 | 69.40 | 90.2 | 66.50 | 13 | 94 | II | 7.67 | 62.79 | 0.0029 | –0.2480 | II | 7.67 | 59.77 | 0.0049 | –0.2163 | II | 7.15 | 58.67 | 0.0052 | –0.1957 | II | 15.86 | 62.96 | 0.0052 | –0.4405 |
| 0530 | 69.20 | 90.8 | 66.48 | 11 | 91 | II | 6.49 | 62.06 | 0.0029 | –0.2128 | II | 6.49 | 58.56 | 0.0048 | –0.1816 | II | 6.05 | 57.33 | 0.0052 | –0.1632 | II | 13.42 | 62.18 | 0.0054 | –0.3714 |
| 0545 | 69.20 | 91.6 | 66.73 | 7 | 112 | II | 4.13 | 60.10 | 0.0029 | –0.1437 | II | 4.13 | 55.13 | 0.0045 | –0.1138 | II | 3.85 | 53.42 | 0.0048 | –0.0997 | II | 8.54 | 59.95 | 0.0054 | –0.2364 |
| 0600 | 68.60 | 92.4 | 66.38 | 9 | 134 | II | 5.31 | 60.85 | 0.0030 | –0.1755 | II | 5.31 | 56.73 | 0.0048 | –0.1450 | II | 2.88 | 49.67 | 0.0044 | –0.0679 | II | 12.51 | 61.56 | 0.0056 | –0.3418 |
| 0615 | 68.00 | 93.8 | 66.20 | 7 | 113 | II | 4.13 | 59.20 | 0.0030 | –0.1381 | II | 4.13 | 54.16 | 0.0046 | –0.1084 | II | 2.24 | 46.17 | 0.0040 | –0.0467 | II | 9.73 | 59.88 | 0.0057 | –0.2604 |
| 0630 | 68.20 | 93.6 | 66.34 | 8 | 131 | II | 4.72 | 60.08 | 0.0031 | –0.1567 | II | 4.72 | 55.54 | 0.0047 | –0.1266 | II | 2.56 | 48.04 | 0.0042 | –0.0572 | II | 11.12 | 60.79 | 0.0057 | –0.3010 |
| 0645 | 68.60 | 93.4 | 66.68 | 8 | 128 | II | 4.72 | 60.49 | 0.0031 | –0.1596 | II | 4.72 | 55.97 | 0.0048 | –0.1294 | II | 2.56 | 48.51 | 0.0042 | –0.0590 | II | 11.12 | 61.19 | 0.0057 | –0.3062 |
| 0700 | 68.20 | 93.2 | 66.22 | 10 | 105 | II | 5.90 | 61.06 | 0.0031 | –0.1906 | II | 5.90 | 57.25 | 0.0049 | –0.1598 | II | 5.50 | 55.91 | 0.0052 | –0.1427 | II | 12.20 | 61.18 | 0.0057 | –0.3295 |
| 0715 | 67.80 | 93.2 | 65.82 | 13 | 104 | II | 7.67 | 61.70 | 0.0031 | –0.2369 | II | 7.67 | 58.62 | 0.0051 | –0.2055 | II | 7.15 | 57.51 | 0.0054 | –0.1854 | II | 15.86 | 61.91 | 0.0056 | –0.4214 |
| 0730 | 68.20 | 91.2 | 65.61 | 11 | 107 | II | 6.49 | 61.05 | 0.0029 | –0.2038 | II | 6.49 | 57.51 | 0.0048 | –0.1729 | II | 6.05 | 56.26 | 0.0051 | –0.1550 | II | 13.42 | 61.20 | 0.0054 | –0.3560 |
| 0745 | 68.60 | 89.4 | 65.45 | 13 | 102 | II | 7.67 | 61.77 | 0.0028 | –0.2374 | II | 7.67 | 58.70 | 0.0047 | –0.2060 | II | 7.15 | 57.59 | 0.0051 | –0.1860 | II | 15.86 | 61.94 | 0.0050 | –0.4216 |
| 0800 | 68.60 | 89.4 | 65.45 | 13 | 102 | II | 7.67 | 61.77 | 0.0028 | –0.2374 | II | 7.67 | 58.70 | 0.0047 | –0.2060 | II | 7.15 | 57.59 | 0.0051 | –0.1860 | II | 15.86 | 61.94 | 0.0050 | –0.4216 |

FIGURE 3. 'SURFICE' Computer Predictions

STS- 37 | TEST S0007 LAUNCH | DATE: 5 April 1991 | T-0 TIME: 09:22:45 DATE: 4/5/91

ORBITER 104 | ET 37 | SRB BI-042 | MLP 1 | PAD B

LO2 CHILLDOWN TIME: 01:19 FAST FILL TIME: 01:56 SLOW FILL TIME: 01:40 REPLENISH TIME: 03:58

LH2 CHILLDOWN TIME: 01:04 FAST FILL TIME: 01:38 SLOW FILL TIME: 01:12 REPLENISH TIME: 03:51

| 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 |
| 0815 | 69.20 | 87.4 | 65.41 | 14 | 100 | II | 8.26 | 62.24 | 0.0026 | -0.2561 | II | 8.26 | 59.37 | 0.0046 | -0.2244 | II | 7.70 | 58.34 | 0.0049 | -0.2033 | II | 17.08 | 62.41 | 0.0046 | -0.4576 |
| 0830 | 70.00 | 85.8 | 65.69 | 13 | 102 | II | 7.67 | 62.48 | 0.0025 | -0.2446 | II | 7.67 | 59.44 | 0.0044 | -0.2130 | II | 7.15 | 58.36 | 0.0048 | -0.1927 | II | 15.86 | 62.61 | 0.0045 | -0.4336 |
| 0845 | 71.60 | 81.4 | 65.80 | 12 | 98 | II | 7.08 | 62.89 | 0.0021 | -0.2343 | II | 7.08 | 59.68 | 0.0041 | -0.2029 | II | 6.60 | 58.56 | 0.0044 | -0.1835 | II | 14.64 | 62.94 | 0.0039 | -0.4112 |
| 0900 | 71.40 | 80.6 | 65.32 | 11 | 91 | II | 6.49 | 62.17 | 0.0021 | -0.2134 | II | 6.49 | 58.70 | 0.0040 | -0.1824 | II | 6.05 | 57.50 | 0.0043 | -0.1642 | II | 13.42 | 62.18 | 0.0039 | -0.3707 |
| 0915 | 72.80 | 81.8 | 67.12 | 12 | 78 | II | 7.08 | 64.25 | 0.0022 | -0.2477 | II | 7.08 | 61.09 | 0.0042 | -0.2160 | II | 6.60 | 60.00 | 0.0046 | -0.1958 | II | 14.64 | 64.29 | 0.0040 | -0.4347 |
| T-0 | 72.20 | 82.4 | 66.73 | 11 | 74 | II | 6.49 | 63.43 | 0.0023 | -0.2249 | II | 6.49 | 60.02 | 0.0042 | -0.1936 | II | 6.05 | 58.83 | 0.0046 | -0.1748 | II | 13.42 | 63.45 | 0.0042 | -0.3911 |
| AVG | 71.48 | 91.2 | 67.92 | 12.9 | E | | 7.60 | 63.95 | | | | 7.60 | 60.57 | | | | 6.86 | 58.66 | | | | 15.88 | 64.15 | | |

Period of Ice Team Inspection

FIGURE 4. 'SURFICE' Computer Predictions

Ice/frost had formed in the LH2 recirculation line bellows and on both burst disks. The upper and lower LH2 feedline bellows were wet with condensate. New foam at the LH2 feedline and recirculation line-to-tank interfaces were intact with no accumulation of ice/frost.

There were no TPS anomalies on the LH2 ET/ORB umbilical. The top and sides of the LH2 ET/ORB umbilical were covered by heavy, but typical, ice/frost. Ice/frost accumulation on the inboard and aft areas of the baggie was light. Ice/frost fingers 6-8 inches in length had formed on the pyro canister purge vents. Ice/frost fingers 4-5 inches in length had formed on the 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. A 3"x0.25" diameter icicle had formed on the LH2 umbilical 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. However, the #1 velcro strap on the pressurization line was 90 percent detached. This condition was probably caused by strong easterly wind loads on the pull line. During removal of the tygon tubes from the vehicle, the winds placed additional load on the exposed tygon tube with a premature release of the #2 velcro strap on the ET fitting. The tygon tube contacted the LH SRB aft booster below the ETA ring but, caused no damage to the flight hardware. The tubing was successfully removed from the #3 attach point on the upper strut fairing without contacting the vehicle.

The summary of ice/frost team observation anomalies consists of 7 OTV recorded items:

Anomaly 001 documented a possible frost formation at the aft edge of the LH2 cable tray PAL ramp. Condition later turned out to be a reflection on wet TPS.

Anomaly 002 recorded a 3"x0.25" icicle on the LH2 cable tray vent hole. The icicle formation was acceptable per NSTS-08303.

A 2-inch test plug on the LH2 tank aft dome apex debonded and protruded 1/4 inch (Anomaly 003). This condition was acceptable per NSTS-08303.

Anomaly 004 documented ice/frost in all LO2 feedline support brackets. The ice/frost was acceptable per NSTS-08303.

Anomaly 005 recorded ice/frost fingers on the LO2 ET/ORB umbilical purge vents and was acceptable per NSTS-08303.

Ice/frost formed on the LH2 ET/ORB umbilical purge barrier top and outboard side (Anomaly 006). Ice/frost fingers formed on the purge vents. These formations were acceptable per NSTS-08303.

Anomaly 007 documented ice/frost accumulations in the LH2 feedline bellows and recirculation line bellows. These accumulations were acceptable per NSTS-08303.

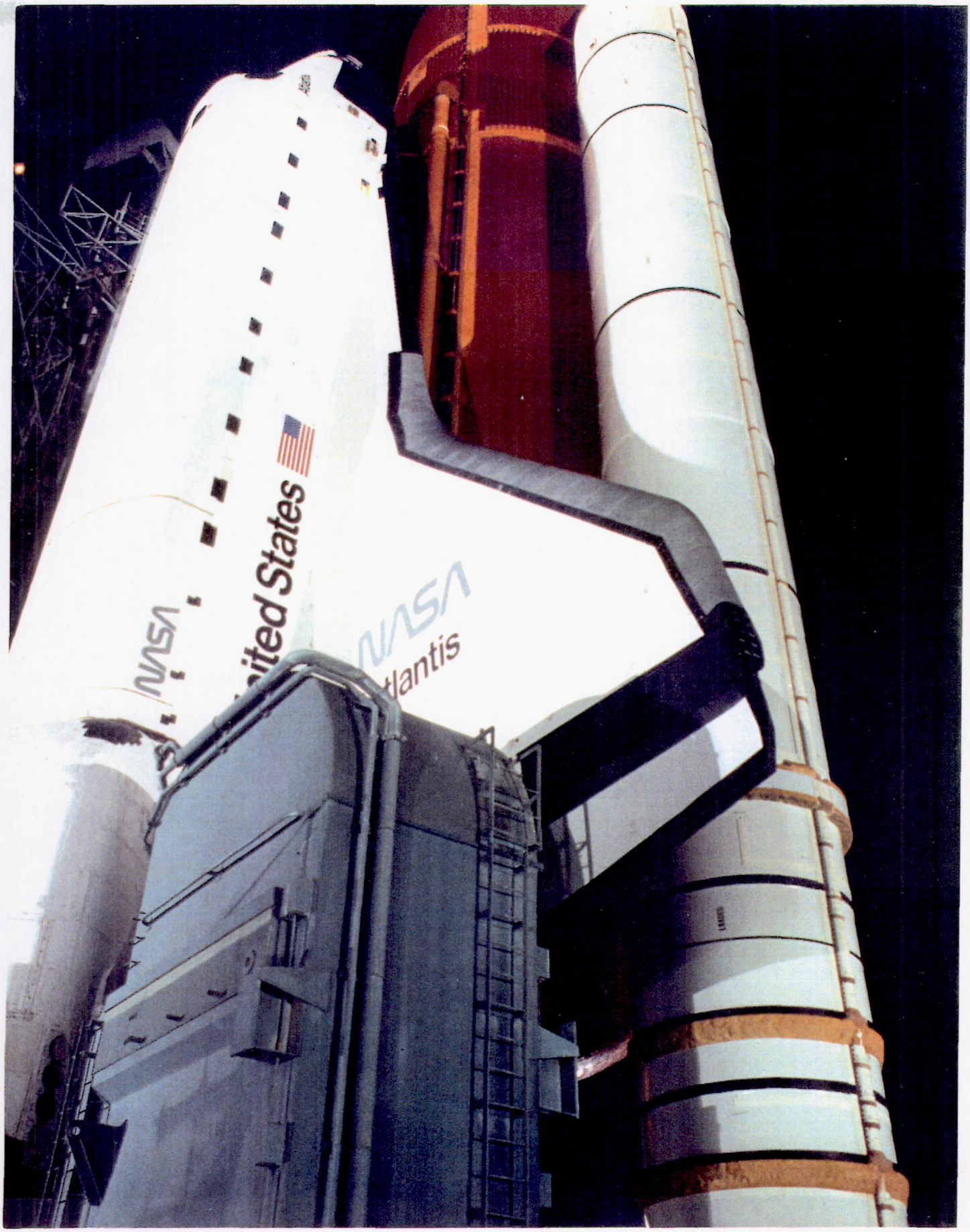
## 4.5 FACILITY OBSERVATIONS

One new debris concern was identified during the Ice Team inspection of the vehicle. Two tie-wraps were attached to a platform pin tether at the southwest corner of the LO2 TSM approximately 2-3 feet away from the RH aft RCS stinger tiles. This condition was documented on IPR 37RV-0150 with disposition to use as-is for launch. The tie-wraps remained attached to the TSM through SSME ignition, T-0, and liftoff. No flight hardware was damaged.

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/vent line interface and on the uninsulated parts of the umbilical carrier plate.

Visual and infrared observations of the GOX seals confirmed no leakage. There were no icicles on the GOX vent ducts.




Overall view of OV-104, ET-37, and RH SRB BI042.



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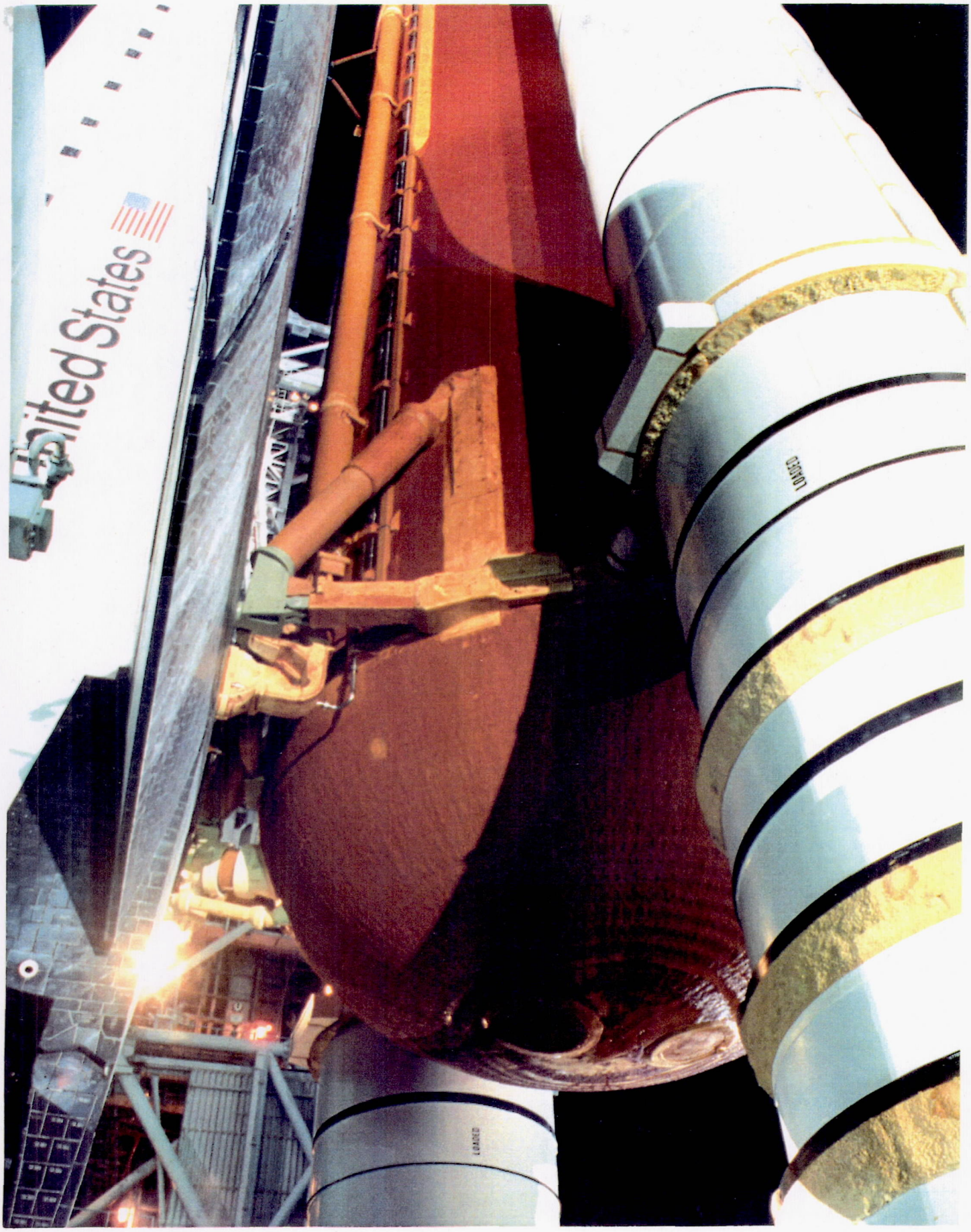


No ice or frost had formed on the LH2 tank TPS acreage area



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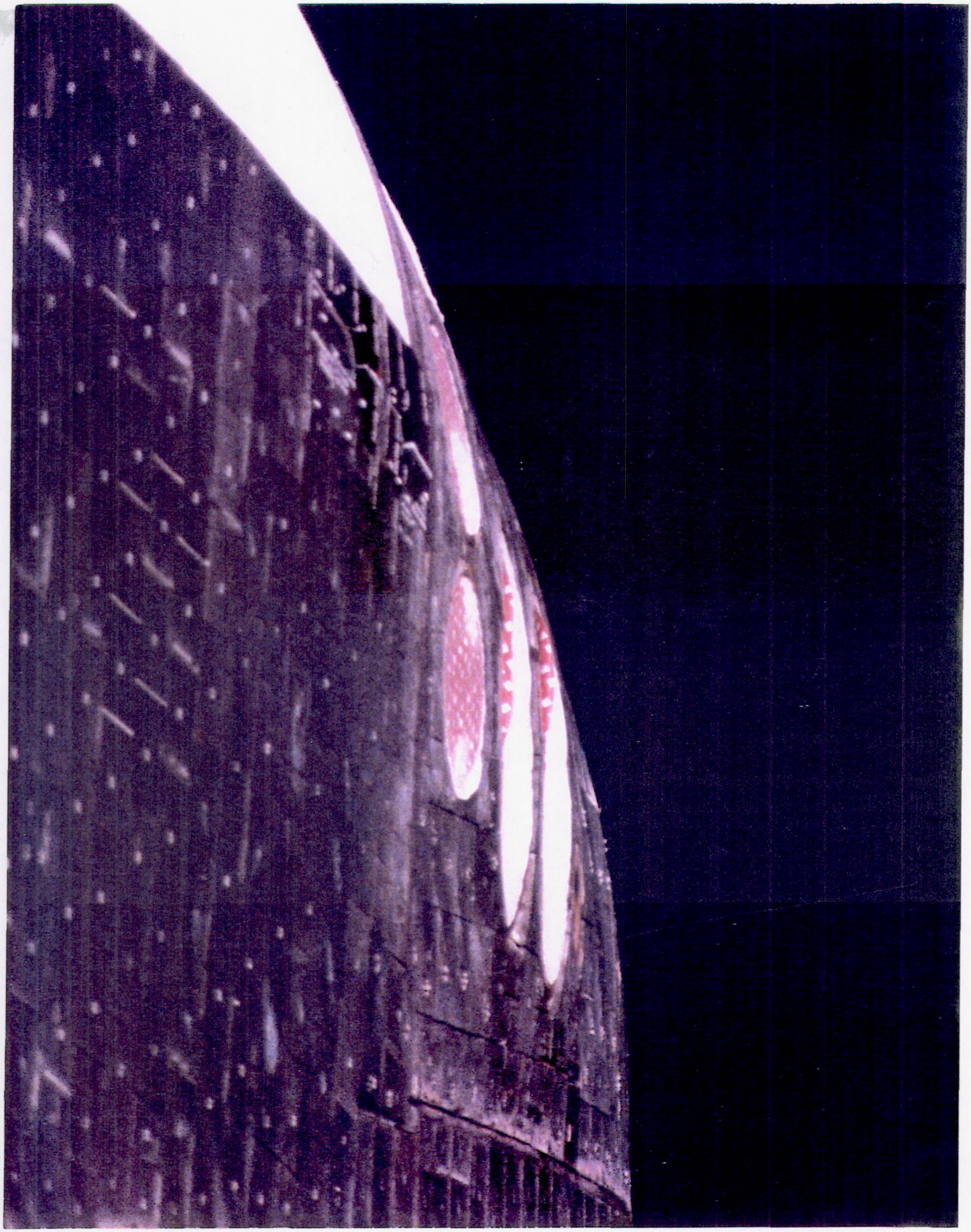

View (from the MLP deck) of Orbiter RH FWD RCS paper covers. Discoloration of the covers was due to recent rainfall.



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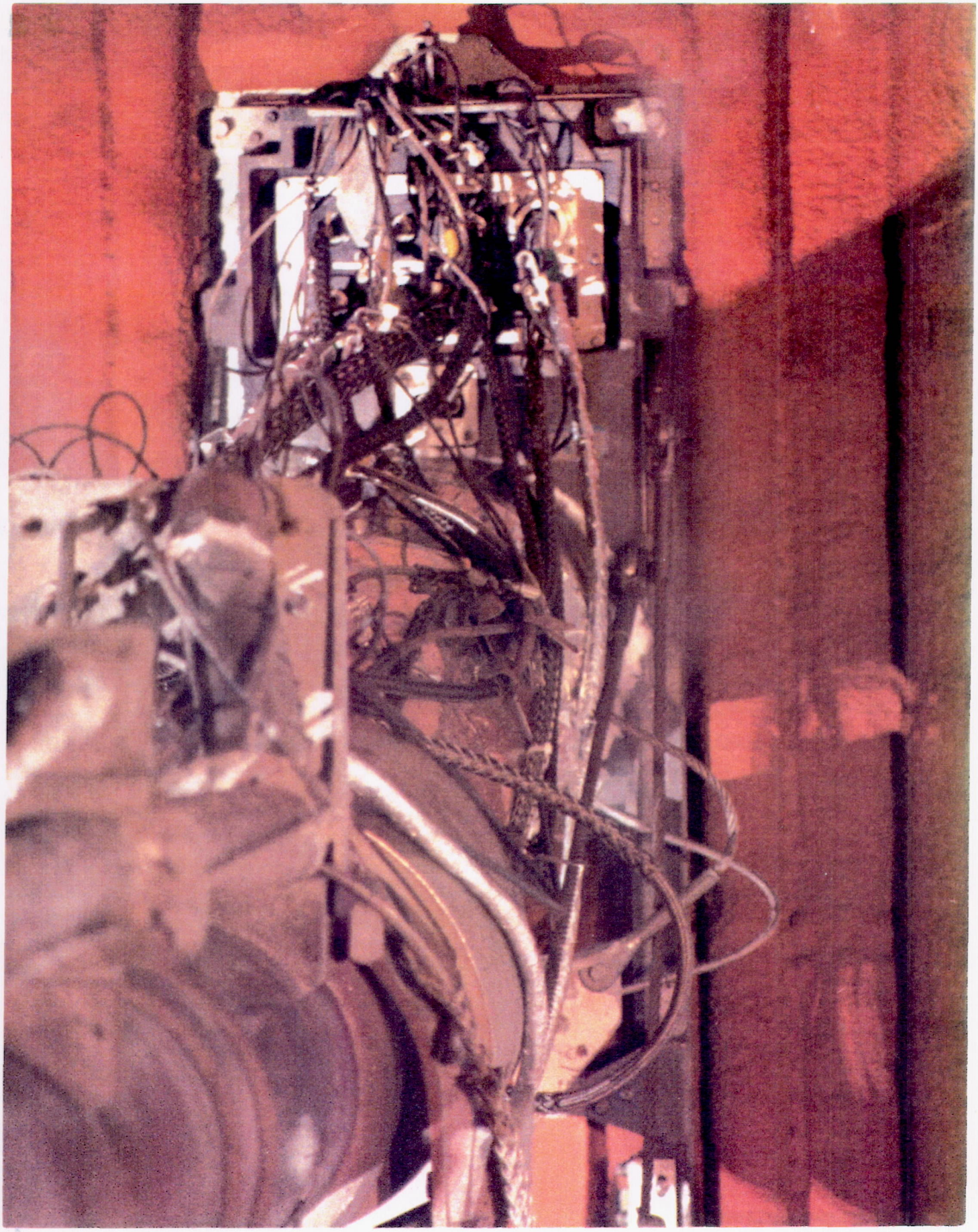

Typical accumulations of ice/frost were present on the GUCP legs and TPS cutout area below the GH2 vent line



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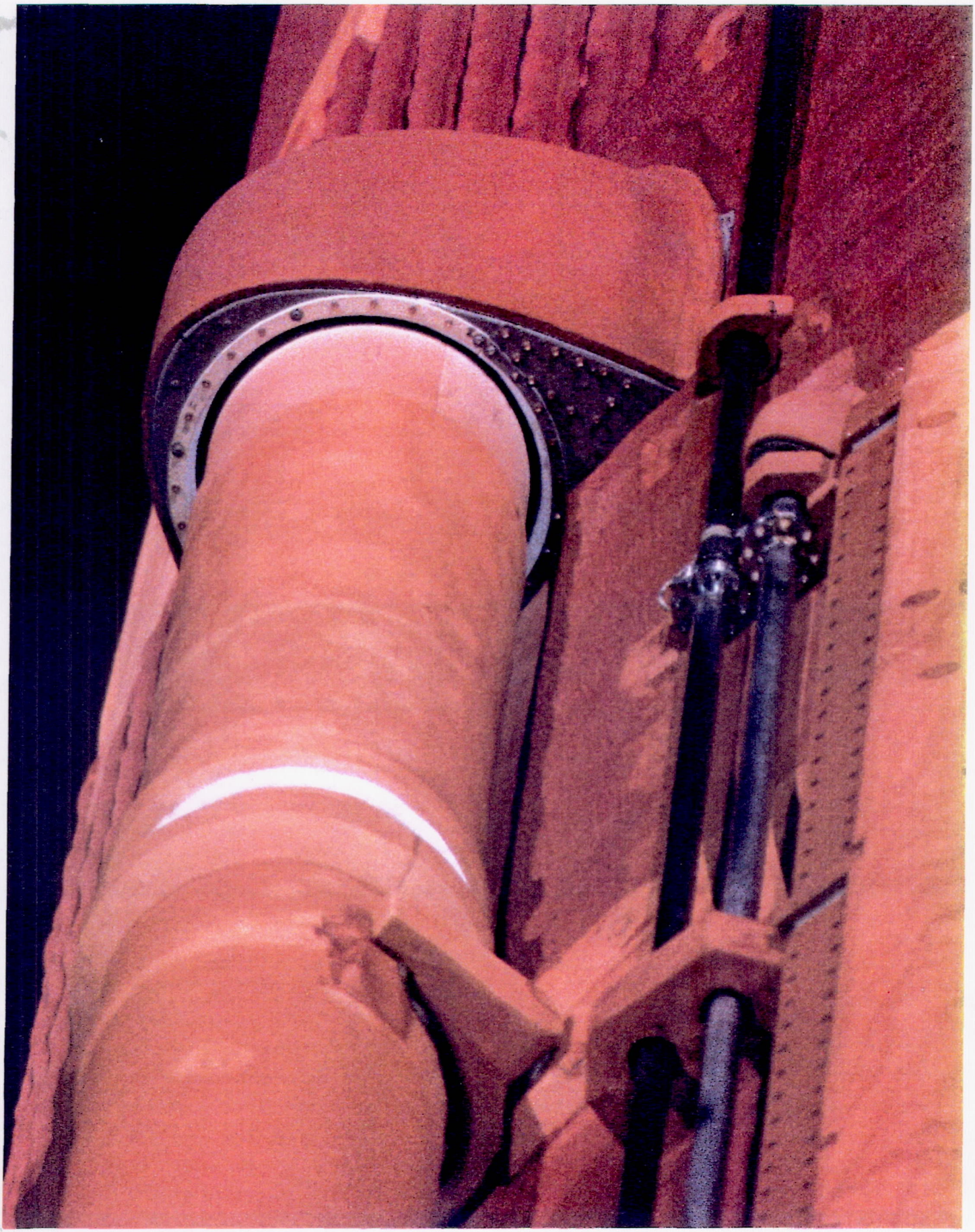

Typical ice/frost had accumulated in the LO2 feedline upper bellows and support brackets



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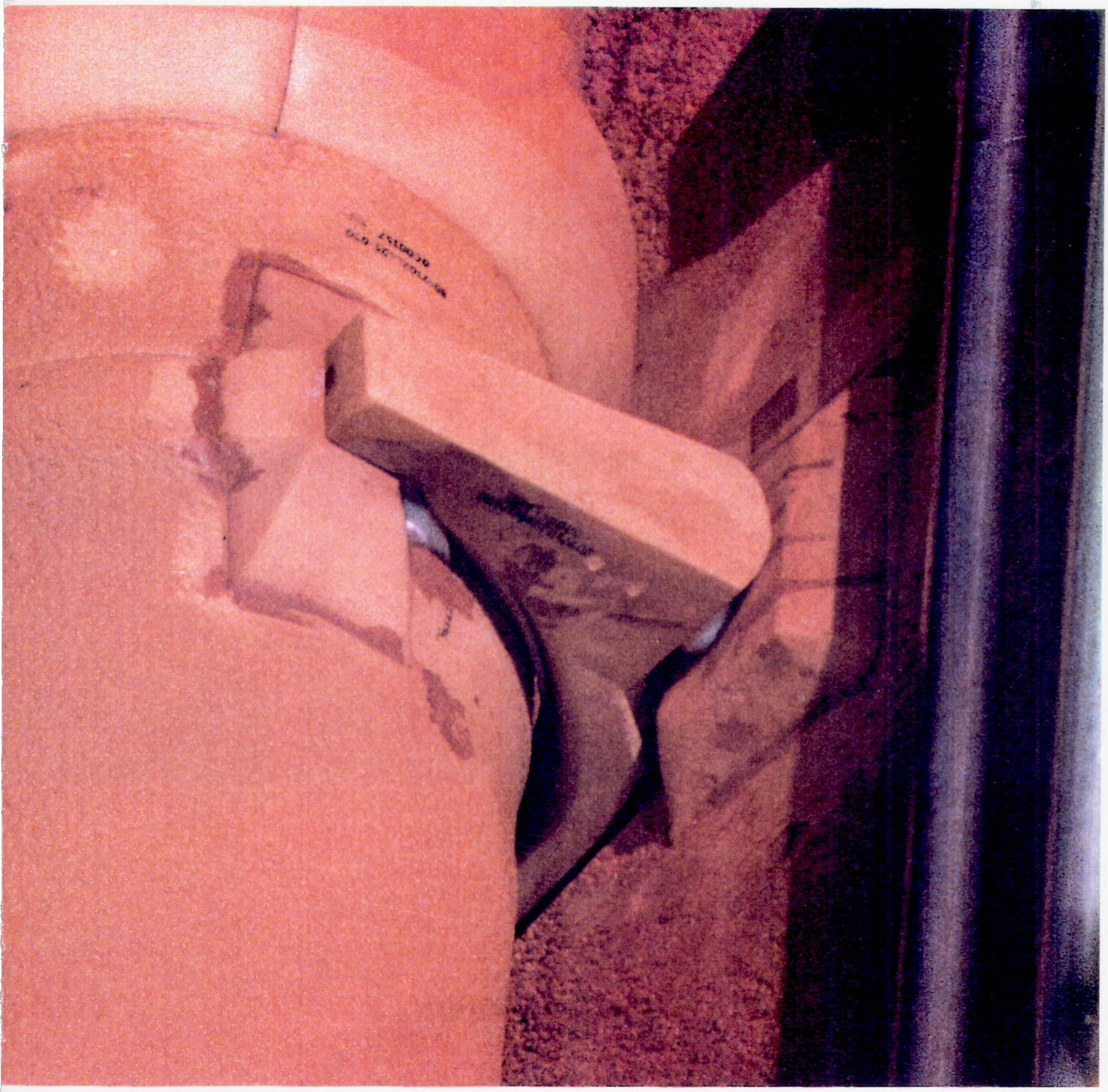

Ice/frost formations were visible in the LO2 feedline support brackets

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Typical ice/frost had accumulated in the LO2 feedline lower bellows

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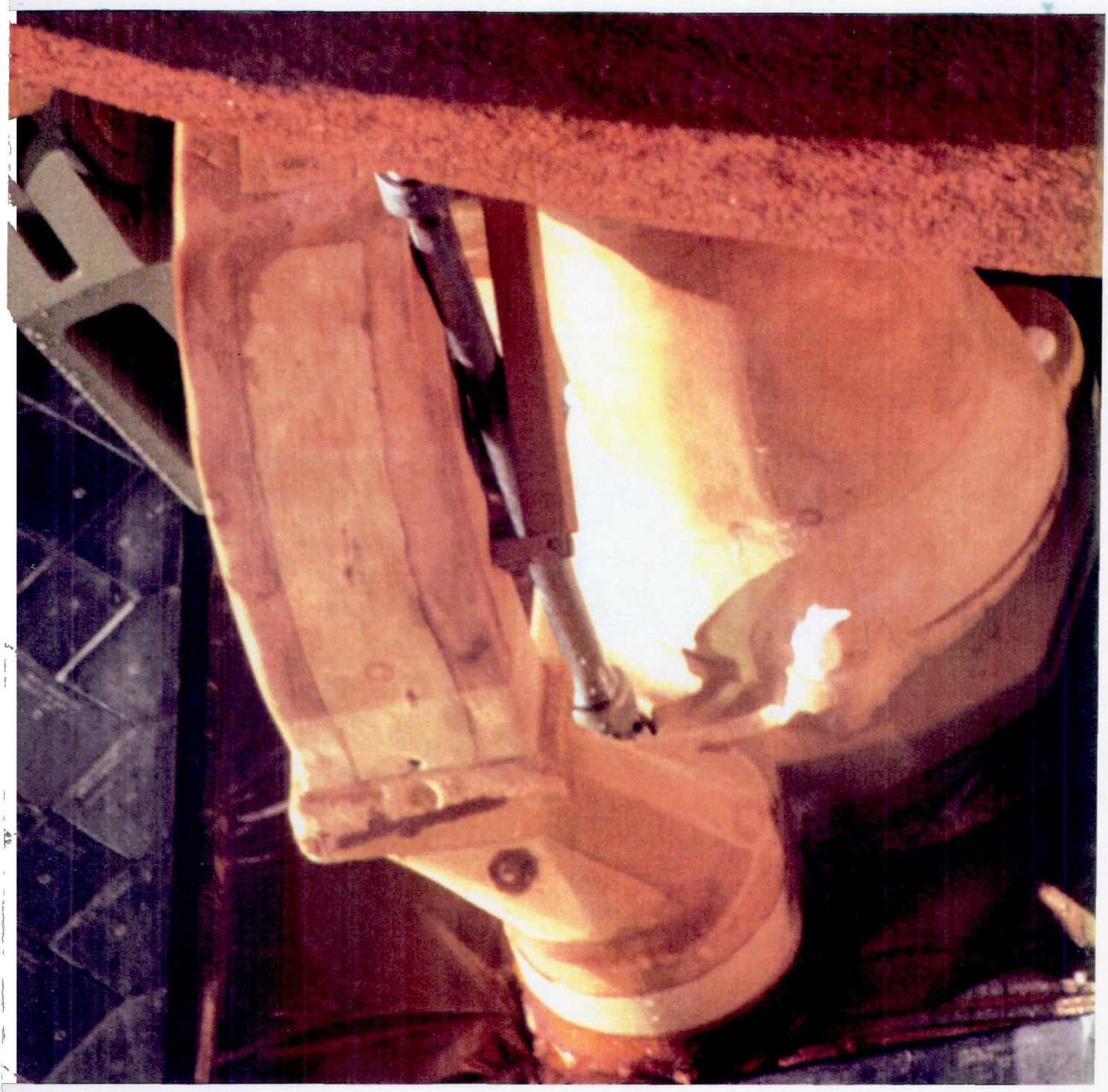

Typical ice/frost fingers had formed on the LO2 ET/ORB umbilical pyrotechnic canister purge vents. Very little ice/frost accumulated on the purge barrier (baggie).



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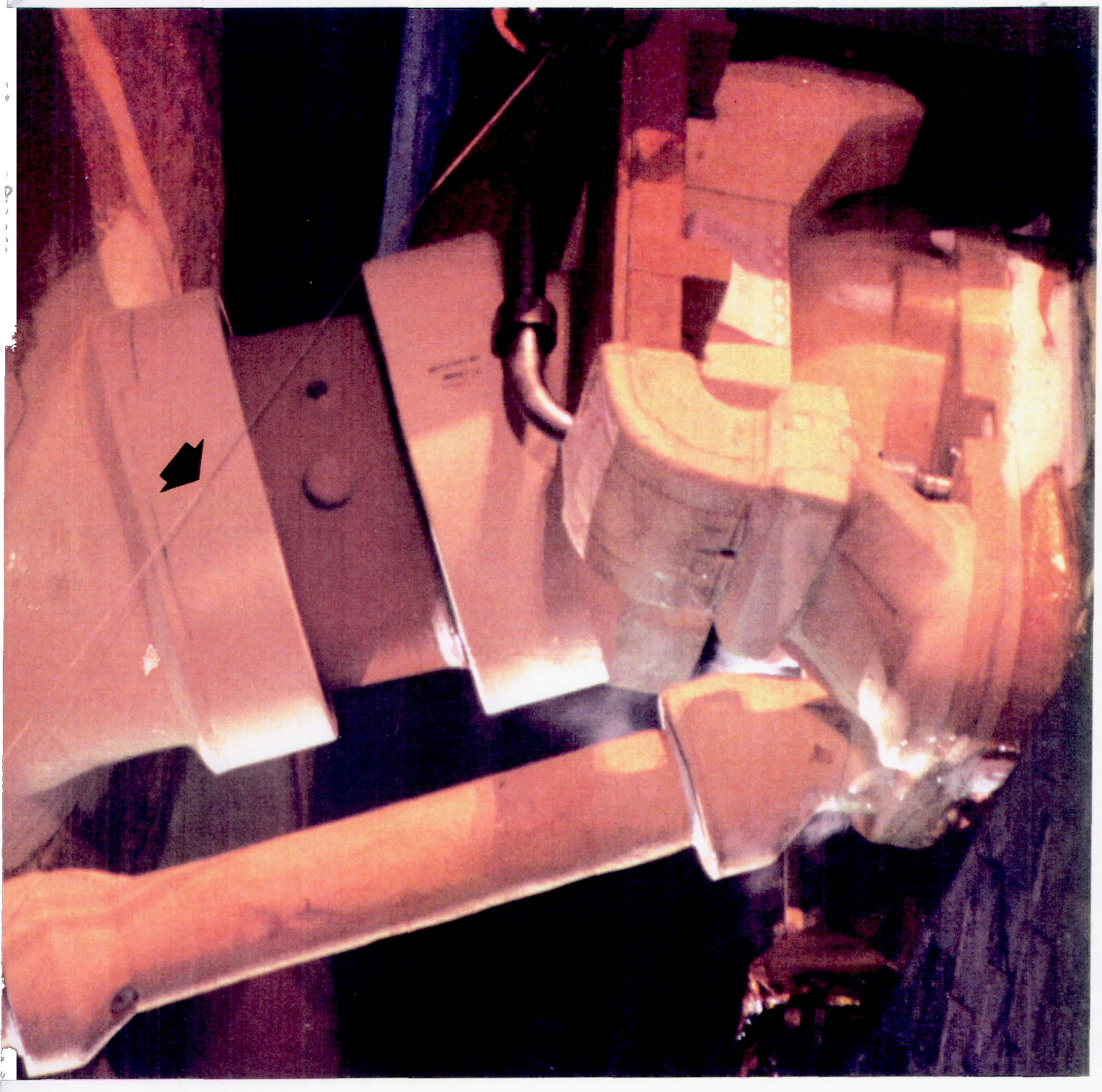

Typical ice/frost accumulations were present on the LH2 ET/ORB umbilical pyrotechnic canister purge vents, plate gap purge vents, and purge barrier (baggie). No ice/frost accumulated on the LH2 feedline and recirculation line-to-tank interface foam repair areas. Note pull-down line for LD 54/55 tygon tubes.



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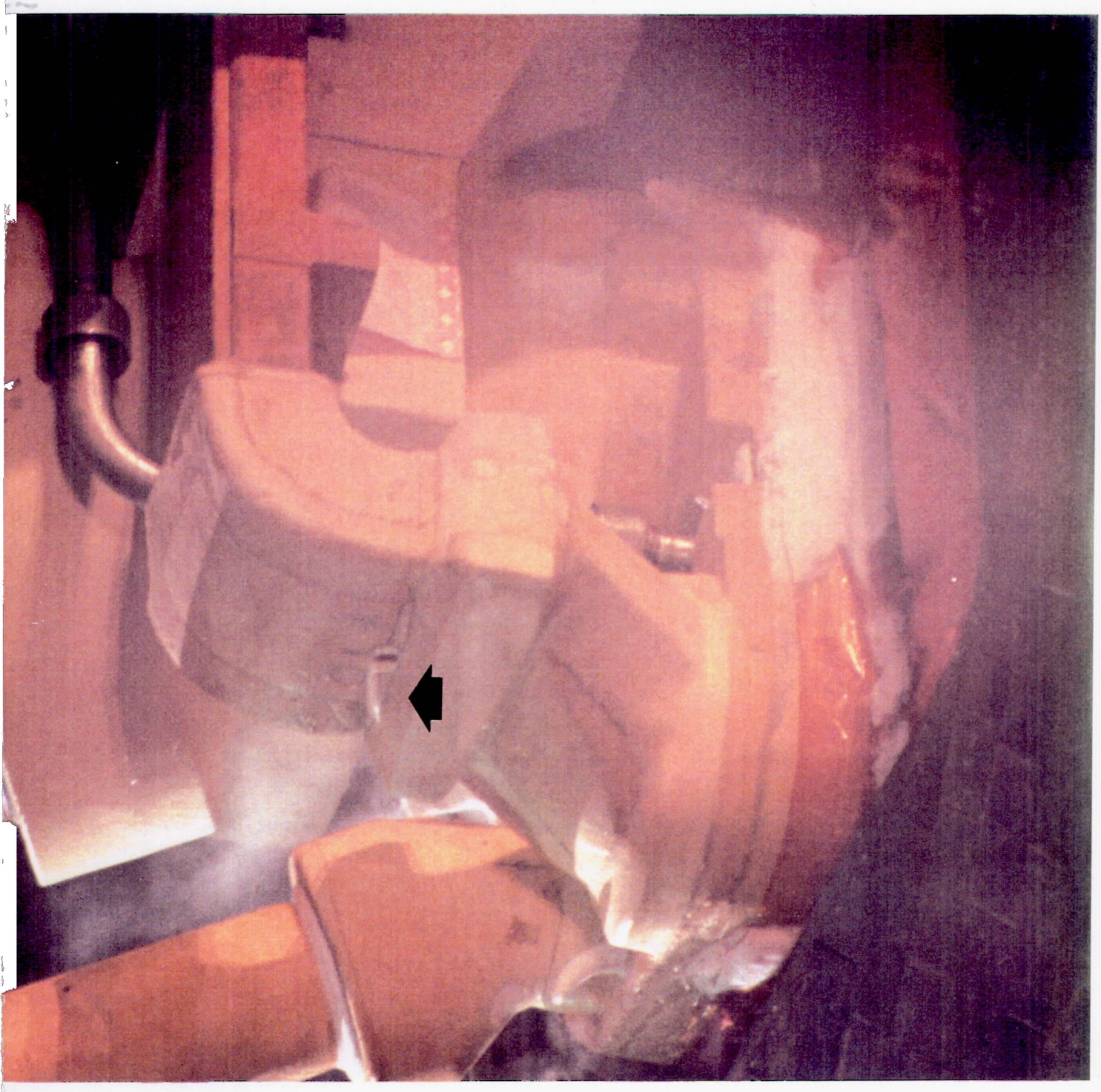

Clear 3"x0.25" icicle had formed on the LH2 umbilical cable tray vent hole due to additional water on the cable tray from recent rainfall. Typical ice/frost had formed on the purge vents and purge barrier. There were no cryogenic drips or unusual vapors during cryogenic loading, stable replenish, and launch.



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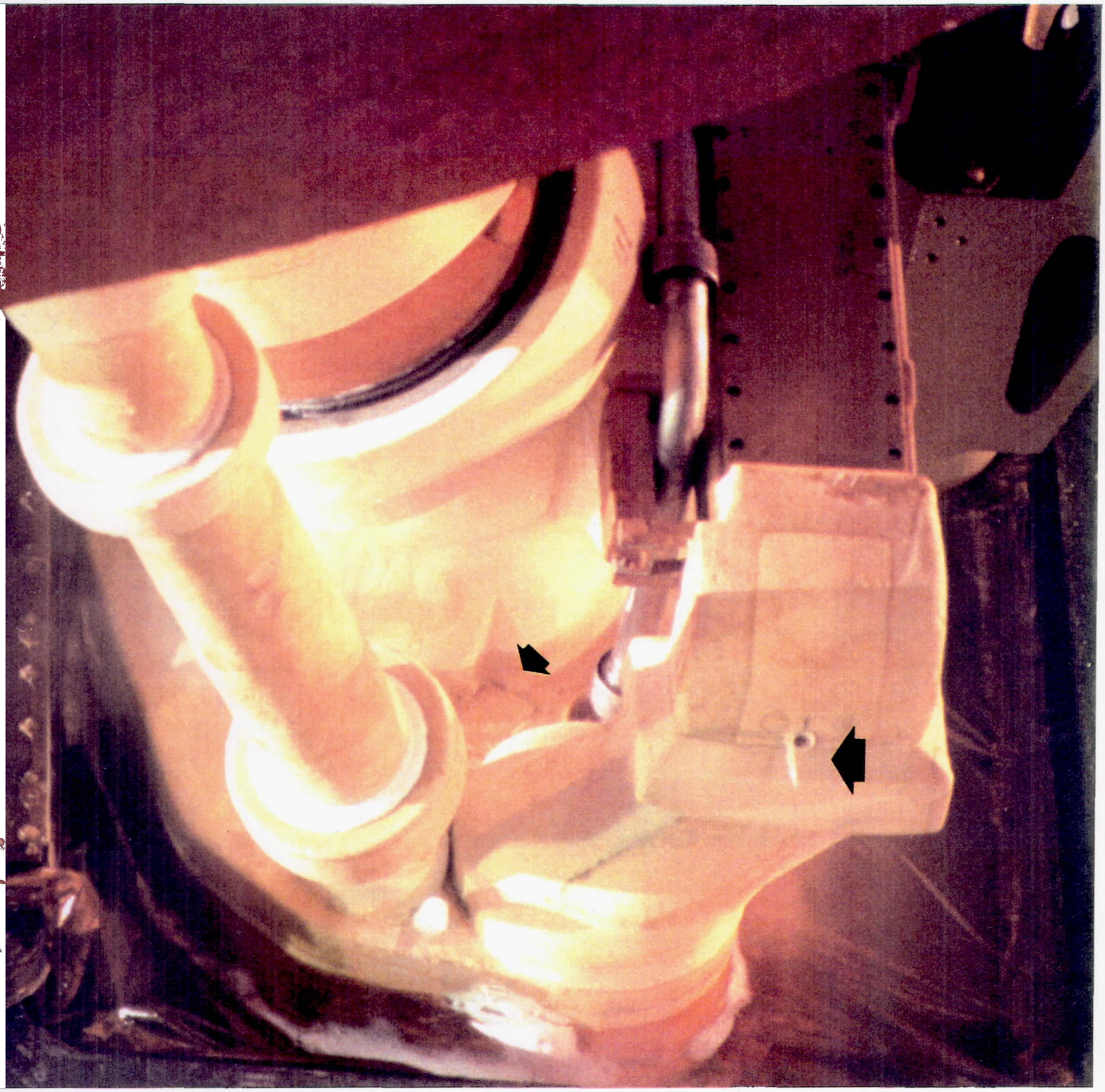

Ice/frost had accumulated in the LH2 recirculation line upper and lower bellows, but only condensate was present in the LH2 feedline bellows. Clear 3"x0.25" icicle had formed on the LH2 umbilical cable tray vent hole due to additional water on the cable tray from recent rainfall. No ice/frost was present on the bondline of the 17-inch flapper valve actuator access port TPS plug closeout.



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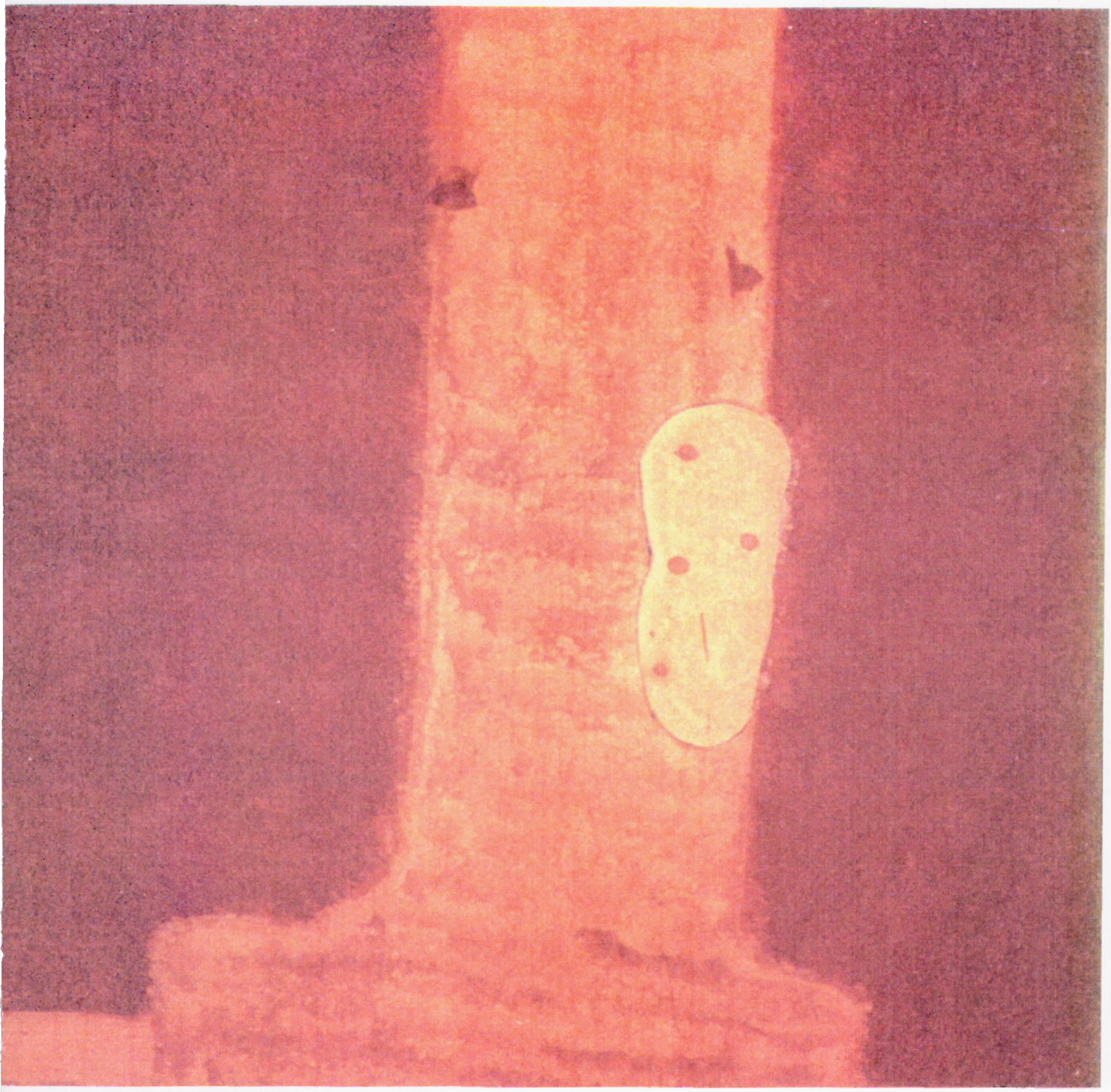

ET aft hard point closeout, part of which had debonded during the previous cryogenic loading, was intact. No ice/frost had formed on the bondline of the repair area.



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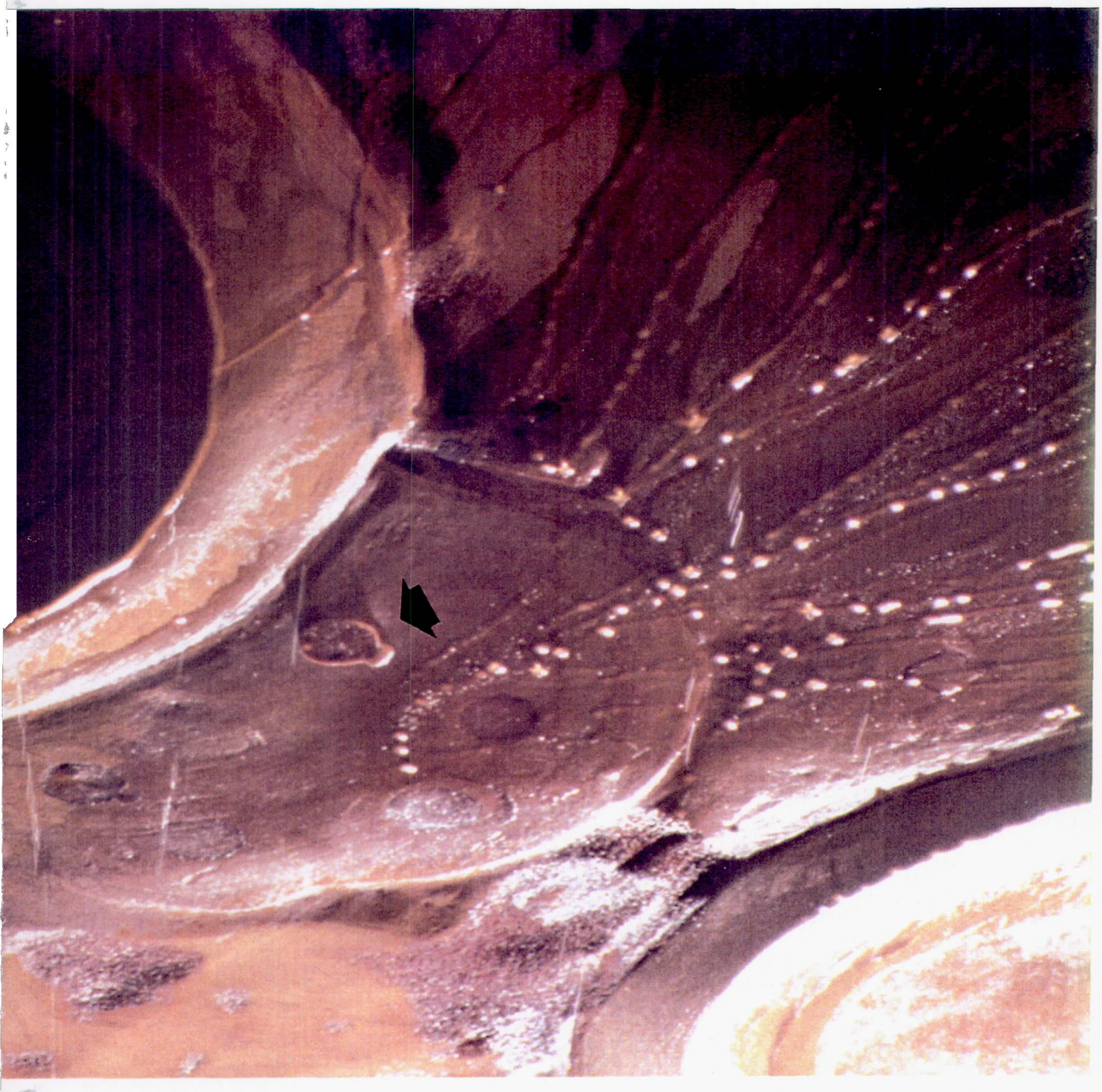

ET LH2 tank aft dome was wet from rain runoff. Plug pull repair on the apex protruded 1/4-inch.

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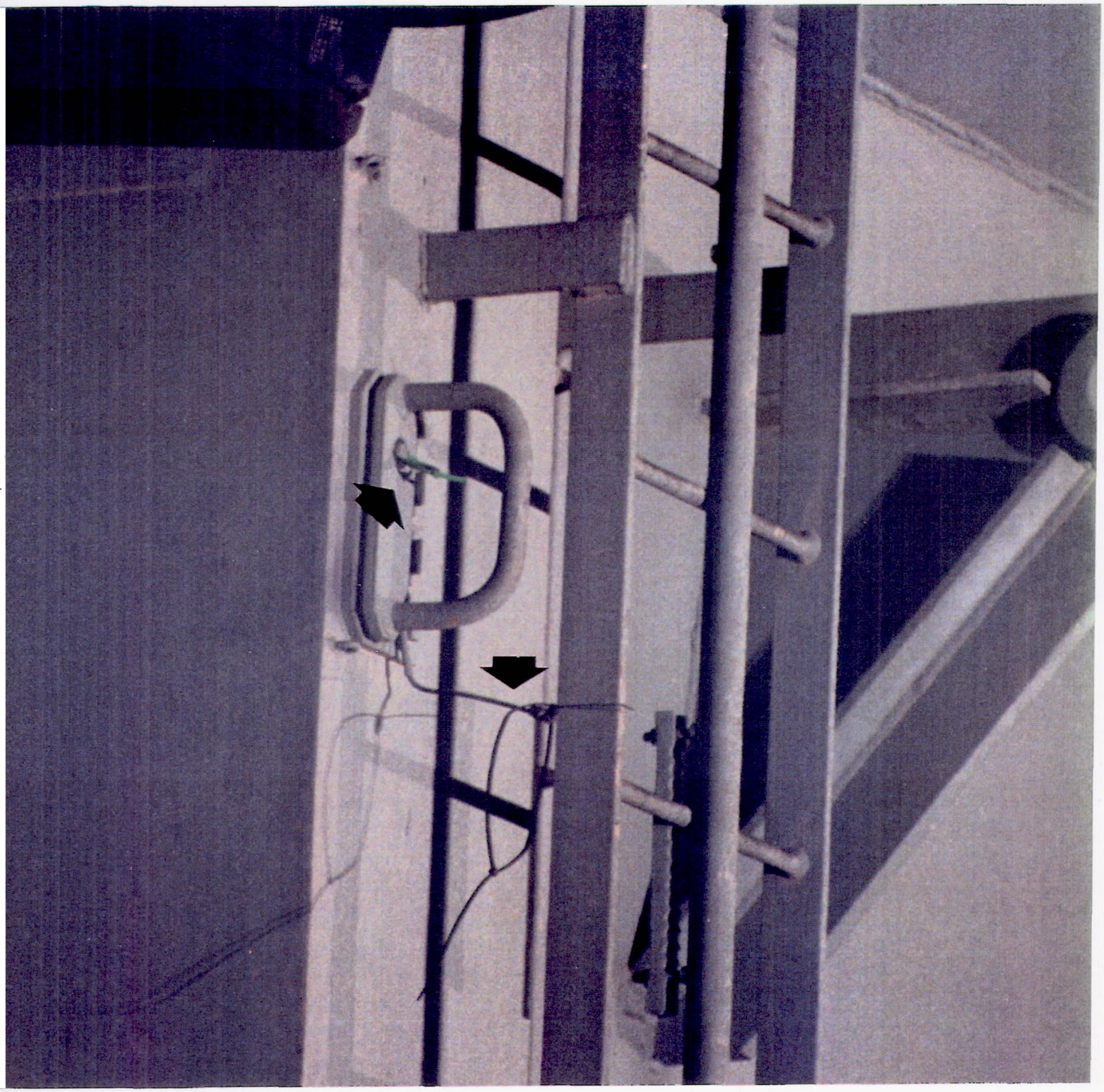

Three tie-wraps, 2 black and 1 green, were attached to LO2 TSM platform pin tethers. The tie-wraps remained in place through liftoff and caused no damage to flight hardware.



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## 5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, pad surface and pad acreage, except for the perimeter area north of the flame trench, was conducted on 5 April 1991 from Launch + 1 to 4 hours. No flight hardware or TPS materials were found with the exception of one Orbiter base heat shield Q-felt plug just west of the crawlerway. These plugs have been found on previous flights.

South SRB holddown post erosion was typical. Shim sidewall material on HDP #1, #2, and #5 was intact, but debonded to various degrees. Shim bottom plate material on HDP #2 was also debonded. A small amount of sidewall shim material was missing from HDP #6. A small piece of NSI cartridge was wedged between the HDP #6 stud and bolt hole. There was no indication of a stud hang-up. North holddown post doghouse blast covers were in the closed position and exhibited typical erosion. The SRB aft skirt purge lines were in place but slightly damaged. The 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, though the west window was broken. The GH2 vent arm appeared to have retracted nominally, was latched on the eighth tooth of the latching mechanism, and had no loose cables. The ET intertank access structure sustained typical plume heating effects.

The new Hydrogen Dispersal System structure welded to the MLP deck showed no sign of damage.

There was a bolt missing from a joint plate on the MLP deck just north of the RH SRB flame hole.

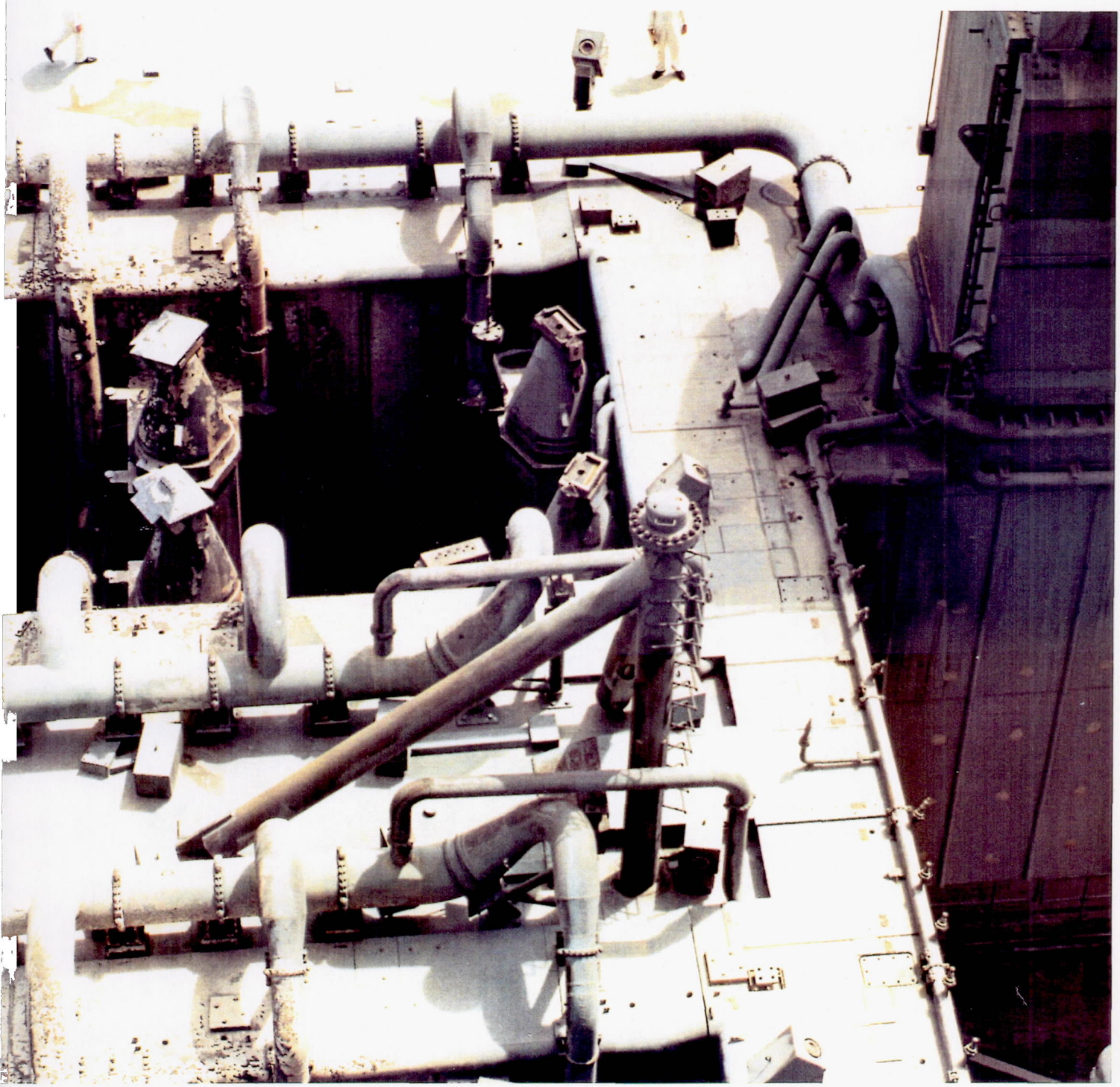
Damage to the facility included 1 loose and 4 missing cable tray covers from the FSS. Two of the missing cable tray covers were found west of the pad apron. In addition, copper tubing was deformed as a result of a damaged containment bracket (FSS 95'level), a light fixture was torn loose from the weather protection system (FSS 135' level), and a fire alarm bell was detached (FSS 195' level).

No emergency egress slidewire baskets had released during launch.

Inspection of the beach from UCS-10 to Complex 40, beach access road, railroad tracks, water areas around the pad, and the ocean areas under the vehicle flight path was completed on December 3, 1990. No flight hardware was found.

Patrick AFB and MILA radars were configured for the purpose of observing any debris falling from the vehicle during ascent. The radar sensitivity initially was low to protect the instrumentation from shock waves. The sensitivity was increased after T+240 seconds. Particle detection is less likely before SRB separation due to the masking effect of the SRB exhaust plume. Although most of the signal registrations were very weak and often barely detectable, which generally compares with the types of particles detected on previous Shuttle flights, a total of 59 particles were imaged in the T+143 to 395 second time period. 30 of the particles were imaged by only one radar, 18 particles were imaged by two radars, and 11 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. None of the particles appeared to be metallic.

Post launch pad inspection anomalies are listed in Section 10.1



Post launch condition of MLP-1. The new hydrogen dispersal system sustained only minor damage from plume impingement.



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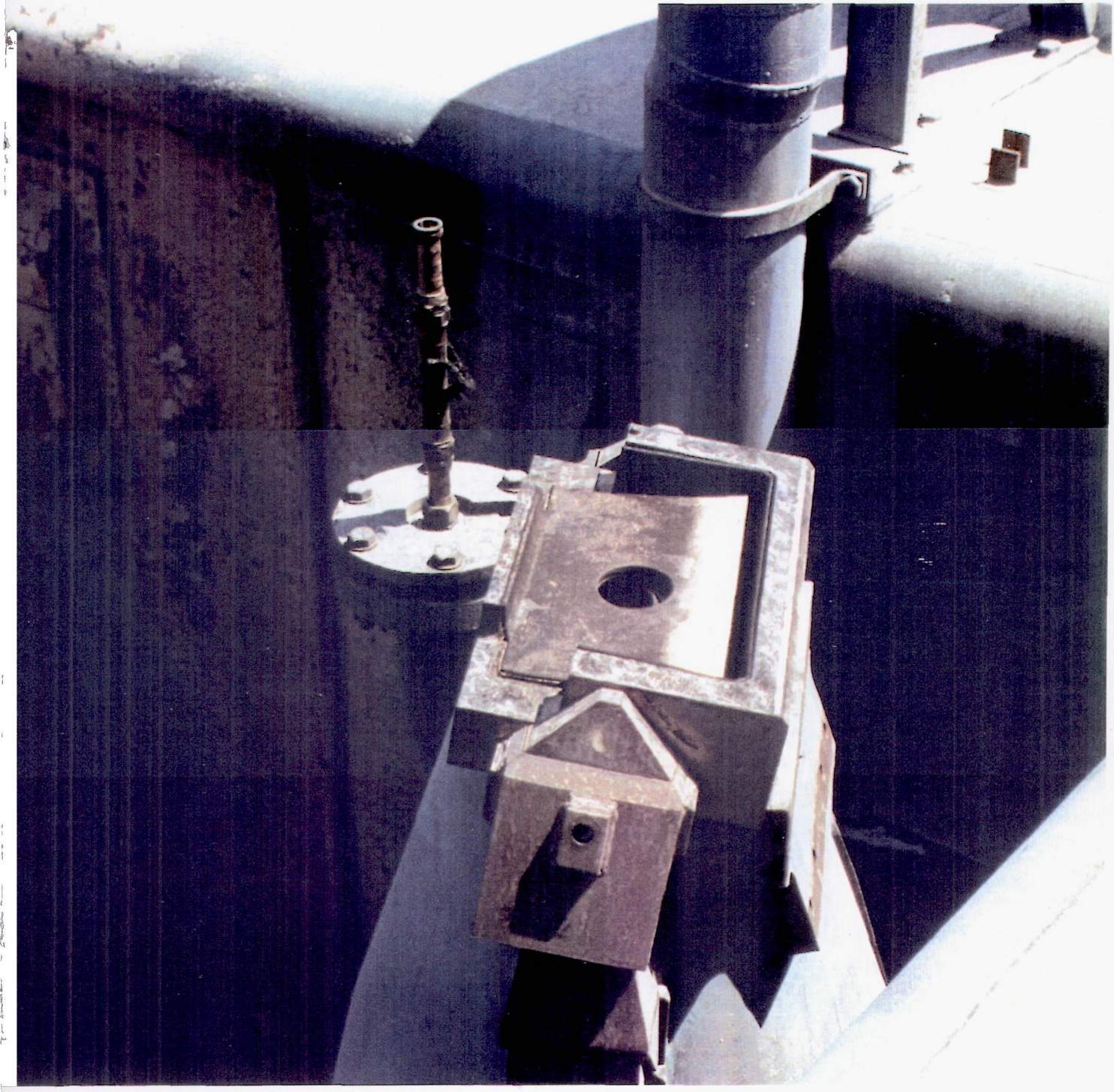

EPON shim material on the south holddown posts was intact but debonded to various degrees



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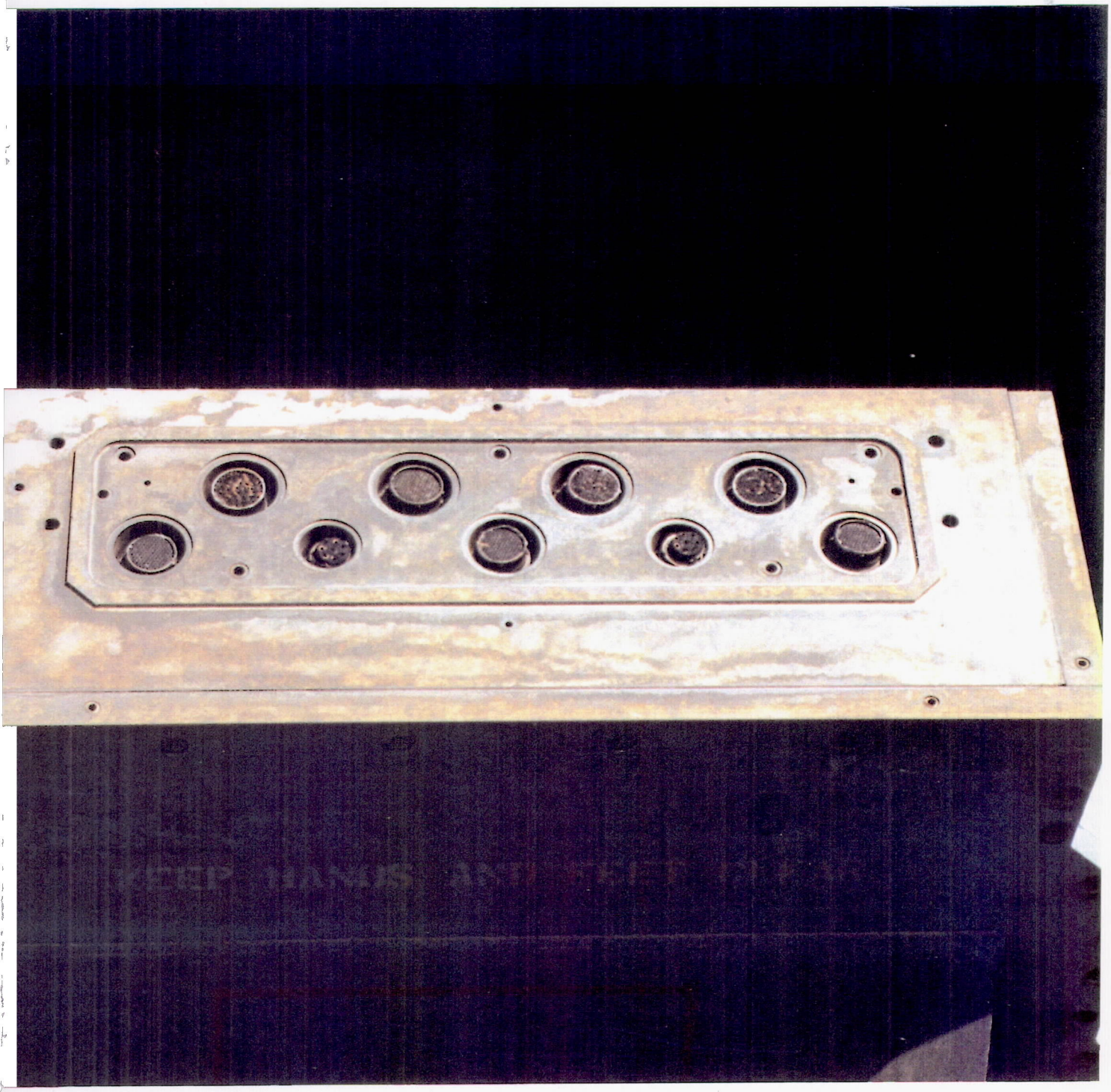

New electrical connector savers (sacrificial pieces) on the SRB joint heater T-0 umbilicals were intact after launch



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SRB exhaust hole sacrificial plates had buckled in 2 places



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Typical post launch pad debris included a cable tray cover and pieces of glass from the GOX vent hood



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## 6.0 FILM REVIEW SUMMARY/PROBLEM REPORT DISPOSITION

A total of 147 film and video data items, which included 48 videos, 54 16mm films, 26 35mm films, seven 70mm films, and 12 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/frost build-up on the LH2 ET/ORB umbilical had been typical during tanking, stable replenish, and launch. There were no unusual vapors or cryogenic drops during liftoff.

SSME ignition vibration/acoustics caused ice to shake loose from the LO2 T-0 carrier plate/cryogenic lines. Some of the ice was drawn to and impacted SSME #3 nozzle by aspiration. No damage to the nozzle was visible. SSME ignition vibration/ acoustics also caused the loss of tile surface coating material from one tile on the RH OMS nozzle heatshield, 5 places on the RH RCS stinger aft face (max size 1 inch square), 1 place on the Orbiter base heatshield, 1 place on the LH OMS nozzle heat shield, and 4 places on the LH RCS stinger aft face. In addition, white tile repair material from the RH OMS pod was shaken loose.

SSME ignition caused numerous pieces of ice to fall from the ET/Orbiter umbilicals. Some of the ice contacted the thermal barrier on the aft edge of the LH2 umbilical cavity sill and were deflected outward away from the Orbiter. No damage to Orbiter tiles was visible.

The 3-inch icicle on the LH2 umbilical cable tray vent hole, as reported by the Ice Team, shook loose during SSME ignition and fell vertically from the cable tray. No contact with Orbiter tiles was observed.

The Ice Team reported two tie-wraps attached to a platform pin tether, located at the southwest corner of the LO2 TSM. The tie-wraps were approximately 2-3 feet away from the RH aft RCS stinger tiles. Due to the precarious location and expectation that the tie-wraps would be drawn into the SSME plume by aspiration without contacting the flight hardware, the decision was made to leave the tie-wraps in place for launch. OTV 151 confirmed that the tie-wraps remained attached to the tether until the SRB's cleared the TSM.

No anomalies were apparent with the new hydrogen dispersal system hardware welded to the MLP deck. Adequate clearance between the Orbiter body flap and the new hardware was observed during liftoff.

There were no major facility anomalies. No swing arms or other pad structures contacted the vehicle during liftoff. All T-0 umbilicals separated cleanly. The GH2 vent line latched properly with no rebound.

Three to four feet of HDP #1 firing cable remained attached to the RH SRB aft skirt and flew with the vehicle (E-9, 25). Normally, the firing cable will stretch/break near the DCS.

Two small ordnance fragments fell from the HDP #6 DCS/stud hole during liftoff (E-13). (Post launch pad inspection revealed an ordnance fragment wedged between the stud and the stud hole wall inside the holddown post. In addition, post flight inspection of the LH SRB at Hangar AF revealed a frangible nut half obstructing the DCS plunger).

Instafoam broke loose near the RH SRB aft skirt GN2 purge line during liftoff (E-8).

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.

Just after initiation of the roll maneuver, the F2U FWD RCS paper cover detached from the thruster and fell aft. Coincident with this event, a puff of reddish/brown vapor, most likely oxidizer, exited the nozzle at 14:22:57.7. There was no further leakage after the initial puff. The event was visible in film items E-213, 220, 222. This thruster had been leaking slightly during ground operations. The presence of the vapor was expected and not considered a mission anomaly.

Pieces of ET/ORB umbilical purge barrier (baggie) material fell aft of the vehicle at 14:23:00.44 shortly after the roll maneuver - a normal occurrence (E-52, 53).

Tracking films yielded less than usual data due to hazy conditions, sun angle/position, cloud cover, and film underexposure. However, ET aft dome charring, formation of localized supersonic flow condensation, plume recirculation, BSM firing, and SRB separation appeared normal.

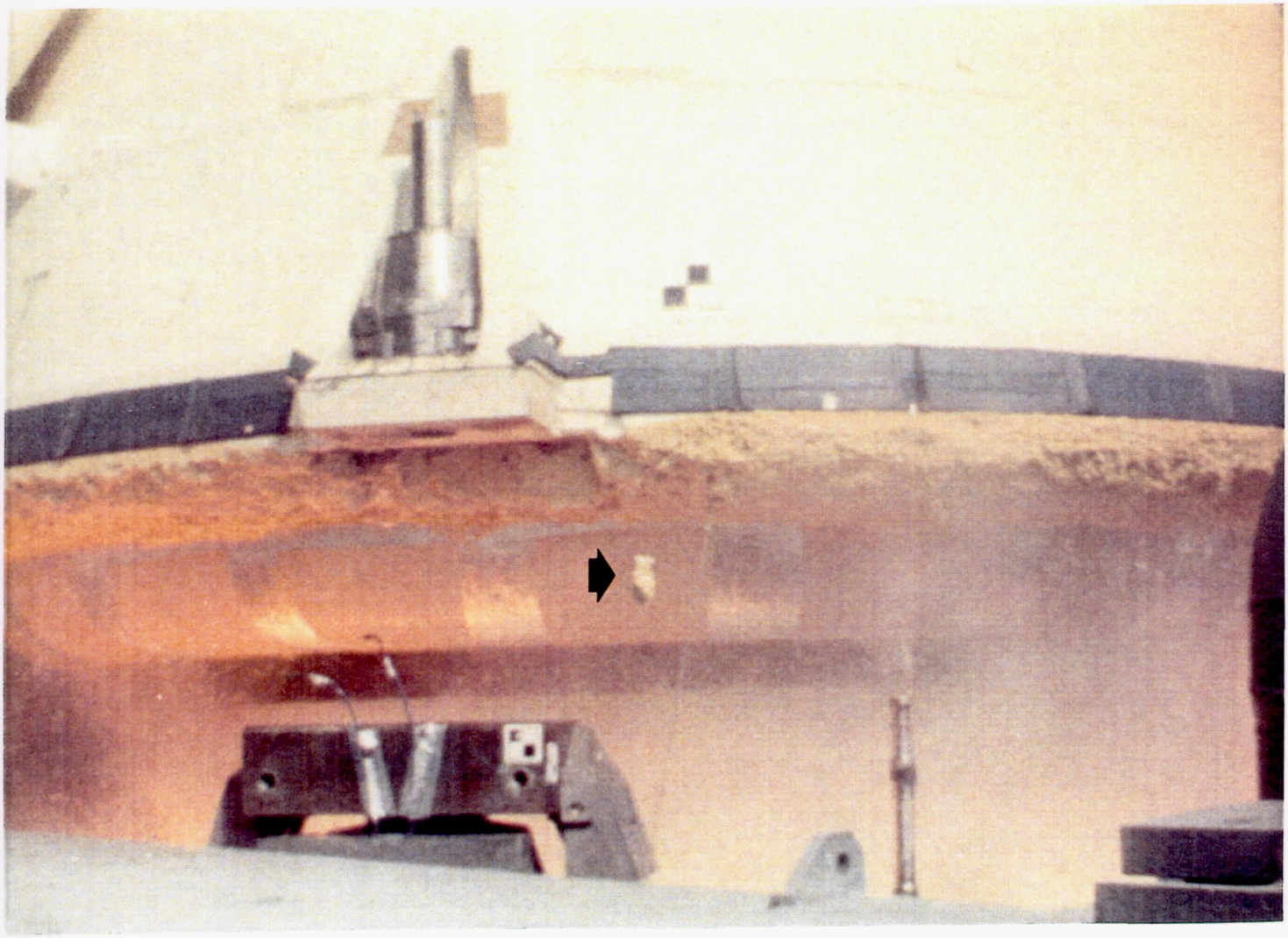
Twelve frames were taken of the External Tank shortly after separation from the Orbiter. There were no anomalies that would have affected the mission or safety-of-flight.

Six divots occurred in the LH2 tank-to-intertank flange (-Y side) closeout during ascent. Two of the divots were 12-14 inches in diameter, three were 6-8 inches in diameter, and one was 4 inches in diameter. Two of the divots were in the -Y+Z quadrant.

The BSM burn scar on the LO2 tank was typical. There were no significant acreage TPS anomalies. Bright spots near the aft hardpoint consisted of the cryogenic witness panel closeout and four circular sanded (TPS thickness verification) areas. Three bright spots on the LO2 tank acreage were also present prior to launch and were previously repaired areas.

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 10.2.



Piece of RH SRB aft skirt instafoam, which originated near the GN2 purge line, broke loose shortly after liftoff. Range Safety System (RSS) GSE coax cable attached to aft skirt has not yet separated.



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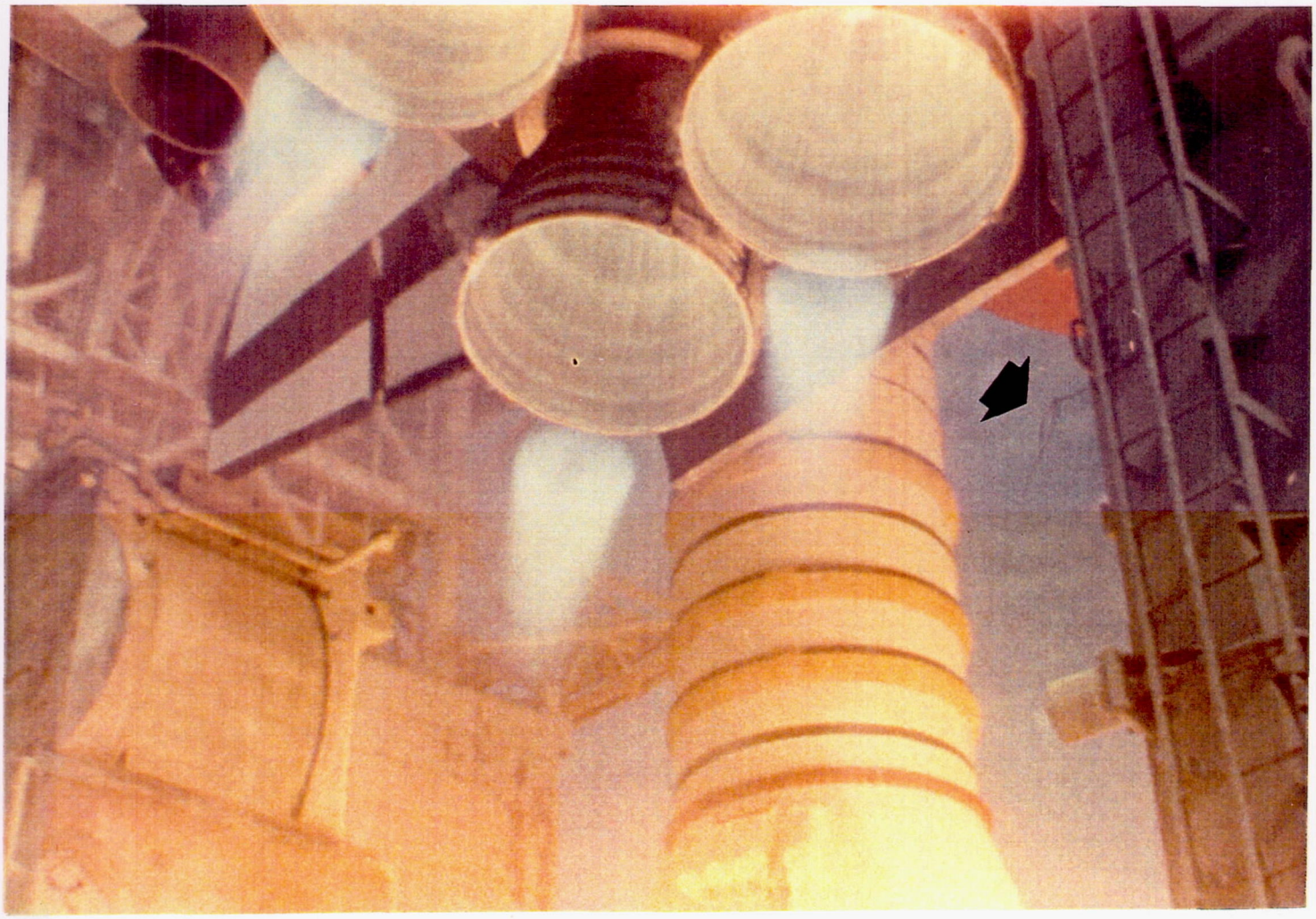

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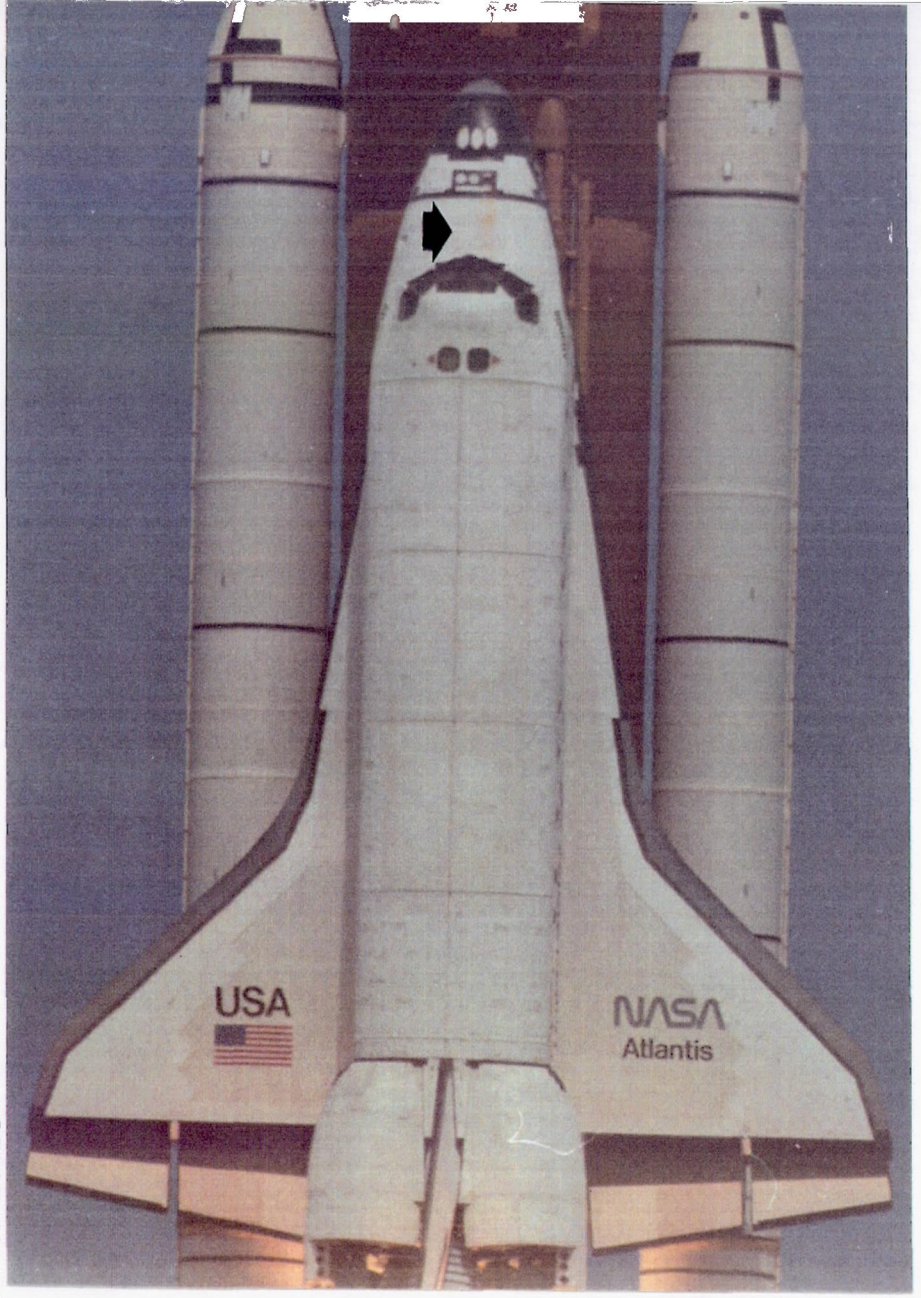
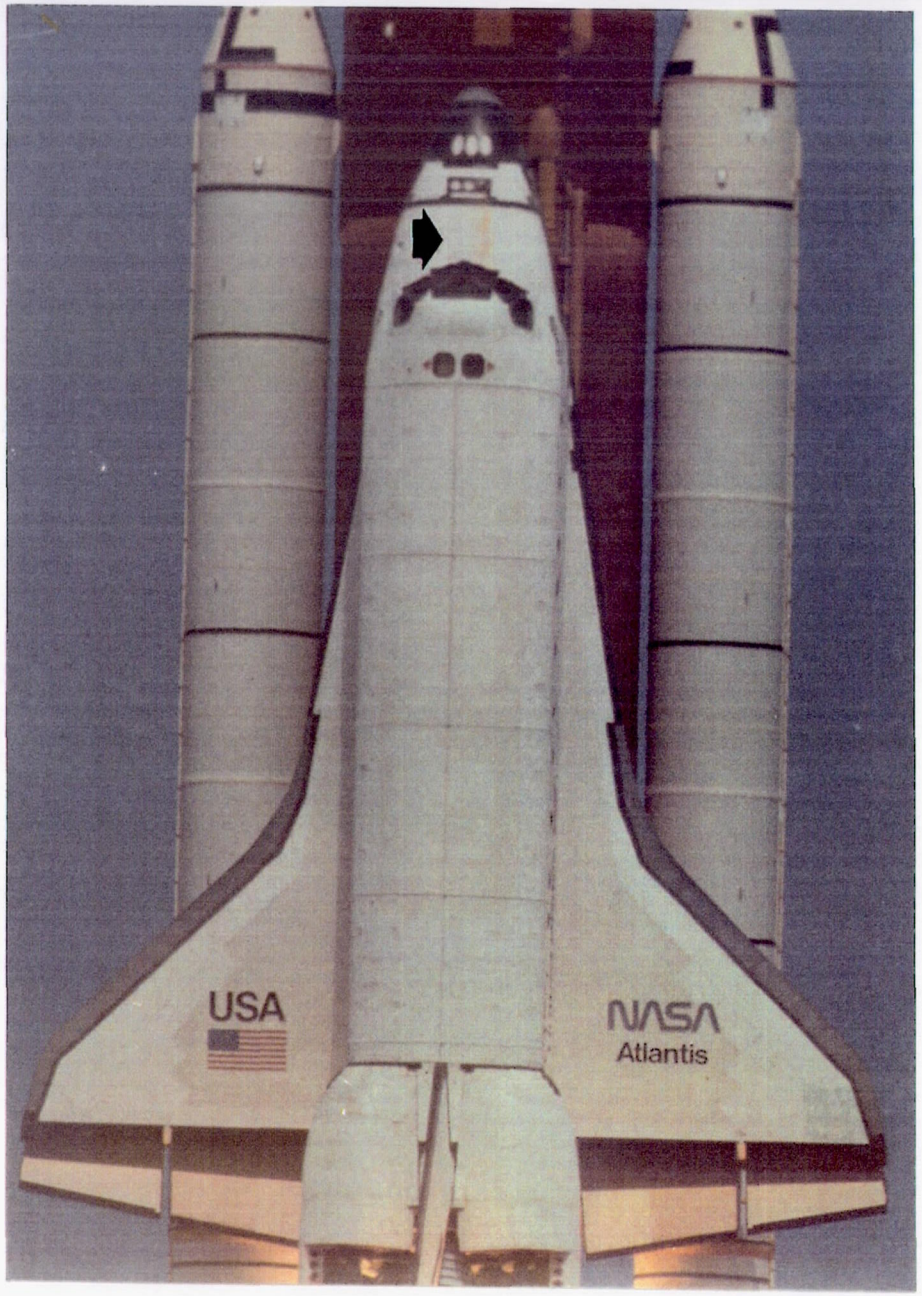
Black tie-wraps, which were attached to a LO2 TSM platform pin tether, remained in place through liftoff and caused no damage to flight hardware.




Just after initiation of the roll maneuver, the F2U FWD RCS paper cover detached from the thruster and released a puff of oxidizer vapor. This thruster had been leaking slightly during ground operations.

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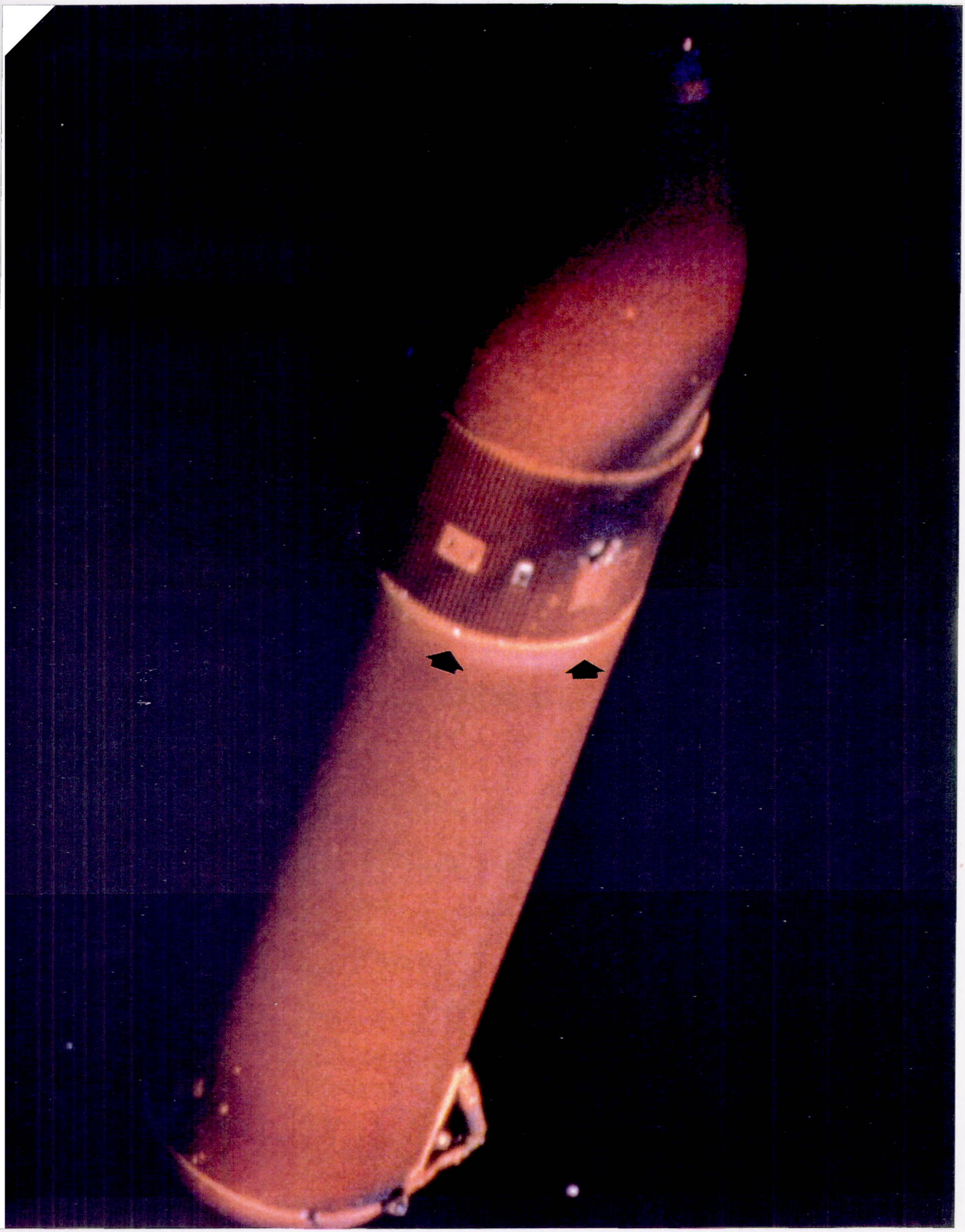

On-orbit view of the External Tank shortly after separation from the Orbiter. Other than 6 divots on the intertank-to-LH2 tank flange closeout, there were no other apparent anomalies.



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## 6.1 LAUNCH FILM AND VIDEO DATA REVIEW

**FILM ITEMS**

| | |
|---|---|
| **EX1**<br>400 FPS<br>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: SSME aspiration pulls several particles from behind DCS's. Instafoam particle broke loose from aft skirt by contact with HDP. Three to four feet of firing cable detached from HDP and flew with vehicle. HDP shoe rocked backward slightly at T-0 and, with vehicle first motion, the shoe rotation continued. Additional debris appeared from behind DCS at T-0. SRB throat plug material and sound suppression water baggies were ejected out of SRB exhaust hole after T-0. A 1 inch piece of SRB grounding strap was torn loose and eventually pulled into exhaust hole.

| | |
|---|---|
| **EX2**<br>400 FPS<br>16mm | Camera is located on the MLP deck west of RH SRB flame duct and looks east to view SRB Heater Umbilical during ignition and liftoff. |

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

Comments: Small debris particles were pulled across MLP deck by SSME aspiration. Instafoam trimmings were blown out of area between the SRB T-0 umbilical and aft skirt. T-0 umbilical separation was not parallel with first motion occurring on the left side.

| | |
|---|---|
| **EX3**<br>400 FPS<br>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: Instafoam trimmings were blown out of area between the SRB T-0 umbilical and aft skirt. T-0 umbilical separation and retraction were parallel. Large foam particle crossed FOV after separation. SRB throat plug material and sound suppression water troughs were ejected out of SRB exhaust hole after T-0.

**EX4**
400 FPS
16mm

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

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

Comments: Instafoam trimmings were blown out of area between the SRB T-0 umbilical and aft skirt. At T-0, the HDP shoe rocked backward slightly and continued backward after separation with the aft skirt. No debris particles fell from the holddown post DCS/stud hole. SRB grounding strap broke away from SRB at first motion. Dark water (with combustion products) flowed from base of DCS at T-0. A small piece of shim putty appeared above shoe before being pulled into exhaust hole by plume.

**E-1**
400 FPS
16mm

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

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

Comments: Ice particles fell from ET/ORB umbilicals during lift-off. Water in SRB stiffener rings vaporized after T-0. SRB plume obscured FOV after T-0.

**E-2**
400 FPS
16mm

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

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

Comments: SSME ignition was nominal. Flashes in plume were caused by RCS paper covers. Deck scale was visible in front of camera lens at frame 4875. LH2 TSM door closed properly.

**E-3**
400 FPS
16mm

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

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

Comments: Ice particles fell from LO2 T-0 umbilical after separation. Protective plastic covers over the extra LD 54 & 55 disconnects at the base of the LH2 TSM were torn loose by vehicle plume after vehicle cleared TSM.

**E-4**
400 FPS
16mm

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

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

Comments: Water on ET aft dome and stiffener rings vaporized. No vehicle anomalies. No debris particles in view until vehicle cleared FOV.

**E-5**
400 FPS
16mm

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

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

Comments: Ice fell from ET/ORB umbilicals during SSME ignition. Residual LOX vapors from LO2 T-0 umbilical and water on base heat shield vaporized around SSME #3. A debris particle moved past camera after vehicle ascended 10 feet. Pieces of ice also fell from SSME nozzles.

**E-6**
200 FPS
16mm

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

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

Comments: Movement of both inboard and outboard elevons occurred during ignition and liftoff. Water on Orbiter base heat shield vaporized. Ice particles fell from ET/ORB umbilicals and LH2 recirculation line bellows during SSME ignition. Residual vapors from LO2 T-0 disconnect were present. Two white particles approx. 2" x 1.5" (frame 2356) appeared to the +Z side of RH wing and fell to the right of body flap with no vehicle contact.

**E-7**
400 FPS
16mm

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

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

Comments: HDP shoe rocked forward with first motion. Blast cover closure was nominal. SRB throat plug material was ejected out of SRB exhaust hole after T-0.

**E-8**
400 FPS
16mm

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

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

Comments: HDP shoe rotated counterclockwise 2-4 inches before complete separation with SRB aft skirt. Instafoam broke loose from area around GN2 purge line when vehicle ascended. SRB throat plug material was ejected out of SRB exhaust hole after T-0.

**E-9**
400 FPS
16mm

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

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

Comments: SSME ignition caused water to be pulled from behind HDP DCS's. Debris particles appeared on MLP deck after SSME ignition. Three to four feet of HDP firing cable stretched and broke near the base of the DCS and flew with the vehicle.

**E-10**
400 FPS
16mm

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

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

Comments: A particle, most likely SRB throat plug material, came out of SRB exhaust hole near HDP #4. After T-0, a second particle was visible moving away from vehicle.

**E-11**
400 FPS
16mm

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

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

Comments: No debris fell from the holddown post DCS/stud hole. HDP doghouse blast cover closed properly. SRB throat plug material was ejected upward out of exhaust 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: Deck debris was drawn across MLP deck by SSME plume aspiration. Ice from LH2 umbilical shook loose during ignition and fell to MLP deck. T-0 caused two particles to be ejected vertically near DCS. No debris fell from HDP #5 DCS/stud hole. HDP shoe movement was minimal. No vehicle anomalies.

**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: SRB HPU exhaust was visible prior to T-0. Small piece of aft skirt instafoam broke loose near GN2 purge line. Two ordnance fragments fell from HDP #6 DCS/stud hole. Two small pieces of debris, most likely K5NA trimmings, appeared near the top of the DCS after T-0. SRB throat plug material was ejected out of SRB exhaust hole after T-0.

**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: Water leaked from a sound suppression water pipe joint. FSS deluge water landed on MLP deck. Water was present on SRB aft skirt during liftoff. SRB throat plug material was ejected out of SRB exhaust hole after T-0.

**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.

Comments: No data. Film did not run.

**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: Water was leaking from joint in LH SRB exhaust hole J-pipe. Ice was shaken loose from ET/ORB umbilicals by SSME ignition. Ice from EB fittings fell north of HDP's. Throat plug particles were ejected upward after T-0. No debris fell from holddown post DCS/stud hole. Doghouse blast covers closed normally.

**E-17**
400 FPS
16mm

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

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

Comments: SSME ignition caused ice to shake loose from T-0 and SSME #3 nozzle. Ice from the LO2 T-0 umbilical impacted the SSME #3 nozzle, but no damage occurred. A paper optical target came loose at T-0 (frame 4074). LO2 T-0 umbilical disconnect and retraction was nominal. Residual LO2 vapors were drawn into SSME #3 plume by aspiration. One tile on RH OMS heatshield was chipped.

**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.

Comments: No data. Film did not run.

**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: Underexposed

Comments: SSME ignition appeared nominal. Vibration/acoustics caused the loss of surface coating material from a tile on the RH OMS heatshield. Ice from LO2 T-0 and SSME's fell during ignition. LO2 T-0 paper optical target came loose at frame 4084. Orbiter T-0 disconnects performed properly. Residual LO2 vapors from T-0 were drawn into plume by aspiration. Tie-wrap was still attached to LO2 TSM until obscured by SSME plume.

**E-20**
400 FPS
16mm

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

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

Comments: Water from base heat shield vaporized during SSME ignition. Ice particles fell from LOX T-0 umbilical after separation. A tile on the LH RCS stinger lost surface coating material after SSME ignition. LO2 TSM door closure was nominal. Residual LOX vapors were present after T-0.

**E-21**
400 FPS
16mm

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

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

Comments: SSME ignition caused ice/frost to fall from LO2 supply line. Optical target from LO2 TSM came loose. Residual LO2 vapors were visible from Orbiter T-0 disconnect. TSM door closed with no rebound.

**E-22**
400 FPS
16mm

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

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

Comments: LH2 TSM purge barrier tore loose at SSME ignition. Residual vapors were visible from the Orbiter T-0 disconnect. TSM door closed with no rebound. Ice particles on T-0 umbilical broke loose when umbilical stopped inside TSM.

**E-23**
400 FPS
16mm

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

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

Comments: Aft RCS paper covers were torn loose by SSME ignition and pulled into SSME plume. Ice particles fell from LO2 TSM during SSME ignition. Water in SRB aft stiffener rings vaporized. Orbiter OMS nozzle moved slightly during SSME startup. SSME ignition caused the loss of tile surface coating in 5 places on RH RCS stinger aft face. The largest area appeared to be 1 sq. inch. One tile chip appeared at the base of the OMS nozzle heatshield.

**E-24**
400 FPS
16mm

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

Focus : O.K.
F. O. V.: FOV too high
Exposure: O.K.

Comments: Residual vapors emanated from the LH2 T-0 umbilical after disconnect. Aft RCS paper covers were torn loose by SSME ignition and pulled into SSME plume. Ice particles fell from ET/ORB umbilicals. No movement of OMS nozzle was apparent. Tile surface coating material was lost from four places on the LH RCS stinger and one place on the Orbiter base heat shield. White tile repair material from the OMS pod broke loose during SSME ignition and fell into the FOV from the top.

**E-25**
400 FPS
16mm

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

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

Comments: Water on base heat shield vaporized at T-0. Firing cable which remained attached to HDP #1 dangled below the aft skirt. Water in SRB stiffener rings vaporized during liftoff.

**E-26**
400 FPS
16mm

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

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

Comments: FOV was obscured by water deluge spray from GH2 vent arm. Retraction of GH2 vent line appeared nominal. Several large ice particles fell from ET/ORB umbilicals during SSME ignition, but no contact with the vehicle was visible.

**E-27**
400 FPS
16mm

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

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

Comments: A small particle, possible shim putty or instafoam, appeared between the blast cover and HDP shoe after T-0.

**E-28**
400 FPS
16mm

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

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

Comments: SRB HDP shoe rocked backward after T-0. A dark particle was visible between blast cover and SRB DCS. SRB throat plug material and sound suppression water trough material were ejected out of SRB exhaust hole after T-0.

**E-30**
400 FPS
16mm

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

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

Comments: Water in SRB sound suppression water troughs geysered from the MPS overpressure. SRB plume then obscured view.

**E-31**
100 FPS
16mm

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

Comments: No data. Film did not run.

**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: Underexposed

Comments: Ice particles fell from GUCP during SSME ignition. GH2 vent line separation and retraction was nominal.

**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: Underexposed

Comments: Several large ice particles fell from ET/ORB umbilicals at T-0 and during liftoff. Water on ET aft dome vaporized. ET hydrogen fire detection paper and Orbiter FWD RCS paper covers were still intact when vehicle cleared FOV.

**E-35**
300 FPS
16mm

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

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

Comments: No data due to filming conditions.

**E-36**
300 FPS
16mm

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

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

Comments: GH2 vent arm water deluge obscured FOV. Residual LH2 vapors emanated from the T-0 disconnect. RCS paper covers were not intact as vehicle cleared FOV.

**E-40**
300 FPS
16mm

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

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

Comments: Frost was present on the southwest louver. After T-0, residual GOX vapors emanated from louvers. As vehicle crossed field of view, LH FWD RCS paper covers were still intact. Ice particles continued to fall from ET/ORB umbilicals. Water on ET aft dome vaporized.

**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., but camera shake was excessive
Exposure: O.K.

Comments: GH2 vent line separation and retraction was nominal. Vent line static lanyard did not contact GUCP. Water on ET aft dome vaporized during liftoff. Numerous small particles were visible after vehicle cleared FOV.

**E-42**
300 FPS
16mm

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

Comments: No data. Film did not run.

**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: SSME ignition caused RCS paper covers to tear and fall into SSME plume. Two particles in the FOV prior to T-0 did not contact vehicle. Additional particles were visible after T-0 at frames 4714, 4917, and 4512.

**E-48**
300 FPS
16mm

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

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

Comments: At SSME ignition and T-0, ice particles fell from the underside of the GUCP. Residual vapors emanated from the flight T-0 disconnect. GUCP disconnect and GH2 vent line retraction and latchback appeared nominal. Ice fell from ET/ORB umbilical during liftoff. Ice/frost was present along the lower edge of the ET carrier plate after separation. Water on ET aft dome and in the SRB stiffener rings vaporized.

**E-50**
60 FPS
16mm

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

Comments: No data. Film did not run.

**E-52**
96 FPS
35mm

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

Focus : O.K.
F. O. V.: O.K., but camera started late
Exposure: O.K.

Comments: Water on ET aft dome and in SRB stiffener rings vaporized during liftoff. A particle was visible aft of ET dome and lingers for 10 to 20 frames before entering plume (frame 38-00). Numerous bright flashes occurred in SSME #1 plume prior to and after roll (frame 39-08). During roll maneuver, FWD RCS thruster F2U paper cover tore loose and released a reddish/brown vapor of accumulated oxidizer (frame 43-13). A particle fell from behind SSME #1 (frame 53-02) and entered plume. LH2 ET/ORB purge barrier baggie was torn loose shortly after roll maneuver (frame 59-11). RCS paper covers and umbilical baggie material enter SSME plume causing orange flashes (frames 55-15 and 89-14).

**E-53**
96 FPS
35mm

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

Focus : O.K.
F. O. V.: O.K., but the camera started late
Exposure: O.K.

Comments: Aft RCS paper covers were torn loose during SSME ignition and caused orange streaks in SSME plume. Water on ET aft dome and in SRB stiffener rings vaporized. Ice particles fell from ET/ORB umbilicals as vehicle cleared tower. Residual vapors were visible in flight T-0 disconnect. FWD RCS paper cover F2U was torn loose and a reddish/brown vapor was released from accumulated oxidizer at 14:22:57.718. LH2 umbilical purge barrier baggie material was torn loose shortly after roll maneuver at 14:23:00.440.

**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., but camera started late
Exposure: O.K.

Comments: Water on ET aft dome and in SRB stiffener rings vaporized. FWD RCS paper covers are torn loose shortly after roll maneuver. A portion of the LH2 umbilical purge barrier baggie came loose after the roll maneuver started.

**E-57**
96 FPS
35mm

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

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

Comments: Ice/frost fell from cross country cryo lines on MLP at T-0. Water on ET aft dome and in SRB stiffener rings vaporized during liftoff. Tracking was lost shortly after roll maneuver.

**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: FSS water was activated properly. Water on ET aft dome and in SRB stiffener rings vaporized during liftoff. Ice/frost was visible on EB-7. LH FWD RCS paper covers remained intact prior to roll maneuver. Charring was visible on ET aft dome shortly after roll. Tracking lost shortly after roll maneuver.

**E-59**
96 FPS
35mm

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

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

Comments: Water on ET aft dome and in SRB stiffener rings vaporized. Ice particles fell from GUCP after T-0. Tracking lost prior to roll maneuver and never reacquired.

**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: Water on ET aft dome and in SRB stiffener rings vaporized. Ice particles fell from ET/ORB umbilicals during lift-off. Residual vapors emanated from Orbiter LO2 T-0 disconnect. GH2 vent line latchback appeared normal. A dark particle appeared in the flame trench north of the MLP.

**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: Water on ET aft dome and in SRB stiffener rings vaporized. Ice particles fell from ET/ORB umbilicals during lift-off. Rust-colored water flowed from LH2 skid firex. No vapors were visible from Orbiter rudder/speed brake trailing edge.

**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: Rust-colored water flowed from LH2 skid. SSME ignition appeared nominal. A streak appeared in the SSME plume at 14:22:44. Ice particles fell from ET/ORB umbilicals. After tower clear, the exhaust plume impinged on the GOX vent hood. Water in SRB stiffener rings vaporized.

**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: Rust-colored water flowed from firex on MLP LH2 skid. Ice particles fell from ET/ORB umbilicals. Residual LH2 vapors emanated from LH2 disconnect after T-0. Residual LO2 vapors appeared from the LO2 disconnect.

**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: Water on ET aft dome and in SRB stiffener rings vaporized. No vehicle anomalies.

**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 was present in upper LO2 feedline bellows. Ice particles fell from ET/ORB umbilicals during liftoff. Water vaporized on ET aft dome. RH outboard RCS paper covers were not intact as vehicle cleared FOV.

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

Comments: SSME ignition appeared nominal, though the shock diamond formed on SSME #1 before SSME #2. T-0 retraction was nominal. Residual LO2 vapors emanated from the T-0 disconnect after separation. Presence of the water spray boiler #2a vent plug could not be verified due to lack of resolution.

**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: Residual vapors emanated from the LH2 T-0 disconnect after separation. Ice/frost at end of SSME #2 vent line greatly reduced the amount of GOX vapors. RCS paper covers were torn loose during SSME ignition and pulled into plume by aspiration. A green tint was visible in the hydrogen-rich preburn flow prior to SSME ignition (frame 15-00). Ice particles fell from LH2 and LO2 T-0 umbilicals at T-0. Firing cable was attached to the HDP #1 DCS through FOV. Ice particles fell from LH2 ET/ORB umbilical. Shock diamond in SSME #2 plume formed after SSME #1. In frame 31-04, a bright white streak appeared in the shock diamond as it formed in SSME #2 plume - possibly due to impurities further up in the nozzle.

**E-78**
400 FPS
16mm

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

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

Comments: Residual vapors emanated from LO2 T-0 umbilical disconnect. Ice particles fell from ET/ORB umbilical during liftoff. Frost particle fell from behind SSME nozzle. Facility debris crossed FOV after vehicle cleared the tower.

**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 : Bad
F. O. V.: O.K.
Exposure: Underexposed.

Comments: Ice particles fell from the SSME and umbilical areas. No anomalies were visible on the ET nosecone and ogive.

**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: Water on ET aft dome and in SRB stiffener rings vaporized. Clouds obscured most of the view. Disturbance in localized supersonic flow condensation was visible. Sun light reflected off nose of RH SRB frustum. SRB separation appeared normal.

**E-202**
30 FPS
70mm

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

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

Comments: Water on ET aft dome and in SRB stiffener rings vaporized. Tracking lost after vehicle passed through clouds. SRB separation appeared normal.

**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: Water on ET aft dome and in SRB stiffener rings vaporized. Tracking lost shortly after roll maneuver and never reacquired.

**E-204**
72 FPS
35mm

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

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

Comments: Clouds obscured most of view. Plume recirculation very visible, but normal. Sun light reflected off of FWD RCS tiles. SRB separation appeared normal.

**E-205**
72 FPS
35mm

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

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

Comments: No data. Clouds obscured view.

**E-206**
72 FPS
35mm

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

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

Comments: No vehicle anomalies.

**E-207**
96 FPS
35mm

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

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

Comments: View of vehicle was hazy due to atmospheric conditions. RCS paper covers caused orange flashes in SSME plume. A piece of RH SRB thermal curtain tape loosened during ascent. SRB separation appeared nominal.

**E-208**
48 FPS
35mm

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

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

Comments: Plume recirculation near ET aft dome was normal. Less than usual SRB slag material was visible falling out of SRB plume. SRB separation appeared normal. Charring effects visible on ET aft dome after separation. SRB BSM scars were discernible after separation.

**E-209**
30 FPS
70mm

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

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

Comments: No data. Clouds obscured view.

**E-210**
30 FPS
70mm

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

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

Comments: Sun light reflected off of Orbiter nose during roll maneuver. Tracking lost in clouds and never reacquired.

**E-211**
96 FPS
35mm

UCS-13 IFLOT intermediate tracking of rear portion of launch vehicle from acquisition to LOV.

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

Comments: No data available due to poor film conditions.

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

Focus : Poor - hazy conditions.
F. O. V.: O.K.
Exposure: O.K.

Comments: Linear optical distortion was visible during ascent. Changes in the appearance of the local supersonic flow condensation shock wave occurred three times, probably due to cloud layers. Plume recirculation and charring on ET aft dome was typical. Fewer than usual SRB slag particles dropped out of SRB plume. SRB separation appeared normal.

**E-213** UCS-12 MOTS 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: Water on ET aft dome and in SRB stiffener rings vaporized. Residual vapors emanated from LO2 T-0 disconnect. FWD RCS paper covers were torn loose by aerodynamic forces. Changes in the appearance of the local supersonic flow condensation shock wave was probably caused by cloud layers. A large piece of LH2 umbilical purge barrier baggie material came loose (frame 93-14). A large ice particle fell from ET/ORB umbilical after baggie material fell aft. Another piece of LH2 baggie particle fell at frame 107-00. A particle aft of vehicle originated from behind Orbiter body flap (frame 146-06).

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

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

Comments: During roll maneuver, FWD RCS paper cover from F2U was torn loose and release a reddish/brown cloud of oxidizer, which flowed aft past PLB doors. Tracking lost shortly after roll maneuver, but reacquired late in flight. No details discernible.

**E-218**
96 FPS
35mm

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

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

Comments: No flashes were visible in SSME plume. Fewer than usual SRB slag particles were visible falling from SRB plume.

**E-219**
30 FPS
70mm

UCS-3 IFLOT close-in tracking of launch vehicle during ignition, liftoff, and early portion of flight through LOV.

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

Comments: Water on ET aft dome and in SRB stiffener rings vaporized. Sun light reflected off of Orbiter windows during roll maneuver. Later view very hazy.

**E-220**
96 FPS
35mm

UCS-15 IFLOT close-in tracking of rear portion of launch vehicle during ignition, liftoff, and early portion of flight through LOV.

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

Comments: During roll maneuver, FWD RCS paper cover from F2U was torn loose and released a reddish/brown vapor cloud, probably oxidizer, which moved aft past the PLB doors. After roll maneuver LH2 umbilical purge barrier baggie material came loose (frame 141-13). Changes in the appearance of the local supersonic flow condensation shock wave was probably caused by cloud layers. SRB separation appeared normal.

**E-221**
96 FPS
35mm

UCS-3 IFLOT close-in tracking of forward portion of ORB and ET during ignition, liftoff, and early portion of flight through LOV.

Comments: No data. Film did not run.

**E-222**
96 FPS
35mm

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

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

Comments: Water on ET aft dome and in SRB stiffener rings vaporized. After roll maneuver, LH2 umbilical purge barrier baggie material came loose. Changes in appearance of local supersonic flow condensation shock wave was probably caused by cloud layers. During roll maneuver FWD RCS paper cover from F2U was torn loose and released a reddish/brown vapor cloud, probably oxidizer.

**E-223**
96 FPS
35mm

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

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

Comments: Visibility was poor due to hazy conditions. Water on ET aft dome and in SRB stiffener rings vaporized. FWD RCS paper covers fell off shortly after roll maneuver. Condensation shock wave changed appearance, possibly by cloud layers.

**E-224**
100 FPS
35mm

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

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

Comments: Water on ET aft dome and in SRB stiffener rings vaporized. No vehicle anomalies.

**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, but was angled away from the frustum after separation from the forward skirt. 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**
VHS

Comments: LH2 T-0 umbilical disconnect and retraction were normal. Residual vapors emanated from the T-0 disconnect.

**OTV-103**
VHS

Comments: Disconnect and retraction of the GH2 vent line was nominal. Ice fell from the GUCP as the vehicle ascended. Water on ET aft dome vaporized shortly after liftoff.

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

Comments: Ice fell from the GUCP during SSME ignition. Vehicle twang looked normal. GUCP disconnect and retraction were normal. ET side of the disconnect showed no anomalies. Small pieces of ice fell aft - no vehicle contact.

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

Comments: Frost was visible in SW nose cone louver. No TPS or tumble valve cover anomalies were observed. Vapors exited louver after T-0. Ice particle fell from upper LO2 feedline upper bellows and was blown west past LH2 umbilical. Ice particles continued to fall from LH2 umbilical during early ascent. Water vapors were present on the ET aft dome.

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

Comments: A 3-inch icicle on the cable tray fell vertically at SSME start up. Ice also fell from the LH2 feedline bellows. Ice on outboard side of LH2 umbilical baggie fell, contacted the umbilical cavity sill, and was deflected outward. No tile damage was observed. No unusual vapors or cryogenic drips were present.

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

Comments: Orbiter wing moved slightly during SSME ignition. No vehicle anomalies.

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

Comments: SSME ignition was nominal. No vehicle anomalies.

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

Comments: SSME ignition and T-0 appeared nominal. No vehicle anomalies. Birds were not near vehicle.

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

Comments: FSS water deluge was activated properly. SSME ignition nominal. No anomalies were noted at T-0. Water vapor was visible on ET aft dome after SSME ignition. Tracking was lost soon after tower clear.

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

Comments: A small amount of ice fell from LO2 T-0. Disconnect and retraction appeared nominal. No vehicle anomalies.

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

Comments: LH2 T-0 umbilical retraction nominal. Ice from purge shroud fell at SSME ignition. Residual vapors emanated from T-0 umbilical after disconnect.

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

Comments: SSME ignition and gimbal appeared nominal. Flashes in plume were caused by RCS paper covers and pieces of ice pulled in by aspiration. The tie-wrap on LO2 TSM remained attached until SRB's cleared TSM envelope.

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

Comments: Ice particles fell from both ET/ORB umbilicals at SSME ignition, no contact or tile damage was visible. No vehicle anomalies.

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

Comments: Ice particles fell from ET/ORB umbilicals during SSME ignition. No anomalies noted with hydrogen dispersal system.

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

Comments: Ice particles fell from ET/ORB umbilicals during SSME ignition. No anomalies noted with hydrogen dispersal system.

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

Comments: GH2 vent line retracted and latched properly with no rebound. No vehicle anomalies.

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

Comments: Frost was present in southwest nosecone louver. No TPS or tumble valve cover anomalies were observed. Vapors exited louver after T-0. Ice particle fell from upper LO2 feedline upper bellows and was blown west past LH2 umbilical. Ice particles continued to fall from LH2 umbilical during early ascent. Water vapors were present on the ET aft dome.

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

Comments: Frost was present in southwest louver. No nosecone or footprint anomalies. Vehicle twang looked normal. Residual GOX vapors emanated from the louver after T-0.

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

Comments: SSME GOX vapors were blown by south winds to right side of wing. SSME ignition caused ice to shake loose from ET/ORB umbilical. Ice particles contacted lower umbilical sill and were deflected outward. No tile contact or damage was observed. No unusual vapors or cryogenic drips were present. LH2 T-0 disconnected and retracted properly. No anomalies were associated with the hydrogen dispersal system.

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

Comments: SSME ignition caused ice to shake loose from ET/ORB umbilical. Ice particles contacted lower umbilical sill and were deflected outward. No tile contact or damage was observed. No unusual vapors or cryogenic drips were present.

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

Comments: Vehicle twang was normal. No vehicle anomalies.

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

Comments: Vehicle twang was normal. No vehicle anomalies.

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

Comments: Vehicle twang was normal. No vehicle anomalies. Water on ET aft dome vaporized shortly after liftoff.

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

Comments: SSME ignition and gimbal appeared nominal. Flashes in plume were caused by RCS paper covers and pieces of ice pulled in by aspiration. The tie-wrap on LO2 TSM remained attached until SRB's cleared TSM envelope.

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

Comments: No data. Vehicle obscured by SSME plume.

**STI (C/S 2)** Infrared view from camera site 2.
VHS

Comments: No vehicle anomalies. Ignition appeared normal.

**STI (RSS)** Infrared view from RSS roof.
VHS

Comments: No vehicle anomalies. Formation of shock diamonds was visible.

**TV-3B** Views launch from UCS-9.
Color M-II

Comments: Vehicle too distant for detail. No plume anomalies.

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

Comments: SSME ignition nominal. No vehicle anomalies at T-0. Water on ET aft dome and in SRB stiffener rings vaporized during ascent.

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

Comments: No vehicle anomalies. Sunlight reflected off of window during roll maneuver. SRB separation appeared nominal.

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

Comments: SSME ignition and T-0 appeared nominal. No vehicle anomalies. Birds were not near vehicle.

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

Comments: Vehicle too distant for detail. No plume anomalies.

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

Comments: Sun reflected off of LH wing tip and forward fuselage. No vehicle anomalies. SRB separation appeared normal.

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

Comments: View was too distant for detail. No plume anomalies.

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

Comments: No data due to late acquisition and erratic tracking.

**TV-21** Views overall vehicle from the south.
Color M-II

Comments: Vehicle obscured by SSME plume and low level clouds.

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

Comments: No vehicle anomalies. Plume recirculation was normal. SRB separation appeared normal.

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

Comments: No data. View too hazy for detail.

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

Comments: Water on ET aft dome vaporized. View too hazy for detail.

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

Comments: No data, view too hazy for detail.

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

Comments: Sunlight reflected off Orbiter window during roll. Two flashes occurred during formation of shock waves. Plume recirculation was normal.

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

Comments: No vehicle anomalies.

## 6.2 ON-ORBIT FILM DATA REVIEW

Twelve frames were taken of the External Tank shortly after separation from the Orbiter. Focus, exposure, and image size were good. Field of view was predominantly centered on the -Y side of the ET.

There were no anomalies that would have affected the mission or safety-of-flight.

Six divots occurred in the LH2 tank-to-intertank flange (-Y side) closeout during ascent. Two of the divots were 12-14 inches in diameter, three were 6-8 inches in diameter, and one was 4 inches in diameter. Two of the divots were in the -Y+Z quadrant.

The BSM burn scar on the LO2 tank was typical. The bright spot near the LO2 tank-to-intertank flange is the RSS antenna. Bright spots in the area of the forward ET/SRB attach point is sunlight reflected off metal parts of the fitting and adjacent sanded areas of TPS. No anomalies were visible on the flight door and the GUCP.

There were no significant acreage TPS anomalies. Bright spots near the aft hardpoint consisted of the cryogenic witness panel closeout and four circular sanded (TPS thickness verification) areas. Three bright spots on the LO2 tank acreage were also present prior to launch and were previously repaired areas. The intertank TPS repair on the Orbiter side of the -Y ET/SRB forward attach point was intact.

## 6.3 LANDING FILM AND VIDEO REVIEW

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

Focus : O.K.
F. O. V.: O.K.,Close-in view, but focus is very soft
Exposure: O.K.

Comments: Landing gear extension, touchdown, and rollout appeared normal. No significant tile damage was visible. SSME #3 closeout blanket was frayed.

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

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

Comments: Gear already deployed when film began. Near simultaneous touchdown of MLG. Nose gear touchdown appeared normal. No orbiter anomalies.

**E-1006** Orbiter landing at Ames-Dryden Flight Research
16mm Facility

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

Comments: Landing gear extension was normal. Near simultaneous touchdown of MLG. Nose gear touchdown appeared normal. No orbiter anomalies.

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

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

Comments: Too distant for detail. No anomalies.

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

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

Comments: Too distant for detail. Touchdown obscurred by sun glare.

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

Focus : OK, but film was severely scratched
F. O. V.: OK
Exposure: OK

Comments: Too distant for detail. Touchdown obscurred by sun glare.

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

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

Comments: Touchdown and rollout appeared normal.

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

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

Comments: Landing gear extension was normal. Near simultaneous touchdown of MLG. Nose gear touchdown appeared normal. Damage occured to RH MLG door corner tile when doors opened. Frayed SSME blankets were visible during rollout.

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

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

Comments: No Orbiter anomalies.

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

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

Comments: No Orbiter anomalies.

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

Comments: Touchdown and rollout appeared nominal. Opening of the ET doors was obscured by the convoy.

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

Comments: Touchdown and rollout appeared nominal. A shiny object tumbled to the runway when the LH2 umbilical ET door was opened 30 degrees.

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

Comments: Too distant for detail during touchdown, but no vehicle anomalies were visible during rollout. A shiny object tumbled to the runway when the LH2 umbilical ET door was opened 30 degrees (best view).

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

Comments: View was too distant for detail.

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

Comments: Normal nose-up attitude during flare. Touchdown was obscured by buildings. No vehicle anomalies during rollout. No debris was visible falling from open ET doors.

| | |
|---|---|
| **NASA SELECT** M-II Video | Orbiter landing at Ames-Dryden Flight Research Facility |

Comments: Deployment of landing gear was nominal. No unusual flight control surface movements. RH main landing gear appeared to contact runway slightly ahead of LH MLG. Nose gear touchdown was normal. No TPS anomalies were visible. LH2 ET/ORB umbilical lightning protection contact tumbled onto runway when the ET doors opened.

## 7.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 7 April 1991 from 0930 to 1200 hours. In general, the SRB's appeared to be in good condition.

## 7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nosecap was not recovered. The RH frustum had no areas of missing TPS but had 26 MSA-2 debonds over fasteners (Figure 5). All four BSM covers were in the open position, but had been bent by parachute riser entanglement.

The RH forward skirt exhibited no debonds or missing TPS. Minor blistering of the Hypalon paint occurred forward of the attach point (Figure 6). 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.

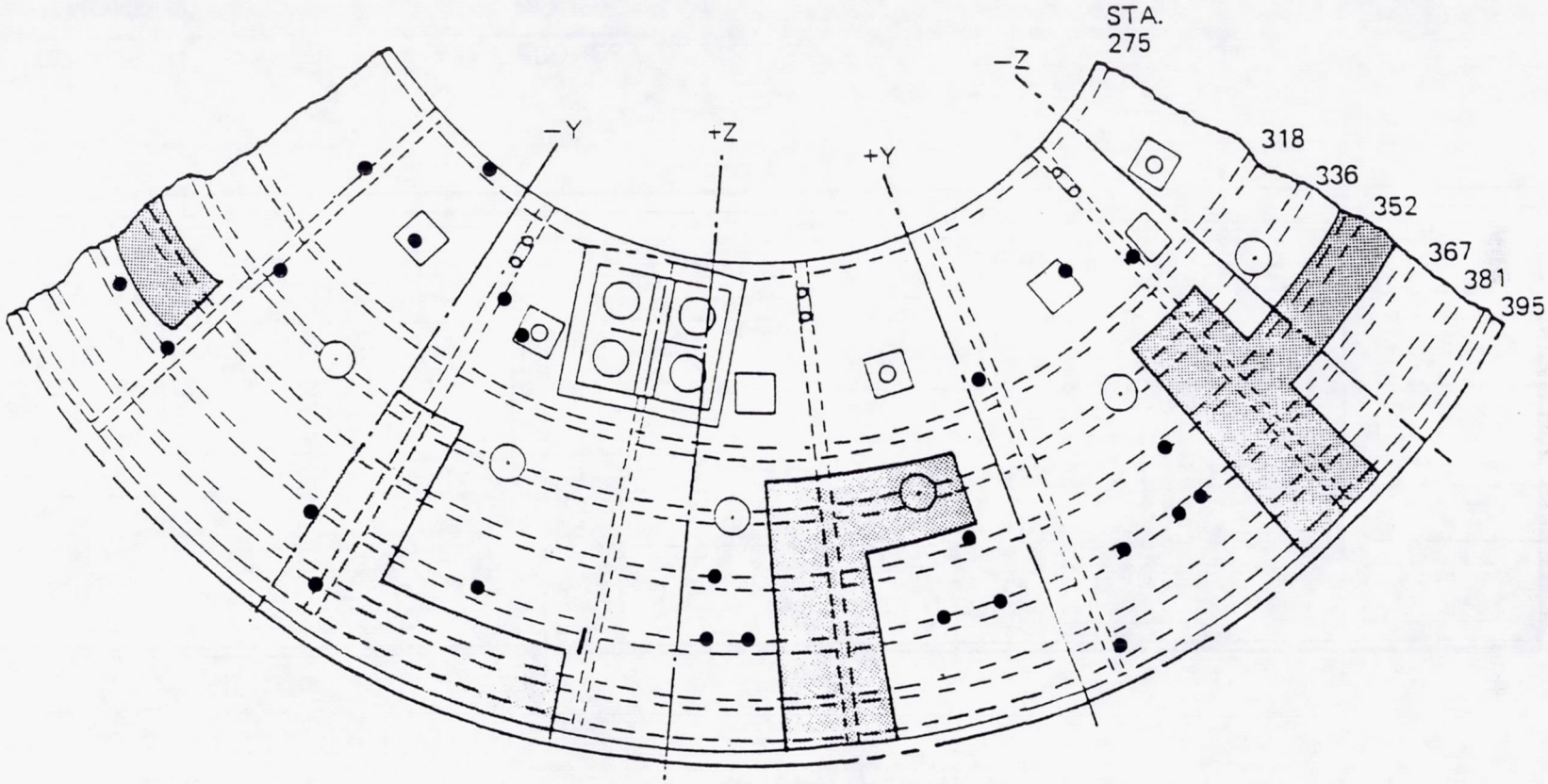
The Field Joint Protection System (FJPS) closeouts were generally in good condition. A 4-inch long crack occurred in the RH forward field joint K5NA at 310 degrees. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris hits from nozzle extension severance.

Separation of the aft ET/SRB struts appeared nominal. The ET/SRB aft struts, ETA ring, and IEA appeared undamaged. A 10-inch diameter by 1.5-inch deep divot occurred in the foam on the forward face of the ETA ring at 50 degrees. The underlying foam was not charred and did not occur during ascent. The center and aft stiffener rings/K5NA closeouts were cracked by water impact.

The phenolic material on the kick ring delaminated in some locations. One of the K5NA protective domes was lost from the aft side of the phenolic kick ring prior to water impact. The aft skirt TPS acreage was in good condition with localized blistering of the Hypalon paint (Figure 7). K5NA was missing from all four aft BSM nozzles. Instafoam was missing from the aft ring around the aft skirt feet, HPU exhaust horns, and the SRB T-0 umbilical.

All four Debris Containment System (DCS) plungers were seated properly. Approximately 10 inches of pyrotechnic cable was still attached to HDP #1. A 10"x1.5" piece of EPON shim material was missing from HDP #4 prior to water impact.

FIGURE 5. RIGHT SRB FRUSTUM




MISSING TPS

NONE

DEBONDS

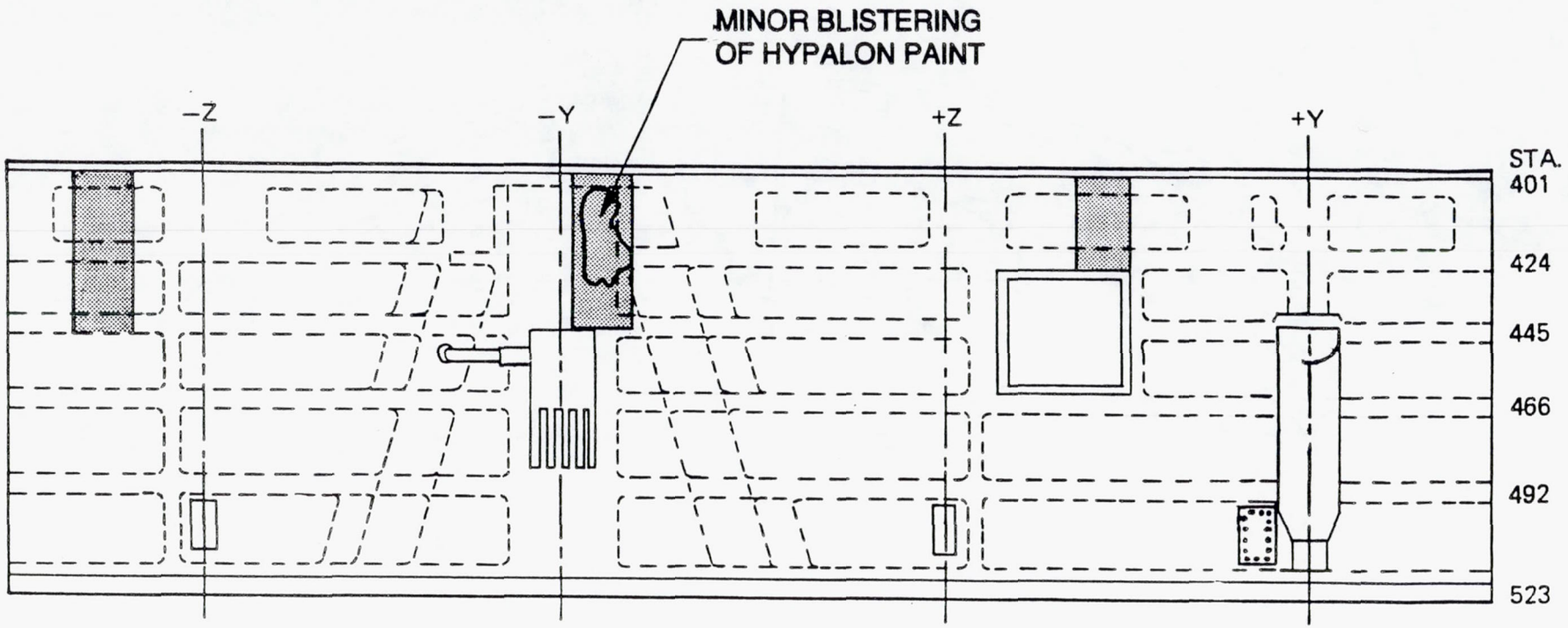
- 26 MSA-2 DEBONDS OVER FASTENERS

EGG/V-326



C-2

FIGURE 6. **RIGHT SRB FWD SKIRT**



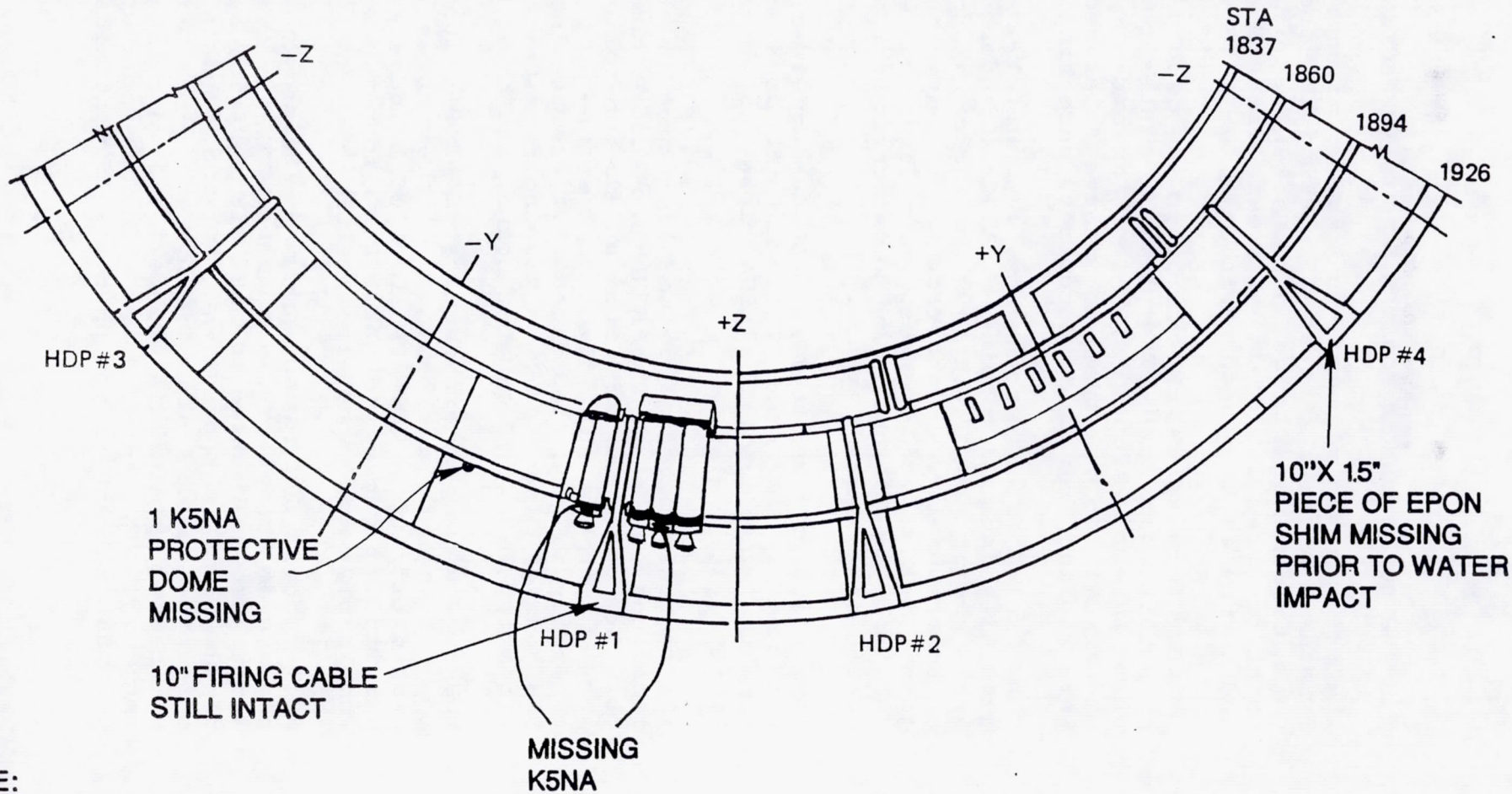

TPS MISSING

NONE

DEBONDS

NONE

FIGURE 7. **RIGHT SRB AFT SKIRT EXTERIOR TPS**




NOTE:
ALL FOUR DCS PLUNGERS
WERE SEATED

## 7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nosecap was recovered and showed no unusual damage. The LH frustum exhibited 2 areas of missing TPS and 41 MSA-2 debonds over fasteners (Figure 8). Minor blistering of the Hypalon paint occurred in localized areas. The BSM covers were intact and in the fully opened position.

The LH forward skirt exhibited no debonds (see note about structural buckling). The phenolic plates on both RSS antennae were intact (Figure 9). 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 generally in good condition. A 12-inch debond occurred in the aft edge of the LH aft center factory joint adjacent to the systems tunnel. A 1-inch crack occurred in the LH forward field joint K5NA at 315 degrees. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris hits from nozzle extension severance.

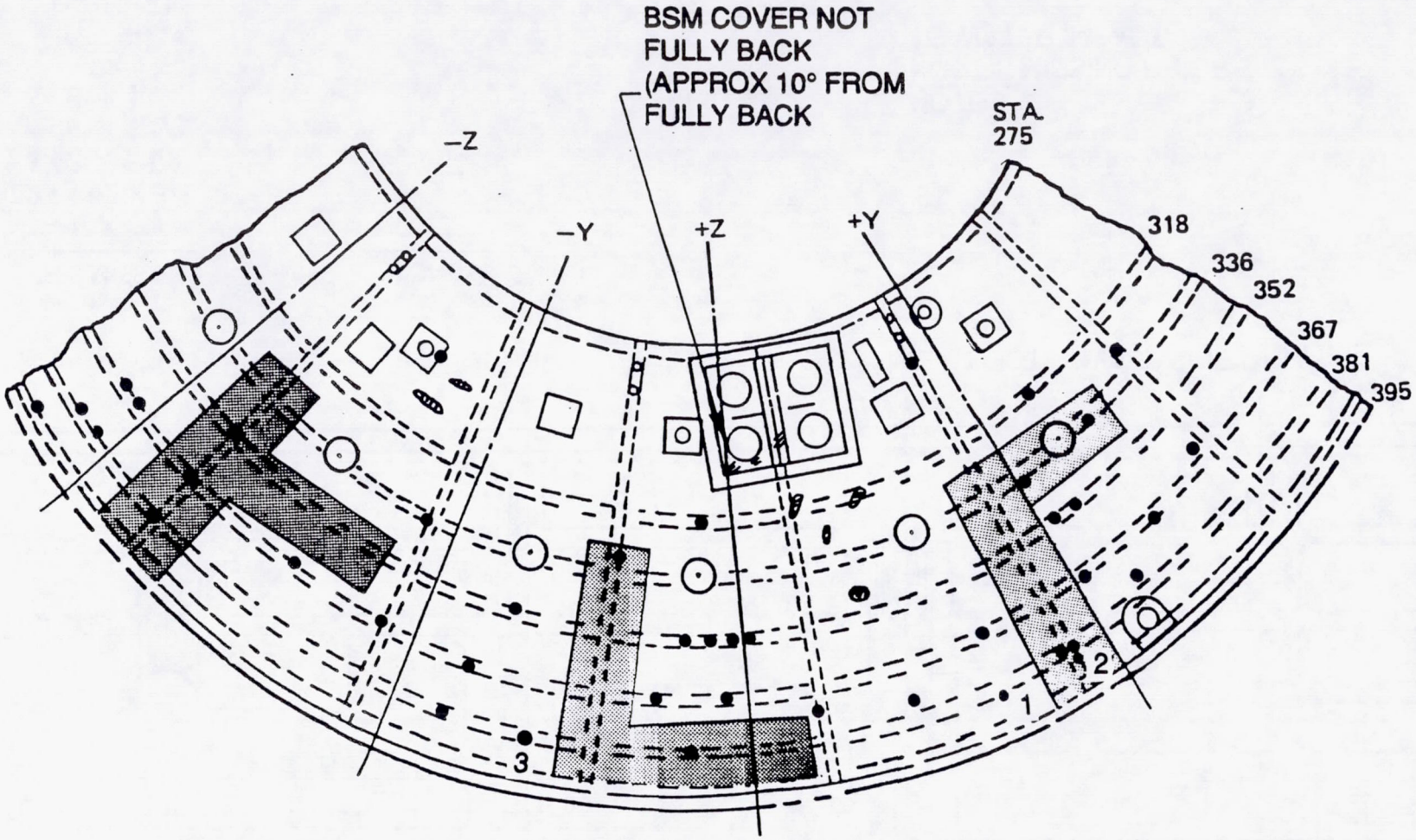
Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and aft booster stiffener rings appeared undamaged. The K5NA closeouts on the IEA covers were intact.

The phenolic material on the kick ring delaminated in several locations. None of the K5NA protective domes were lost from bolt heads on the aft side of the phenolic kick ring during ascent (Figure 10). The TPS over the aft skirt acreage was generally in good condition. K5NA was missing from all four aft BSM nozzles. Instafoam was missing from the aft ring around the aft skirt feet, HPU exhaust horns, and the SRB T-0 umbilical.

HDP #6 Debris Containment System (DCS) plunger was obstructed by a frangible nut half. The other three DCS plungers were seated properly. A 4"x1" piece of holddown post sidewall shim was still attached to the HDP #6 foot. Sidewall shim material should remain attached to the HDP #6 shoe.

NOTE: The LH SRB forward skirt sustained damage in the area of the system tunnel. TPS (K5NA and MSA) was cracked and the metal substrate was buckled on both sides of the systems tunnel. Some of the Hypalon topcoat was missing. Initial assessment indicates the forward skirt damage was not a source of debris nor was caused by a debris problem. The most likely causes, according to MSFC, were unusual loads induced by water impact 'slapdown' loads or parachute deployment side loads.

FIGURE 8. **LEFT SRB FRUSTUM**




MISSING TPS

1 - 3/16 X 3/8
2 - 3/8 X 5/8
3 - 1 X 1 1/4 (HANDLING DIVOT)

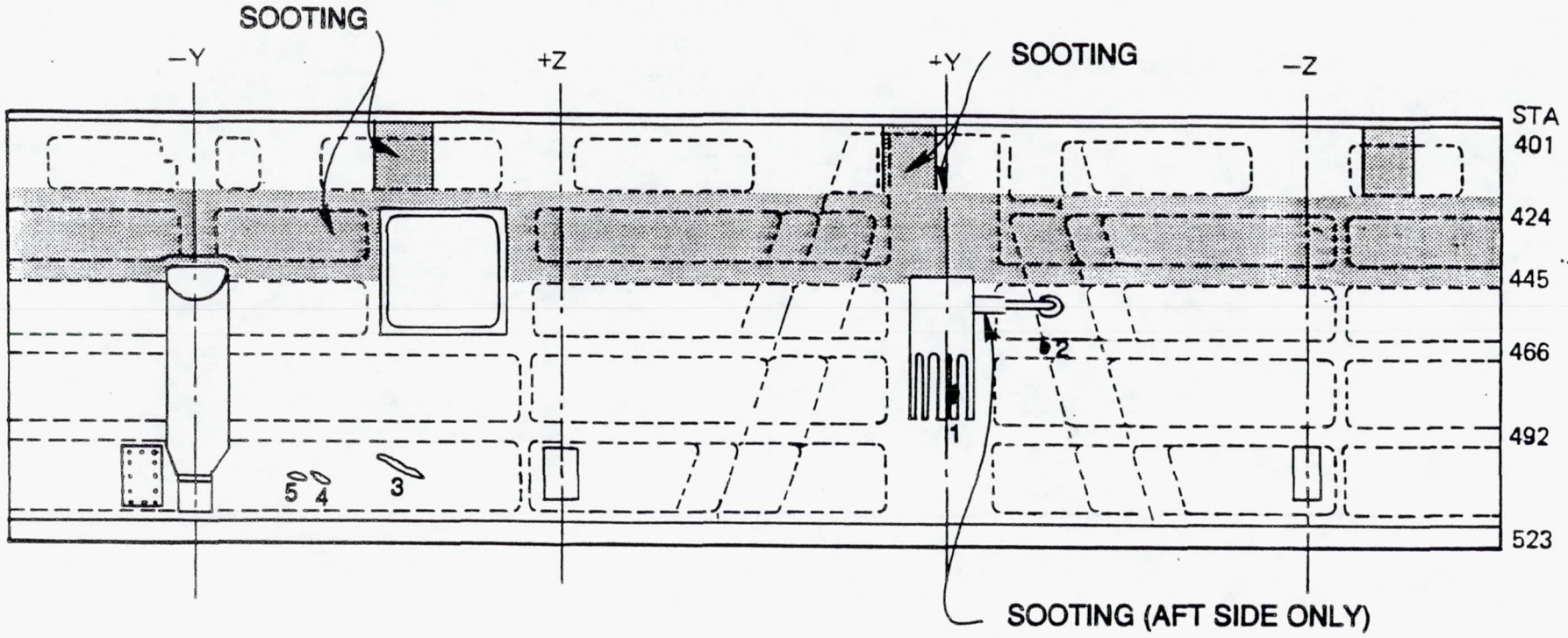
DEBONDS

- 41 MSA-2 DEBONDS OVER FASTENERS

PAINT BLISTER

EGG/V-326E

FIGURE 9. **LEFT SRB FWD SKIRT**

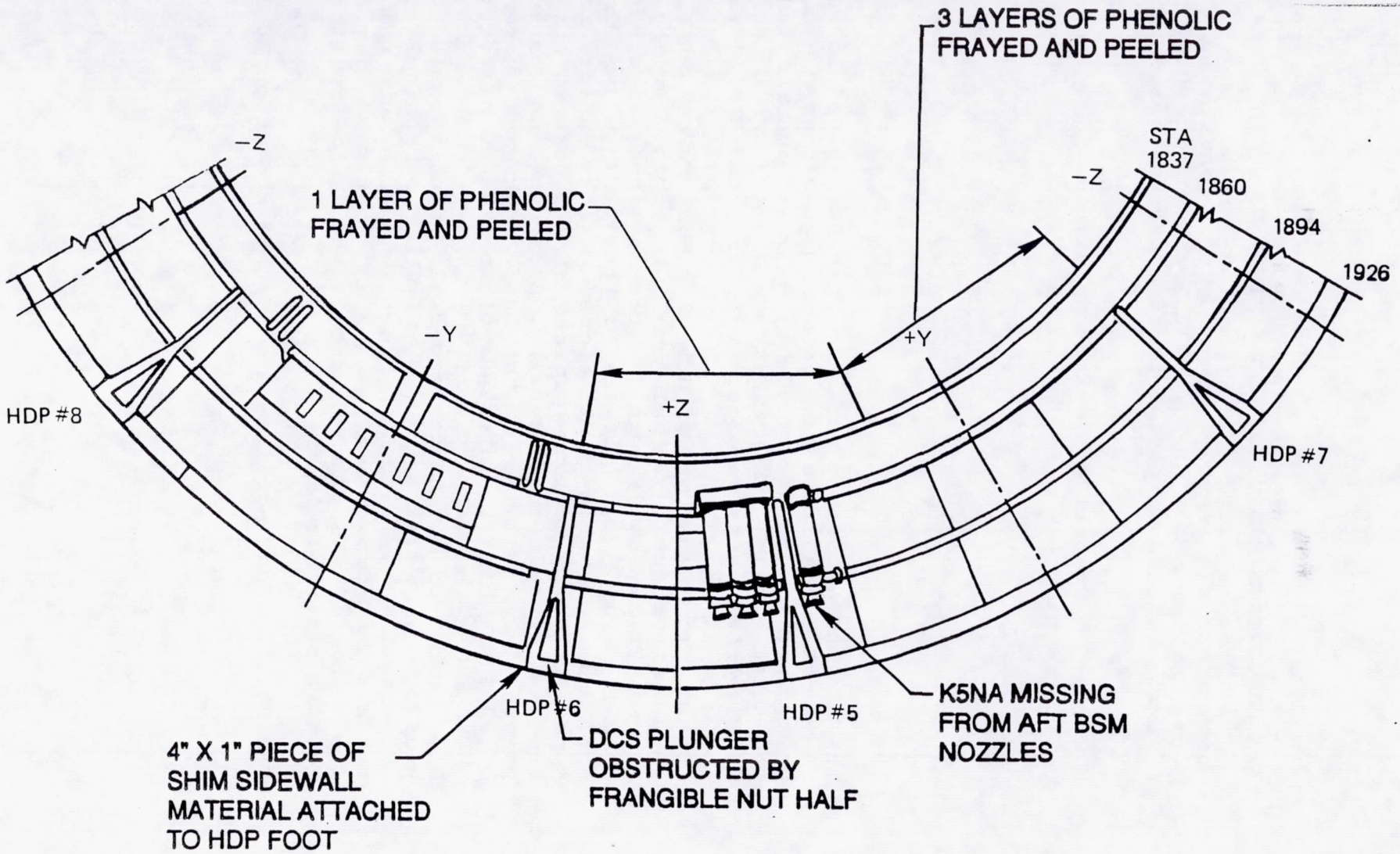



| TPS MISSING | DEBONDS |
|---|---|
| 1 - 1" X 5" | NONE |
| 2 - 11/2 X 5/8 | |
| 3 - 2' X 1 1/2 | |
| 4 - 6" X 1 1/2 | |
| 5 - 6" X 1 1/2 | |

NOTE: Missing TPS was attributed to the buckling damage and water impact.

**NOTES:**
**NO TPS MISSING PRIOR TO WATER IMPACT**

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

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## 7.3 RECOVERED SRB DISASSEMBLY FINDINGS

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 96% and individual holddown post retention percentages as listed:

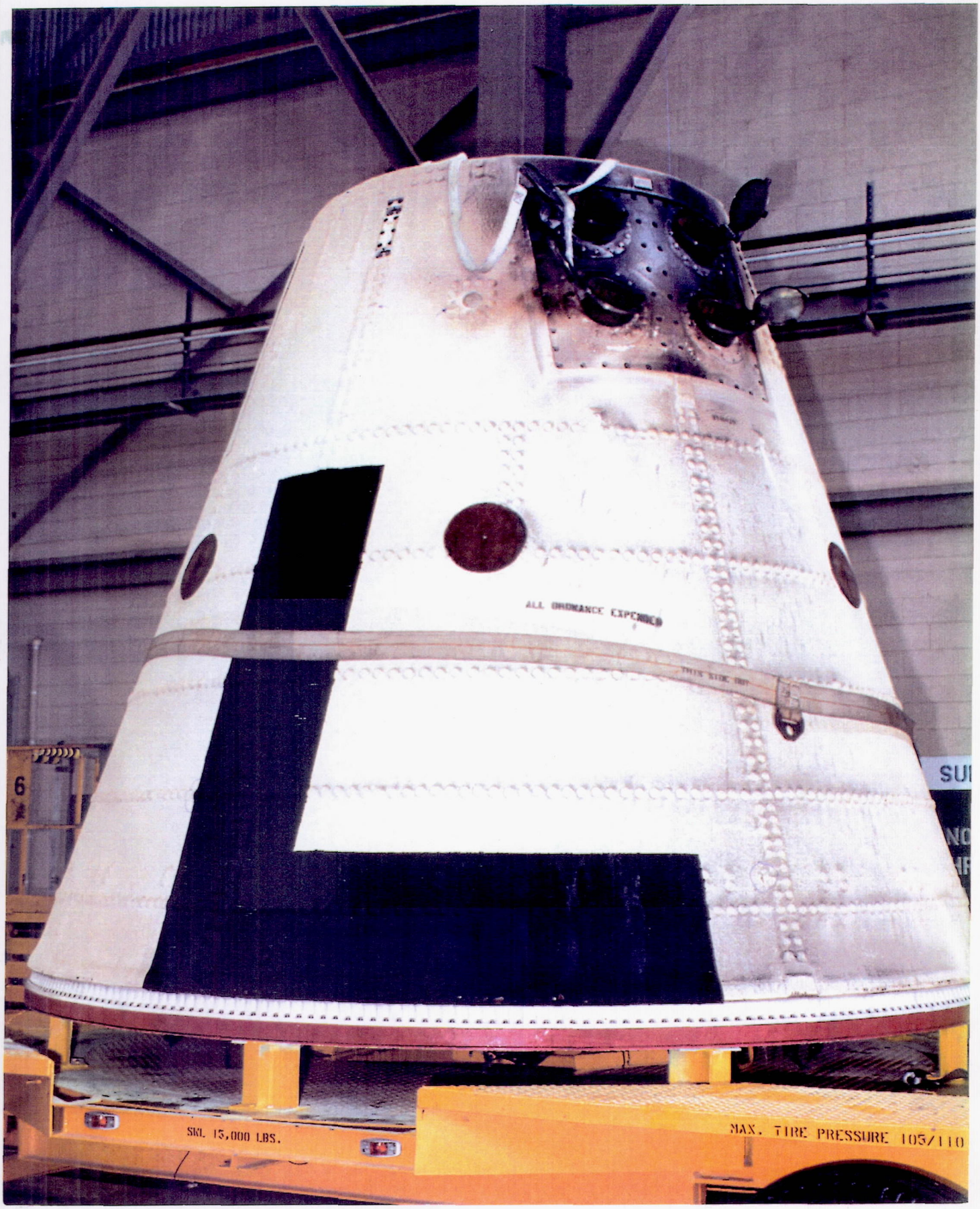
| HDP # | Overall % | % of Nut without 2 large halves | % of Ordnance |
|---|---|---|---|
| 1 | 100 | 100 | 98.1 |
| 2 | 100 | 100 | 94.4 |
| 3 | 100 | 100 | 94.4 |
| 4 | 100 | 100 | 98.1 |
| 5 | 100 | 100 | 98.1 |
| 6 | 60.6 | 61.2 | 59.3 |
| 7 | 100 | 100 | 96.3 |
| 8 | 100 | 100 | 96.3 |

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 #6. A frangible nut half had prevented the DCS plunger from seating properly. Small pieces of ordnance debris were recovered from the HDP #6 sandbox.

Further examination of the LH FWD skirt buckling damage revealed circumferential wrinkles approximately 10 feet in length. The wrinkles were located on either side of the systems tunnel about 2 feet forward of the field joint. Cracks in the K5NA and MSA showed no signs of sooting or charring. No apparent damage occurred to the ET/SRB forward attach fitting, frustum, frustum ordnance ring, parachute, and parachute attach points. Bump recorder in the LH SRB recorded a slap down load of 92 G's, which is in excess of the 12-40G history.

Disassembly of the LH forward field joint revealed both forward and forward center segments had flat spots displaced inward by approximately 1/2-inch at the 0 degree location and displaced outward by approximately 1/2-inch at the 45 degree location. The cause of the damage is believed to be related to the LH forward skirt buckling.

SRB Post Launch Anomalies are listed in Section 10.3.




Post flight condition of the RH SRB frustum. There were 26 MSA-2 debonds over fasteners, but no missing material. BSM covers were bent by entanglement with the parachute risers.



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MSA-2 debonds have typically occurred over frustum fasteners. Loss of Hypalon paint with layers of MSA attached can damage tiles during ascent.



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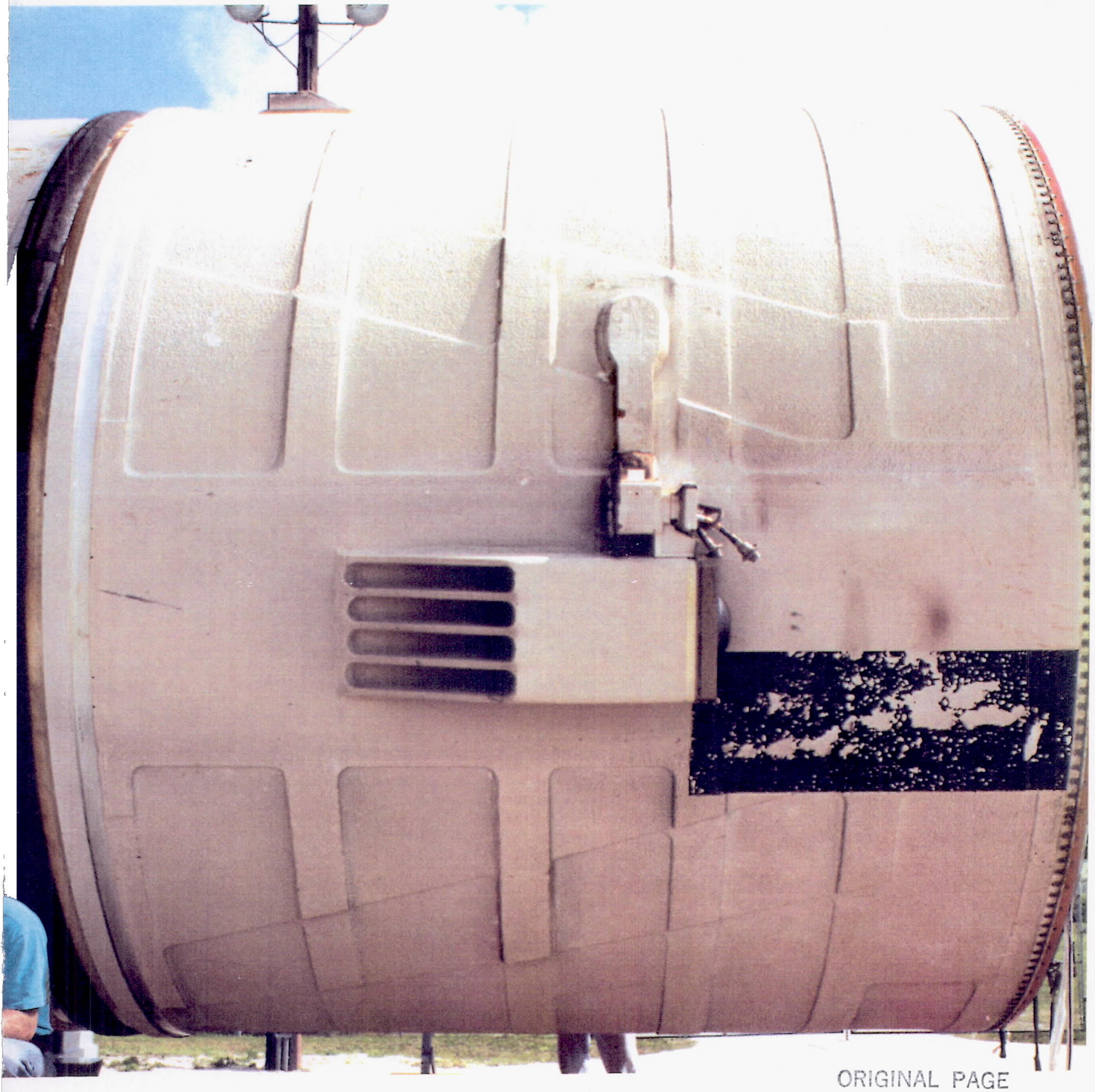

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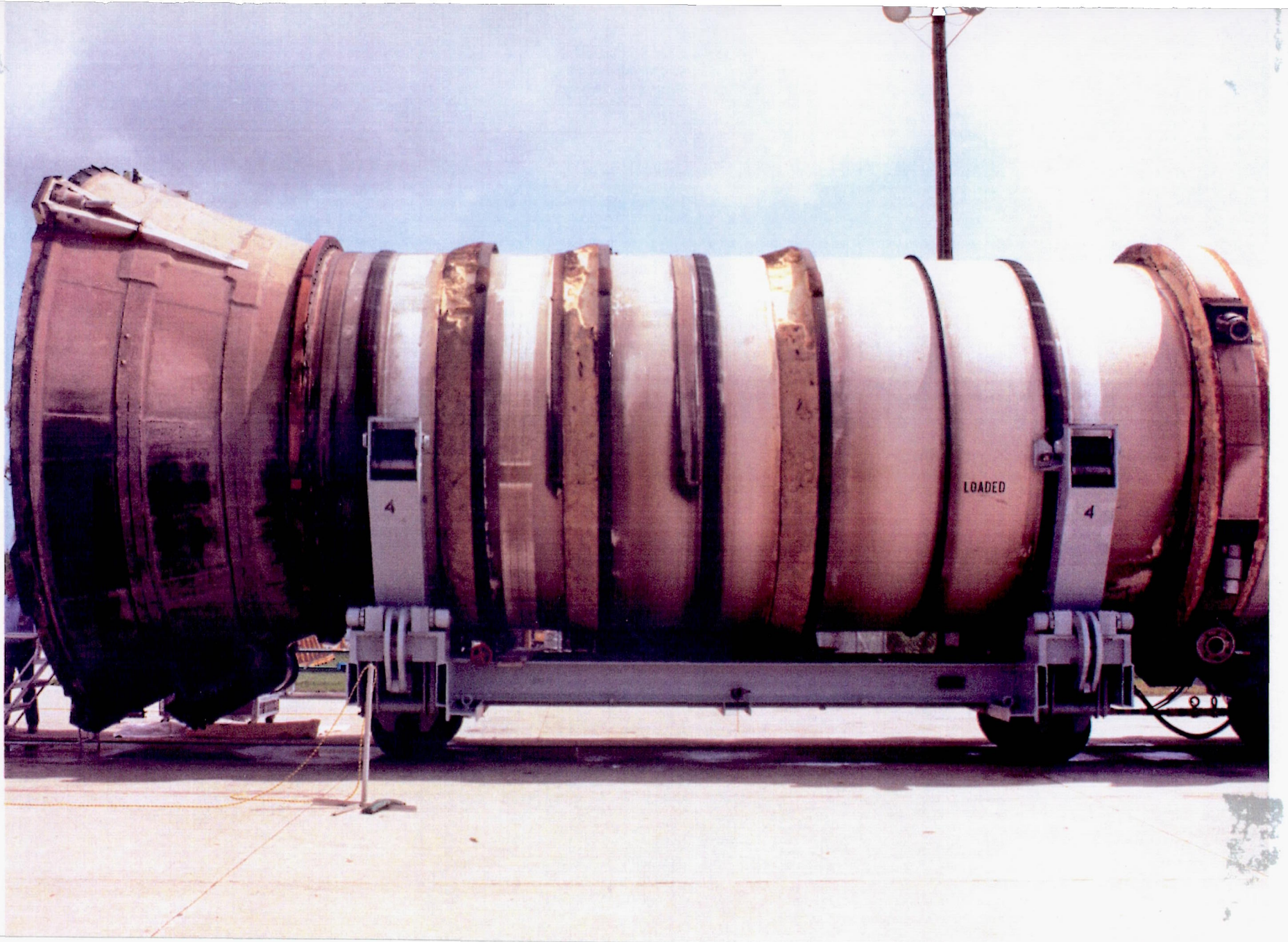
Post flight condition of the RH forward skirt. There were no debonds or missing TPS. Localized blistering of the Hypalon paint occurred forward of the ET/SRB attach fitting.




Post flight condition of the RH aft booster/aft skirt. The ET/SRB aft struts, ETA ring, and IEA appeared undamaged.

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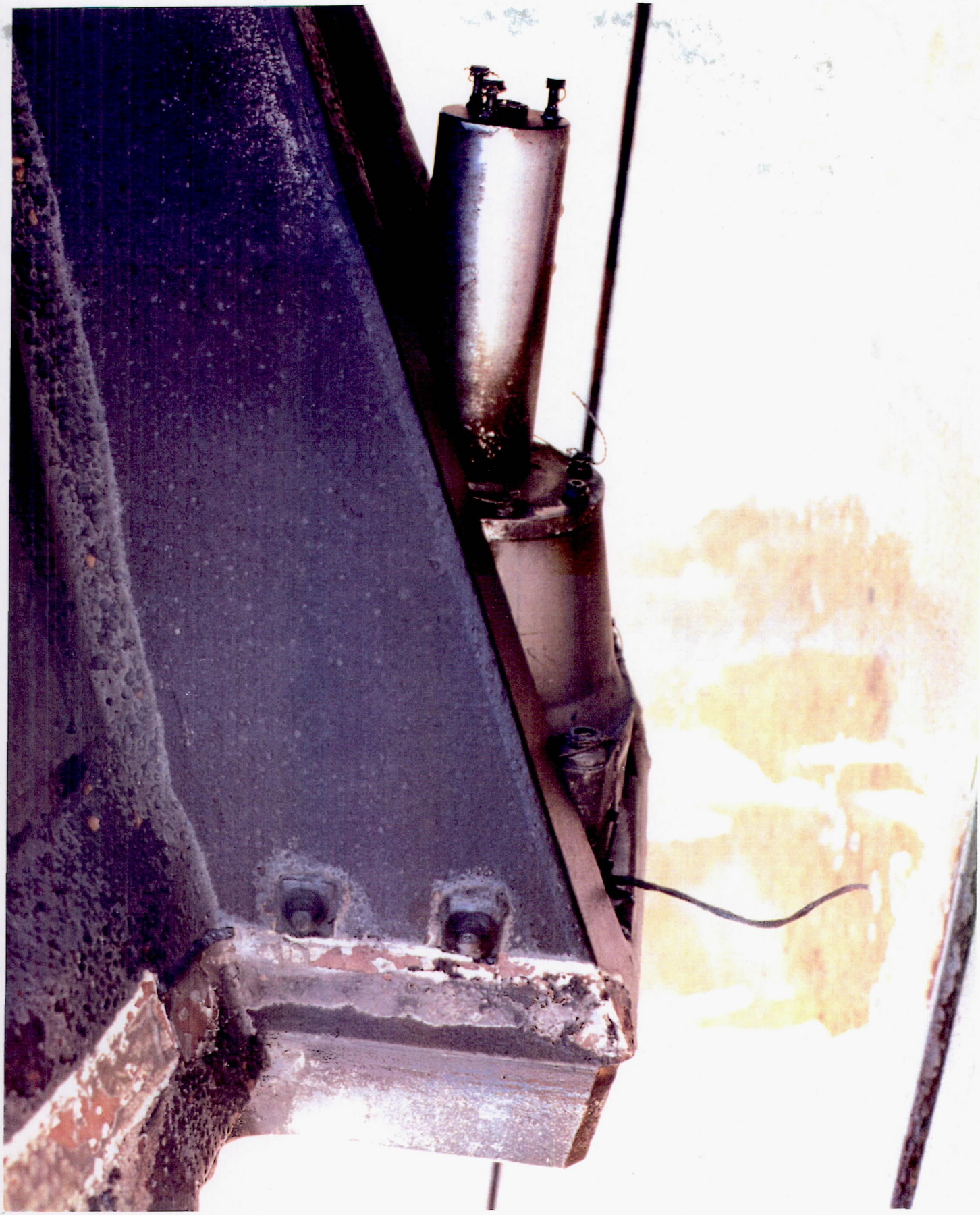

Approximately 10 inches of pyrotechnic cable was still attached to the HDP #1 DCS. Three to four feet of the cable had flown with the vehicle at liftoff.



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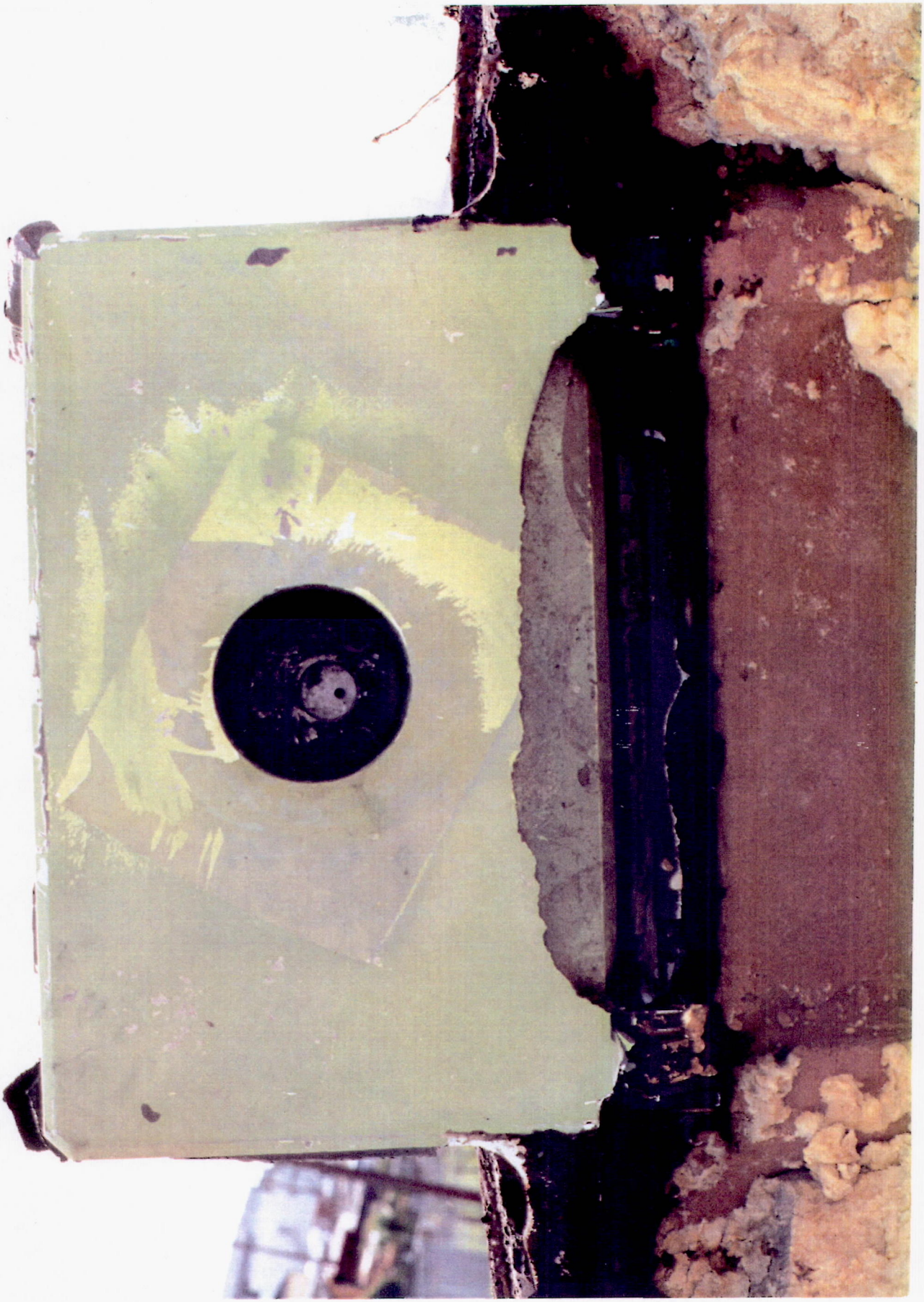

The HDP #4 DCS plunger was properly seated. A 10"x1.5" piece of EPON shim material was missing prior to water impact.



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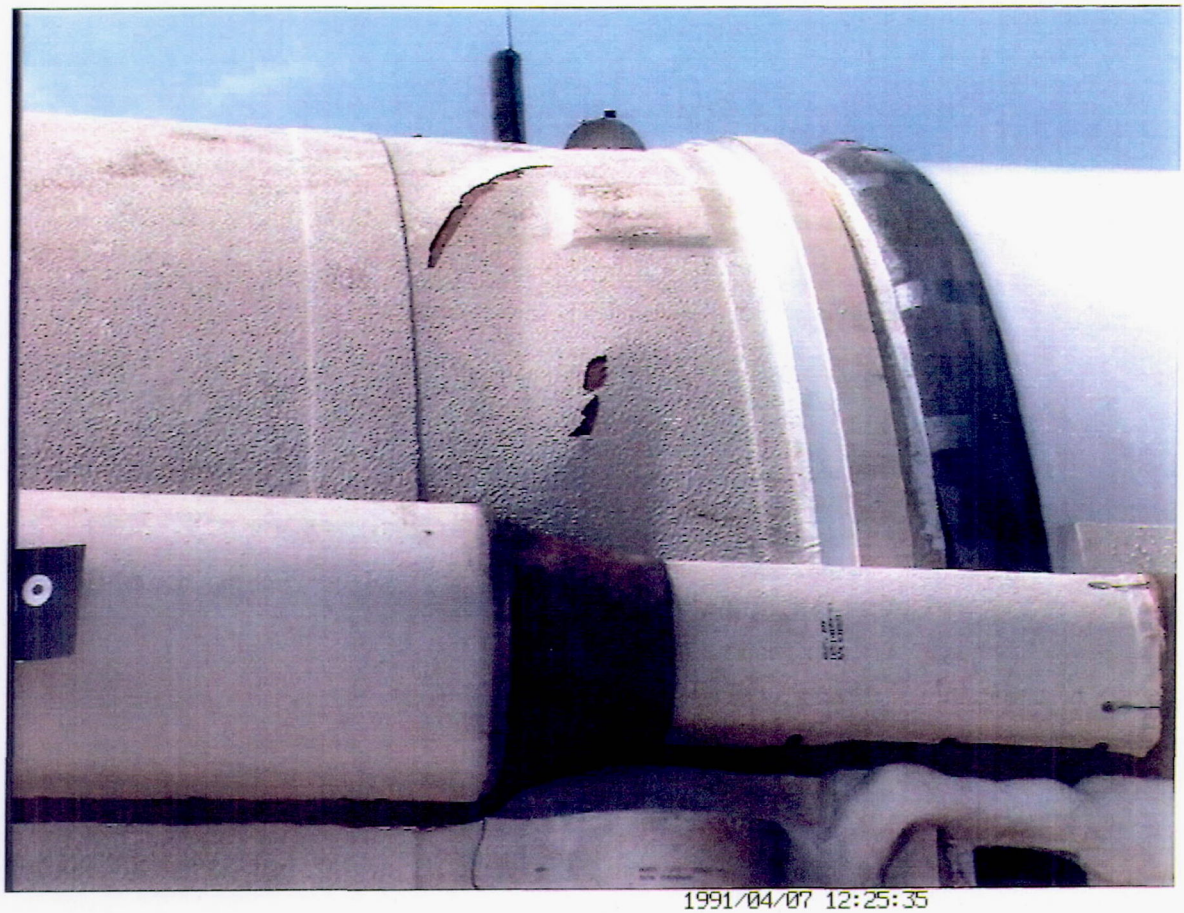
All BSM covers on the LH SRB frustum were fully opened and locked



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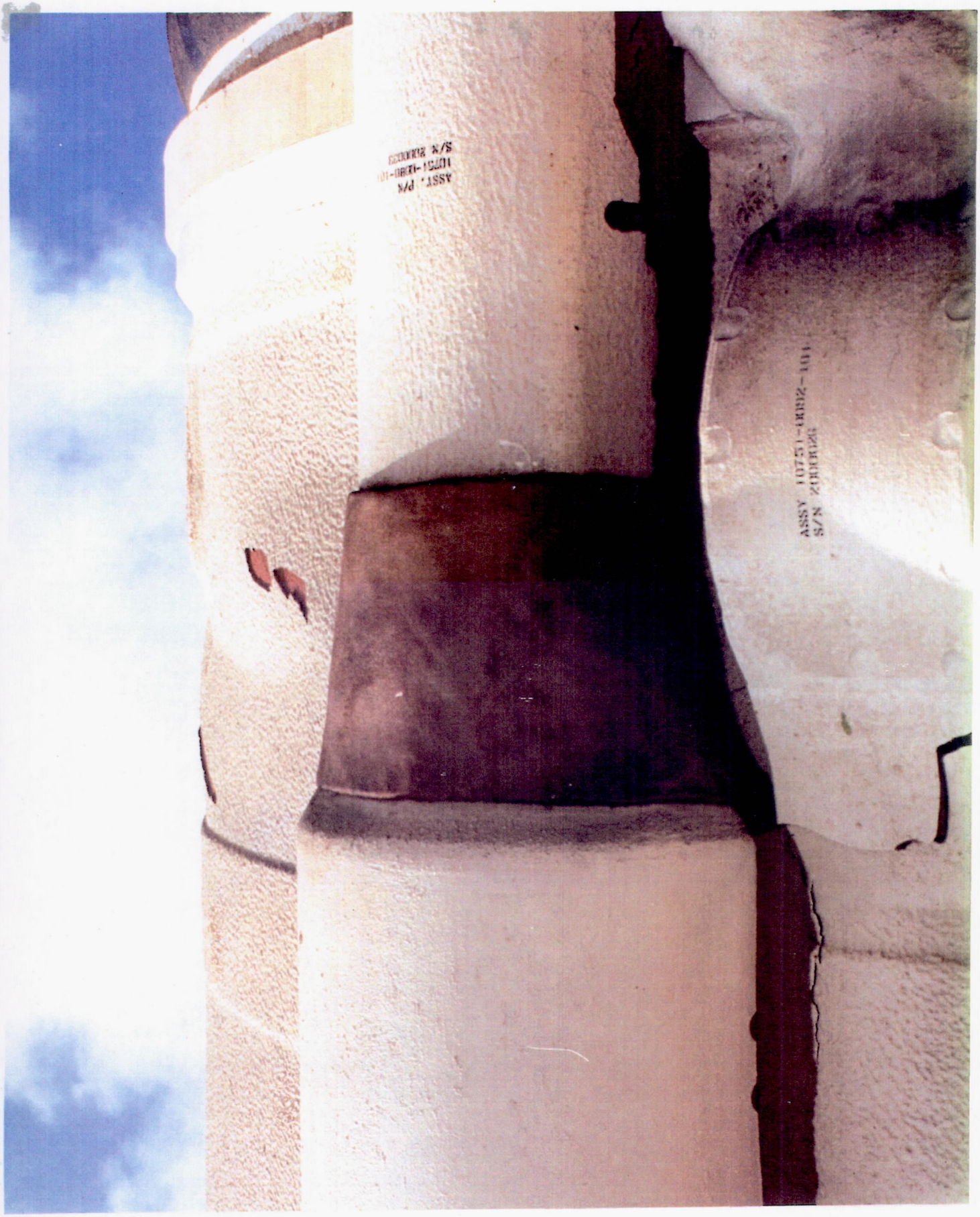
The LH SRB FWD skirt sustained buckling damage (circumferential wrinkles) approximately 2 feet forward of the field joint. Initial assessment indicated the damage was not a source of debris nor was caused by a debris problem.




Cracks in the K5NA and MSA showed no signs of sooting or charring. The most likely causes of the damage are unusual loads induced by water impact 'slapdown' or parachute deployment side loads.



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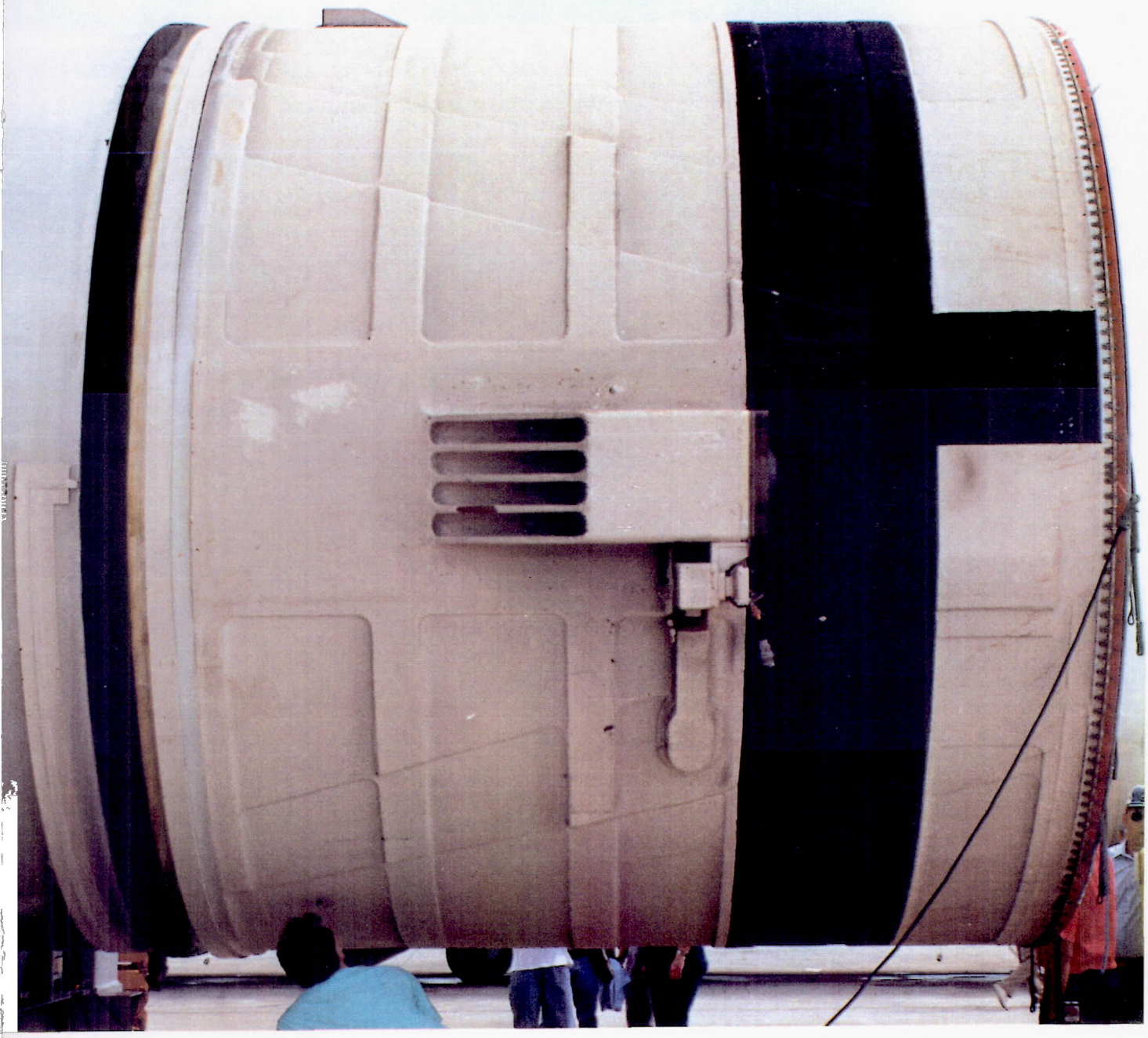

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Post launch condition of the LH FWD skirt. There were no TPS debonds, areas of missing TPS, or other damage on the ET side of the FWD skirt (opposite side of the buckling damage).

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Overall post flight view of the LH SRB cases. Factory and field joint closeouts were generally in good condition.

A 12-inch debond occurred along the aft edge of the LH aft center factory joint adjacent to the systems tunnel



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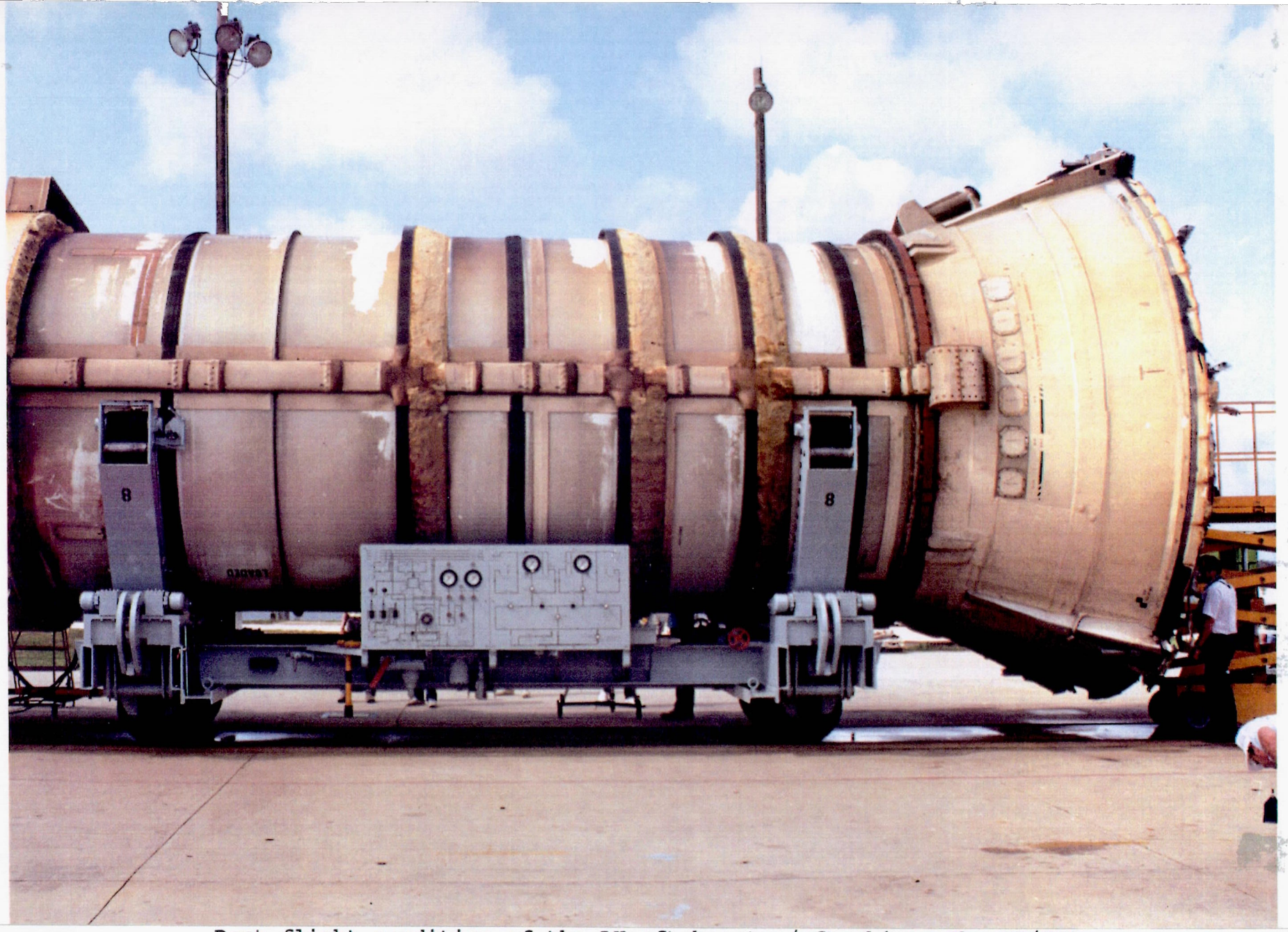

Post flight condition of the LH aft booster/aft skirt. The ET/SRB aft struts, ETA ring, IEA, and aft booster stiffener rings appeared undamaged.



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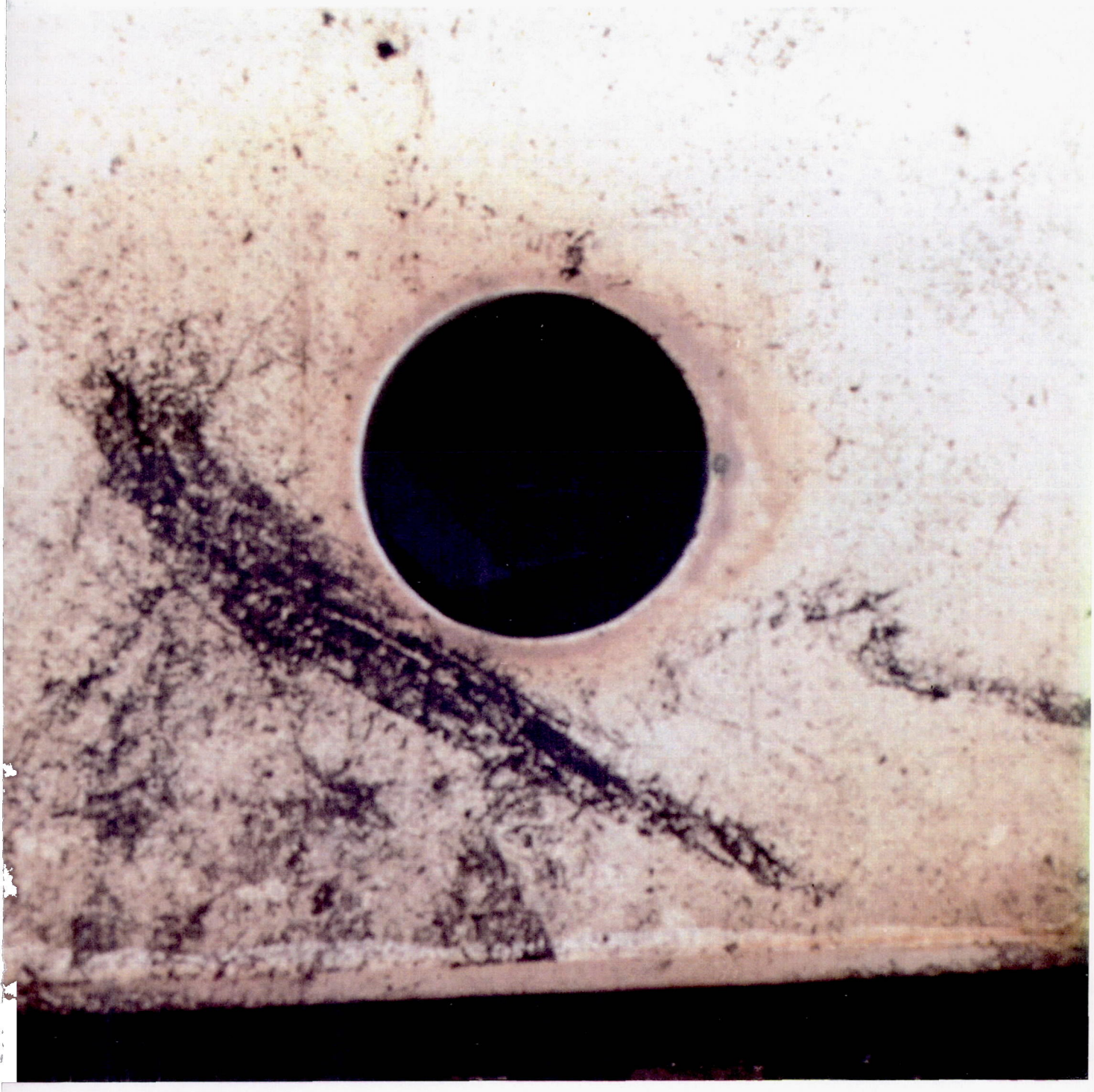

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The HDP #6 Debris Containment System (DCS) plunger was obstructed by a frangible nut half

## 8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A detailed post landing inspection of OV-104 was conducted on April 11 and 12, 1991 at Ames-Dryden (EAFB) on Runway 33 and in the Mate/Demate Device (MDD) to identify debris impact damage, and if possible, debris sources. The Orbiter TPS sustained a total of 113 hits, of which 10 had a major dimension of one inch or greater. This total does not include the approximately 100 hits on the base heat shield.

The Orbiter lower surface had a total of 91 hits of which 7 had a major dimension of one inch or greater. A comparison of these numbers to statistics from 25 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 greater than average, but the number of hits with a major dimension of 1" or larger was less than average. Figures 11-14 show the TPS debris damage assessment for STS-37. Figure 15 indicates the sites where samples were taken for laboratory chemical analysis.

A cluster of 12 hits (with none larger than one inch) occurred just aft of the LH2 ET/Orbiter Umbilical opening. Similar clusters of hits have been observed in this area on previous flights and are attributed to ice/debris impacts during ET separation and/or damage from purge barrier baggie and ice during ascent. A cluster of 8 hits (1 larger than one inch) was observed just forward of the LO2 ET/Orbiter umbilical opening. This cluster may also be attributable to ice/debris impacts during ET separation.

All ET/Orbiter separation ordnance device plungers appeared to have functioned properly. The stop bolts on the EO-1 separation assembly device did not sustain any damage/bending.

A lightning protection contact, part number V527-415110-004, fell onto the runway when the LH2 ET/Orbiter umbilical door was opened. This contact, which is approximately 17.5" long by 2.5" wide, is normally bonded to the ET half of the LH2 umbilical and should have stayed with the ET after separation. The condition was documented on PR MPS-4-09-0759. Subsequent laboratory analysis (Report Number 284-202-91-031) revealed adhesive failure with very little adhesive present on the inner surface (bonding side of the part to the umbilical). There was no evidence of foam material or contaminants. The polyurethane adhesive had been poorly cured. The cause of the bonding problem is unknown, but the use of self tapping screws to secure the lightning contact is under review. The new 14 inch disconnects were designed with fastened lightning protection contacts.

No TPS damage was attributed to material from the wheels, tires, or brakes. The main landing gear tires were considered to be in good condition for a lakebed landing. All main gear tires exhibited cuts that were attributed to rocks in or on the runway. The left outboard main gear tire was removed and replaced due to a cut that was out of specification.

Damage to the base heat shield tiles was less than average (approximately 100 sites). However, the edge of one tile, approximately 5"x2"x1.5", was missing between SSME #2 and #3. The main engine #3 closeout blanket had an area of peeled and frayed material from 7:00 to 9:00 o'clock, the main engine #1 blanket had minor fraying at 5:00 o'clock, and the main engine #2 blanket had no apparent damage.

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

The forward end of a piece of plume shield thermal barrier, approximately 2" long, was frayed and protruding between two of the forward RH RCS thrusters.

A larger than usual quantity of white streaks were present on the RH wing leading edge RCC panels #5 through #17. The largest streak, on panel #8, was approximately 24" long by 4" wide. Only a few very small white streaks were present on the LH wing RCC panels. Samples of selected streaks were taken for laboratory analysis (reference Figure 15).

Orbiter windows #3 and #4 were moderately hazed with a few small streaks. Windows #2 and #5 were lightly hazed. Laboratory analysis will be performed on samples taken from all windows.

The KSC Shuttle Thermal Imager (STI) was used to measure the surface temperatures of several areas. Twenty-seven minutes after landing the Orbiter nosecap RCC was 101 degrees F and both the RH wing leading edge RCC panels #9 and #17 were 65 degrees F (reference Figure 16). These temperatures were lower than usual due to the low ambient temperature and high winds.

Runway 33 was inspected by the Debris Team on April 10, 1991, and potentially damaging debris removed. Runway 22 was inspected and swept by Air Force personnel. Both runways were found to be in acceptable condition.

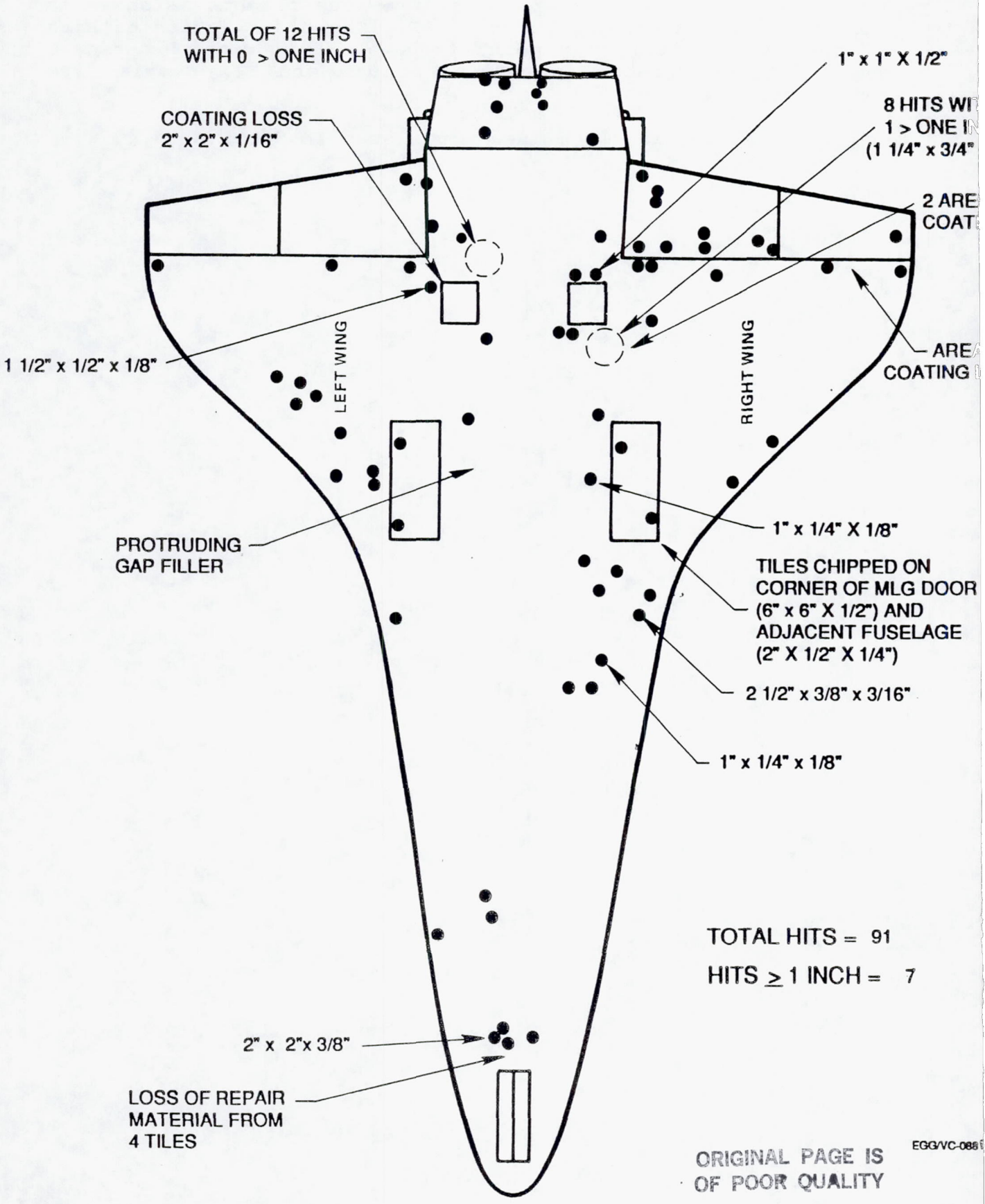
The post landing inspection of Runway 33 was performed approximately 1/2 hour after landing. The only flight hardware found were several pieces of the broken tile from the RH main landing gear door. This corner tile was broken during gear extension/door opening - a common occurrence.

In summary, although the total number of Orbiter TPS debris hits was average, the number of hits larger than one inch was less than average when compared to previous flights as shown in the comparison charts (Figures 17-19). The distribution of hits on the Orbiter does not point to a single source for ascent debris, but indicates a shedding of ice and TPS debris from random sources.

Orbiter Post Landing Anomalies are listed in Section 10.4.

## STS-37

FIGURE 11. **DEBRIS DAMAGE LOCATIONS**

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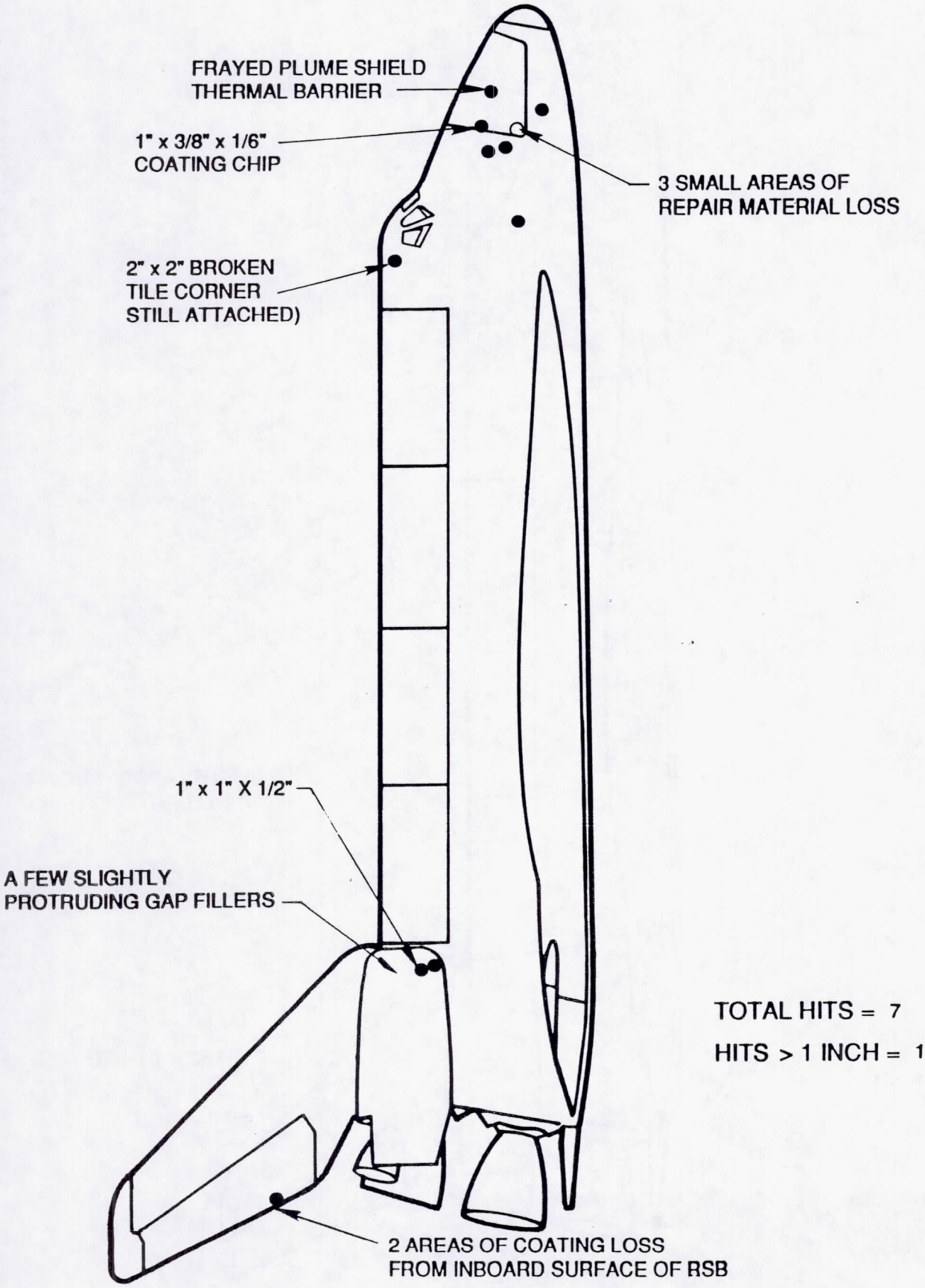
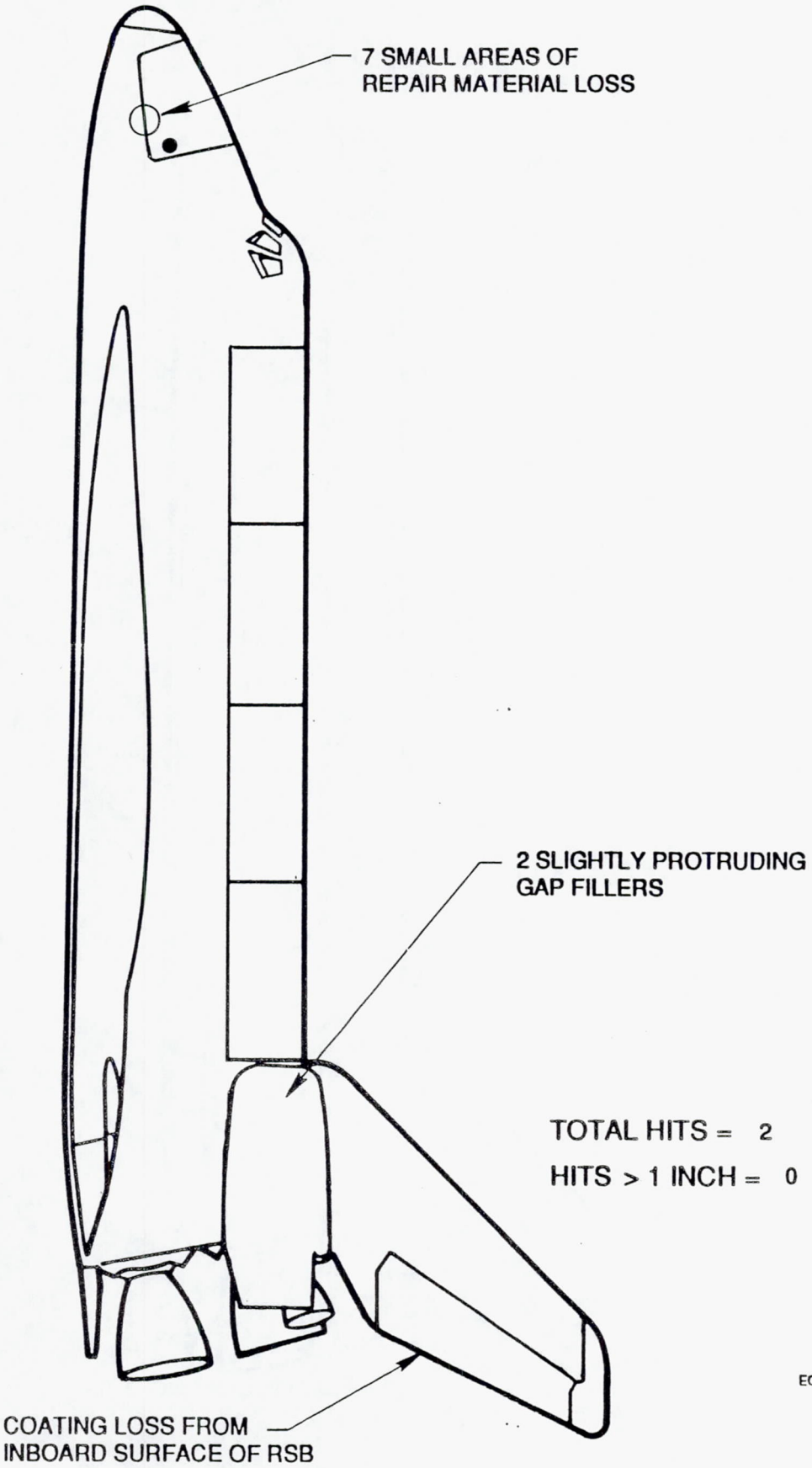
STS-37

FIGURE 12. **DEBRIS DAMAGE LOCATIONS**



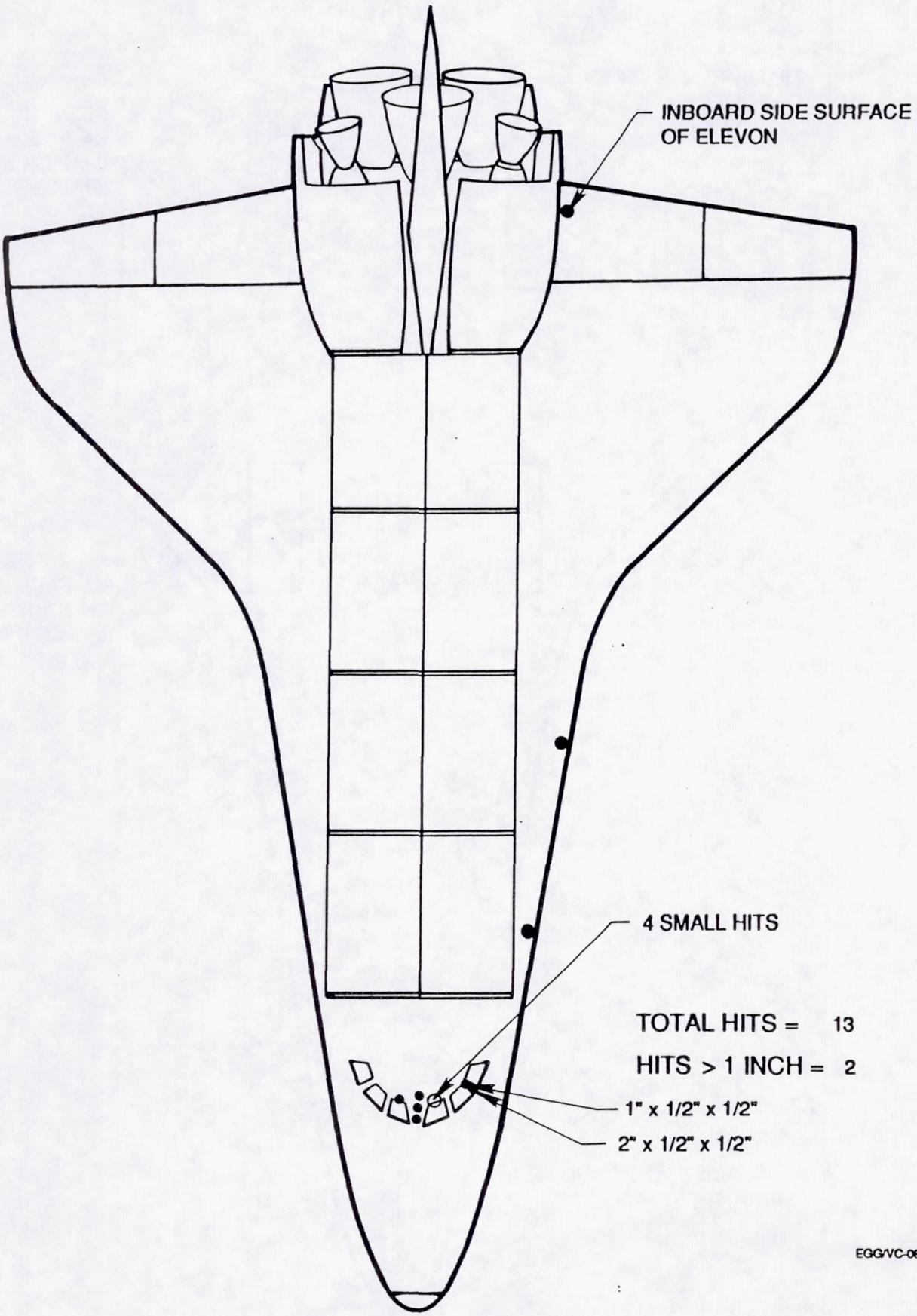
## STS-37

FIGURE 13. **DEBRIS DAMAGE LOCATIONS**



STS-37

FIGURE 14. **DEBRIS DAMAGE LOCATIONS**



STS-37

FIGURE 15. **CHEMICAL SAMPLE LOCATIONS**

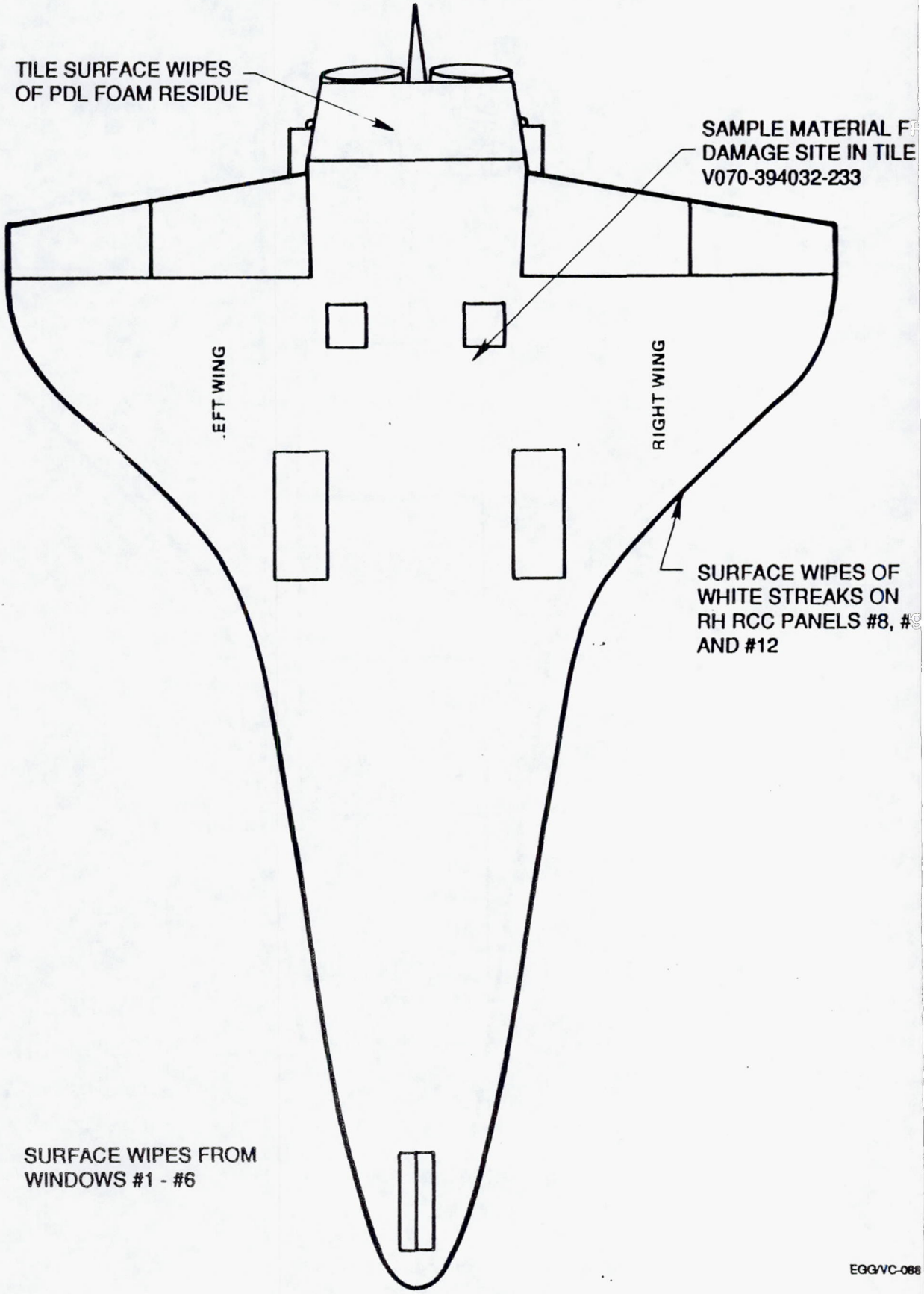


FIGURE 16. **STS-37 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**

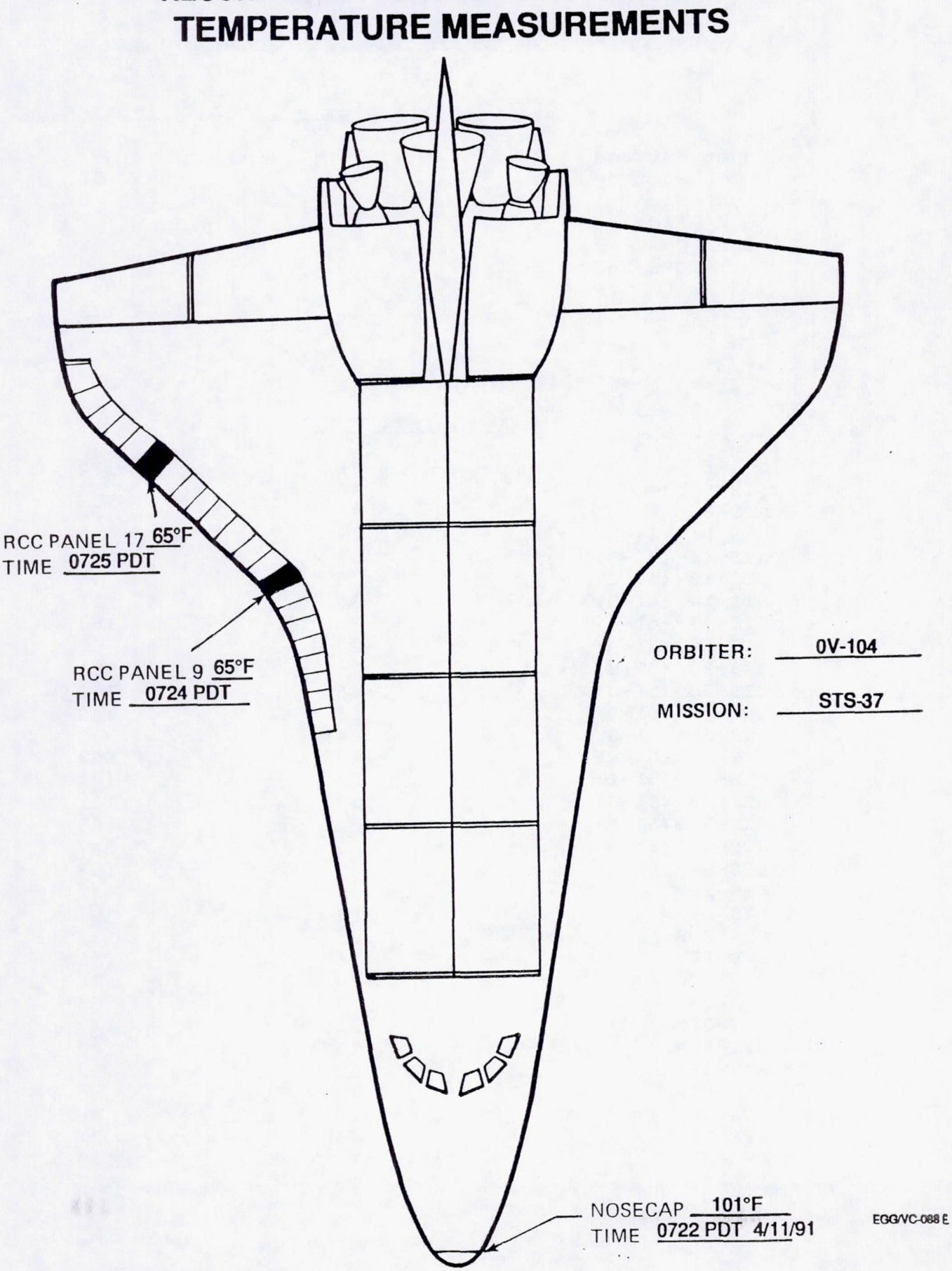


**FIGURE 17. STS-37 DEBRIS DAMAGE ASSESSMENT SUMMARY**

| | Hits > or = 1" | Total Hits |
|---|---|---|
| Lower Surface | 7 | 91 |
| Upper Surface | 2 | 13 |
| Right Side | 0 | 5 |
| Left Side | 0 | 2 |
| Right OMS Pod | 1 | 2 |
| Left OMS Pod | 0 | 0 |
| TOTALS | 10 | 113 |

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 |

FIGURE 18. COMPARISON TABLE

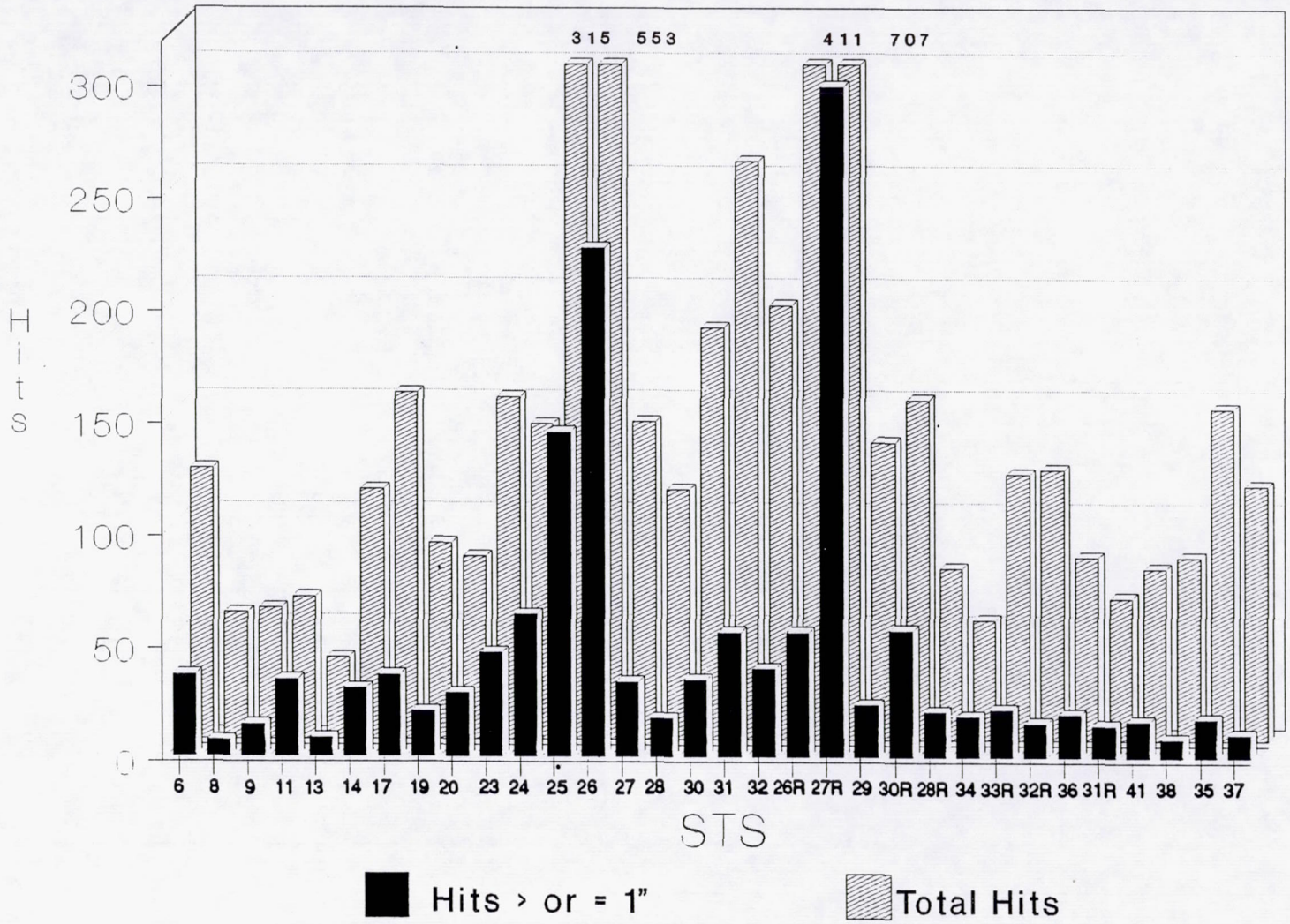
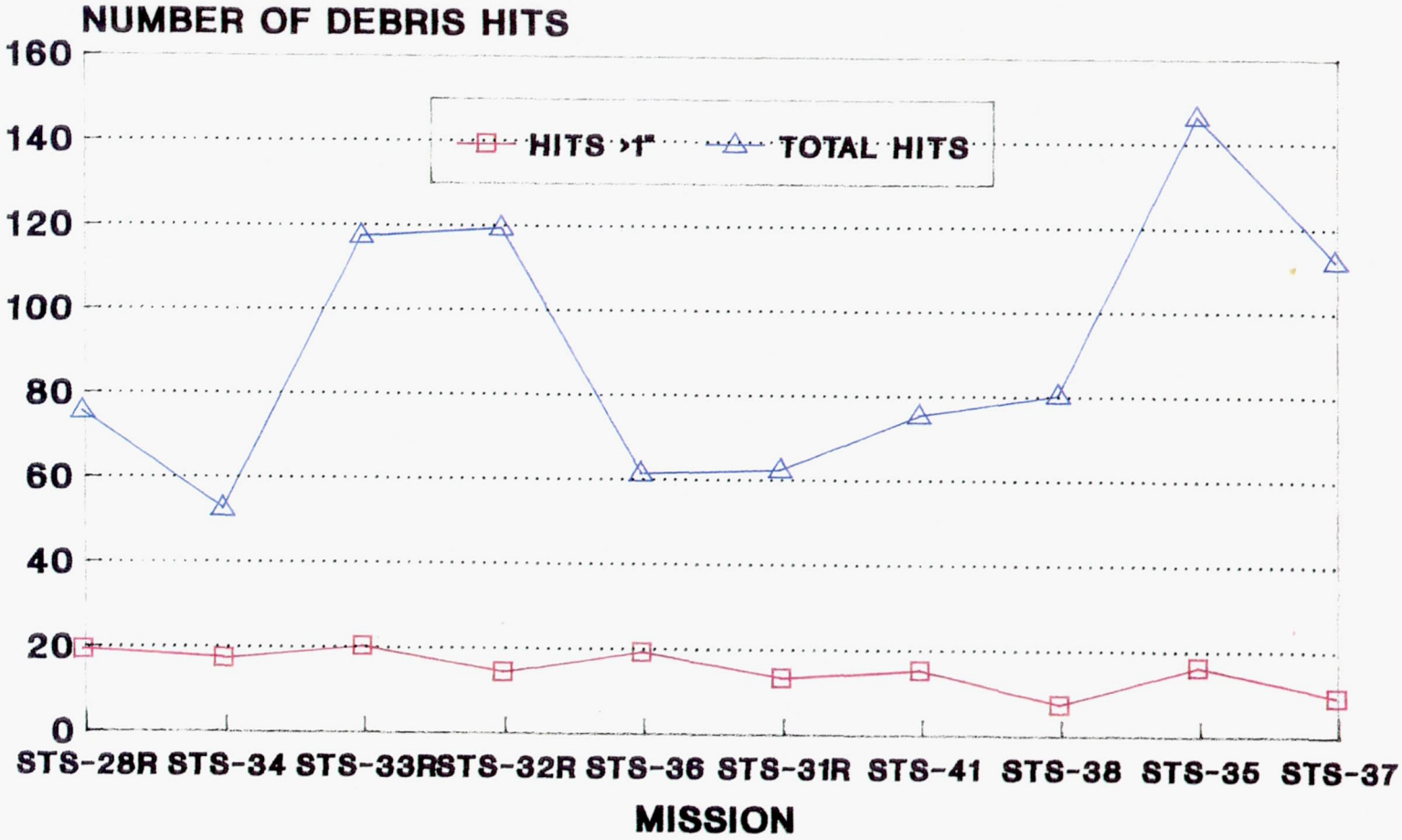


FIGURE 19. ORBITER TPS DEBRIS DAMAGE
STS-28R THROUGH STS-37



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Overall view of OV-104 right side

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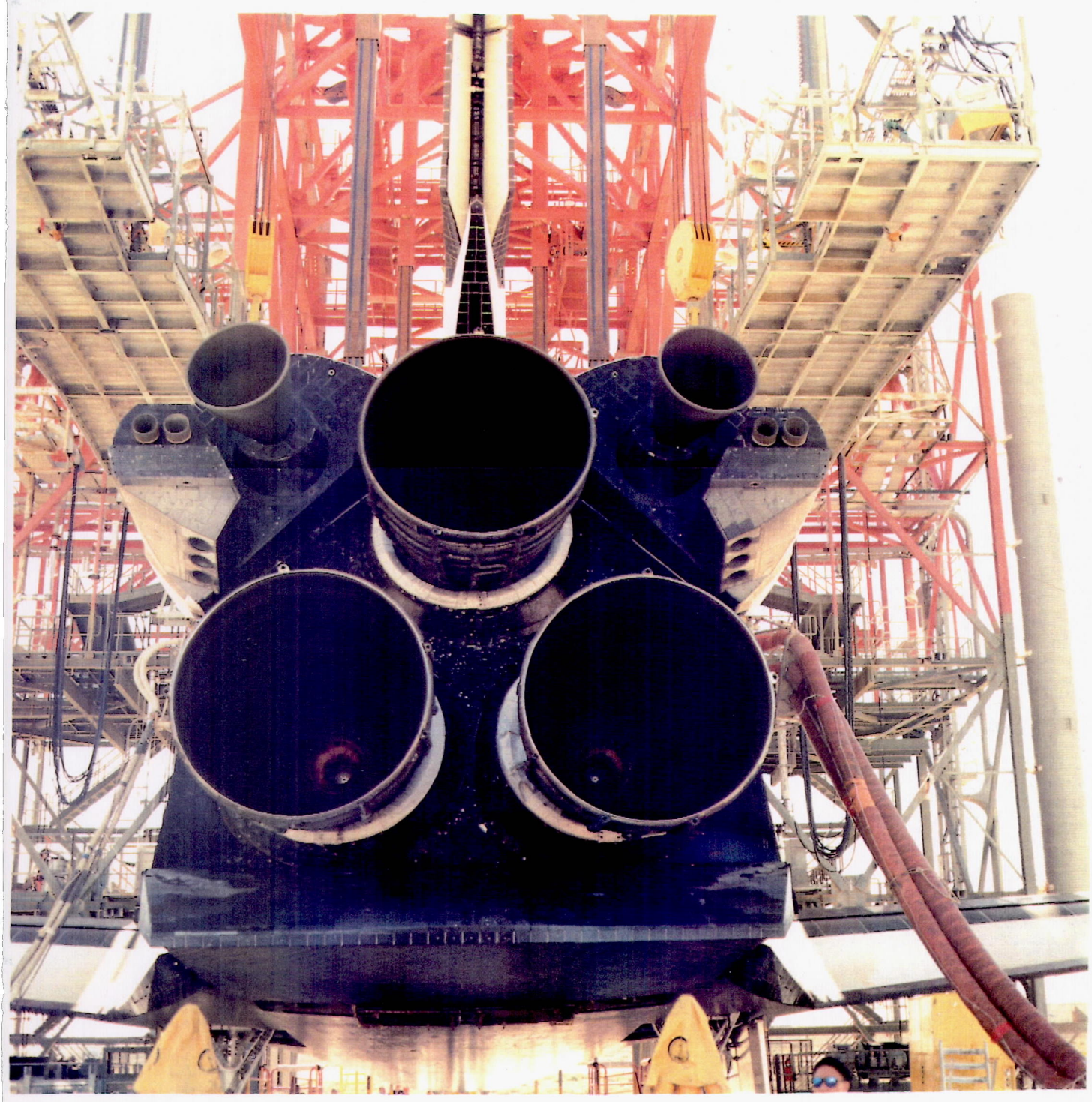
Overall view of OV-104 left side



Overall view of SSME's and base heat shield



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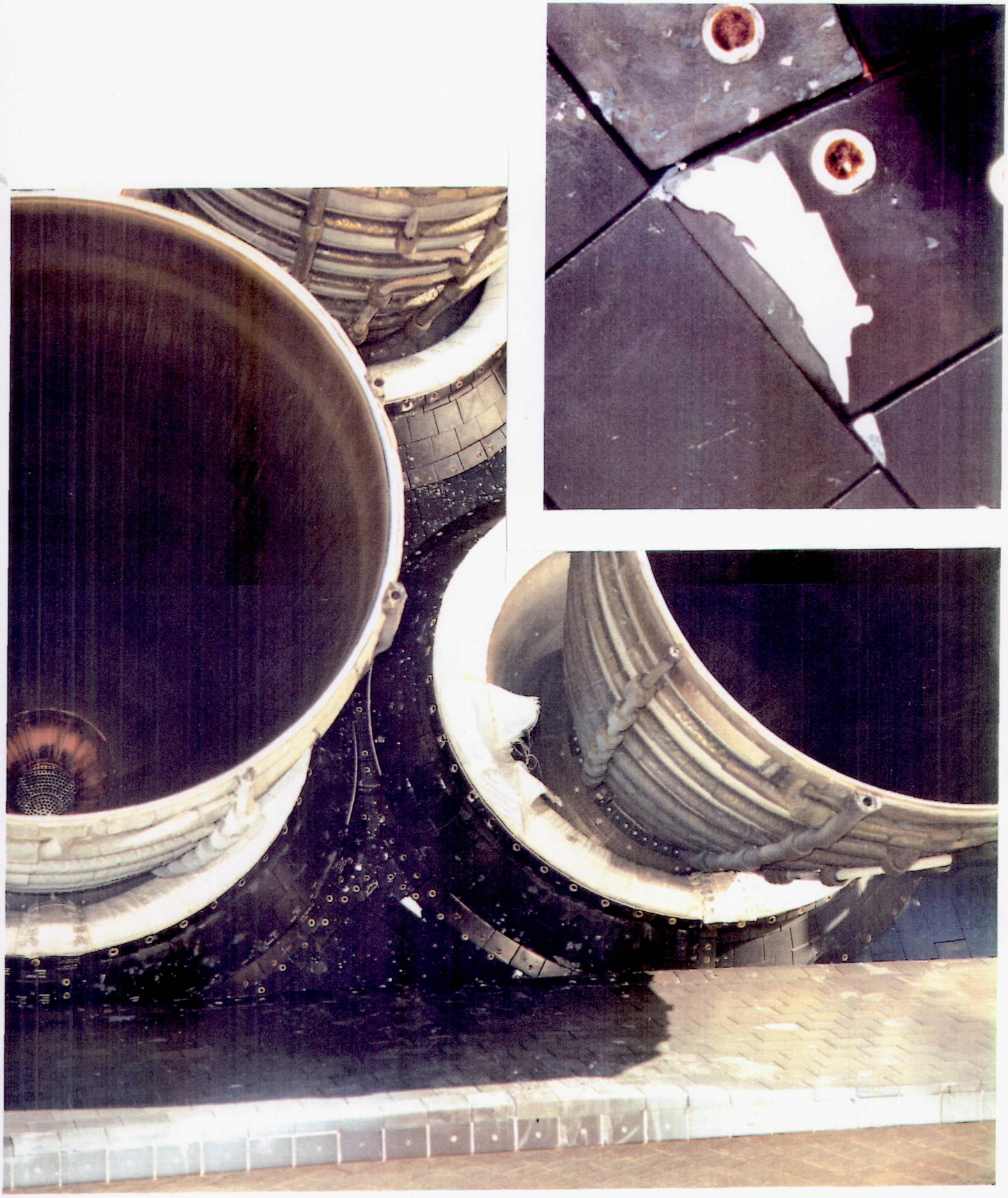

A 5"x2"x1.5" piece of tile was missing between SSME #2 and #3. Inset shows close-up view of the damage. SSME #3 closeout blanket was frayed from 7-9:00 o'clock.



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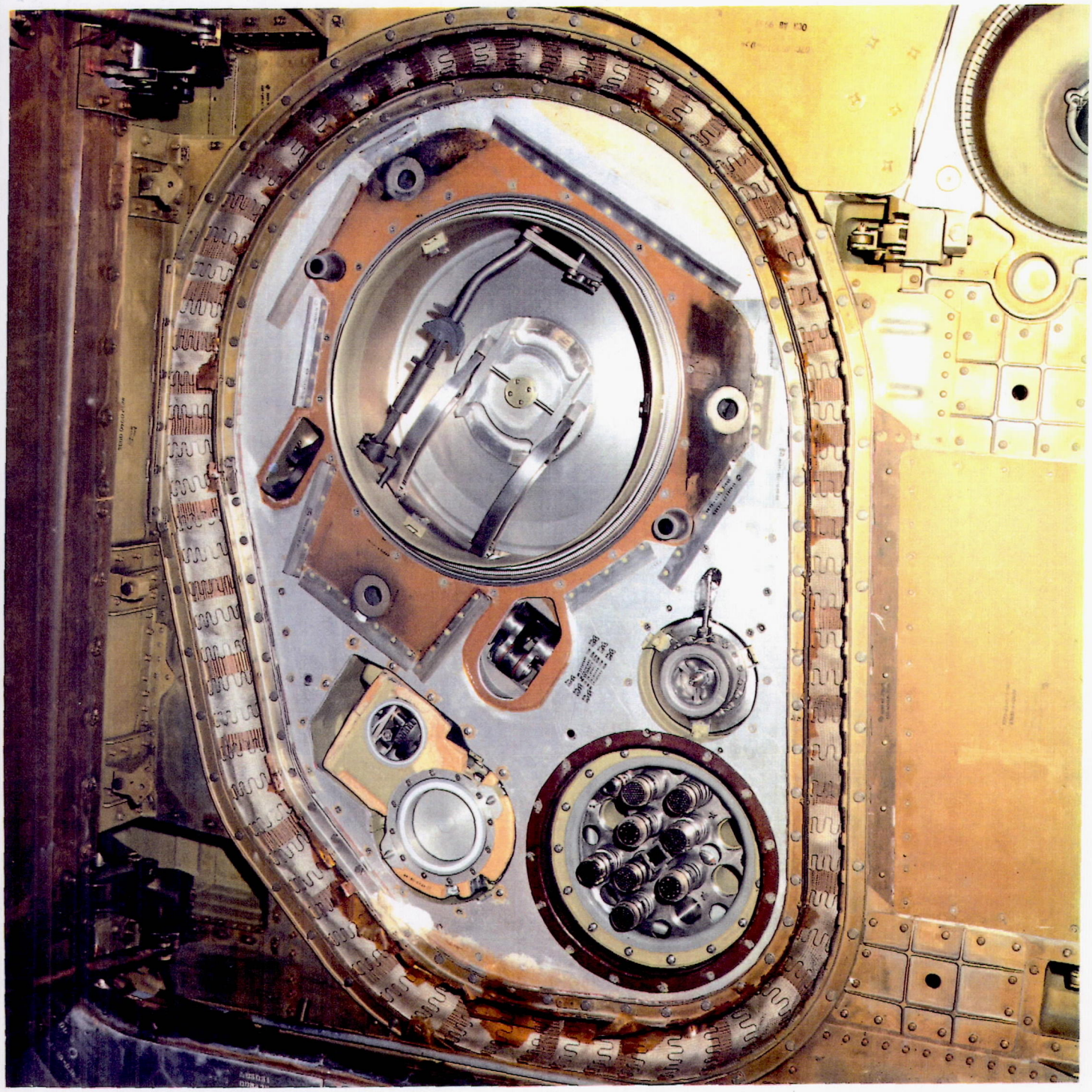

Overall view of LH2 ET/ORB umbilical



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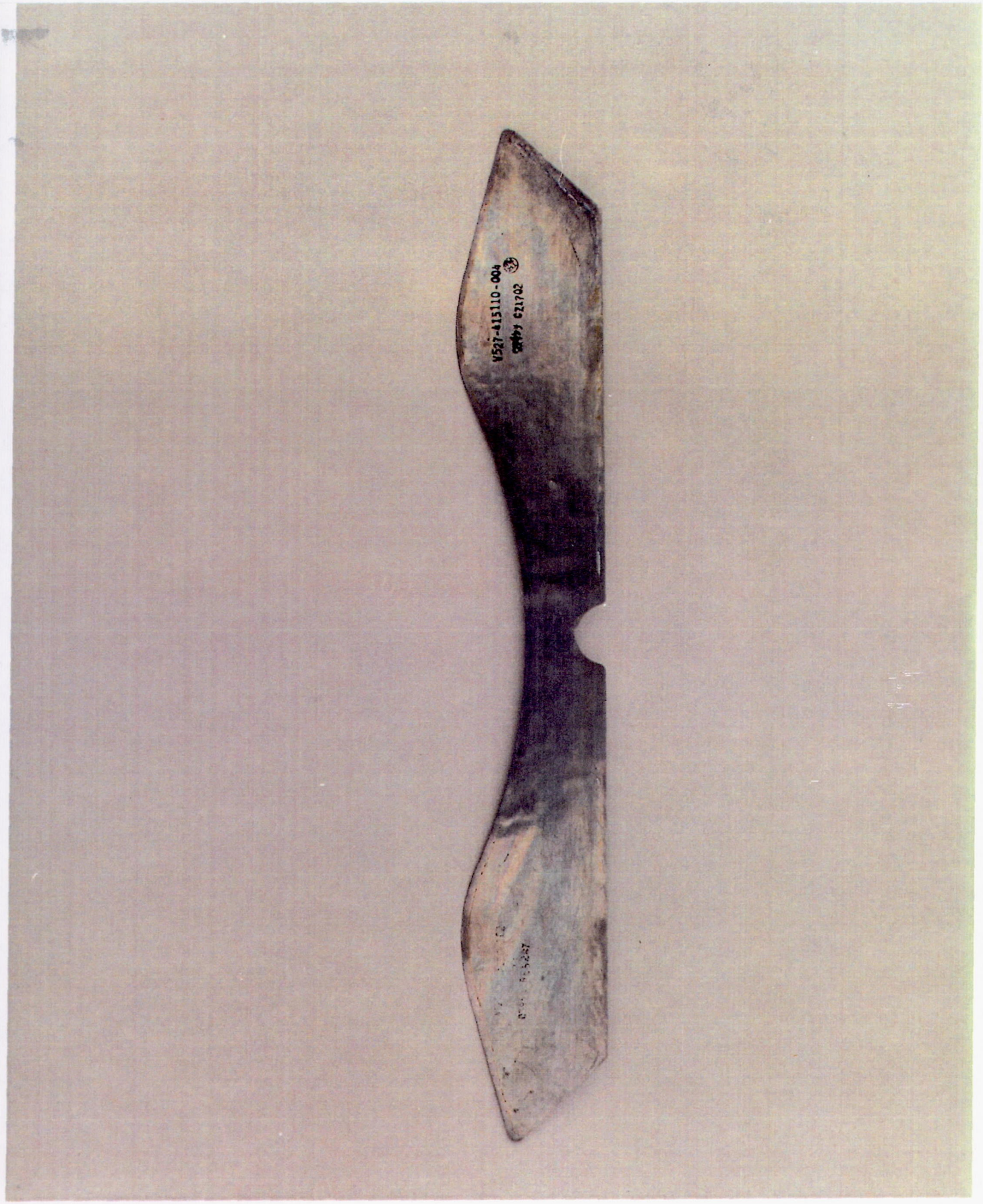


Lightning protection contact that fell onto the runway when the LH2 ET/ORB umbilical ET door was opened. The contact is normally bonded to the ET half of the umbilical and should have stayed with the ET after separation.



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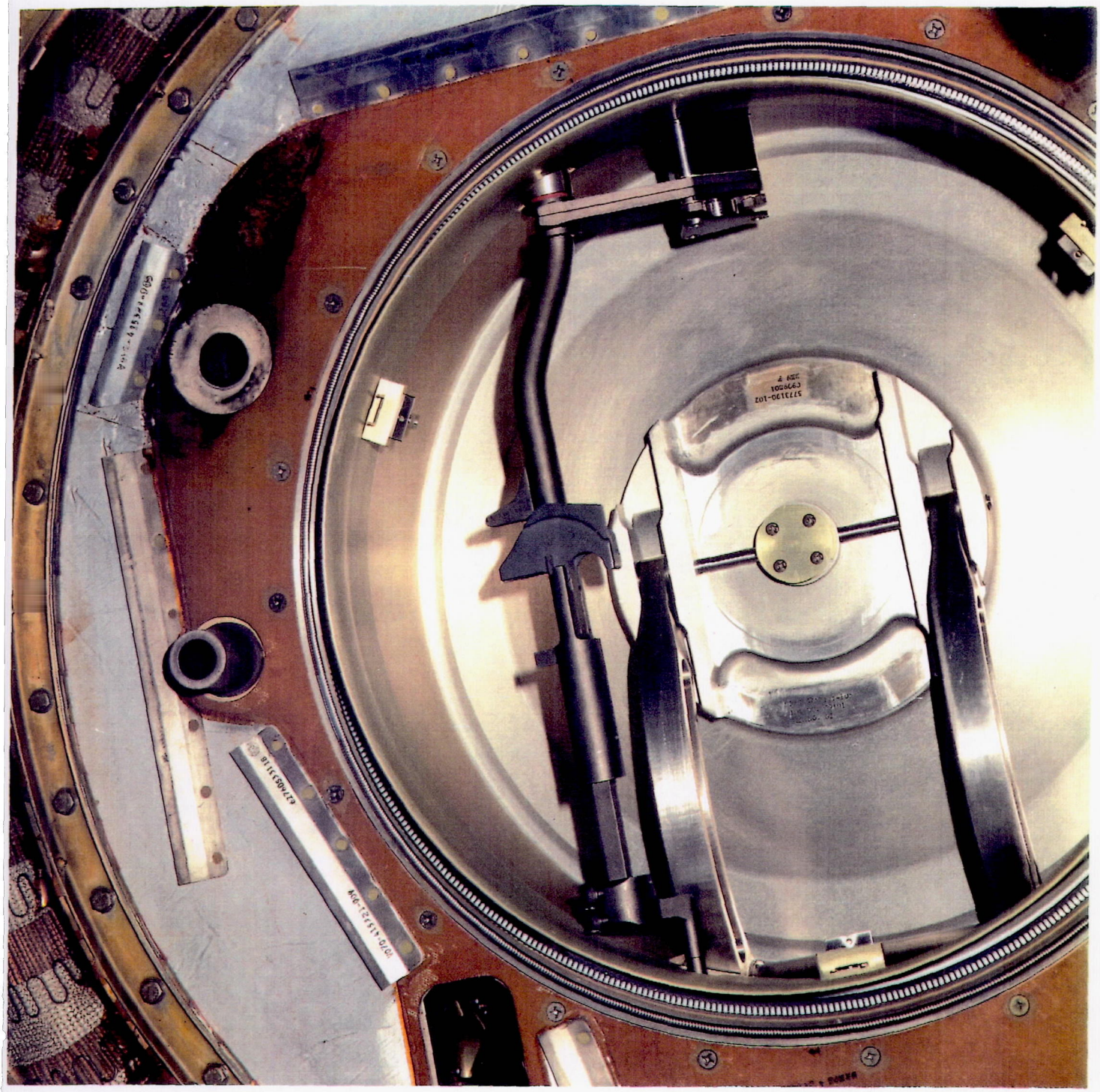

Orbiter side of LH2 ET/ORB umbilical. Metal strip above 17-inch flapper valve is the lightning protection contact that makes contact with the ET side of the lightning protection.



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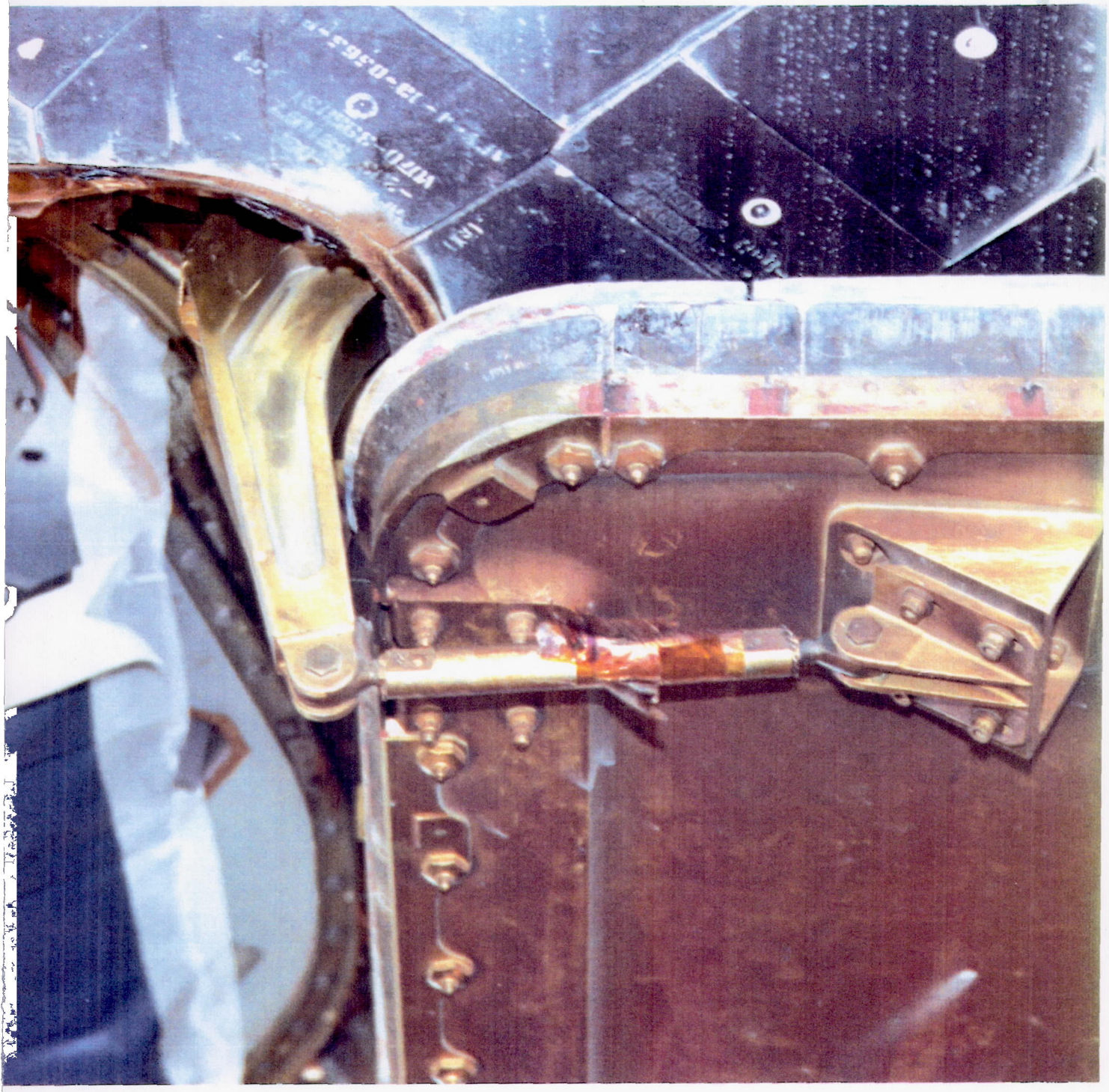

ET/ORB umbilical purge barrier (baggie) was attached to the ET door struts outside of the umbilical cavity and may have contributed to the tile damage aft of that location.



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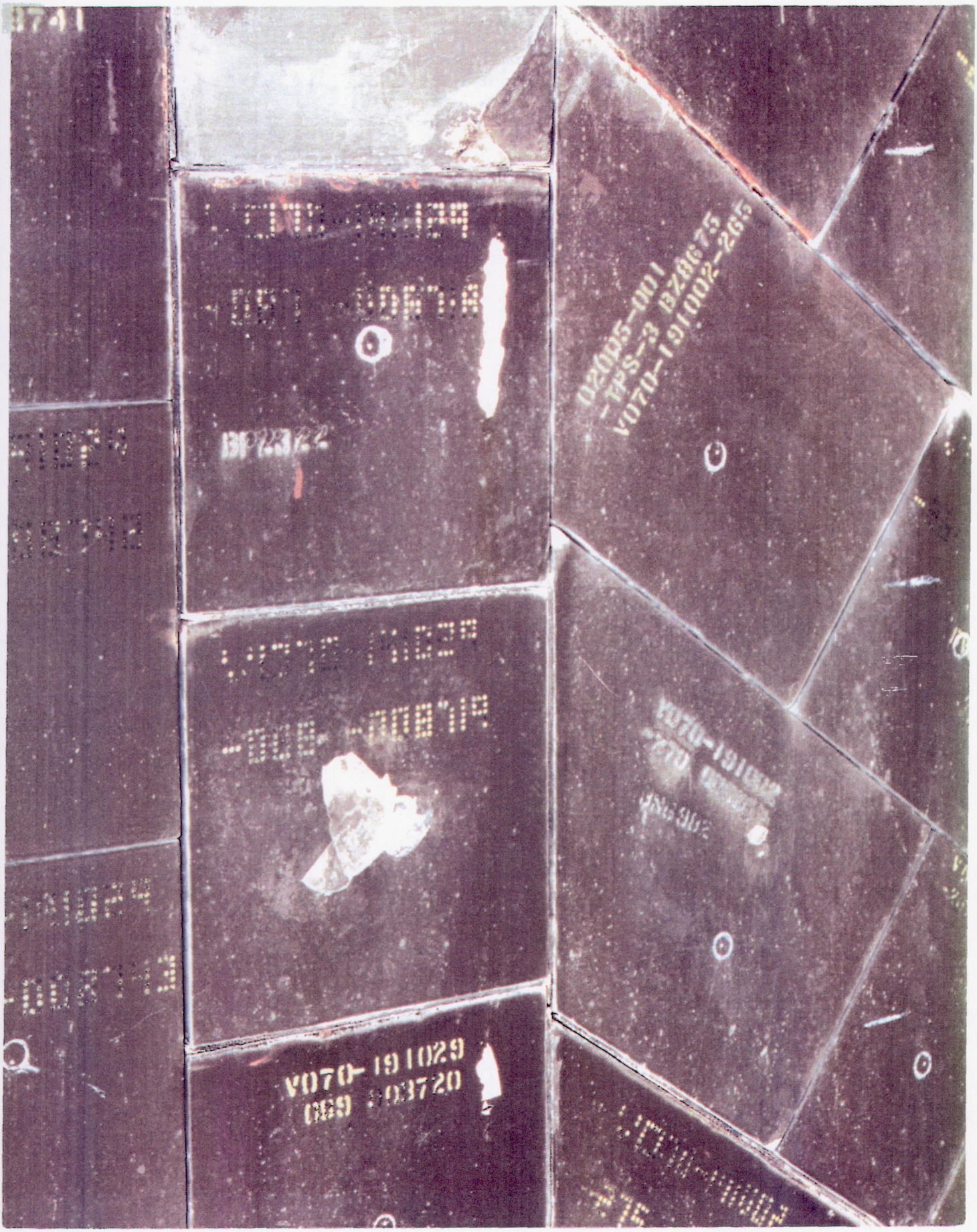


Typical tile damage from debris impacts



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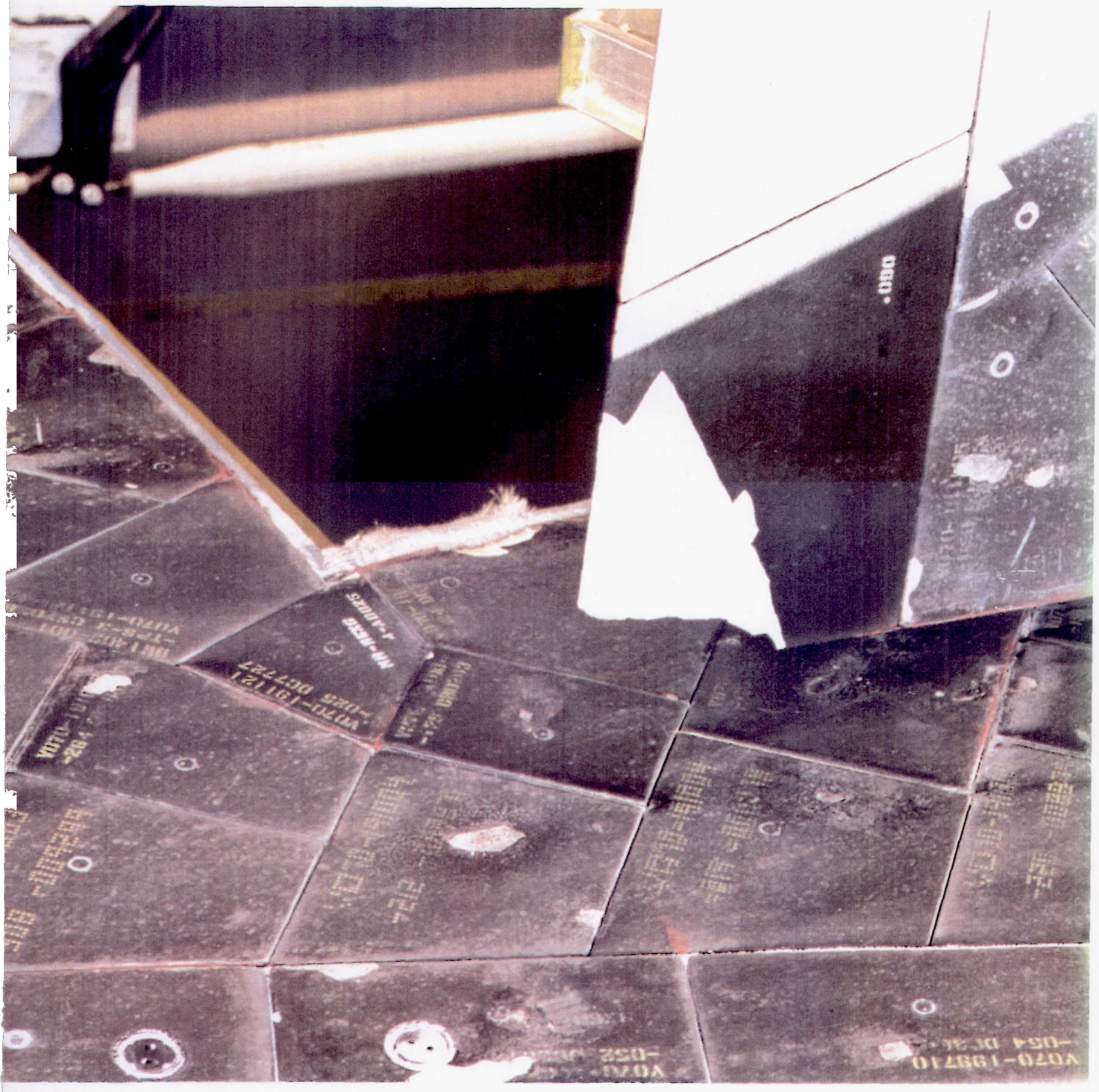
Orbiter windows #3 and #4 were moderately hazed with a few small streaks. Windows #2 and #5 were lightly hazed. Two tile hits greater than 1-inch in size occurred aft of window #1.



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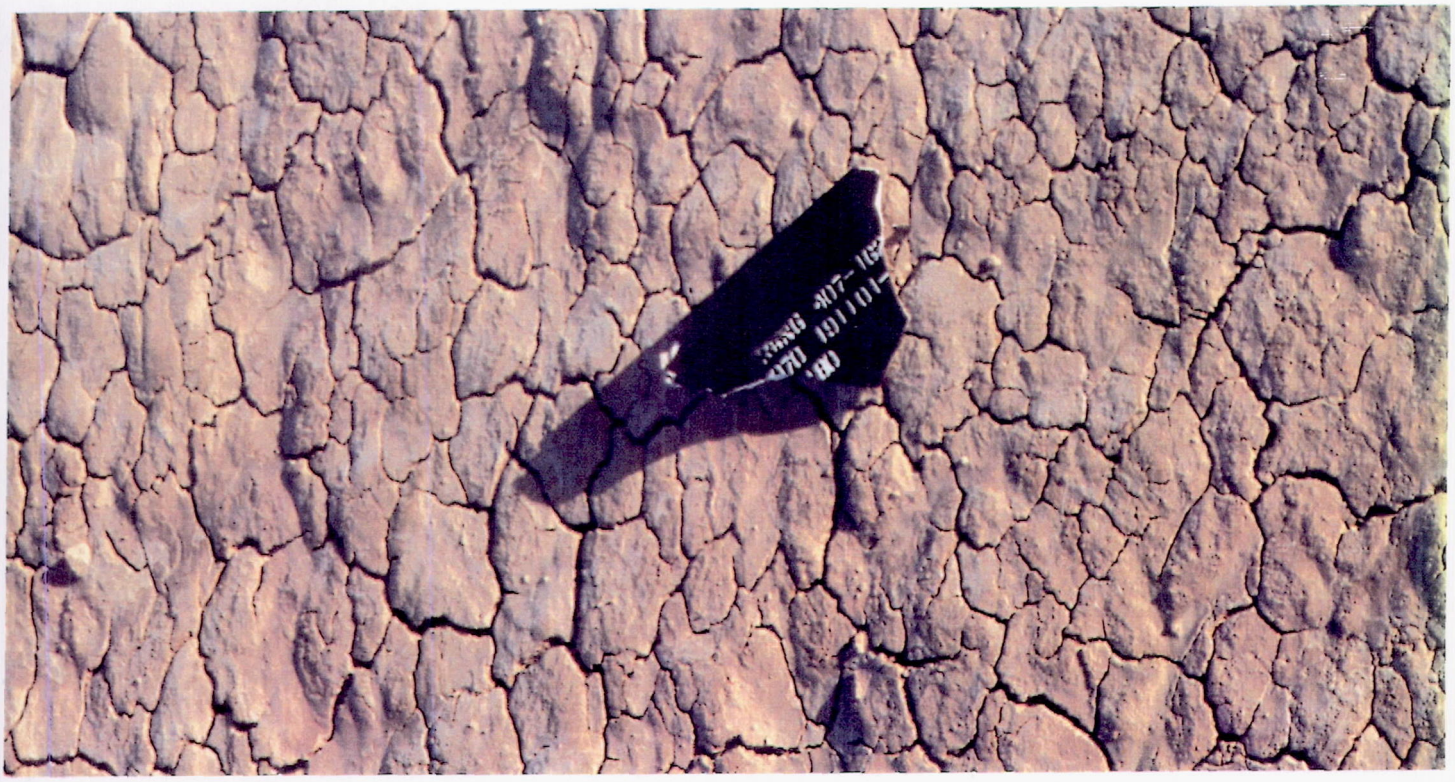
Damage to corner tile on the RH MLG door occurred when the door was opened for landing



The only flight hardware found on the runway were pieces of the broken tile from the RH main landing gear door

Typical debris recovered during the pre-landing walkdown of Runway 33



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## 9.0 DEBRIS SAMPLE LAB REPORTS

A total of 18 samples were obtained from Orbiter OV-104 during the STS-37 post-landing debris assessment at Ames-Dryden Flight Research Facility, California (Figure 15). The 18 submitted samples consisted of 8 Orbiter window wipes, 6 RH wing leading edge RCC samples, 3 wipes of Orbiter body flap tiles, and 1 tile debris sample. 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 reports. Debris analysis involves the placing and correlating of particles with respect to composition, availability and thermal (mission) effects. Debris samples and analyses are provided by Orbiter location in the following summaries.

### Orbiter Windows

Results of the window wipe chemical analysis indicates the presence of the following materials:

1. Metallic particles
2. Albite, Calcite
3. Rust, Dust and Salt
4. Muscovite, Plagioclase (clay minerals)
5. RTV and Insulation glass fibers
6. Organics and trace organic fibers

Debris analysis provides the following correlations:

1. Metallic particles (stainless steel; aluminum, zinc, and carbon steel alloys) are common to the landing site and SRB/BSM exhaust, but are not considered a debris concern in this quantity (micrometer), and have not demonstrated a known debris effect.

2. Albite and Calcite are naturally-occurring landing site products.

3. Rust, dust and salt are landing site products.

4. Muscovite and Plagioclase are naturally-occurring landing site products.

5. RTV and insulation glass fibers originate from Orbiter thermal protection system (TPS).

6. Organic materials are probably insect/animal remains and deposits, or tile waterproofing agents. The trace organic fibers (cellulose) appear to be of sampling cloth origin.


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**Orbiter wing RCC panels**

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

1. Metallic particles
2. Rust and Salt
3. Muscovite, Albite, Calcite
4. Alpha-quartz, Tile and Insulation glass fibers
5. Paint
6. Organics and trace organic fibers

Debris analysis provides the following correlations:

1. Metallic particles (stainless steel; nickel, aluminum, and carbon steel alloys) are common to SRB/BSM exhaust residue and the landing site, but are not considered a debris concern in this quantity (micrometer) and have not demonstrated a known debris effect.

2. Rust and salt are landing site products.

3. Muscovite, Albite, Calcite are naturally-occurring landing site products.

4. Alpha-quartz, tile and insulation glass fibers are common to Orbiter thermal protection system (TPS).

5. Paint is common to the flight elements, facility, and ground support equipment (GSE).

6. Organic materials are probably insect/animal remains and deposits, or tile waterproofing agents. Larger than normal quantity (80-90% of sample) did not allow for positive identification due to small sample size. The organic fibers (cellulose) appear to be of sampling cloth origin.

**Orbiter Body Flap Wipes**

Results of the body flap wipe sample chemical analysis revealed the presence of the following materials:

1. Tile and Insulation glass
2. Metallic particles
3. Muscovite, Albite, Calcite
4. Salt, Rust and Dust
5. Organics and trace organic fibers

Debris analysis provides the following correlations:

1. Tile and insulation glass materials are used on the Orbiter thermal protection system (TPS).

2. Metallic particles (copper and aluminum) are common to SRB/BSM exhaust and the landing site, but do not provide evidence of a debris concern.

3. Muscovite, Albite, Calcite are naturally-occurring landing site products.

4. Salt, rust and dust are landing site products.

5. Organics in these samples could have originated from the residual PDL foam material (observed prior to launch), or Shuttle/environmental sources. The fibers (cellulose) appear to be of sampling cloth origin.

**Orbiter Tile Damage Site**

Results of the tile damage site chemical analysis indicates the presence of the following materials:

1. Black and White tile
2. RTV
3. Organics and trace organic fibers

Debris analysis provides the following correlations:

1. Black and white tile materials originate from Orbiter thermal protection system (TPS).

2. RTV originates from the Orbiter thermal protection system (TPS).

3. Organics did not provide sufficient material for analysis. The organic fibers (cellulose) appear to be of sampling cloth origin.

**Conclusions**

The STS-37 mission, as evidenced by the debris analysis report, was successful in minimizing damage from debris. This is also shown to be true by the chemical analyses that was performed on post-flight samples.

The Orbiter window sampling provided results that indicate exposure to SRB/BSM exhaust residue, thermal protection system materials, and landing site products. The presence of a variety of metallic particles demonstrates window exposure to differing environments; however, the absence of window debris damage supports analysis that metallic particulate is not a debris threat in this area.

The Orbiter wing RCC sampling indicated metallic particles, thermal protection system materials, paint, landing site products, and organics. This residual variety indicates the wing's exposure to differing environments, and ability to provide sample material. No RCC debris damage was noted.

The Orbiter body flap wipe sampling provided evidence of exposure to Orbiter thermal protection system materials (TPS), SRB/BSM residue, and landing site products. The presence of polyamide (Orbiter/ET umbilical purge barrier material) has been noted on previous mission's umbilical sampling. The variety of materials did not appear to provide a debris concern, and no debris damage was associated with this sampling.

The Orbiter tile damage site sample provided indication of Orbiter thermal protection system (TPS) material and organic (trace) material. The source of this impact was not retained in the damage area.

This mission's post landing tile inspection provided no evidence of an impact from on-orbit debris.

**Hypalon topcoat and "Elephant hide" testing**

As a result of the continued streaking of Orbiter wing RCC panels, additional testing of Hypalon topcoat and "Elephant hide" materials was performed. These materials were selected for testing because their presence had been detected in previous post-landing chemical samples (STS-35). The additional testing consisted of exposing test material to elevated temperature (2600 F). This testing was intended to show thermal/chemical effects of Orbiter "re-entry" heating.

The samples were analyzed by the KSC Microchemical Analysis Branch (MAB) by means of optical microscopy and electron microprobe with energy dispersive spectroscopy (EDS). Results of this testing can be summarized:

| | | ELEMENTAL COMPOSITION |
|---|---|---|
| HYPALON TOPCOAT | (as rec'd) | Al,Si,Cl,Ti,S |
| " | (2600 F 1Hr) | Al,Si,Ti |
| "ELEPHANT HIDE" | (as rec'd) | Cl,Sb,Ca,Si,S,Ti, organics |
| " | (2600 F 1Hr) | Ca,Ti,Si |

ELEMENTS O,C,H, and B not detectable using EDS.

In conclusion, all of the chlorine and sulfur was removed during the heating process of the Hypalon topcoat sample. Most organics and chlorine were removed during the heating process of the "Elephant hide" sample. The heat treated "Elephant hide" was fused to the test crucible. The EDS spectrum showed peak intensities from each chemical element, and were comparable to EDS spectrum of RCC panel post-landing samples. This data provided more correlation to debris analyses.

## 10.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 13 Post Launch Anomalies were observed for STS-35. This list includes 1 IFA candidate.

### 10.1 LAUNCH PAD/FACILITY

1. Two tie-wraps were attached to a platform pin tether at the southwest corner of the LO2 TSM approximately 2-3 feet away from the RH aft RCS stinger tiles. The tie-wraps remained attached to the TSM through SSME ignition, T-0, and liftoff. No flight hardware was damaged (KSC ground processing item).

2. Holddown post #1, 2, 5, and 6 EPON shim sidewall material was debonded. A 4"x1" piece of sidewall shim material was missing from HDP #6. Shim bottom plate material on HDP #2 was also debonded (Project item).

3. There were 1 loose and 4 missing cable tray covers from the FSS. Two of the missing cable tray covers were found west of the pad apron (KSC ground processing item).

### 10.2 EXTERNAL TANK

1. The LH2 ET/ORB umbilical lightning protection contact from the ET half of the umbilical (Rockwell hardware) fell from the Orbiter umbilical cavity when ET doors were opened on the runway. The 17.5"x2.5"x0.005" piece, P/N V527-415110-004, should have remained attached to the ET during separation. (IFA candidate).

2. Six divots occurred in the LH2 tank-to-intertank flange (-Y side) closeout during ascent. Two of the divots were 12-14 inches in diameter, three were 6-8 inches in diameter, and one was 4 inches in diameter. (Project item).

### 10.3 SOLID ROCKET BOOSTERS

1. A small debris particle, possibly a piece of NSI cartridge, was wedged between the HDP #6 stud and stud hole wall. Film item E-13 showed two small ordnance fragments falling from the HDP #6 DCS/stud hole during liftoff. Post flight inspection of the LH SRB at Hangar AF revealed a frangible nut half obstructing the DCS plunger (Project item).

2. Instafoam broke loose near the RH SRB aft skirt GN2 purge line during liftoff. Instafoam should remain attached to the aft skirt during liftoff and flight (Project item).

3. 26 MSA-2 debonds occurred on the RH frustum. The LH frustum exhibited 2 areas of missing TPS and 41 MSA-2 debonds over fasteners (Project item).

4. A 4-inch crack occurred in the RH forward field joint K5NA at 310 degrees. A 12-inch debond occurred in the aft edge of the LH aft center factory joint adjacent to the systems tunnel. A 1-inch crack was visible in the LH forward field joint K5NA at 315 degrees (Project item).

5. K5NA was missing from all aft BSM nozzles (Project item).

6. A 10"x1.5" piece of EPON shim material was missing from HDP #4 prior to water impact. This shim should remain attached to the HDP #4 foot through water impact (Project item).

7. A 4"x1" piece of holddown post sidewall shim was still attached to the HDP #6 foot. Sidewall shim material should remain attached to the HDP #6 shoe on the launch pad (Project item).

NOTE: The LH SRB forward skirt sustained damage in the area of the system tunnel. TPS (K5NA and MSA) was cracked and the metal substrate was buckled on both sides of the systems tunnel. Some of the Hypalon topcoat was missing. Initial assessment indicates the forward skirt damage was not a source of debris nor was caused by a debris problem.

**10.4 ORBITER**

1. SSME ignition vibration/acoustics caused the loss of tile surface coating material from one tile on the RH OMS nozzle heatshield, 5 places on the RH RCS stinger aft face (max size 1 inch square), 1 place on the Orbiter base heatshield, and 4 places on the LH RCS stinger aft face (film items E-23, 24). In addition, white tile repair material from the RH OMS pod was shaken loose. (Project item).

APPENDIX A.
MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
FEBRUARY 14, 1991

SUBJECT: Hypalon Topcoat And Elephant Hide Protective Cover

LABORATORY REQUEST NO: MCB-0988-90

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 flight equipment spares (Hypalon) and bench stock (Elephant hide). The samples were identified as follow

1. Elephant hide, as received.
2. Elephant hide, 2600 degree F for 1 hour.
3. Hypalon topcoat, as received.
4. Hypalon topcoat, 2600 degree F for 1 hour.

1.3 REQUESTED: Perform analysis on "as received" and "2600 at 1 hour."

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

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

2.2 Results:

2.2.1 Figures 1, 2, 3, 4, and 5 are EDS spectrum of sample numbers 1, 2, crucible, 3, and 4, respectively, to show peak intensities from each element.

2.2.2 The analytical results are summarized in Table 1

Table 1

| Sample NO | Elemental Anal sis By EDS* | |
|---|---|---|
| | Major | Minor |
| 1.Ele,as rcvd | Cl, organics | Sb,Ca,Si,S,Ti |
| 2.Ele,2600F,1 Hr | Ca,Ti | Si |
| 3.Crucible | Al,Si | K,Ti,Fe |
| 4.Hyp,as rcvd | Al,Si,Cl,Ti | S |
| 5.Hyp,2600F,1 Hr | Al,Si,Ti | |

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

3.0 CONCLUSIONS:

3.1 The sample 2 (2600 F, 1 Hr) was composed mainly Ca, and Ti. Most organics and Cl was evaporated during heating process. The EDS pattern of crucible (used for container during heating) indicated that the crucible was composed of Al and Si with small amounts of Ti, K, and Fe. The heat treated elephant hide was fused together with crucible.

3.2 The Hypalon "as received" sample was composed manly of Al, Si, Cl, and Ti with small amounts of S. The Hypalon "heated to 2600F for 1 Hr" sample was composed mainly of Al, Si, and Ti. The Cl and S were completely removed during heating process.

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

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

MC B0988-90

Figure 1. ELE HIDE, AS RCVD, 988-90

SPECTRUM LABEL

SPECTRUM FILE NAME

291

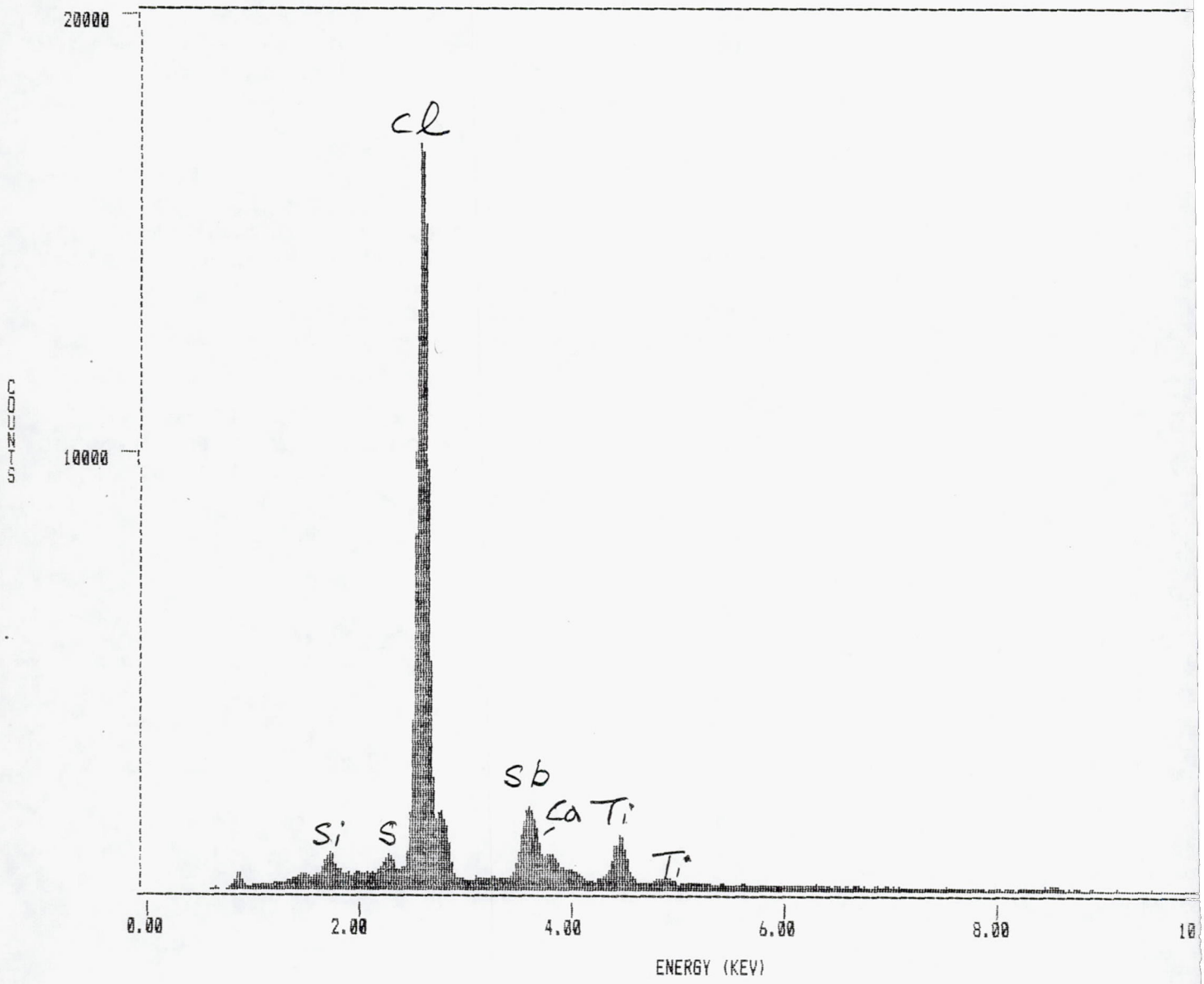


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Figure 2. ELE HIDE,2600F,1HR,988-90

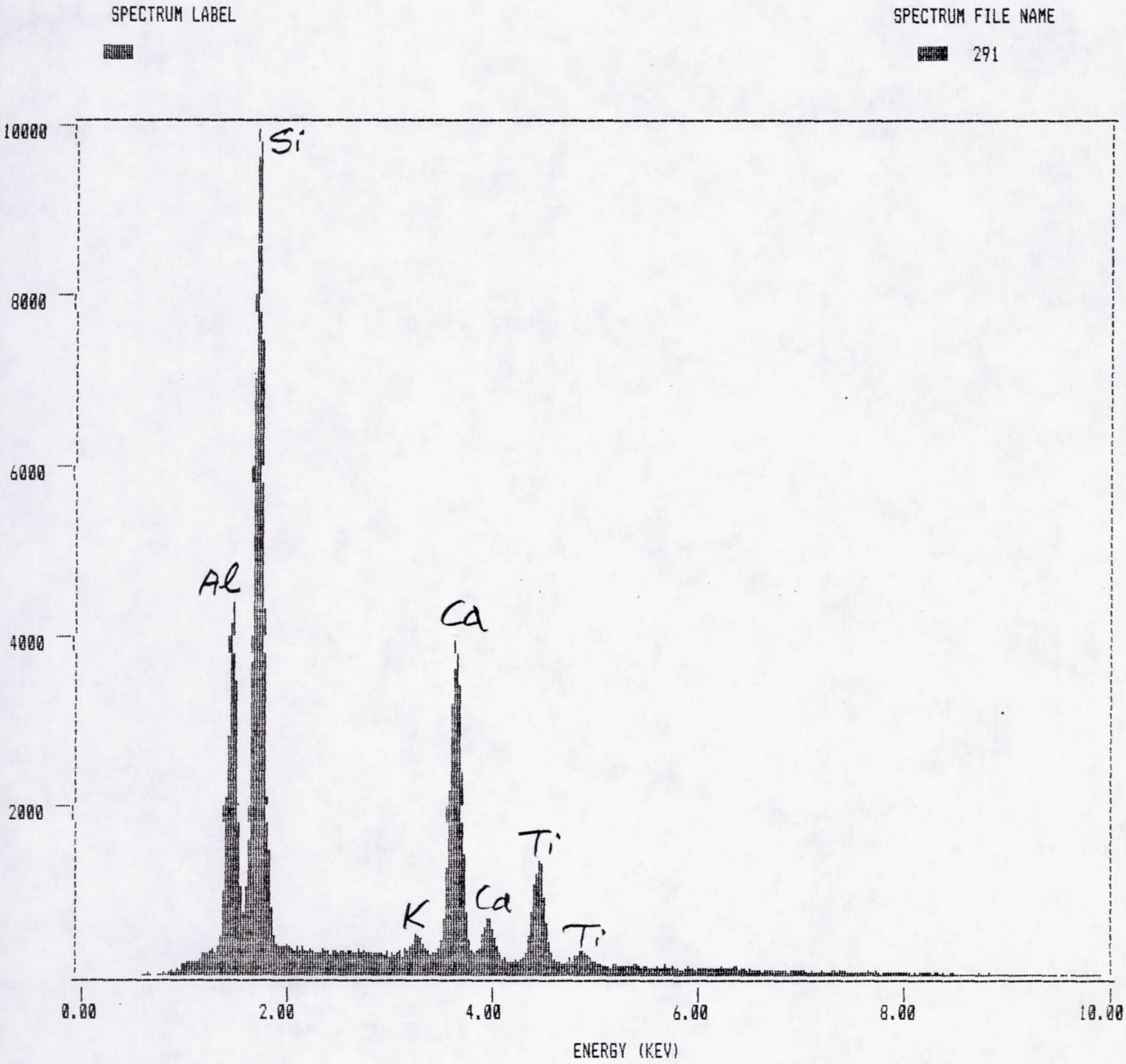


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Figure 3. CRUCIBLE,988-90

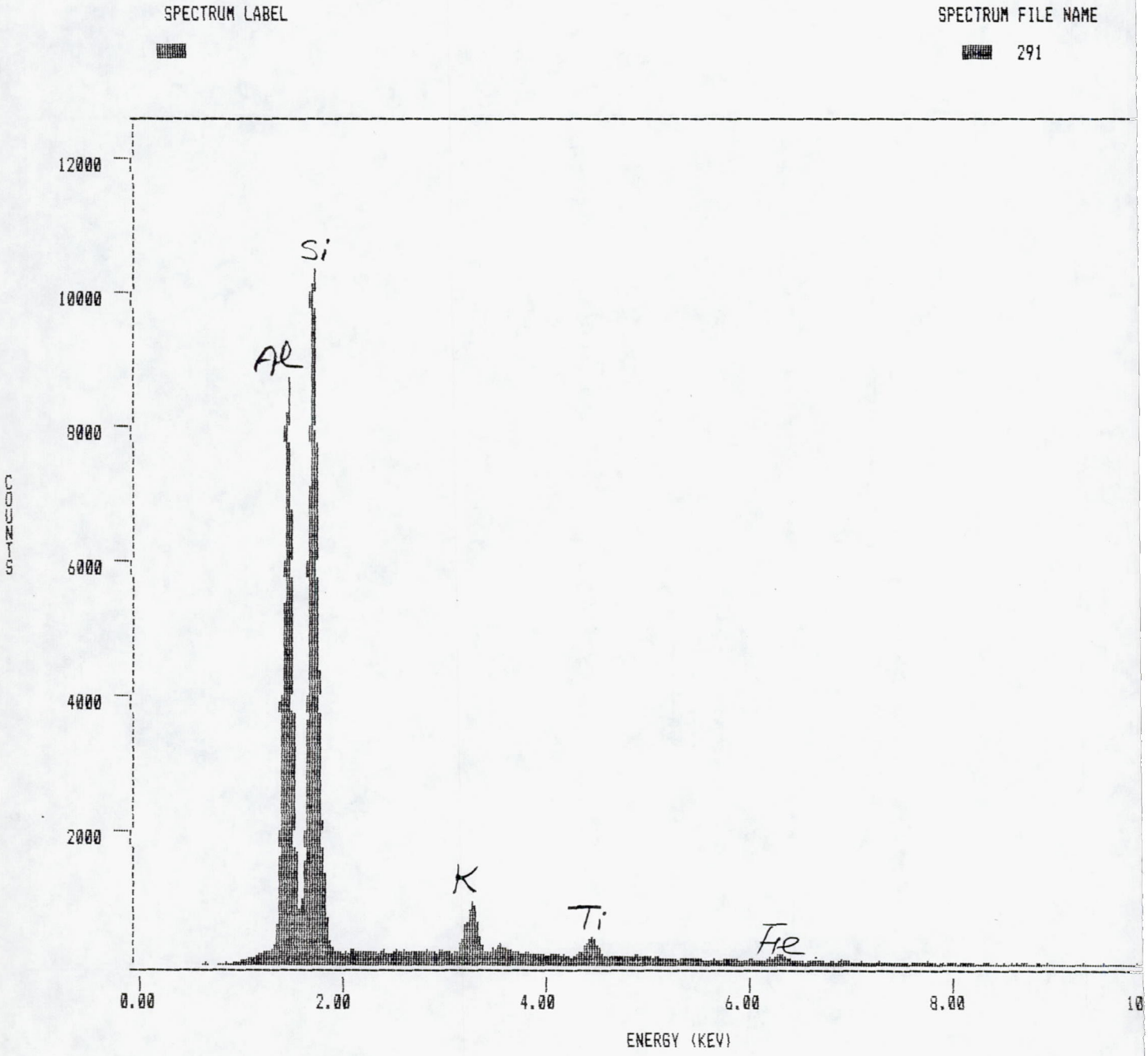


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Figure 4 HYPALON, AS RCVD, 988-90

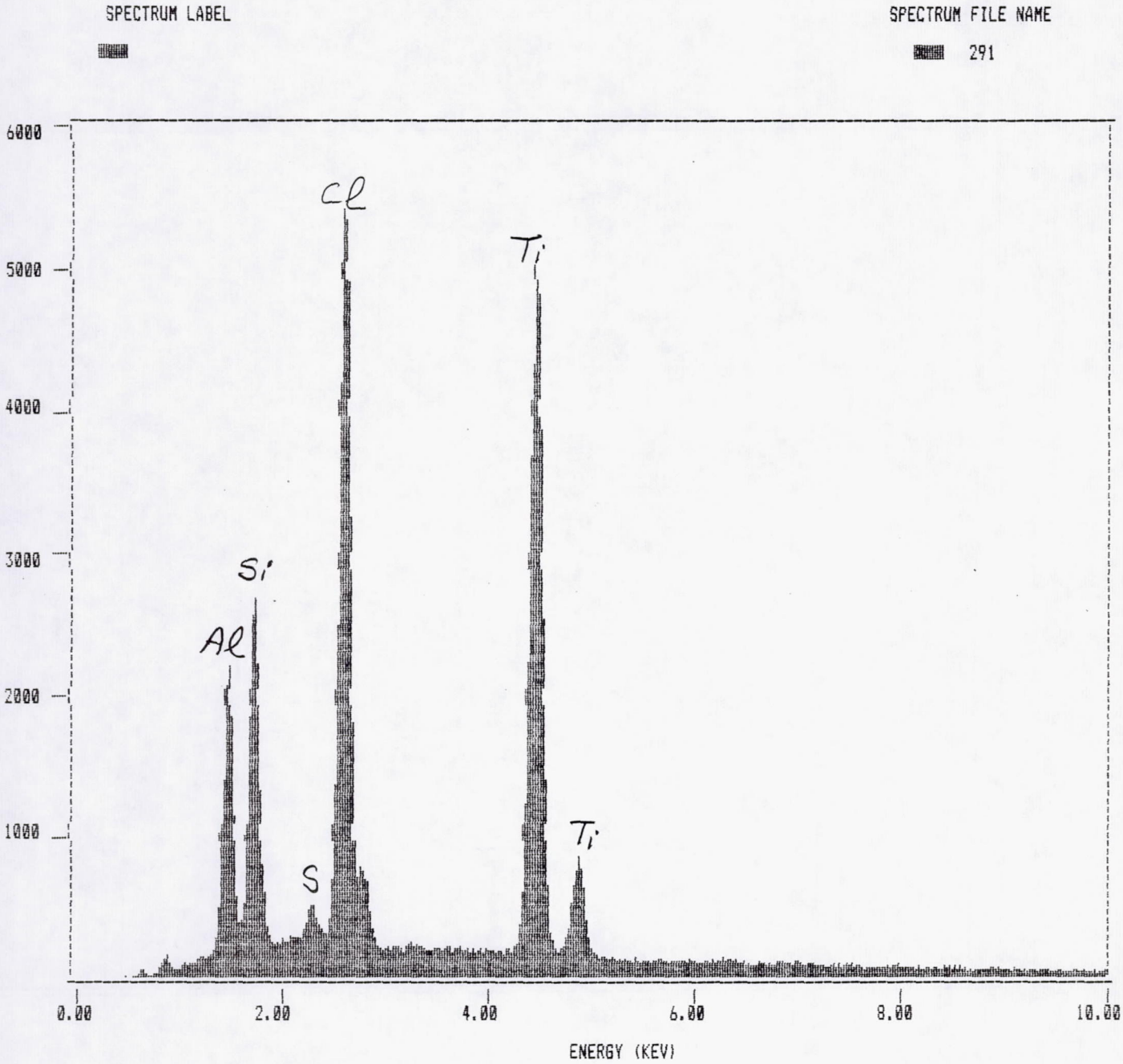


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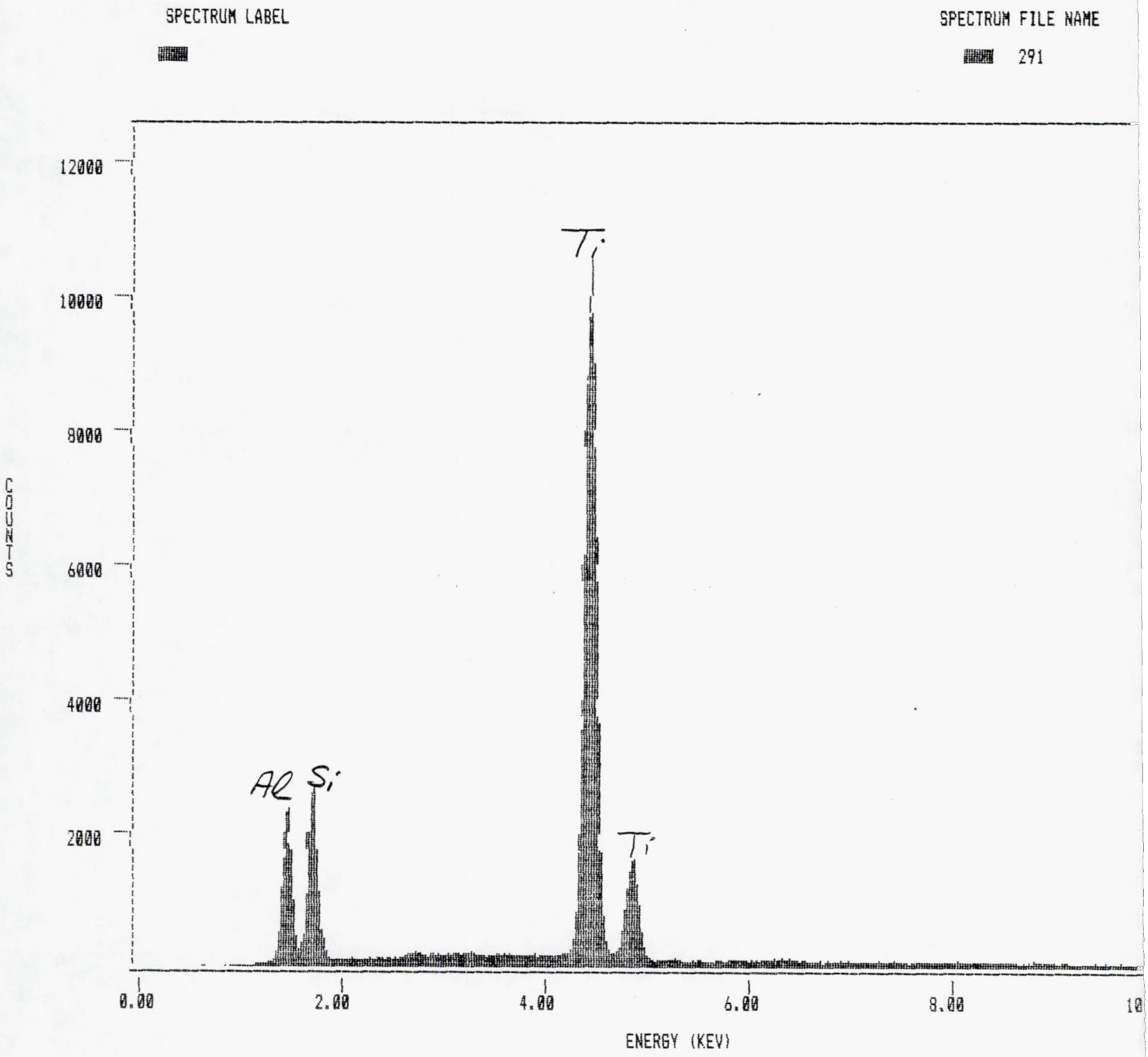
Figure 5. HYP,2600F,1HR,988-90

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MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
MAY 14, 1991

SUBJECT: Orbiter Debris/Residue Samples From STS-37 Landing

LABORATORY REQUEST NO: MCB-0286-91

RELATED DOCUMENTATION: Intercenter Debris Team Requirements.

1.0 FOREWORD:

1.1 REQUESTER: R. F. Speece/TV-MSD-22/7-0806

1.2 REQUESTER'S SAMPLE DESCRIPTION: The samples were from OV-104, STS-37 landing DFRF, and were identified as:

I. Window wipe
1. #1, OV-104
2. #2, OV-104
3. #3, OV-104
4. #4, OV-104
5. #5, OV-104
6. #6, OV-104
7. #7, OV-104
8. #8, OV-104

II. RCC panels
9. RCC panel #8, IPA wipe of white streaks
10. RCC panel #8, dry wipe of white streaks
11. RCC panel #9, IPA wipe of white streaks
12. RCC panel #9, dry wipe of white streaks
13. RCC panel #12, IPA wipe of white streaks
14. RCC panel #12, dry wipe of white streaks

III. Tile surface
15. V070-3950154-110, body flap, IPA wipe of tile surface with suspect PDL.
16. V070-3950154-110, body flap, dry wipe of tile surface with suspect PDL.
17. V070-395015-115, body flap, IPA wipe of tile surface with suspect PDL.
18. V070-394032-233, sample, discoloration in tile impact, 4/13/91, V6028, task II.

1.3 REQUESTED: Perform chemical analysis, compare results to known STS materials, and estimate temperature exposure of "PDL samples."

## 2.0 CHEMICAL ANALYSIS AND RESULTS:

### 2.1 Procedure:

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

### 2.2 Results:

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

Table 1

| Component ID | Elemental Analysis by EDS* | |
|---|---|---|
| | Major | Minor |
| 1.Metallics | Fe,Cr,Zn,Al,Ni,Cu | |
| 2.Brn mtls | Fe,Si,Ti,Cl,K,Al | S,Ca,Mg |
| 3.Blk mtls | Ca,Si,Al,Fe,Cl,K | Mg,Ti,P,S |
| 4.Wht mtls | Si,Cl,Na,Al,K,Ca,Fe | Mg,Ti,S |
| 5.Amber mtls | Fe,K,Si,Al | Mg,Ti |
| 6.Red mtls | Fe,Ti,Si,Cl,Al | S,K,Zn |
| 7.Glass fiber | Si,Al | Ca |
| 8.Organics | carbohydrate, ester,polyamide | |
| 9.Organic fibers | cellulose fibers | |

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

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

Table 2

| Sample NO<br>Components | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.Metallics | x | T | x | T | T | x | T | x | T | T |
| 2.Brn mtls | 10 | 6 | 2 | 1 | 1 | 1 | 3 | 2 | x | x |
| 3.Blk mtls | 3 | 3 | 1 | 1 | 2 | 2 | 2 | 3 | 10 | 4 |
| 4.Wht mtls | 77 | 87 | 95 | 97 | 85 | 80 | 85 | 80 | 2 | 6 |
| 5.Amber mtls | 8 | 4 | 2 | 1 | 12 | 17 | 10 | 15 | 3 | 5 |
| 6.Red mtls | x | x | x | x | x | x | x | x | 2 | 3 |
| 7.Glass fiber | T | T | T | T | T | T | x | T | T | T |
| 8.Organics | 7 | T | 2 | T | T | T | T | T | 88 | 80 |
| 9.Organic fibers | T | T | T | T | T | T | T | T | T | T |
| Particle size in um | 1-110 | 1-60 | 1-80 | 1-70 | 1-70 | 1-80 | 1-120 | 1-130 | 1-180 | 1-250 |

Table 2 continue

| Sample NO<br>Components | #11 | #12 | #13 | #14 | #15 | #16 | #17 | #18 |
|---|---|---|---|---|---|---|---|---|
| 1.Metallics | 5 | 2 | 3 | T | T | T | x | 1.Blk tile |
| 2.Brn mtls | x | x | x | x | x | x | x | 2.Wht tile |
| 3.Blk mtls | 2 | 3 | 3 | 10 | 3 | 5 | 5 | 3.Organics |
| 4.Wht mtls | 1 | 2 | T | 2 | 1 | 2 | 3 | 4.RTV |
| 5.Amber mtls | 6 | 8 | 2 | T | 1 | T | 2 | |
| 6.Red mtls | x | 1 | 1 | x | x | x | x | |
| 7.Glass fiber | x | T | T | x | T | T | x | |
| 8.Organics | 86 | 84 | 91 | 88 | 95 | 93 | 90 | |
| 9.Organic fiber | T | T | T | T | T | T | T | |
| Particle size in um | 1-300 | 1-260 | 1-300 | 1-350 | 1-300 | 1-180 | 1-190 | |

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

## 3.0 CONCLUSIONS:

3.1 All samples contained trace to small amounts of particulates.

3.2 The following samples contained metallics:

#2: 300 series stainless steel.
#4: Al-alloy and Zn-alloy.
#5: Al-alloy.
#7: carbon steel.
#9: 300 series stainless steel, Ni-alloy, and Al-allo
#10: carbon steel and Al-alloy.
#11: Al-alloy.
#12: carbon steel and Al-alloy.
#13: Al-alloy.
#14: Al-alloy.
#15: Al-alloy and Cu-metal.
#16: Al-alloy.

3.3 The sample numbers 1 through 8 contained brown material The brown materials were composed of salt, rust, Si-Fe-Ti rich materials, Si-Fe rich materials, and RTV.

3.4 All samples except sample number 18 contained black materials. The black materials appeared to be composed of rust, Si rich materials, paints, Fe-S rich materials dust, and Ca-S-Si-Al rich materials. The black material from sample 18 was composed of black dense tile.

3.5 All samples contained white materials. The white materials were composed of Si-rich materials, alpha-quartz (alpha-$SiO_2$), NaCl, albite ($NaAlSi3O_8$), calcite ($CaCO_3$) Si-Mg rich materials, Si-Al-Ca rich materials, and paints.

3.6 All samples except sample 18 contained amber flakes. Th amber flakes were identified as muscovite [KAl2(AlSi3O20)(OH)2].

3.7 The samples 9 through 13 contained red materials. The red materials were composed of a combination of paints, rust, and RTV particles.

3.8 The samples 1 through 10, 12, 13, 15, 16, and 18 contained trace to small amounts of glass fibers. The glass fibers were composed of Si rich tile, Si-Al rich high temperature insulation, and Si-Al-Ca rich glass fibers.

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3.9 The samples 1 through 8 contained trace to small amounts of organics, while samples 9 through 17 contained large amounts of organic materials. The organics were composed of carbohydrate like a sugar or starch proteinaceous materials, ester or urethane with inorganic silicate, and polyamide. The IRS spectrum from all organic materials appeared to be not matched to the standard elephant hide or hypalon paints.

3.10 The organic fibers were identified to be composed mainly of cellulose materials.

3.12 No evidence of high temperature exposure of "PDL foam" samples were noted.

3.13 The particle sizes were estimated to be in the range of 1 350 micrometers.

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

APPROVED: Leo D Underhill
for J. F. Jones

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15. Supplementary Notes

16. Abstract

A Debris/Ice/TPS assessment and photographic analysis was conducted for Space Shuttle Mission STS-37. 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-37, and their overall effect on the Space Shuttle Program.

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