NASA Technical Memorandum TM 103814

Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-41

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DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-41

October 6, 1990

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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-41 was launched at 7:45 a.m. EST 10/6/90

1.0 Summary

Debris and Photo Analysis Team activities for Mission STS-41 began with the pre-launch debris inspection of the launch pad and Shuttle vehicle on 5 October 1990. No major anomalies were observed on OV-103 Discovery, BI040, or ET-39. Minor facility discrepancies, which included loose MLP deck bolts and loose access covers, were corrected prior to cryoloading.

The vehicle was cryoloaded for flight on 6 October 1990. No Orbiter or SRB anomalies were detected during the Ice Team inspection. Condensate, but no ice or frost, was present on all acreage areas of the External Tank. There was one Launch Commit Criteria violation. A resin sealant crack in the LH2 umbilical 17-inch flapper valve actuator access port foam plug closeout emitted cold helium purge gas vapors and formed condensate ice/frost (ref IPR 41V-0226). This area was not an "acceptable ice area" per LCC Appendix F. Waiver LW-023 approved this condition for flight based on the rationale that the low-density ice from this area, and/or loss of the foam plug itself, would not contact Orbiter TPS. In addition, three Ice/Frost console observation anomalies were documented and found acceptable for launch per the LCC and NSTS-08303. The hydrogen umbilical leak sensors detected no significant hydrogen during the cryoload and was removed by the Ice Inspection Team during the T-3 hour hold. At launch, the ET ice condition was well within the data base for ice/frost/condensate formation.

A post launch debris inspection of Pad 39B was performed after launch. No significant flight hardware or TPS material was found, except for one Orbiter Q-felt plug. Launch damage to the holddown posts was minimal. No evidence of stud hang-ups or ordnance fragments from HDP debris containers was visible. The GH2 vent line had latched properly. More than usual facility debris was found. The most significant facility debris consisted of seven FSS/RSS cable tray covers, the largest of which measured approximately 8 feet x 2 feet. Numerous other covers on the FSS/RSS were loose.

A total of 125 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. A 3.5"x0.25" ordnance debris fragment dropped from the LH SRB HDP #6 stud hole. No debris was visible falling from any of the other holddown post stud holes. Numerous pieces of debris fell from the vehicle during ascent. Most have been identified as ice/frost particles from the ET/Orbiter umbilicals, RCS thruster paper covers, and instafoam particles from the SRB aft skirts. The particles falling from the vehicle after Max Q are either pieces of SRB aft skirt instafoam or chunks of propellant/inhibitor. Objects in the SRB plumes prior to and just after separation from the External Tank are chunks of SRB propellant slag (clinkers). Movement of the Orbiter body flap was visible after the roll maneuver and

through most of the ascent. The motion appears to have an amplitude and frequency similar to that observed on previous flights.

On-orbit photos of the External Tank after separation from the Orbiter revealed no significant anomalies. During the Ulysses/ IUS deployment, three curved objects appeared near the aft end of the Orbiter and in the field-of-view with the payload. The objects were rectangular in plan form, but curved when viewed along the edge. The concave side of the objects were smooth while the opposite side was rough - similar to the frozen ice observed during ET separation. These objects are believed to be pieces of ice from the Orbiter MPS area.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both forward skirts and frustums exhibited a total of 79 debonds, but no TPS was lost during ascent. The frustum severance ring, which utilized the new pin retainer clips, was missing no pins. Generally, the new Field Joint Protection System (FJPS) closeouts on all 6 field joints were in good condition. HDP #6 DCS plunger was jammed open by a frangible nut half and 73 percent of the ordnance debris was lost. Although HDP #8 DCS plunger was seated properly, only 22 percent of the ordnance debris was found in the DCS after disassembly.

A post landing inspection of OV-103 was performed on Runway 22. The Orbiter TPS sustained a total of 76 hits, of which 16 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 64 hits, of which 13 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the number of hits on the lower surface is less than average. Also, based on the severity of damage as indicated by surface area and depth, this flight is better than average. The debris plunger in the EO-2 (LH2) separation fitting debris container was obstructed by the frangible nut halves and failed to seat properly. Three pieces of spent ordnance assembly (detonator, booster fragment, and connector piece) were found on the runway beneath the LH2 ET/ORB umbilical cavity and were attributed to this failure. This anomaly was documented on PR PYR-3-12-0153. The debris plunger had been modified prior to return-to-flight, but has experienced failures in approximately 33% of the Shuttle flights.

White 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 earth minerals. The lower surface Orbiter tile samples indicated localized heating from re-entry, but the only materials recovered from the damage sites were tile TPS elements.

A total of 11 Post Launch Anomalies were observed during this mission assessment. One Anomaly was elevated to an IFA.

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 - LSS

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

3) Ice/Frost TPS and Debris Inspection

Objective:	Evaluate any ice formation as potential debris material. Identify and evaluate any ORB, ET, or SRB TPS anomaly which may be a debris source or safety of flight concern. Identify and evaluate any other possible facility or vehicle anomaly.
Areas:	MLP deck, FSS, Shuttle vehicle 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 shuttle 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 shuttle 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 vehicle during launch.
Areas:	MLP deck, flame exhaust holes and trenches, FSS, pad surfaces and slopes, extension of trenches to perimeter fence, walkdown of the beach from Playalinda to Complex 40, aerial overview of inaccessible areas.
Time:	Launch + 3 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/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 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. Any anomalies must be documented/ photographed and coordinated with the results of the post launch shuttle and 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 damage to Orbiter TPS due to debris and correlate, if possible, source and time of occurrence. Additionally, runways are inspected for debris and 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 or corrected by the Team shall be documented and photographed; and the proper management 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 preliminary 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/Frost/Debris Team briefing for launch activities was conducted on 5 October 1990 at 0800 hours with the following key personnel present:

G. Katnik	NASA - KSC	Lead, Ice/Debris Assess Team ET Mech./TPS, STI
P. Rosado	NASA - KSC	Chief, ET Mechanical Systems
S. Higginbotham	NASA - KSC	STI, Ice/Debris Assessment
B. Speece	NASA - KSC	ET Processing, Ice/Debris
J. Rivera	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	ET Processing, Debris Assess
B. Davis	NASA - KSC	STI, Debris Assessment
K. Tenbusch	NASA - KSC	"SURFICE", Debris Assess
J. Hoffmann	LSOC - SPC	ET Processing, Ice Assess
J. Blue	LSOC - SPC	ET Processing, Ice Assess
R. Seale	LSOC - SPC	ET Processing, Ice Assess
F. Huneidi	NASA - MSFC	TPS & Ice Assessment
Z. Byrns	NASA - JSC	Level II Integration
C. Gray	MMC - MAF	ET TPS & Materials Design
S. Copsey	MMC - MAF	ET TPS Testing/Certif
S. Otto	MMC - KSC	ET Processing, LSS
J. McClymonds	RI - Downey	Debris Assess, LVL II Integ
K. Mayer	RI - LSS	Vehicle Integration
K. Yamasaki	USBI - LSS	SRB Processing
K. Parsons	MTI - LSS	SRM Processing
J. Cook	MTI - LSS	SRM Processing

These personnel participated in various team activities, assisted in the collection and evaluation of data, and wrote 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 5 October 1990 from 0900 - 1200 hours. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-103 Discovery (11th flight), ET-39 (LWT-32), and BI040. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and new vehicle configurations.

There were no vehicle anomalies. The new Field Joint Protection System (FJPS) closeout had been applied to the 6 SRB field joints. According to the original plan, STS-38 would have flown a test FJPS closeout on the BI039 RH aft field joint. This location would have prevented Orbiter damage in the event of a FJPS failure. STS-41, which is the first vehicle to fully incorporate the new configuration, flew before STS-38 due to the rearranged launch schedule and Ulysses payload priority. The new FJPS will be the subject of a post flight assessment.

Due to the hydrogen leakage from the ET/ORB LH2 umbilical interface area during the cryoloading of STS-29R, STS-35, and STS-38, a temporary hydrogen detector was installed at the ET/ORB LH2 umbilical until a permanent sensor could be designed and installed. The temporary detectors LD54 and LD55 consist of two tygon tubes that run from the LH2 umbilical area to the hazardous gas detection equipment located in the MLP. The tubes were attached to the vehicle by three velcro strap assemblies. A length of parachute cord attached to these assemblies enable the entire apparatus to be quickly removed from the vehicle without causing TPS damage. The hydrogen sensor is intended to remain in place during cryoloading and be removed by the Ice Inspection Team during the T-3 hour hold.

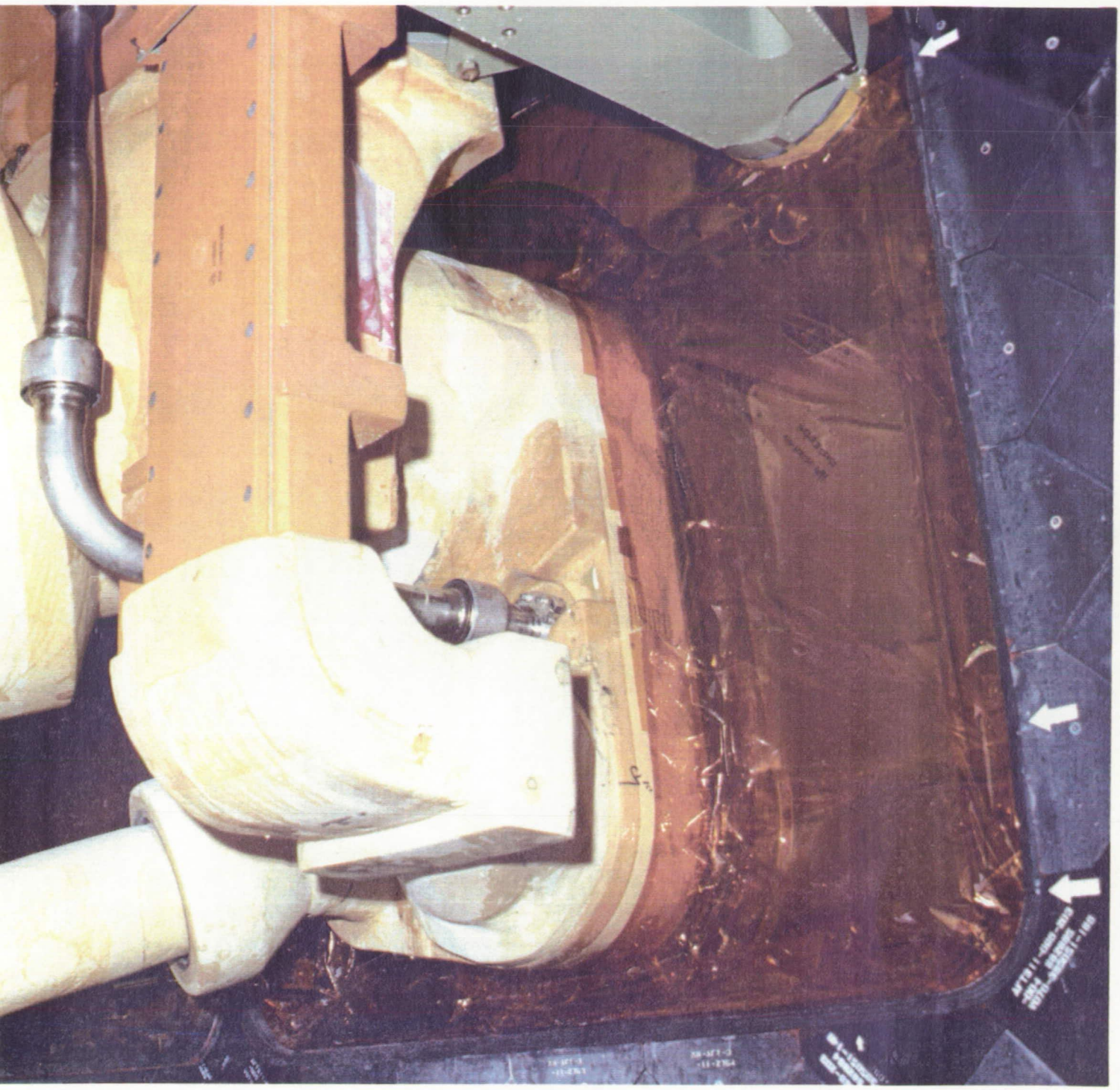
A recurring problem is loose MLP deck bolts. This inspection revealed 8 raised, or shanked, bolts on the deck north of the SSME exhaust hole.

Other discrepancies included loose covers on an electrical connector box, on a junction box north of the zero-level egress route on the MLP east side, and on a junction box adjacent to the Portable Purge Unit (PPU) connection. A deck splice plate adjacent to the north side of the SSME exhaust hole was loose.

Trash and debris was visible in the gutters around the MLP zero level and in the SRB holddown post haunches. These areas were vacuumed prior to cryoload. A parts bag floated in the SRB sound suppression water trough west of the LH SRB nozzle.

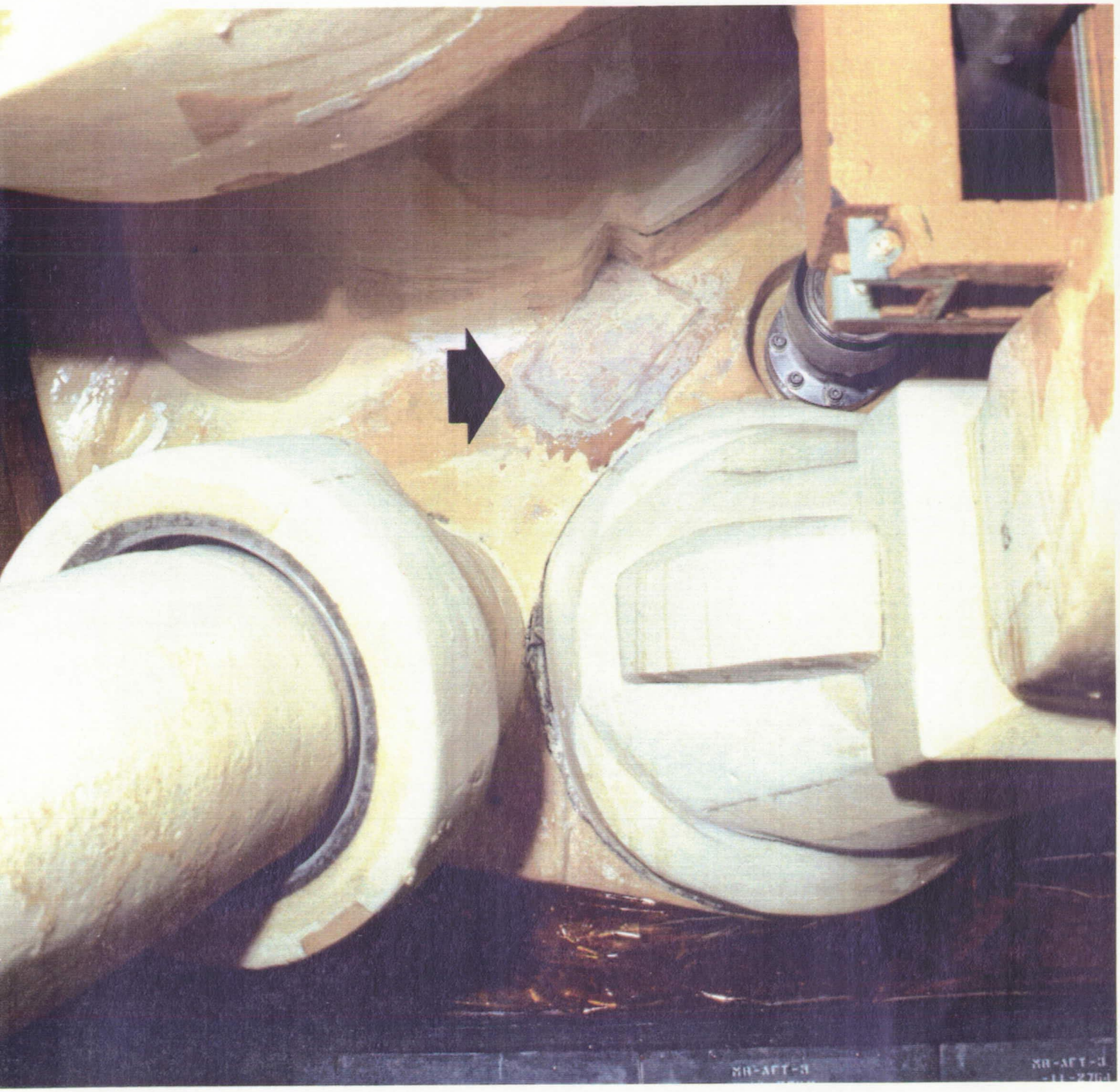
Cleanup of the MLP deck and pad surface was almost complete at the time of the inspection. The facility discrepancies were worked real-time or transferred to the pad leader for resolution prior to vehicle tanking.

Overall view of ET-39 (LWT 32) and BIO40 -Z side

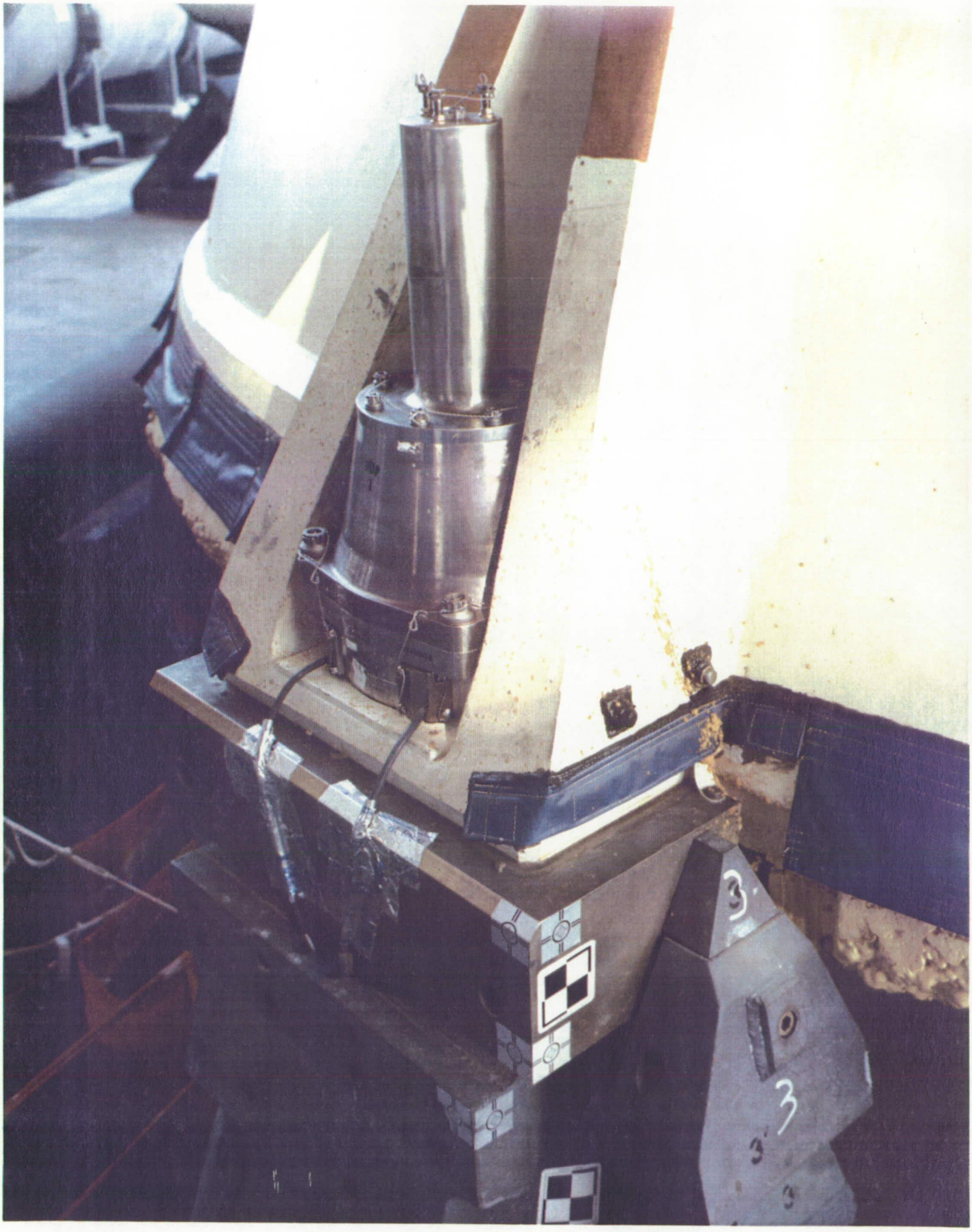


ORIGINAL PAGE
COLOR PHOTOGRAPH

Pre-launch configuration of ET/ORB LH2 umbilical



LH2 umbilical 17" flapper valve actuator access port foam plug used thicker material, tighter fit, and 3 part resin sealant



Additional optical targets on holddown post #1 will be used to measure relative displacements between holddown post and shoe

4.0 LAUNCH

STS-41 was launched at GMT 06:11:47:15 on 6 October 1990.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 6 October 1990 from 0215 to 0420 hours during the two hour built-in-hold at T-3 hours in the countdown. There was one Launch Commit Criteria violation. A resin sealant crack in the LH2 umbilical 17-inch flapper valve actuator access port foam plug closeout emitted cold helium purge gas vapors and formed condensate ice/frost (ref IPR 41V-0226). This area was not an "acceptable ice area" per LCC Appendix F. Waiver LW-023 approved this condition for flight based on the rationale that the low-density ice from this area, and/or loss of the foam plug itself, would not contact Orbiter TPS.

Ambient weather conditions at the time of the inspection were:

Temperature:	80.9 F
Relative Humidity:	79.8 %
Wind Speed:	10 Knots
Wind Direction:	081 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. All forward and aft RCS thruster paper covers were intact. The average Orbiter surface temperature ranged from 77-79 degrees F. A small amount of condensate was visible on the SSME #1 engine mounted heat shield. Some ice/frost had formed on the nozzle to engine mounted heat shields of SSME #2 and #3. Condensate that had frozen to a clear type of ice (glazed) was present at the 5-7 o'clock positions of SSME #2 and #3.

4.3 SRB OBSERVATIONS

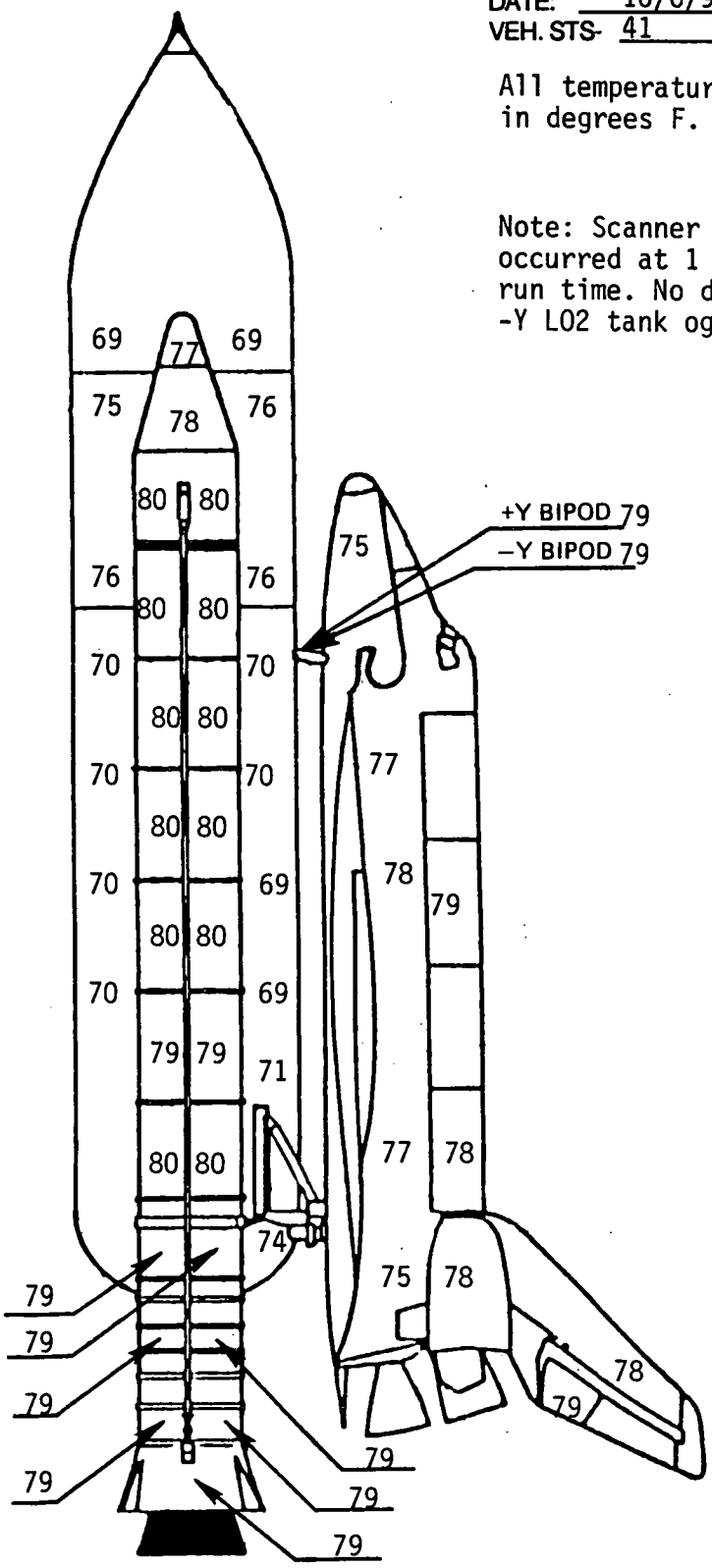
No SRB anomalies or loose ablator/cork were observed. There were no discrepancies on the new field joint protection system (FJPS) closeouts. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 77-80 degrees F. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 82 degrees F.

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

TIME: 0215-0420
DATE: 10/6/90
VEH. STS- 41

All temperatures are in degrees F.

Note: Scanner freeze-up occurred at 1 H 18 Min run time. No data on -Y LO2 tank ogive.



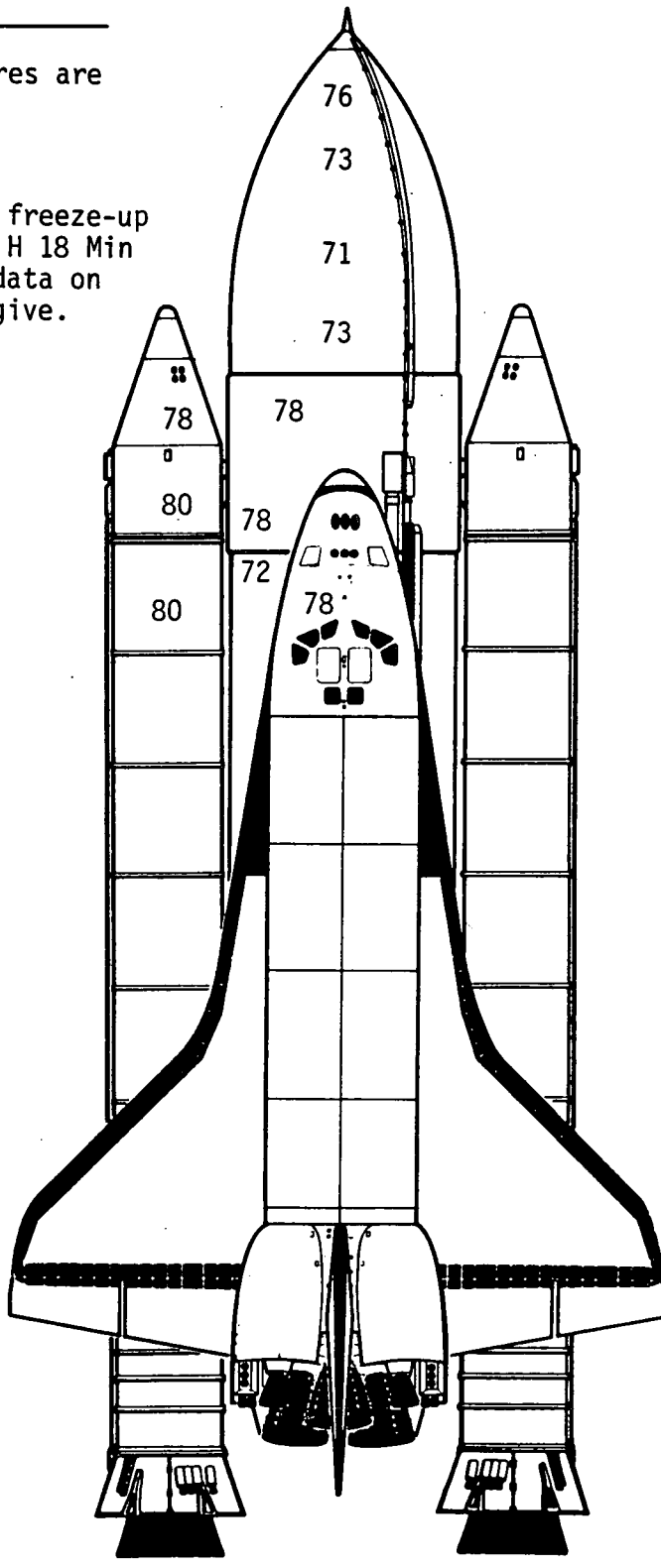


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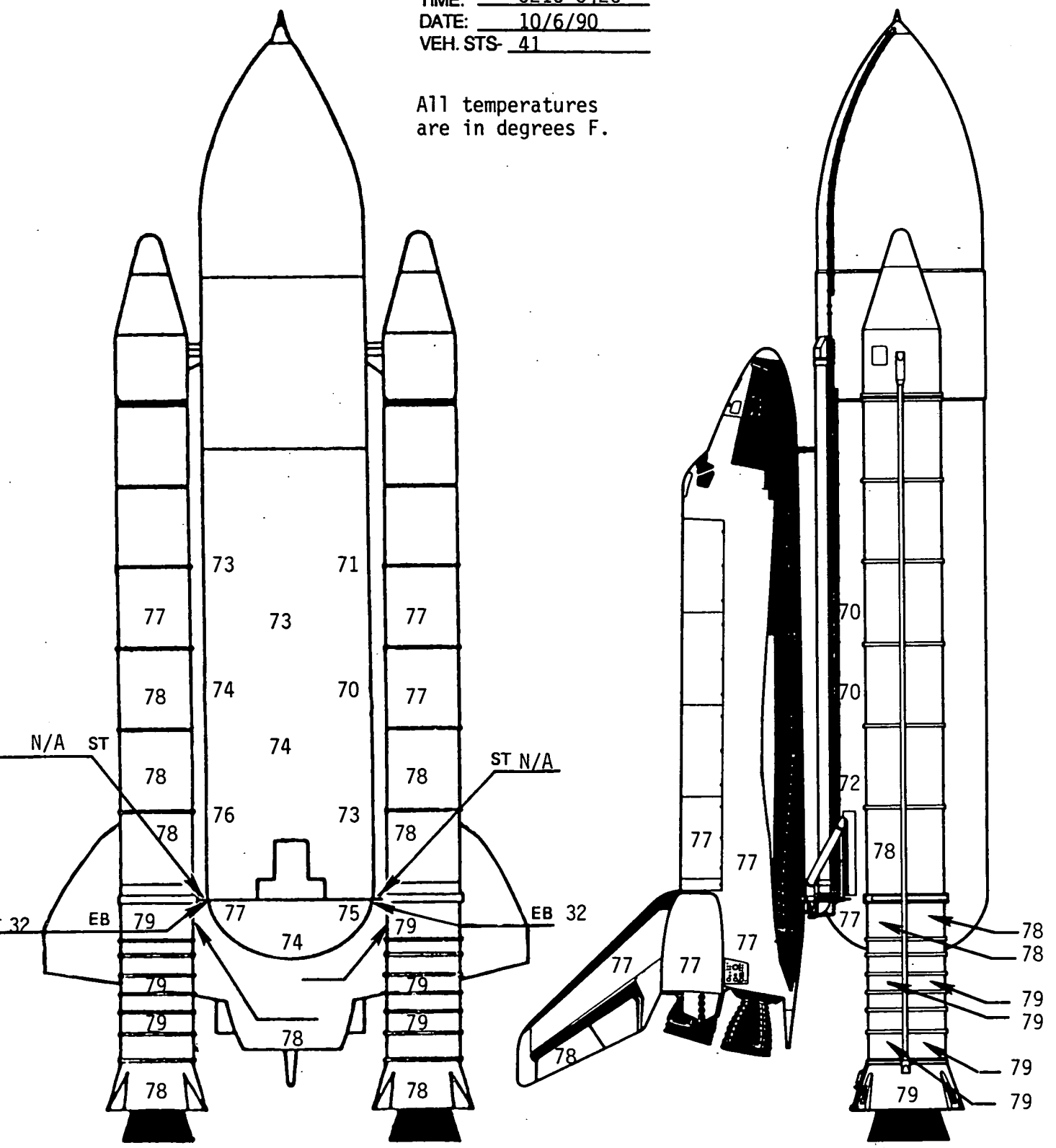
FIGURE 2. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**



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4.4 EXTERNAL TANK OBSERVATIONS

The ice/frost prediction computer program was run from 2330 to 0745 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 ogive was dry. Light condensate, but no ice or frost, was present on the -Z side of the tank. There were no TPS anomalies. The tumble valve cover was intact. The STI IR scanner measured an average surface temperature of 75 degrees F on the ogive and 72 degrees F on the barrel section. This compares to Mikron IR instrument readings of 64 and 63 degrees F, respectively. SURFICE predicted 73 degrees F on the ogive and 70 degrees F on the barrel section.

Moderate run-on condensate was present on the intertank. The only TPS anomaly consisted of a 1/2-inch frost spot on the LH2 tank-to-intertank flange where the -Y thrust panel meets the first +Z stringer. There was no ice/frost in the stringer valleys on the +Z side of the tank. Ice/frost did form, however, in -Y-Z quadrant stringer valleys: one near the LO2 tank-to-intertank splice and 7 near the LH2 tank-to-intertank splice. The STI IR scanner measured an average surface temperature of 77 degrees F. There were no anomalies on the bipods.

A moderate amount of condensate trickled down the LH2 tank and ran off the aft dome. There was no acreage ice/frost and no TPS anomalies. The average surface temperatures as measured by the STI IR scanner were 72 degrees F on the upper LH2 tank and 74 degrees F on the lower LH2 tank. This compares to 68 and 75 degrees F, respectively, as measured by the Mikron instrument. SURFICE predicted 69 degrees F on the upper LH2 tank and 73 degrees F on the lower LH2 tank.

There were no anomalies on the PAL ramp, cable tray/press line ice/frost ramps, thrust struts, longerons, aft dome apex, or manhole covers. Ice/frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry.

Normal amounts of hard, crusty 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 there was no ice/frost accumulation on the acreage areas of the umbilical. Ice/frost fingers 6-8 inches in length had formed on the three pyro canister purge vents. Normal venting of nitrogen purge gas was occurring. The only TPS anomaly appeared to be a small 2-3 inch crack in the fire barrier paint near the forward outboard pyro canister.

STS- 41	TEST S0007 LAUNCH																									
																							DATE: 6 October 1990			T-0 TIME: 07:47:15 DATE: 10-6-90
ORBITER 103	ET 39	SRB BI-041	MLP 2	PAD B	LO2 CHILLDOWN TIME: 23:27 SLOW FILL TIME: 23:52					FAST FILL TIME: 00:05 REPLENISH TIME: 02:09					LH2 CHILLDOWN TIME: 22:59 SLOW FILL TIME: 23:25					FAST FILL TIME: 23:52 REPLENISH TIME: 01:54					
TIME (EDT)	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
2330	80.60	81.00	74.56	8	70	II	4.72	70.84	0.0024	-0.2387	II	4.72	66.93	0.0046	-0.2062	II	4.40	65.62	0.0049	-0.1874	II	9.76	70.58	0.0048	-0.3997
2345	80.40	81.80	74.64	8	70	II	4.72	70.83	0.0025	-0.2386	II	4.72	66.92	0.0046	-0.2061	II	4.40	65.60	0.0050	-0.1873	II	9.76	70.58	0.0050	-0.3997
0000	79.60	81.80	73.85	6	62	II	3.54	68.72	0.0025	-0.1834	II	3.54	63.78	0.0044	-0.1521	II	4.20	64.29	0.0049	-0.1727	II	7.26	68.15	0.0050	-0.2920
0015	80.20	81.60	74.37	7	72	II	4.13	70.02	0.0025	-0.2121	II	4.13	65.66	0.0045	-0.1801	II	3.85	64.20	0.0049	-0.1629	II	8.54	69.65	0.0050	-0.3486
0030	80.80	81.40	74.90	8	66	II	4.72	71.16	0.0025	-0.2414	II	4.72	67.27	0.0046	-0.2088	II	5.60	67.74	0.0051	-0.2388	II	9.68	70.86	0.0049	-0.4012
0045	80.20	82.60	74.72	8	74	II	4.72	70.81	0.0026	-0.2385	II	4.72	66.90	0.0047	-0.2060	II	4.40	65.58	0.0051	-0.1872	II	9.76	70.57	0.0051	-0.3997
0100	80.80	82.40	75.25	8	84	II	4.72	71.41	0.0026	-0.2436	II	4.72	67.53	0.0047	-0.2109	II	4.40	66.22	0.0051	-0.1918	II	9.76	71.16	0.0051	-0.4083
0115	80.60	83.20	75.32	9	83	II	5.31	71.84	0.0026	-0.2683	II	5.31	68.31	0.0048	-0.2351	II	4.95	67.10	0.0052	-0.2144	II	10.98	71.68	0.0051	-0.4565
0130	80.60	82.60	75.12	8	76	II	4.72	71.24	0.0026	-0.2422	II	4.72	67.35	0.0047	-0.2096	II	4.40	66.04	0.0051	-0.1905	II	9.76	71.00	0.0051	-0.4059
0145	80.80	81.00	74.76	10	83	II	5.90	71.87	0.0024	-0.2892	II	5.90	68.62	0.0046	-0.2557	II	5.50	67.51	0.0050	-0.2338	II	12.20	71.74	0.0046	-0.4977
0200	80.80	80.20	74.47	11	76	II	6.49	71.98	0.0022	-0.3110	II	6.49	68.97	0.0045	-0.2772	II	6.05	67.94	0.0050	-0.2539	II	13.42	71.89	0.0043	-0.5407
0215	80.60	80.00	74.21	11	82	II	6.49	71.72	0.0022	-0.3081	II	6.49	68.69	0.0045	-0.2744	II	6.05	67.66	0.0049	-0.2512	II	13.42	71.63	0.0042	-0.5356
0230	80.80	79.80	74.33	10	83	II	5.90	71.56	0.0022	-0.2860	II	5.90	68.30	0.0045	-0.2527	II	5.50	67.19	0.0049	-0.2309	II	12.20	71.43	0.0044	-0.4919
0245	80.60	79.20	73.92	10	80	II	5.90	71.20	0.0022	-0.2823	II	5.90	67.92	0.0044	-0.2491	II	5.50	66.80	0.0048	-0.2276	II	12.20	71.06	0.0043	-0.4853
0300	80.80	79.80	74.33	10	83	II	5.90	71.56	0.0022	-0.2860	II	5.90	68.30	0.0045	-0.2527	II	5.50	67.19	0.0049	-0.2309	II	12.20	71.43	0.0044	-0.4919
0315	80.60	80.00	74.21	11	74	II	6.49	71.72	0.0022	-0.3081	II	6.49	68.69	0.0045	-0.2744	II	6.05	67.66	0.0049	-0.2512	II	13.42	71.63	0.0042	-0.5356
0330	81.20	80.40	74.94	9	77	II	5.31	71.77	0.0024	-0.2675	II	5.31	68.25	0.0046	-0.2344	II	4.95	67.05	0.0050	-0.2139	II	10.98	71.58	0.0047	-0.4546
0345	80.80	80.00	74.40	11	72	II	6.49	71.93	0.0022	-0.3104	II	6.49	68.91	0.0045	-0.2766	II	6.05	67.88	0.0049	-0.2534	II	13.42	71.84	0.0043	-0.5396
0400	81.00	80.40	74.74	9	89	II	5.31	71.56	0.0024	-0.2655	II	5.31	68.02	0.0046	-0.2325	II	4.95	66.82	0.0050	-0.2120	II	10.98	71.37	0.0046	-0.4512
0415	80.80	78.20	73.76	10	82	II	5.90	71.15	0.0021	-0.2818	II	5.90	67.87	0.0043	-0.2486	II	5.50	66.76	0.0047	-0.2271	II	12.20	71.00	0.0041	-0.4842
0430	81.20	80.60	75.01	13	93	II	7.67	73.00	0.0021	-0.3650	II	7.67	70.41	0.0045	-0.3302	II	7.15	69.51	0.0050	-0.3035	II	15.86	72.97	0.0041	-0.6457
0445	81.00	79.20	74.31	12	97	II	7.08	72.20	0.0020	-0.3341	II	7.08	69.40	0.0044	-0.2999	II	6.60	68.44	0.0048	-0.2752	II	14.64	72.13	0.0039	-0.5859
0500	79.60	78.80	72.79	10	98	II	5.90	70.04	0.0021	-0.2708	II	5.90	66.71	0.0043	-0.2379	II	5.50	65.57	0.0047	-0.2170	II	12.20	69.91	0.0041	-0.4653
0515	81.00	77.80	73.81	12	89	II	7.08	71.84	0.0019	-0.3297	II	7.08	69.02	0.0042	-0.2957	II	6.60	68.06	0.0047	-0.2712	II	14.64	71.76	0.0036	-0.5779
0530	81.00	77.40	73.66	10	99	II	5.90	71.16	0.0020	-0.2817	II	5.90	67.88	0.0042	-0.2486	II	5.50	66.77	0.0046	-0.2271	II	12.20	70.99	0.0039	-0.4840
0545	80.60	76.80	73.04	12	98	II	7.08	71.16	0.0017	-0.3218	II	7.08	68.32	0.0040	-0.2880	II	6.60	67.35	0.0045	-0.2640	II	14.64	71.08	0.0034	-0.5637
0600	80.60	75.80	72.67	12	94	II	7.08	70.90	0.0016	-0.3187	II	7.08	68.05	0.0039	-0.2851	II	6.60	67.08	0.0044	-0.2612	II	14.64	70.81	0.0032	-0.5580
0615	80.60	75.80	72.67	12	94	II	7.08	70.90	0.0016	-0.3187	II	7.08	68.05	0.0039	-0.2851	II	6.60	67.08	0.0044	-0.2612	II	14.64	70.81	0.0032	-0.5580
0630	81.00	75.20	72.84	13	90	II	7.67	71.39	0.0014	-0.3442	II	7.67	68.73	0.0038	-0.3102	II	7.15	67.83	0.0043	-0.2848	II	15.86	71.32	0.0028	-0.6075
0645	80.60	76.00	72.75	14	97	II	8.26	71.39	0.0014	-0.3643	II	8.26	68.89	0.0038	-0.3299	II	7.70	68.04	0.0043	-0.3032	II	17.08	71.35	0.0028	-0.6477

FIGURE 3. SURFICE Ice/frost computer predictions

STS- 41	TEST S0007 LAUNCH																									
																	DATE: 6 October 1990				T-0 TIME: 07:47:15 DATE: 10-6-90					
ORBITER 103	ET 39	SRB BI-041	MLP 2	PAD B	LO2 CHILLDOWN TIME: 23:27 FAST FILL TIME: 00:05 SLOW FILL TIME: 23:52 REPLENISH TIME: 02:09						LH2 CHILLDOWN TIME: 22:59 FAST FILL TIME: 23:52 SLOW FILL TIME: 23:25 REPLENISH TIME: 01:54															
TIME (EDT)	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0700	80.60	74.60	72.22	15	95	II	8.85	71.20	0.0011	-0.3814	II	8.85	68.84	0.0035	-0.3469	II	8.25	68.03	0.0040	-0.3191	II	18.30	71.18	0.0022	-0.6821
0715	80.80	72.20	71.49	12	95	II	7.08	70.15	0.0012	-0.3099	II	7.08	67.27	0.0035	-0.2766	II	6.60	66.30	0.0039	-0.2533	II	14.64	70.02	0.0024	-0.5416
0730	80.80	72.80	71.72	13	93	II	7.67	70.54	0.0011	-0.3337	II	7.67	67.86	0.0034	-0.3000	II	7.15	66.95	0.0039	-0.2753	II	15.86	70.45	0.0023	-0.5883
0745	80.80	72.60	71.64	15	85	II	8.85	70.87	0.0008	-0.3767	II	8.85	68.50	0.0032	-0.3423	II	8.25	67.69	0.0038	-0.3148	II	18.30	70.83	0.0017	-0.6730
AVG	73.25	65.43	62.78	8.92	73.2		5.27	67.27				5.54	64.20				5.22	61.56				11.46	63.59		

▒▒▒ Period of Ice Team Walkdown

FIGURE 4. SURFICE Ice/frost computer predictions

There was some frost, but no ice, in the LH2 feedline upper bellows. Condensate was present in the lower bellows. Ice/frost had formed in the LH2 recirculation line bellows and on both burst disks. The top and sides of the LH2 ET/ORB umbilical were covered by heavy, but typical, ice/frost. Cold helium purge gas venting from a small 1-inch tear in the baggie material at a location near the top of the umbilical cavity may have contributed to the greater build-up of ice/frost on the top side of the umbilical and the plugging of the LD55 tygon tube. Ice/frost accumulation on the inboard and aft sides of the baggie was light. Frost had formed around the closeout line of the aft pyro canister and in an adjacent minimum thickness TPS area. No frost was visible on the cable tray vent hole. Ice/frost fingers 6-8 inches in length had formed on the pyro canister purge vents. Normal venting of helium purge gas was occurring. There were no unusual vapors emanating from the umbilicals or any evidence of hydrogen leakage.

The ET/ORB hydrogen detection sensor tygon tubing was successfully removed with no contact to the vehicle or TPS damage. Ice plugged the LD55 tygon tube to a depth of 1/2 inch.

The summary of ice/frost team observation anomalies consists of 3 OTV recorded items:

Anomaly 001 documented a frost ball 1-inch in diameter on the +Y side of the LH2 feedline-to-aft dome interface closeout. The frost ball associated with a foam closeout or repair was acceptable per NSTS-08303.

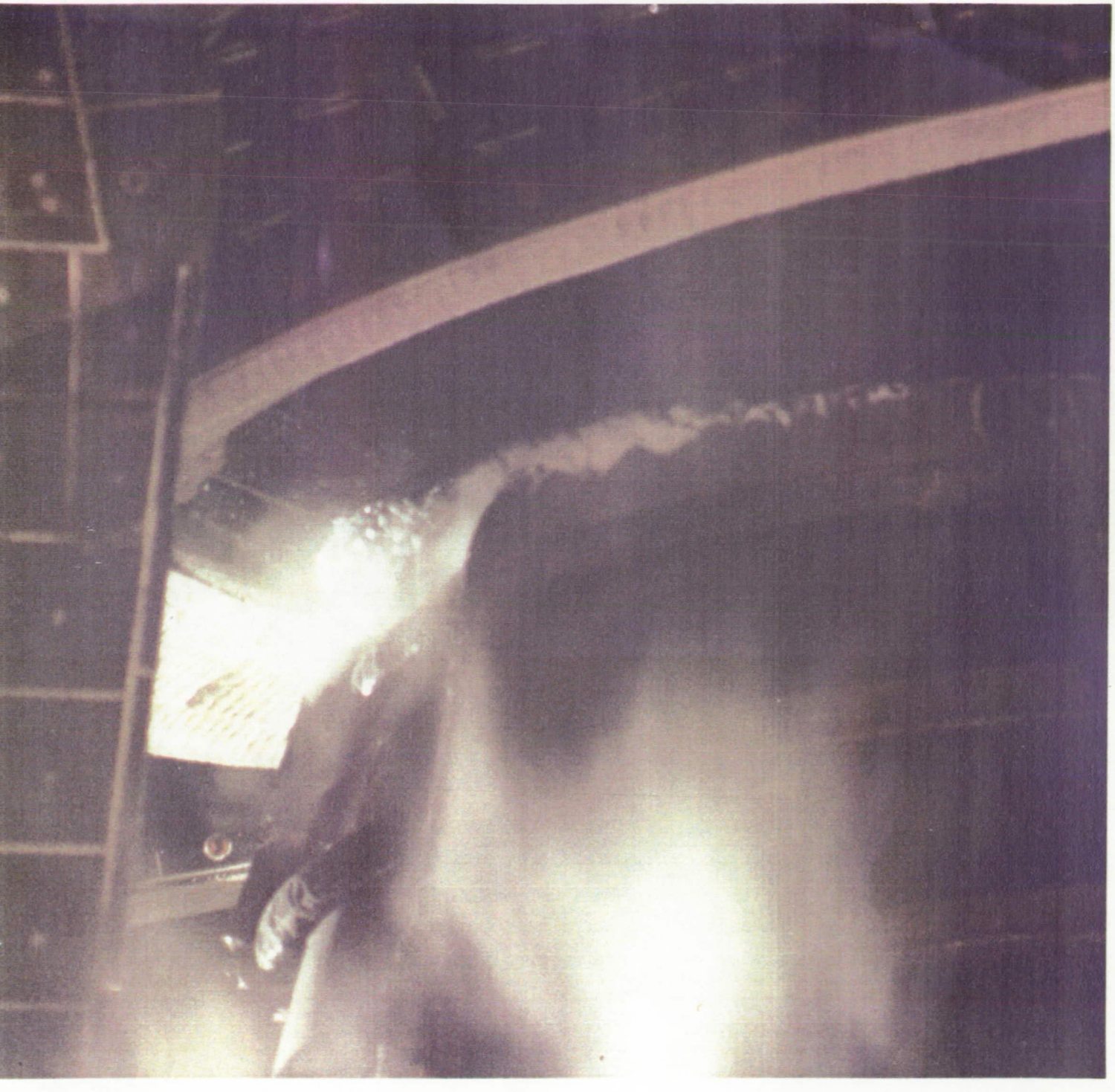
Anomaly 002 recorded a resin sealant crack in the upper corner of the LH2 17-inch umbilical disconnect flapper valve actuator tool access port foam plug closeout. Ice/frost build-up and purge vapors were present. This anomaly, observed during the Ice Inspection, was documented on IPR 41V-0226. The presence of ice in this area was an LCC violation. Waiver LW-023 was granted based on the rationale that ice/foam plug debris would not contact Orbiter tiles. If contact did occur, the damage was expected to be minor due to the impact angle and the light density of both materials.

A frost ball 1/2-inch in diameter formed on the LH2 tank-to-intertank flange closeout where the -Y thrust panel interfaces with the first +Z intertank stringer valley (Anomaly 003). Later OTV views showed the frost ball had disappeared.

4.5 FACILITY OBSERVATIONS

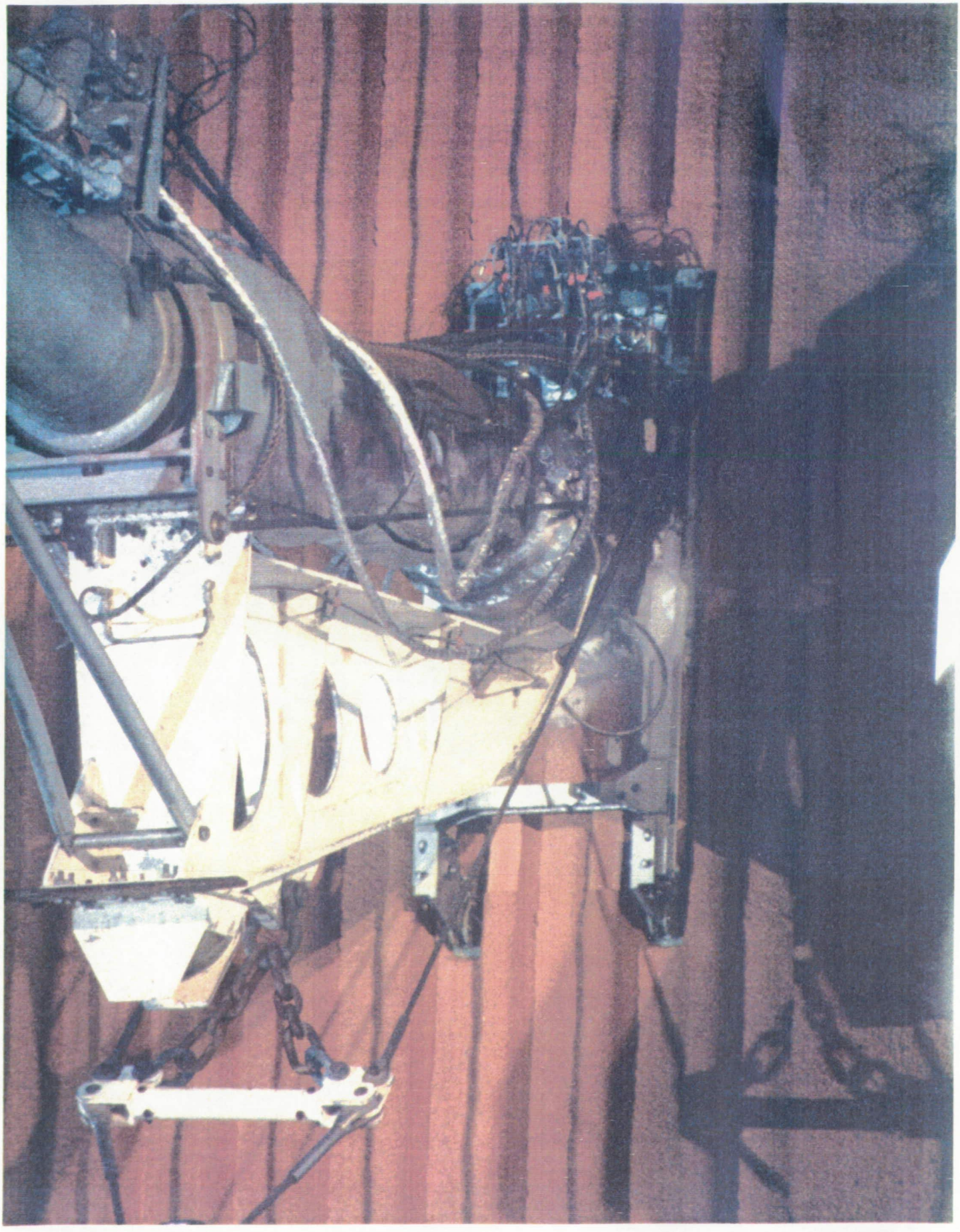
No new debris concerns had been identified during the ice/frost inspection of the vehicle. All SRB sound suppression water troughs were filled and properly configured for launch. No leaks were observed on either the LO2 or LH2 ORB T-0 umbilicals, though typical accumulations of ice/frost were present on the cryogenic lines. There was also no apparent leakage anywhere on the GH2 vent line or GUCP. The modification to the GH2 vent line prevented ice from forming but some ice/frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate. Visual and infrared observations of the GOX seals confirmed no leakage. There were no icicles on the GOX vent ducts. Gaseous oxygen venting from the south duct formed a larger cloud than on the north side.

Overall view of SSV after cryoload stable replenish. There was no ice/frost accumulation on the LH2 tank acreage.

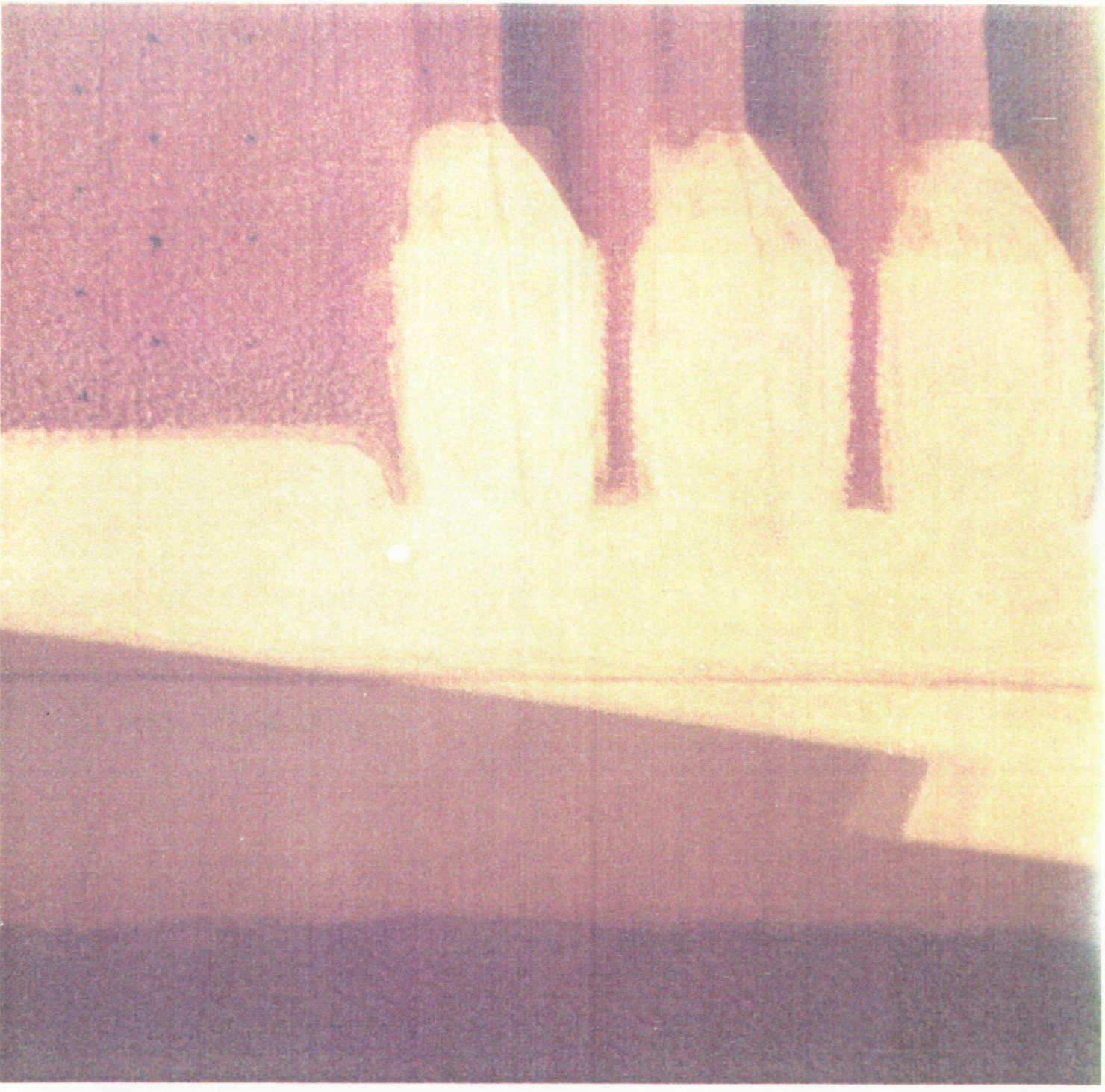


Typical ice/frost formation at the SSME nozzle to heat shield interface. Condensate had frozen on the SSME heat shield.

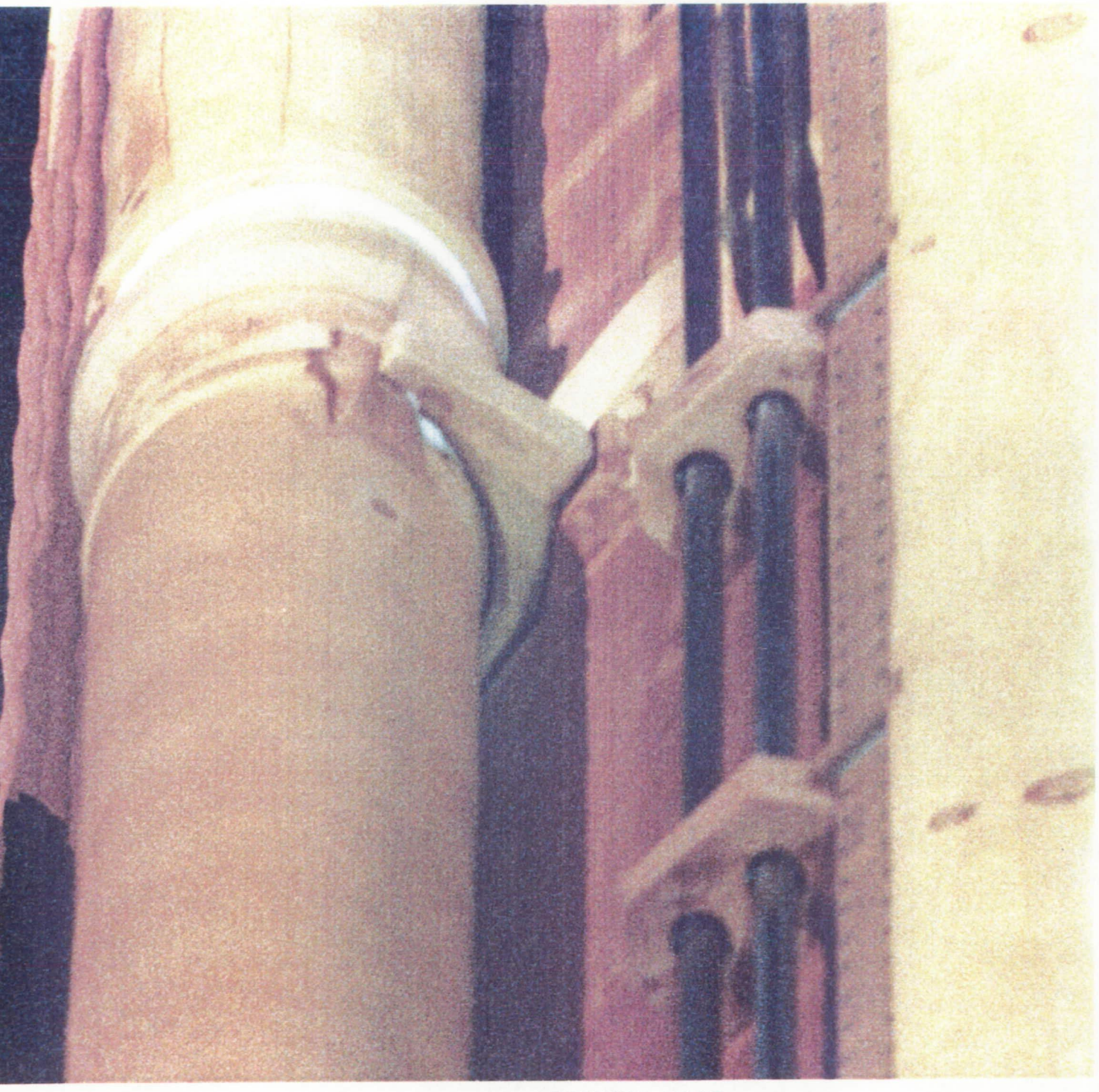
Overall view of LO2 tank -Y ogive and barrel section.
No ice/frost had formed on any TPS acreage area.



Typical ice/frost formation on the GUCP legs and in the uninsulated ET interfaces - an expected occurrence



Small 1/2-inch diameter frost spots had formed on the intertank-to-LH2 tank flanges



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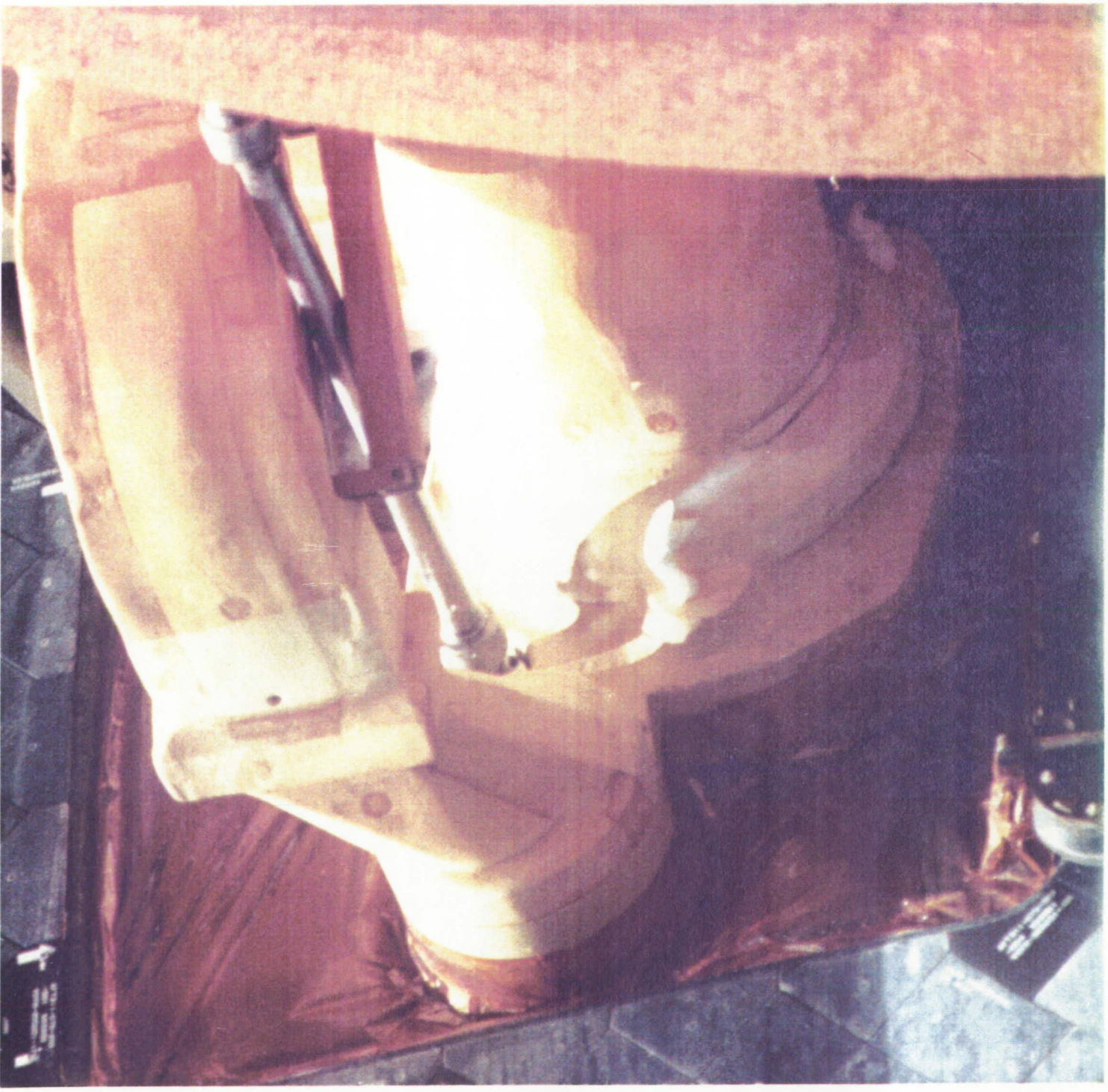
Typical ice/frost accumulation in the LO2 feedline upper bellows and support brackets

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

Overall view of LO2 ET/ORB umbilical outboard side. Note 6-inch frost finger on the forward outboard pyro cannister purge vent.



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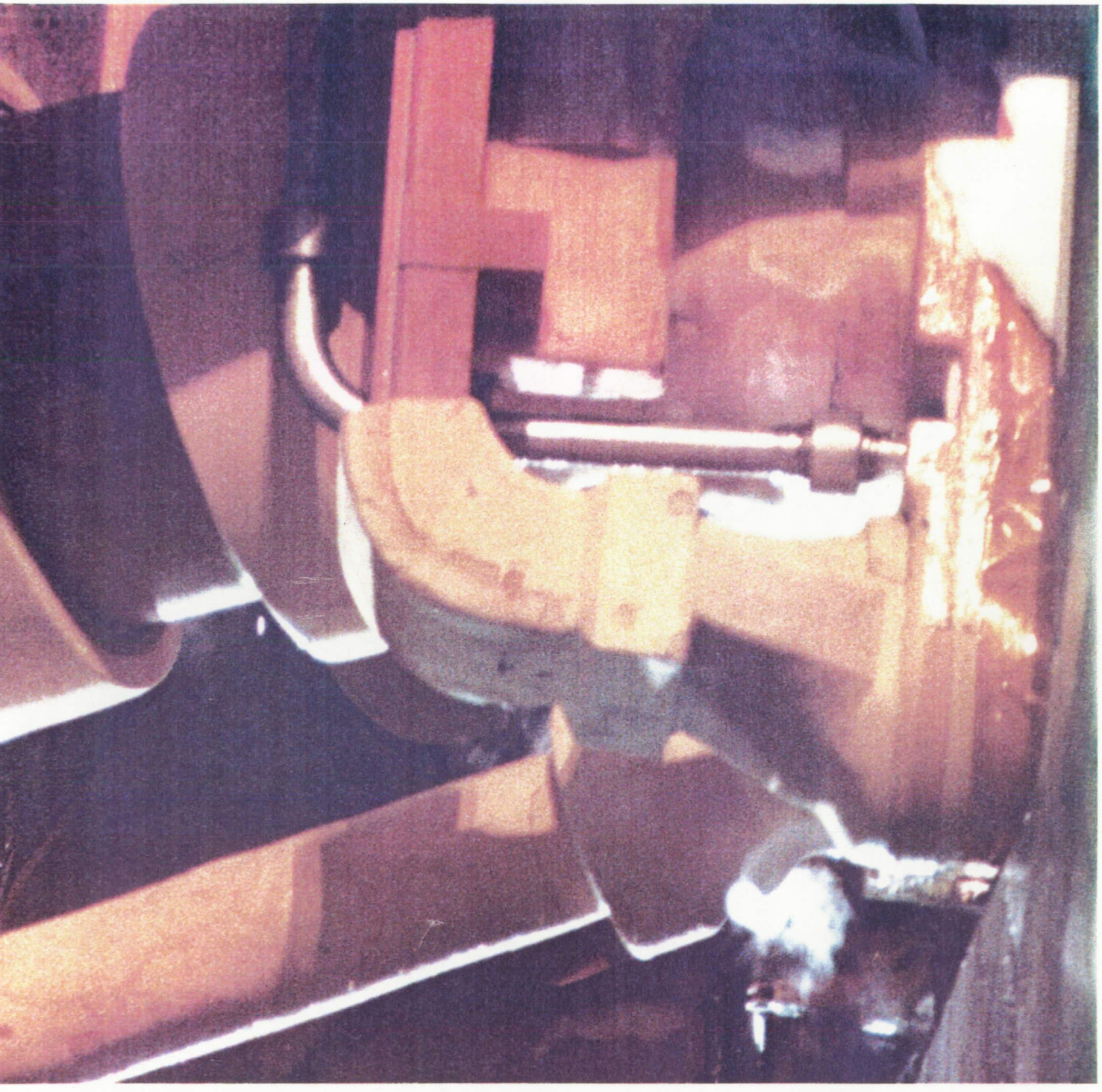
6-8 inch frost fingers on the fwd and aft pyro cannister purge. vents. Venting of LO2 umb cold nitrogen purge gas was normal.



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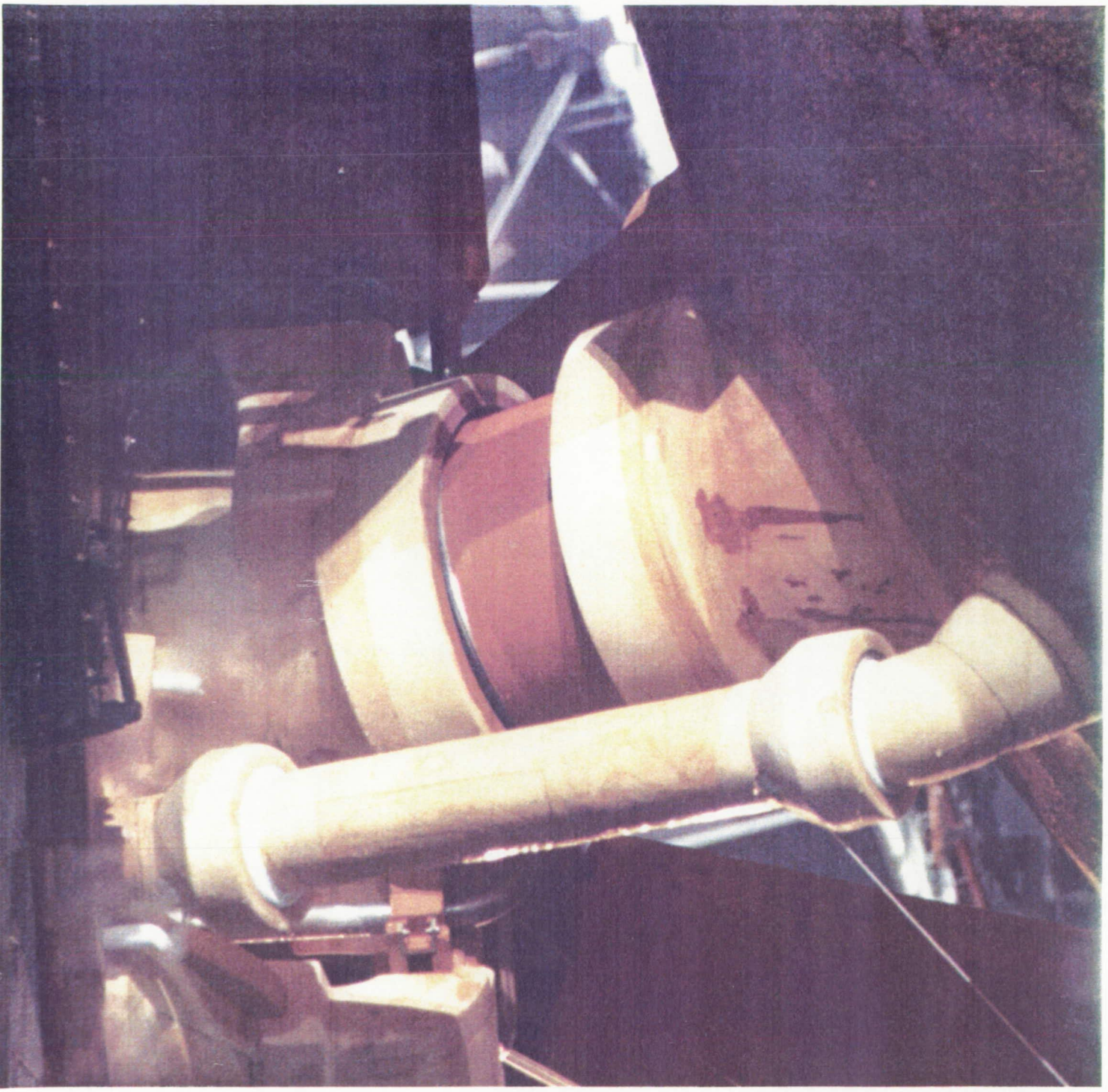
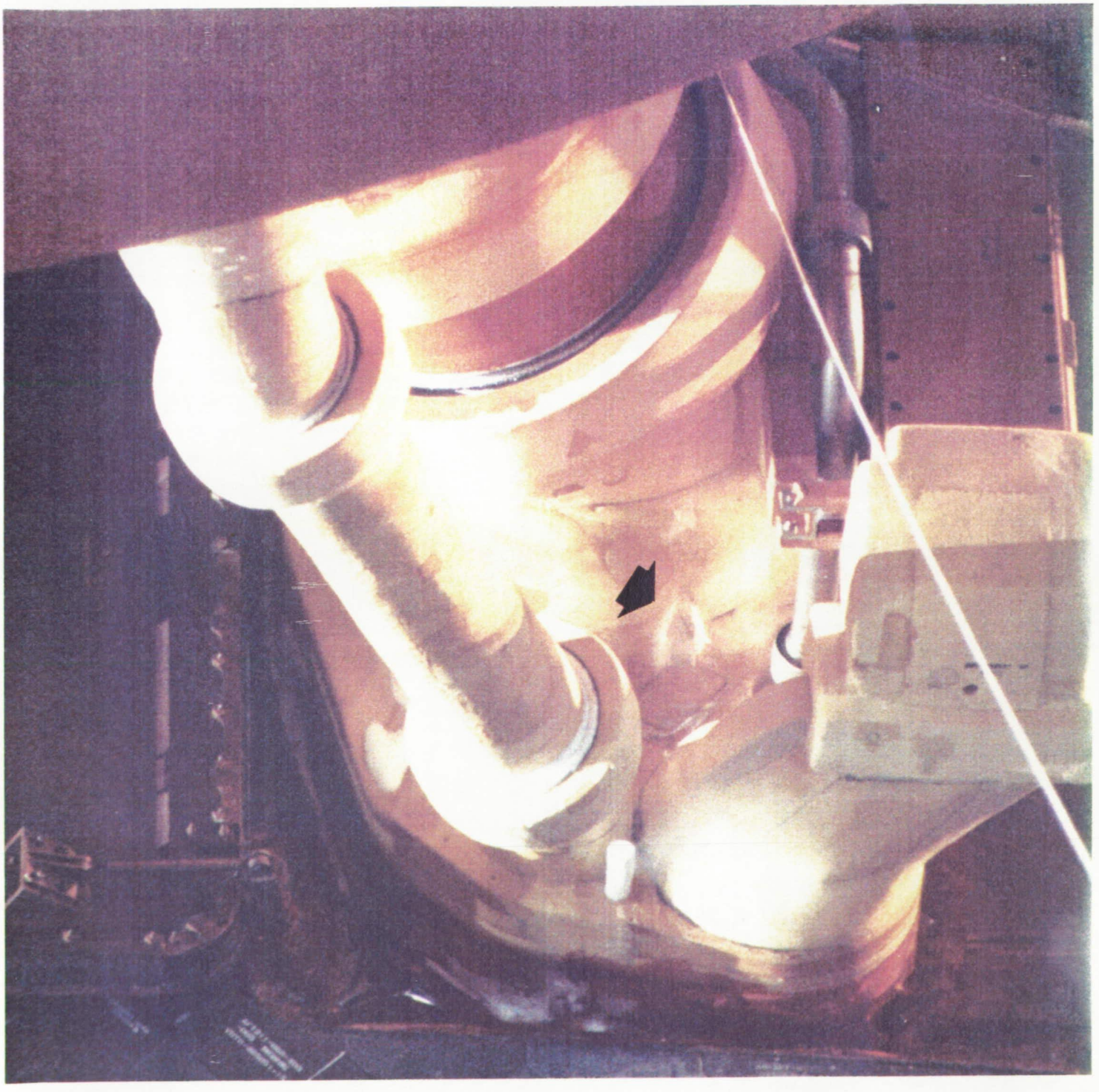
Typical ice/frost/condensate on outboard side of ET/ORB LH2 umbilical. Venting of cold helium purge gas was normal.



Typical ice/frost accumulation in LH2 recirculation line bellows. Six inch frost fingers on purge vents were normal.



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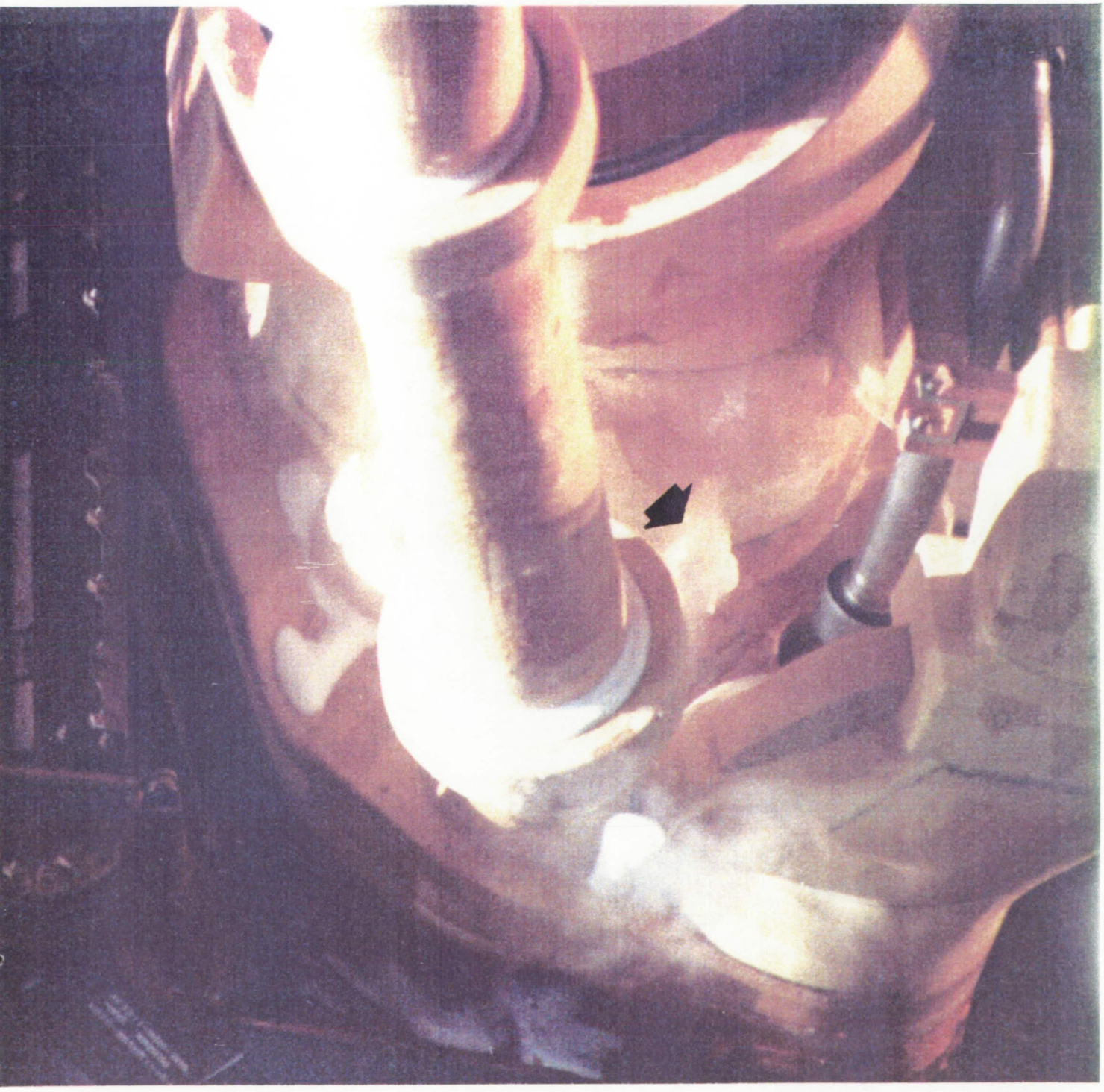
Formation of ice/frost had begun on 17-inch flapper valve actuator foam plug closeout due to cracks in resin sealant



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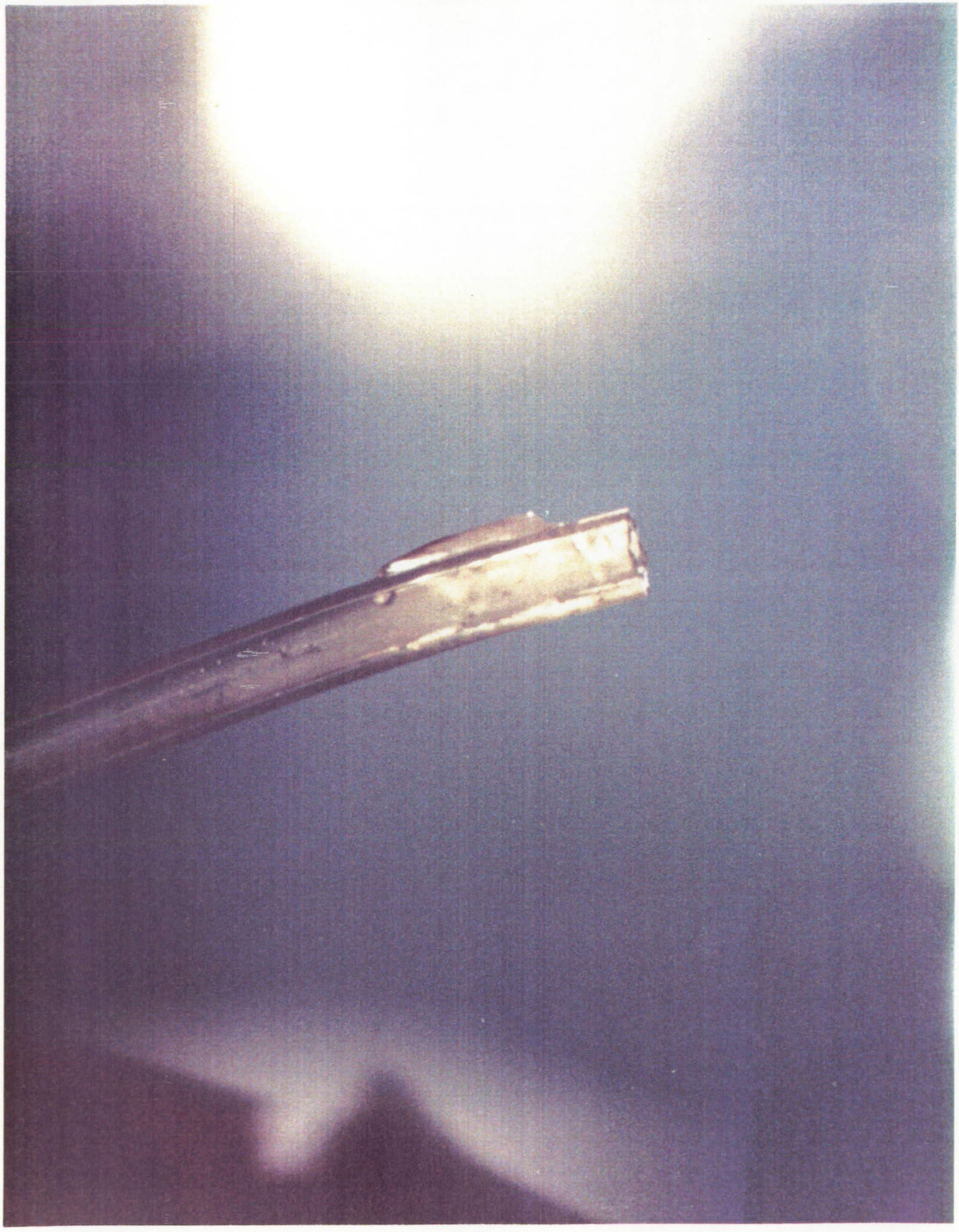
Venting of cold helium purge gas through resin sealant crack caused ice/frost formation from moisture in the air

No run-off condensate was present on ET LH2 tank aft dome apex



Ice/frost build-up on top side of LH2 umbilical had plugged leak detector LD55

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the pad and surrounding area was conducted on 6 October 1990 from launch + 3 to 6 1/2 hours. The MLP, FSS, pad apron, and acreage areas were inspected. No flight hardware or TPS materials were found with the exception of one Q-felt FRSI Plug (2 1/2" x 1/2"), which was recovered on the southwest concrete slope of the pad apron. A less than usual amount of SRB throat plug material (foam and RTV) and sound suppression water trough material from the SRB exhaust holes was found.

SRB holddown post erosion was typical. Initially, the belly bands attached to the base of holddown posts #3, #4, and #8 appeared to have separated from the posts. However, the bands are not a tight fit structurally and some gaps will occur between the posts and the bands. RTV, which had previously been used to fill the gaps, has been eliminated as potential debris. All south holddown post shim material was intact, but was slightly debonded from the shoe sidewalls on posts 2 and 5. All of the doghouse blast covers on the north posts were in the closed position and exhibited typical erosion. The SRB aft skirt nitrogen purge lines and T-0 (joint heater) umbilicals sustained minor damage. Post flight inspection of the sandboxes inside the holddown posts revealed no significant debris.

More than usual facility debris was found. The most significant facility debris consisted of seven FSS/RSS cable tray covers, the largest of which measured approximately 8 feet x 2 feet. This cover, found in front of the trailers to the west of the pad, had damaged the door of the trailer, hand rails, and a traffic sign. The remaining 6 cable tray covers were found on the FSS 95 foot level, FSS 115 foot level, against the fence on the pad southwest slope, south and west of the boxcars. Numerous other cable tray covers on the FSS/RSS were loose.

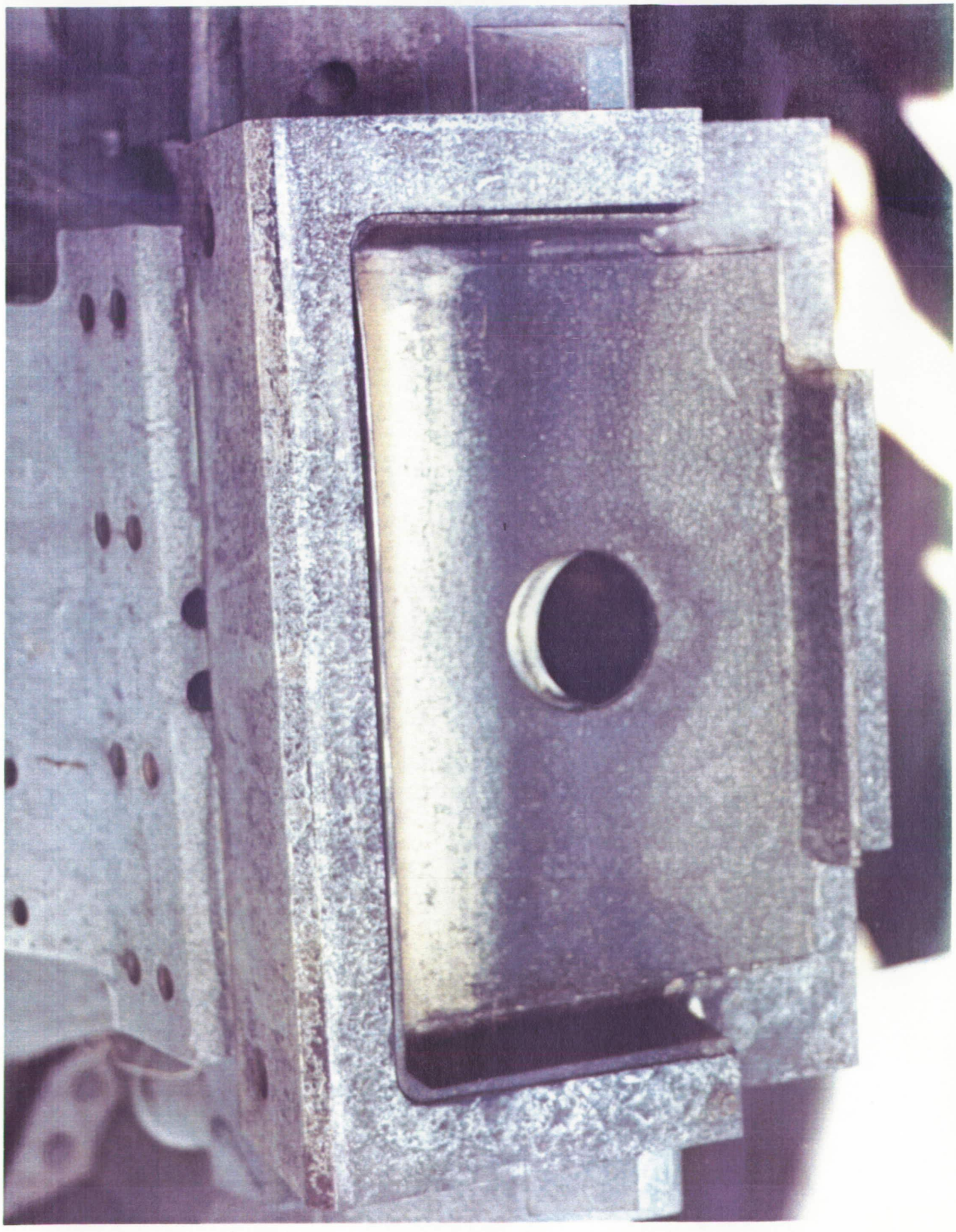
The OAA, TSM's, and GOX vent arm showed typical, but minor, launch damage. Some foam was lost from the top of the GOX vent hood. The GH2 vent arm appeared to have retracted nominally, with the exception of the north latch hitting and riding against the north saddle stabilizer. The GH2 vent arm was latched on the eighth tooth of the latching mechanism and had no loose cables. A lighter, smaller diameter static retract lanyard had been installed as part of a recent modification to prevent entanglement with the GUCP during retraction. (The Pad A system will be similarly modified during the next available downtime). SRB plume impingement from the east wind resulted in greater than normal damage to the GH2 vent line. These phenomena have occurred on previous launches.

All seven emergency egress slidewire baskets were secured on the FSS 195 foot level.

Patrick AFB and MILA radars were configured in a mode for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent but after SRB separation (due to the masking effect of the SRB exhaust plume). 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 52 particles were imaged in the T+143 to 399 second time period. 33 of the particles were imaged by only one radar, 17 particles were imaged by two radars, and 2 particles were imaged by all three radars.

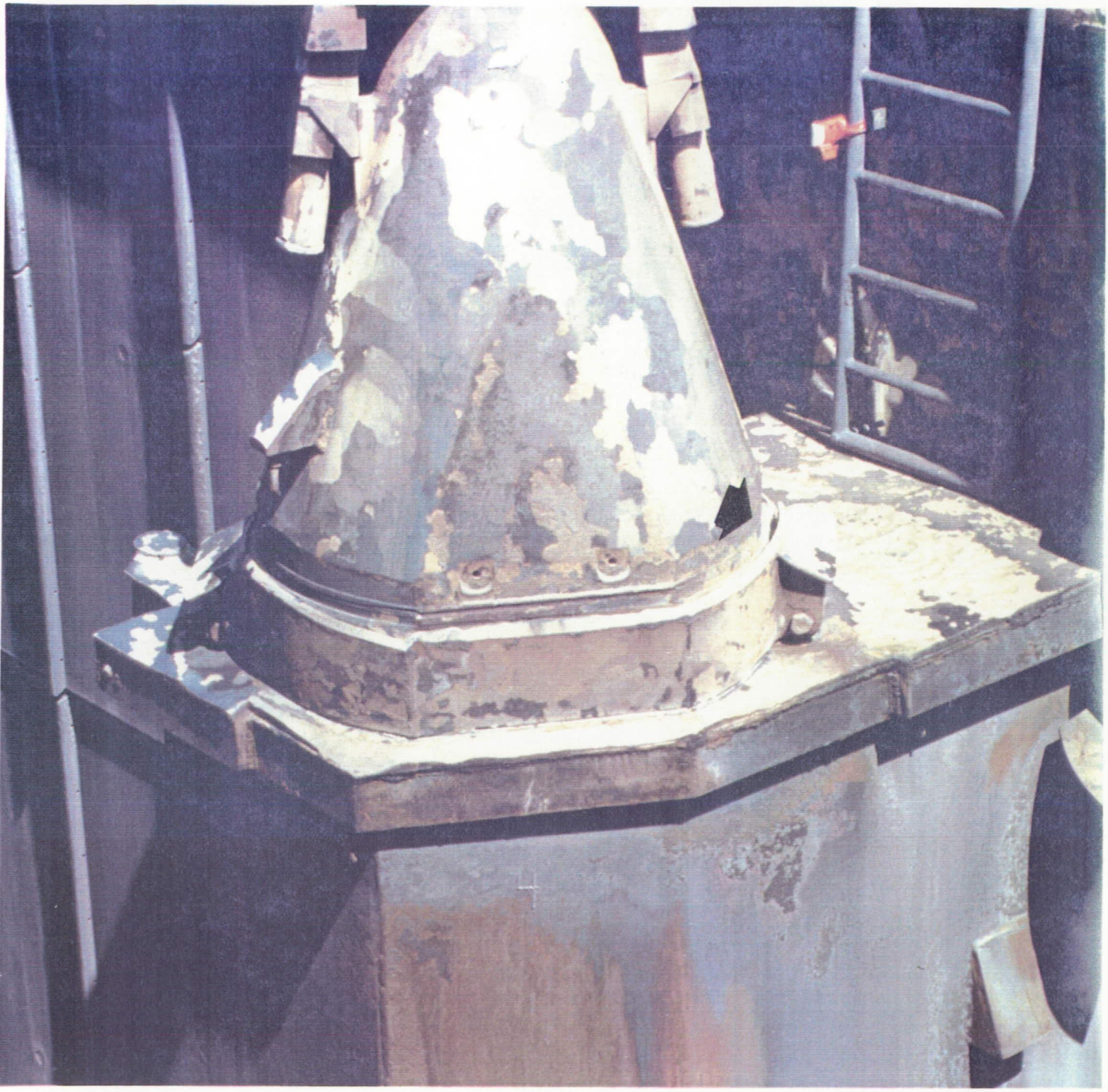
Ground teams continued the post launch debris inspection on Sunday 7 October 1990 by searching the beach, railroad tracks, and the beach road from the northern KSC boundary to the Titan complex. The NASA helicopter was utilized to cover the water areas around the pad, the beach from Complex 40 to a point 10 miles north of the pad, and the ocean area under the flight path. No flight hardware was found.

Post launch pad inspection anomalies are listed in Section 10.1



EPON shim material on south holddown post shoes was intact but had debonded along the sidewalls

Typical erosion of north holddown posts. All HDP doghouse blasts covers had closed properly.



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RTV, which had previously filled gaps between belly bands and bases of holddown posts, had been removed as potential debris

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A cable tray cover torn loose from the FSS/RSS by the SRB plume impacted a traffic sign, boxcar door, and hand rail

The cable tray cover and associated debris were found on the pad access road west of the FSS/RSS

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Seven cable tray covers were torn loose from the FSS/RSS by the SRB plume. Numerous other covers on the structure were loose.

6.0 FILM REVIEW SUMMARY/PROBLEM REPORT DISPOSITION

A total of 125 film and video data items, which included 35 videos, 56 16mm films, 26 35mm films, and 8 70mm films were reviewed starting on launch day.

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

SSME ignition acoustics/vibration caused small pieces of tile surface coating material to shake loose from base heatshield and RH OMS stinger tiles (E-6, 17, 19, 23). A heavy shower of ice/frost particles from the ET/ORB LH2 and LO2 umbilicals fell past the body flap during SSME ignition, but no tile damage was visible (E-5, 6). One piece of ice, as large as 4"x3"x1", fell on the LH2 umbilical cable tray, but caused no damage (OTV 109)

One 4"x4" piece of RH SRB aft skirt instafoam broke loose near holddown post #2 just after T-0 as the vehicle pulled away from the shoe (E-8). The piece either stuck to the shoe when the instafoam was applied or broke away due to lack of clearance with shoe movement.

A 3.5"x0.25" ordnance debris fragment dropped from the LH SRB HDP #6 stud hole (E-13). No debris was visible falling from any of the other holddown post stud holes. There was no sign of HDP stud hang-ups in any of the films.

Aft RCS paper covers, which are pulled into the SSME plume by aspiration, fell from the vehicle at T-0 and through early ascent. Forward RCS paper covers began to detach after the roll program and continued through ascent.

There were no major facility anomalies. No swing arms or other pad structures contacted the vehicle during liftoff. The GH2 vent line latched properly. This was the first launch using the static retract lanyard modification. A lighter, smaller diameter lanyard retracts faster and decreases the chance of entanglement with the GUCP. Film items E-34, 42, 48, 50 showed less slack in the lanyard during retraction.

Many film and video items recorded various amounts of flying debris on and around the pad after the vehicle cleared the tower. This debris is SRB throat plug material and shredded sound suppression water troughs - an expected occurrence.

Numerous bright white flashes (E-52, 218) and a few orange streaks (E-223) occurred in the SSME plume during ascent. ET aft dome charring and plume recirculation (91-112 seconds MET) at altitude were normal.

Movement of the Orbiter body flap was clearly visible during flight and appeared to have magnitude/frequency similar to previous flights (E-207, 212, 220, 223). Good tracking coverage and resolution captured views of the LO2 ET/ORB umbilical baggie tearing and falling from the vehicle at 30 seconds MET (E-207, 220, 223).

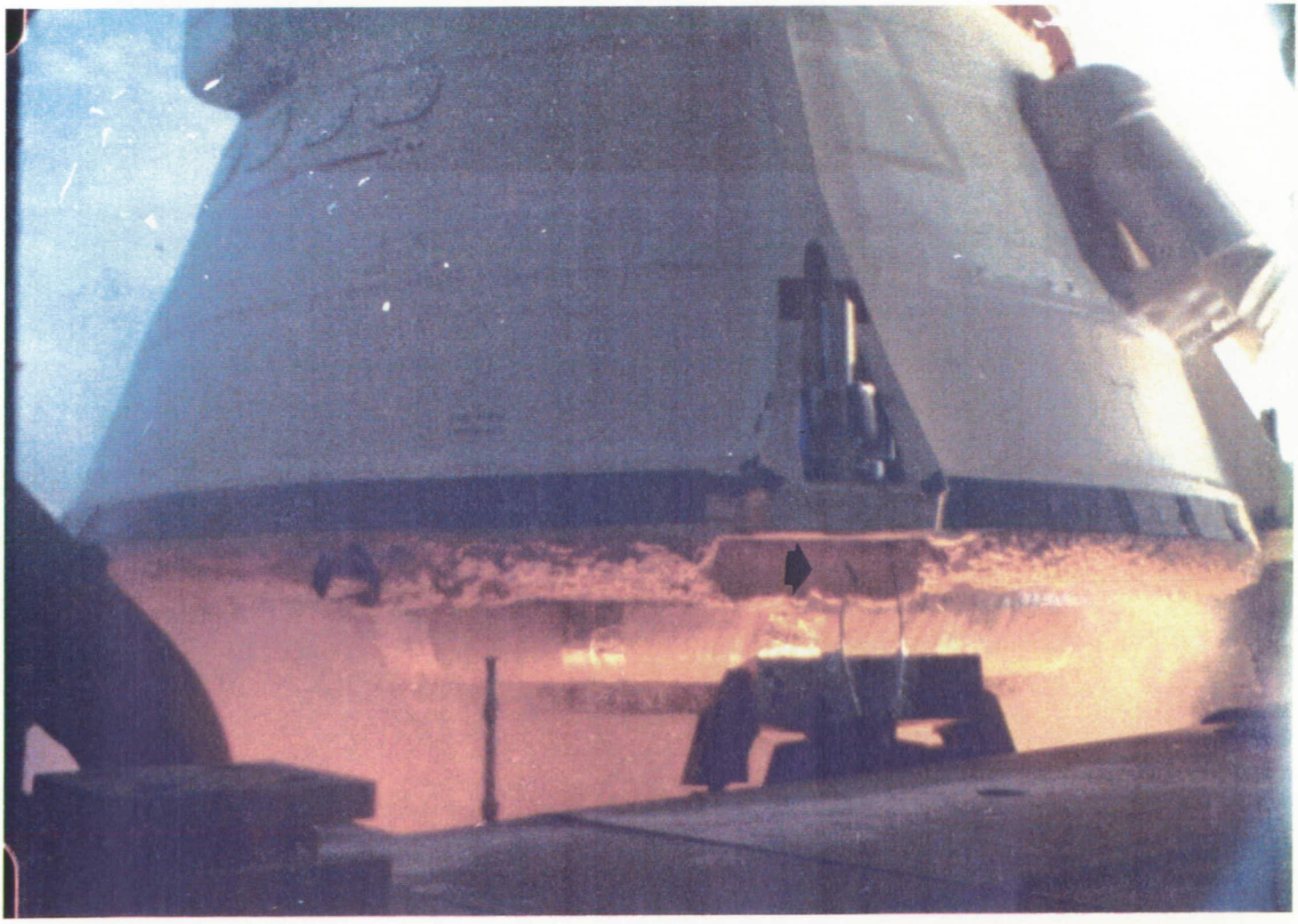
Due to vehicle attitude and sun angle, reflections appeared on the Orbiter windows at GMT 279:11:47:49 and 279:11:48:04 (E-206). An optical linear distortion was visible at MET 55-58 seconds.

Numerous pieces of debris from the vehicle were visible during ascent. Most have been identified as ice/frost particles from the ET/ORB umbilicals or RCS paper covers from the Orbiter. Other pieces falling out of the SRB plumes at approximately 72 seconds MET are believed to be chunks of burning SRB propellant/inhibitor or pieces of SRB aft skirt instafoam (E-203, 212, 223, TV-4).

On-orbit photos of the External Tank after separation from the Orbiter revealed no significant anomalies. During the Ulysses/ IUS deployment, three curved objects appeared near the aft end of the Orbiter and in the field-of-view with the payload. The objects were rectangular in plan form, but curved when viewed along the edge. The concave side of the objects were smooth while the opposite side was rough - similar to the frozen ice observed during ET separation. Inspection of the Orbiter and payload bay after landing revealed no missing hardware. Ulysses and IUS payload engineers researched design drawings, but found nothing similar in size and shape. Therefore, these objects are believed to be pieces of ice from the Orbiter MPS area.

Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing at Edwards AFB were normal.

No PR's or IPR's were generated as a result of the film and video data review. However, the 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.



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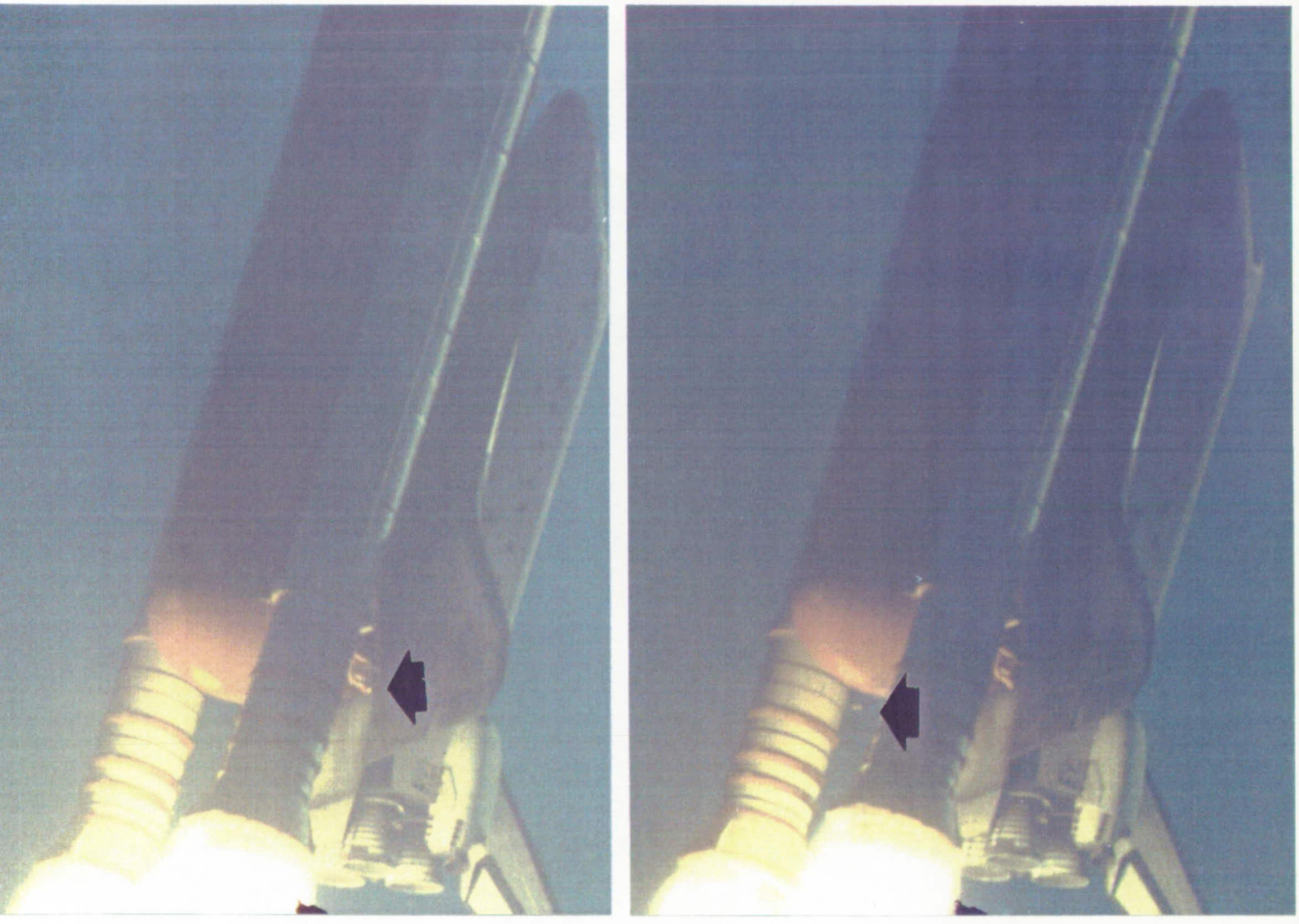
Ordnance fragments fell from the HDP #6 DCS after liftoff

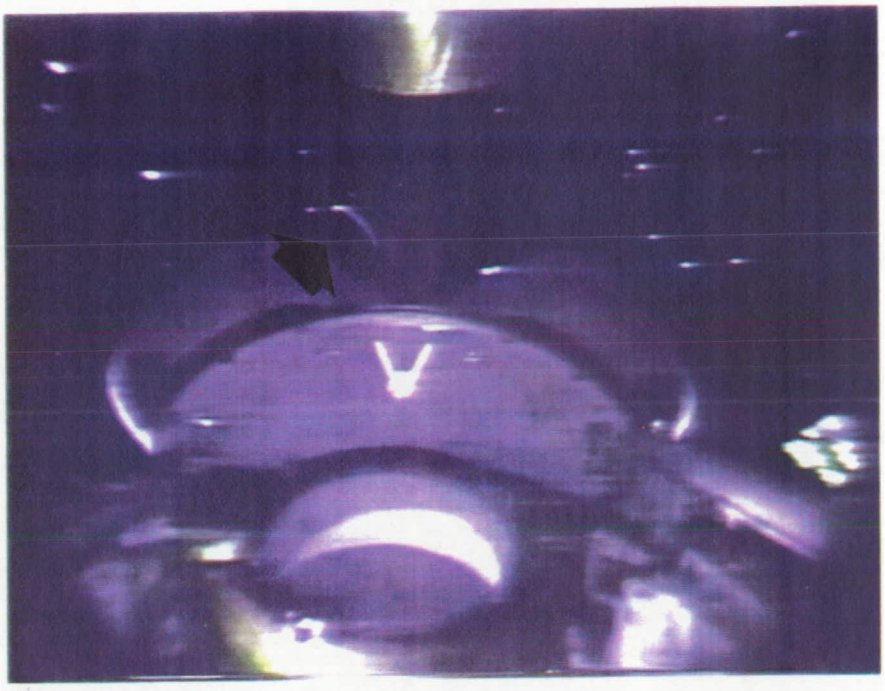


ORIGINAL PAGE
COLOR PHOTOGRAPH

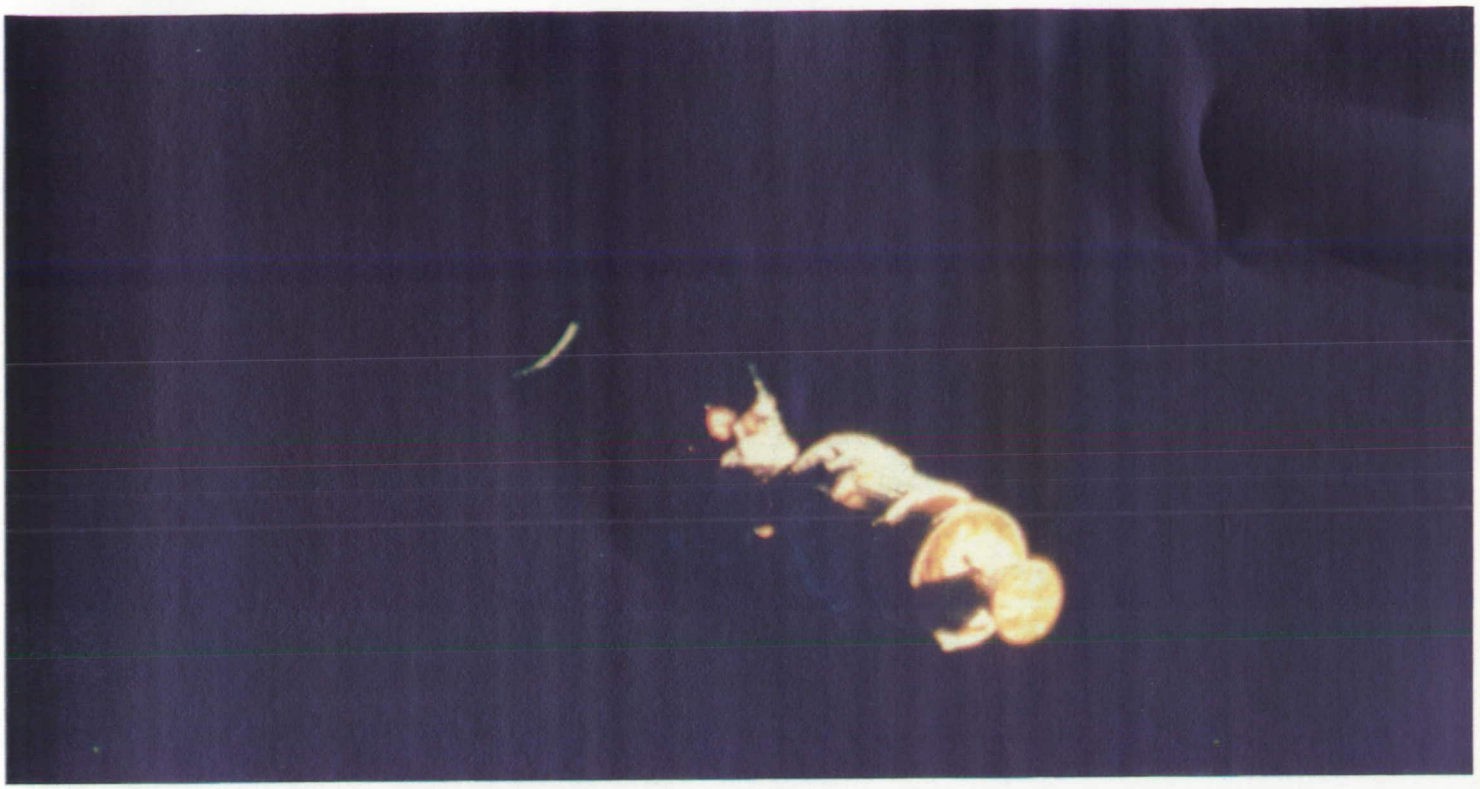
Tracker captured tearing and separation of the baggie material from the LO2 umbilical approximately 35 seconds into flight

ORIGINAL PAGE
COLOR PHOTOGRAPH

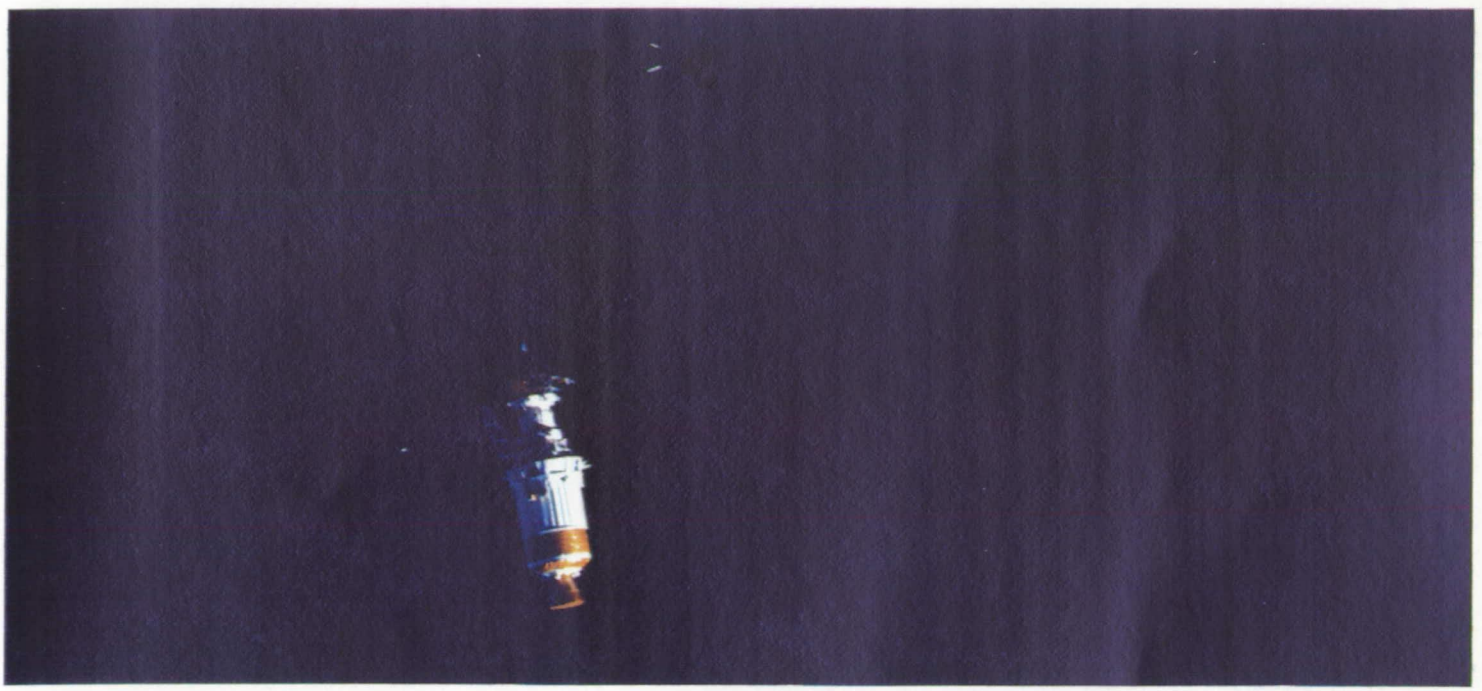
On-orbit view of External Tank after separation from the Orbiter revealed no significant anomalies



Light-colored debris object was visible near aft end of Orbiter and in field-of-view with Ulysses/IUS after deployment



Curved debris object was smooth on the concave side
and rough on the opposite, or external, side



Analysis of on-orbit photography revealed three debris objects,
which are all believed to be pieces of ice from the MPS area

6.1 LAUNCH FILM AND VIDEO DATA REVIEW

FILM ITEMS

EX1
400 FPS
16mm

Camera is located on MLP deck south of RH SRB exhaust duct and looks close-up on SRB holddown post #1 during ignition and liftoff.

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

Comments: Small deck debris is blown around after SSME ignition. HDP shoe rises initially at T-0 due to twang affect. HDP shoe rises approximately 2 inches and then settles before final lift off.

EX2
400 FPS
16mm

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

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

Comments: Separation of the SRB T-0 umbilical was normal.

EX3
400 FPS
16mm

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

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

Comments: Right hand side of umbilical releases first. Retraction otherwise normal.

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

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

Comments: Separation of the SRB T-0 umbilical is normal. After liftoff, small pieces of deck debris move through the FOV.

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

Focus : Camera shaky. Five lens mounting screws were sheared.
F. O. V.: O.K.
Exposure: Slightly underexposed.

Comments: Ice falls from both umbilicals during SSME ignition, T-0, and early ascent, but no tile damage was visible. Light colored particle falls to right of LH SRB aft skirt, probably GUCP ice. Particle rising vertically out of exhaust hole as vehicle clears frame does not contact vehicle. Deck debris is blown toward camera after T-0.

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

Focus : Camera loose in dovetail mount.
F. O. V.: O.K.
Exposure: Slightly underexposed.

Comments: Camera loose in dovetail mount. SSME ignition is normal. No SRB anomalies. TSM (LH2) door closes properly.

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

Focus : Camera loose in dovetail mount.
F. O. V.: O.K.
Exposure: O.K.

Comments: Paper covers from the RCS nozzle are torn loose by engine acoustics and enter plume.

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

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

Comments: No data. Five lens mounting screws sheared.

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

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

Comments: Throat plug material is ejected out of exhaust hole. Large pieces of ice fall from both umbilicals, but no tile damage is visible. No unusual vapors in vicinity of umbilicals. Facility debris passes in front of camera as vehicle clears frame.

E-6 Camera is located on the east side of the MLP deck
200 FPS and views the RH lower Orbiter wing, body flap, ET
16mm lower LOX feedline,and ET/Orbiter umbilical area.

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

Comments: Large piece of ice falls from LO2 umbilical (10"x5"), but does not contact vehicle. Elevon movement is noted after SSME ignition. Three tile dings are visible on RH aft stinger. Ice particles continues to fall from ET/Orb umbilicals during early ascent.

E-7 Camera is located on the MLP deck and views the
400 FPS RH SRB northeast holddown post (HDP #4).
16mm

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

Comments: Ice from GH2 vent line falls to the north of left SRB. Numerous pieces of throat plug material is ejected from SRB exhaust hole after T-0. SRB blast cover closure is nominal. Dark smoke/sparks from plume deflection off haunch is visible between SRB nozzle and haunch.

E-8 Camera is located on the MLP deck and views the
400 FPS RH SRB southeast holddown post (HDP #2).
16mm

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

Comments: Deck debris (paint chips, throat plug material) are visible after T-0. A 4"x4" piece of aft skirt instafoam near the HDP shoe is torn loose from contact with the HDP shoe and pulled into the plume as the vehicle rises.

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

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

Comments: After liftoff a small particle rises out of exhaust hole from area of SRB T-0 umbilical. A second particle enters frame from right, horizontal to the BSM's, then down. No debris is visible from aft skirt stud hole.

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

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

Comments: MLP paint chip crosses over HDP from opposite side. Throat plug material is ejected out of SRB exhaust hole after T-0. SRB blast covers closure is nominal.

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

Focus : O.K.
F. O. V.: Film started too late.
Exposure: O.K.

Comments: MLP paint chip enters from left side and is drawn into plume. Debris crosses FOV close to camera. Sound suppression trough chord is whipped about after T-0.

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

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

Comments: Camera shaky. Large piece of SRB throat plug material is ejected out of the SRB exhaust hole after T-0. No visible debris from debris containment system.

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

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

Comments: After SSME ignition facility paint chips and water spray are blown across FOV. Ice crosses FOV from GH2 vent line. As vehicle rises, an ordnance fragment (3"x1/4") falls from HDP #6 debris containment system.

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

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

Comments: After SSME ignition facility paint chips and water spray are blown across FOV. HDP blast covers closure is nominal.

E-15 Camera is located on the MLP deck and views the RH
400 FPS SRB skirt, sound suppression water troughs, and RH
16mm lower Orbiter body flap.

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

Comments: Much ice falls from LO2 umbilical, but no tile damage is visible. HDP blast covers close properly. Numerous pieces of throat plug material is thrown from exhaust hole. No debris from aft skirt stud holes #3 and 4. Some burning of instafoam outgas products occurs.

E-16 Camera is located on the MLP deck and views the LH
400 FPS SRB skirt, sound suppression water troughs, and LH
16mm lower Orbiter body flap.

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

Comments: Free burning H2 is blown under body flap visible. Ice particles fall from LH2 umbilical. Ice falls from GH2 vent line at SSME ignition. Three particle visible from E-26. Holddown post cover closure is nominal.

E-17 Camera is located on the MLP deck and views the
400 FPS -Z side of the LO2 T-0 Umbilical and TSM.
16mm

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

Comments: Free burning hydrogen is blown past body flap. Body flap and SSME #3 movement is visible during ignition. Approximately 20 tile dings appear on base heat shield. Ice particles fall from LO2 T-0 umbilical. Umbilical separation and retraction nominal. After liftoff, numerous ice/frost particle enter FOV from ET/Orb LO2 umbilical.

E-18
400 FPS
16mm

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

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

Comments: Body flap movement at SSME ignition. Ice/frost fall from LH2 umbilical. Residual vapors visible from Orbiter T-0 umbilical.

E-19
400 FPS
16mm

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

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

Comments: SSME ignition nominal. Two base heat shield tile dings appear, one on RH stinger. T-0 umbilical separation and retraction nominal. Large amount of ice falls from SSME's, LO2 T-0 umbilical, and ET/Orb umbilicals. LH2 TSM door bounces before closing fully. Minimal amount of residual vapors from LO2 T-0 area.

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.: Camera shaky.
Exposure: O.K.

Comments: Camera shaky. Ice falls from LH2 T-0 umbilical, after retraction residual vapors visible. LO2 TSM door closure is nominal. RCS paper covers are torn loose and pulled into SSME plume.

E-21
200 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: Underexposed.

Comments: Residual vapors visible in T-0 umbilical. After SSME ignition a piece of tape falls from upper RH corner of T-0 carrier plate. Ice continues to fall from LO2 T-0 umbilical after retraction. As door closes debris particles come out of inside lower lip of door.

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

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

Comments: T-0 umbilical purge barrier tears loose at SSME ignition. Dirt/trash flies out of inside lower lip of door as door closes. Residual vapors visible in orbiter T-0 disconnect.

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

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

Comments: Approximately 10 tile dings appear on the heat shield between SSME#1 and RH OMS nozzle. LO2 T-0 umbilical ice falls after SSME ignition. RCS paper covers are torn loose. Slight vibration/movement of OMS nozzle is visible.

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

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

Comments: LH2 T-0 umbilical ice falls after SSME ignition. RCS paper covers are torn loose. Slight vibration/movement of OMS nozzle is visible.

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

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

Comments: See E-5. Exhaust from RH SRB HPU's visible. One piece of throat plug material ejected upward out of exhaust hole.

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

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

Comments: Ice particles fall from ET/Orbiter umbilical at SSME ignition and T-0. Condensate vaporizes on SRB aft skirt and ET aft dome. Dark particle travels south on west side of LH SRB. Second dark particle on east side of LH SRB.

E-27 Camera is located on the MLP deck and views RH SRB
400 FPS northwest holddown post (HDP #3) blast cover.
16mm

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

Comments: Water baggie chord was torn loose from water baggies. Dark smoke is visible from HDP #4 as seen in E-8. HDP blast cover closure is nominal.

E-28 Camera is located on the MLP deck and views LH SRB
400 FPS northeast holddown post (HDP #7) blast cover.
16mm

Comments: Did not run. Camera loose in mount.

E-30 Camera is located on the FSS 195 foot level and
400 FPS views LH SRB and sound suppression water troughs.
16mm

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

Comments: Ice from GH2 vent line crosses FOV from above. Free burning hydrogen is blown behind body flap. SSME steam recirculates through SRB exhaust hole onto deck. Ice from ET/Orb umbilical area falls as vehicle rises. Two particle are ejected from SRB exhaust hole to the north, most probably throat plug material.

E-31 Camera is located on the FSS 95 foot level and
100 FPS views the LH Orbiter wing, body flap, and
16mm ET/Orbiter LH2 umbilical area.

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

Comments: Ice particles fall from LH2 umbilical after T-0. Elevon movement occurs at T-0. Condensate vaporize on aft SRB stiffener rings. Dark particle (4 x 4) from behind diagonal strut falls to the north between SRB's (frame 1464).

E-33 Camera is located on the FSS 235 foot level and
400 FPS views the ET GH2 vent line and GUCP.
16mm

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

Comments: ET/Orbiter umbilical ice falls at SSME ignition. ET twang effect evident. Residual GH2 vaporizes is visible after disconnect in vent line. Ice falls from GUCP legs and Carrier Plate interface.

E-34 Camera is located on FSS at 255 foot level and
400 FPS views upper Orbiter tile surfaces.
16mm

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

Comments: GH2 vent line retraction nominal. Ice particles fall from LH2 umbilical with no apparent impacts to orbiter tiles. Residual GH2 vapors visible from GH2 vent line after GUCP separation.

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

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

Comments: Ice falls from ET/Orb umbilical and GUCP after SSME ignition and liftoff. Geysering of water in sound suppression water troughs nominal. Residual vapors still emanating from LH2 T-0 umbilical plate. GUCP retraction nominal.

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

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

Comments: Ice particles fall from GH2 vent line after SSME ignition. Ice particles fall from ET/Orbiter umbilicals. Particle moves from left of SRB heading NE. HPU exhaust visible next to HDP #5 prior to T-0.

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

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

Comments: Frost in SW louver. ET twang is nominal. Forward RCS covers still intact. Ice still falling from ET/Orb umbilical and residual vapors emanate from T-0 umbilical. Facility debris is visible in FOV after vehicle clears frame.

E-41
400 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.

Comments: Not available for this launch. Recent facility modifications dictate camera move to a new position.

E-42
400 FPS
16mm

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

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

Comments: GUCP retraction and latching nominal no bounce. Slack was visible in static lanyard but less than previous missions due to facility modifications. Two large facility debris crosses FOV after vehicle clears tower.

E-43
200 FPS
16mm

Camera is located on the SW side of pad apron and views the underside of the SSME exhaust hole during ignition and liftoff.

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

Comments: Water is first visible from RH side of SSME exhaust hole. Numerous ignitor sparks fall from SSME exhaust hole into flame trench.

E-44
400 FPS
16mm

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

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

Comments: Residual vapors in T-0 umbilical disconnect. T-0 umbilical retraction nominal.

E-48
400 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: Ice falls from GUCP at SSME ignition. FSS water deluge is late. Ice fall from GUCP after T-0. Residual vapors visible after separation from ET.

E-50
400 FPS
16mm

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

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

Comments: GUCP retraction nominal.

E-52
96 FPS
35mm

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

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

Comments: FSS water deluge is late. Ice particles fall from ET/Orbiter umbilicals after SSME ignition and through T-0. White flashes occur in SSME #3 plume. Bird visible between vehicle and camera.

E-53
96 FPS
35mm

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

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

Comments: Same as film item E-52.

E-54
96 FPS
35mm

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

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

Comments: Numerous pieces of RCS paper covers fall during ascent. Condensate on aft dome and SRB stiffener rings vaporizes, much less than normal. GH2 vent arm latches properly. Bird flies across FOV away from vehicle.

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.

Comments: No data. Tracking mount malfunction.

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.

Comments: No data. Tracking mount malfunction.

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.

Comments: No data. Tracking mount malfunction.

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: Bird visible in FOV does not contact vehicle. GH2 vent line latches properly with no rebound.

E-61
100 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: SSME ignition is nominal. Bird seen in film item E-54 not visible.

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: T-0 umbilical retraction nominal.

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: SSME plume obscures view of vehicle due to east wind.

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 vapor off aft dome and SRB stiffener ring less than seen previously.

E-65
100 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: Bird near vehicle heads away. Ice falls from ET/Orb umbilical. No unusual vapors or liquid drips in vicinity of umbilicals. Piece of RCS paper cover aft of SSME's.

E-76
96 FPS
35mm

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

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

Comments: Ice and RCS paper covers are drawn into SSME plume. Free burning hydrogen is blown toward H2 TSM. LO2 T-0 disconnect functioned nominally.

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: SSME ignition and LH2 T-0 umbilical disconnect nominal. Free burning hydrogen rises as high as LH OMS pod. Ice and RCS paper covers come loose.

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: Underexposed.

Comments: Ice particle falls from ET/Orbiter umbilicals as vehicle rises.

E-79
100 FPS
16mm

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

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

Comments: Frost is visible on louvers. ET nosecone tip deflection was approximately 30-34 inches. ET/Orbiter umbilical ice is still visible as vehicle crosses FOV.

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 condensate on SRB aft stiffener rings vaporizes.

E-202
30 FPS
70mm

UCS-15 IFLOT tracking of launch vehicle from ignition and early flight through LOV.

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

Comments: Same as E-201.

E-203
30 FPS
70mm

UCS-6 IFLOT tracking of launch vehicle from ignition and early flight through LOV.

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

Comments: No vehicle or plume anomalies.

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

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

Comments: Recirculation visible. SRB separation nominal. SRB slag falls out of plume after separation.

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

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

Comments: No data collected, camera shaky.

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

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

Comments: Three reflections off cockpit windows, 2 before and 1 after shock waves. Recirculation visible. Larger features on ET visible after separation, no anomalies.

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

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

Comments: Body flap motion is similar in magnitude and frequency to previous flights. SRB separation at frame 51-11. SRB slag is visible after separation. LO2 umbilical baggie torn loose approximately 30 seconds into flight.

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: Recirculation visible. Slag falls from SRB's after separation. SRB separation occurs at frame 253-13.

E-209
30 FPS
70mm

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

Comments: No data taken, clouds obscure view.

E-210
30 FPS
70mm

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

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

Comments: Film defect visible on lower forward surface of orbiter in one frame.

E-211
96 FPS
35mm

UCS-13 IFLOT intermediate tracking of forward portion of ORB and ET from acquisition to LOV.

Comments: No Data. Film broke.

E-212
64 FPS
35mm

UCS-23 MIGOR tracking of launch vehicle from acquisition to LOV.

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

Comments: Body flap motion similar in magnitude and frequency to previous flights. Slag falls from SRB's after separation.

E-213 UCS-7 MOTS tracking of forward portion of ORB and
96 FPS ET from acquisition to LOV.
35mm

Comments: No data. Tracking lost T+30 to T+80 sec.

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

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

Comments: No vehicle anomalies.

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

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

Comments: Flashes occur in SSME plume shortly after acquisition. Tracking unsteady.

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

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

Comments: NO VEHICLE ANOMALIES.

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

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

Comments: Forward RCS paper covers fall into plume. Body flap motion is similar in magnitude and frequency to previous flights. LO2 baggy falls from vehicle at frame 129-13. Five or six pieces fall into plume (frame 127-05).

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

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

Comments: SRB separation appears nominal. Shock waves visible off orbiter and SRBs.

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

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

Comments: No vehicle anomalies.

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

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

Comments: LH2 umbilical ice falls during roll maneuver. Particles from RH SRB (431-06), particles from LH SRB (441-14) fall out of plume. Body flap motion is similar in magnitude and frequency to previous flights. Orange flash visible in SSME plume (239-10). LO2 baggie material flapping. Several pieces of forward RCS paper covers blown downstream.

E-224 UCS-6 IFLOT close-in tracking of entire launch
100 FPS vehicle during ignition, liftoff, and early flight
35mm through LOV.

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

Comments: Shock waves visible @ 47:54. NO VEHICLE ANOMALIES.

E-233 Castglance airborne tracking
35mm

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

Comments: Nozzle separation normal. Frustrum separation nominal. Three good chutes.

E-234 Castglance airborne tracking
16mm

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

Comments: Same as E-233.

VIDEO ITEMS

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

Comments: No data taken, camera shake.

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

Comments: Ice particles fall from GUCP at SSME ignition. GUCP retraction nominal.

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

Comments: Ice/frost particles fall at T-0, hit cable tray, but no visible damage.

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

Comments: Video synch problem. No vehicle anomalies.

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

Comments: Ice particles fall from ET/Orbiter umbilicals.

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

Comments: No data due to camera mound malfunction.

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

Comments: LO2 T-0 umbilical retraction nominal. Possible tile dings on base heat shield.

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

Comments: LH2 T-0 umbilical retraction nominal.

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

Comments: No vehicle anomalies.

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

Comments: Ice/frost particles fall from LH2 and LO2 umbilicals at SSME ignition. Large ice particles fall from LO2 umbilical.

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

Comments: Ice/frost particles fall from ET/Orbiter umbilicals. LH2 TSM door closure nominal.

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

Comments: No data taken, image overexposed.

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

Comments: Light frost coating in NE louvers.

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

Comments: Frost in louvers and bolt holes. Grid, footprint and fairing nominal.

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

Comments: Free burning hydrogen blown under body flap. Ice/frost particle fall from ET/Orbiter umbilical, no damage visible. LH2 T-0 separation nominal, residual H2 vapors in disconnect.

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

Comments: SSME ignition nominal. Free burning hydrogen blown west near TSM. L02 T-0 disconnect nominal.

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

Comments: SSME plume obscures vehicle.

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

Comments: SSME ignition nominal. Large ice particle fell from LH2 ET/ORB umbilical.

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

Comments: SSME ignition nominal. Free burning hydrogen visible near OMS pod. SRB holddown post blast covers were in excess of 700 degrees F after liftoff.

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

Comments: No data taken, too distant.

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

Comments: View too distant for engineering analysis. No vehicle anomalies.

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

Comments: No data taken, too distant.

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

Comments: Too distant for engineering analysis. No vehicle anomalies.

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

Comments: Liftoff nominal. Bird near north side of FSS did not appear to contact vehicle.

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

Comments: Too distant for engineering analysis.

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

Comments: Plume recirculation and SRB separation nominal. Slag particles visible after separation.

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

Comments: View too distant for engineering analysis. No vehicle anomalies.

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

Comments: Video synch problem. View hazy due to atmospheric conditions. SRB separation nominal. Slag particle visible after separation.

TV-20 UCS-3 infrared tracker.
B/W M-II

Comments: View too distant for engineering analysis. No vehicle anomalies.

TV-21B Views Pad B launch from DLTR-3.
Color M-II

Comments: View initially obscured. Too distant for engineering analysis.

TV-23 UCS-23 long range tracking of launch vehicle
Color M-II from CCAFS.

Comments: View too distant for engineering analysis. No vehicle anomalies.

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

Comments: Recirculation visible. SRB separation nominal. SRB slag falls out of plume after separation.

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

Comments: Recirculation visible. No vehicle anomalies.

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

Comments: SRB separation nominal. SRB slag visible after separation.

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

Comments: Recirculation visible. Slag falls from SRB after separation. SRB separation nominal.

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

Comments: SRB separation nominal. SRB slag falls from SRB plume after separation.

ET-213 UCS-3 MOTS video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: No vehicle anomalies.

6.2 ON-ORBIT FILM DATA REVIEW

29 color transparencies, 29 8x10 color prints, and 9 color print enlargements of the ET on-orbit after separation from the Orbiter were reviewed. Due to the separation maneuver and lighting angle, views of the ET -Y side were not available. Views of the nosecone area were generally underexposed and could not provide detail for analysis.

No TPS anomalies were readily apparent. Five light-colored spots on the +Y LH2 tank-to-intertank flange and two spots on the third hardpoint may be indicative of TPS divots. The nosecone, EB-2 attach point, and +Y thrust strut areas appeared normal. The BSM burn scar on the LO2 tank barrel section was typical. Direct insertion trajectory aeroheating charred the TPS on the nosecone and -Z side of the tank.

70mm still photographs, video downlink, and 16mm motion picture footage provided views of a debris object visible during the Ulysses/IUS deployment.

The object was first visible between the vertical stabilizer and the RH OMS pod after the IUS cleared the payload bay. The object drifted upward past the vertical stabilizer as the Orbiter performed a separation maneuver. Later views of the deployed payload showed the light-colored object to be slowly tumbling. It's shape was rectangular when viewed in plan form. The edge view revealed a concave shape; smooth on the internal side, rough and jagged on the external side. The crescent shape, as previously described in the video downlink, was visible when the object had rotated to some point between the plan view and the edge view. The rough, jagged appearance and concave shape is consistent with expectations of frozen propellant from the SSME area.

Additional on-orbit 70mm photographs revealed the presence of two more similar objects. Similar in shape to the first object, the internal side was also smooth with rough, jagged outer sides. All three objects were most likely pieces of frozen propellant from the Orbiter MPS area.

6.3 LANDING FILM DATA REVIEW

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

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

Comments: Landing gear was already deployed at beginning of film. Main landing gear touchdown was virtually simultaneous. Nose landing gear touchdown nominal. View too distant for TPS analysis.

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

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

Comments: Landing gear was already deployed at beginning of film. Main landing gear touchdown was virtually simultaneous. Nose landing gear touchdown nominal. View too distant for TPS analysis.

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

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

Comments: No anomalies during touchdown and rollout. MLG touchdown was virtually simultaneous with RH side touching first. NLG touchdown was very smooth. Tile damage sustained during ascent was visible under CM hatch.

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

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

Comments: View is too distant for detail. No vehicle anomalies.

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

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

Comments: Landing gear was already deployed at beginning of film. Main landing gear touchdown was virtually simultaneous. Nose landing gear touchdown nominal. View too distant for TPS analysis.

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

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

Comments: Landing gear was already deployed at beginning of film. Main landing gear touchdown was virtually simultaneous. Nose landing gear touchdown nominal. View too distant for TPS analysis.

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

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

Comments: Landing gear was already deployed at beginning of film. Main landing gear touchdown was virtually simultaneous. Nose landing gear touchdown nominal. View too distant for TPS analysis.

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 was already deployed at beginning of film. Main landing gear touchdown was virtually simultaneous. Nose landing gear touchdown nominal. View too distant for TPS analysis.

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

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

Comments: Landing gear was already deployed at beginning of film. Main landing gear touchdown was virtually simultaneous. Nose landing gear touchdown nominal. View too distant for TPS analysis.

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

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

Comments: Landing gear was already deployed at beginning of film. Main landing gear touchdown was virtually simultaneous. Nose landing gear touchdown nominal. View too distant for TPS analysis.

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

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

Comments: Landing gear was already deployed at beginning of film. Main landing gear touchdown was virtually simultaneous. Nose landing gear touchdown nominal. View too distant for TPS analysis.

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 9 October 1990 from 0800 to 1200 hours. In general, the SRB's appeared to be in good condition.

7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum had no areas of missing TPS but had 38 debonds over fasteners (Figure 5). Three of the BSM covers were fully opened and locked in the 180 degree position. One BSM cover was locked but bent to approximately the 90 degree position.

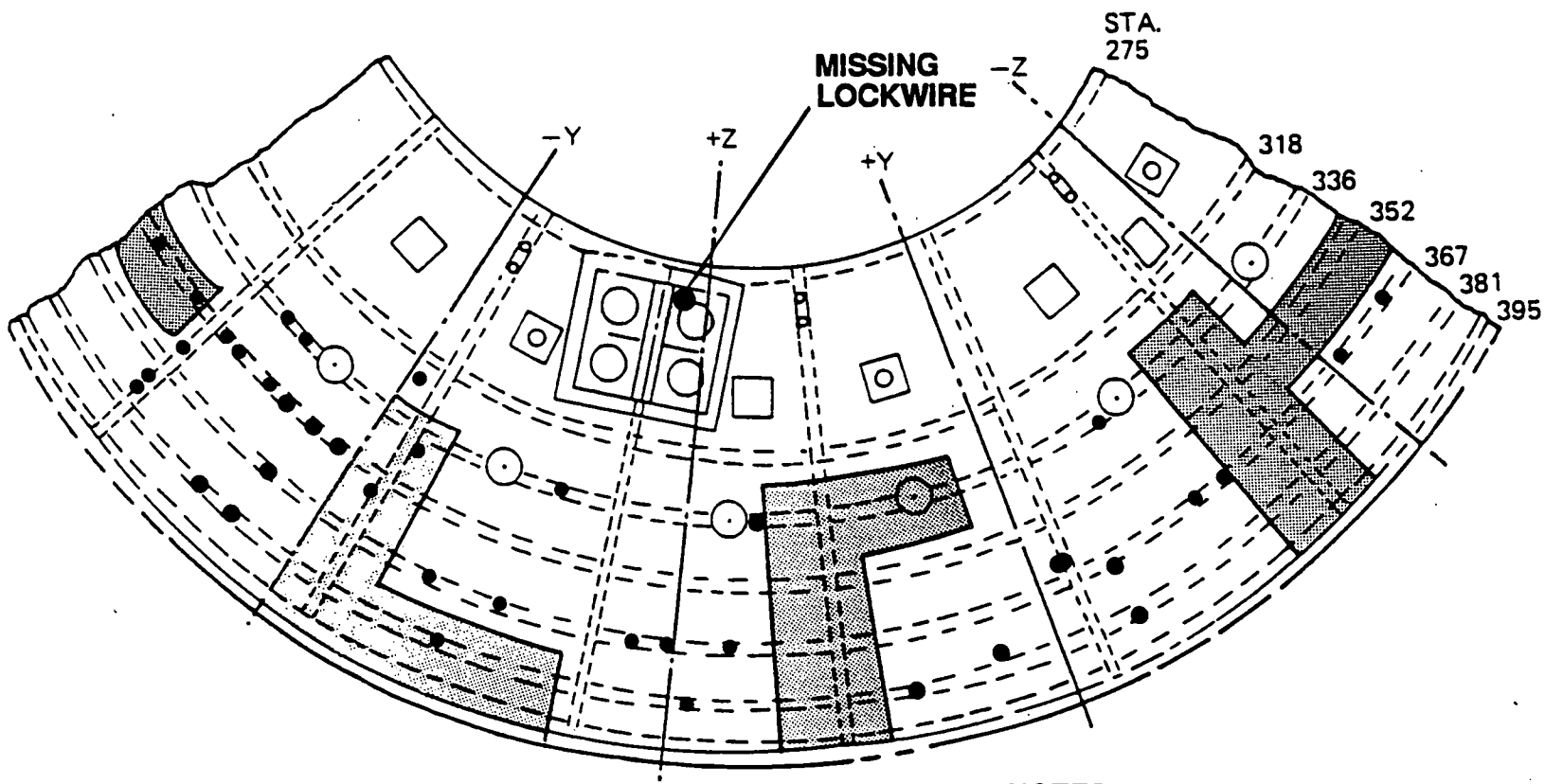
The RH forward skirt exhibited no debonds or missing TPS (Figure 6). The frustum severance ring, which utilized the new pin retainer clips, was missing no pins. Separation of the forward attach bolt appeared normal.

Generally, the new Field Joint Protection System (FJPS) closeouts were in good condition. K5NA closeouts blistered, or delaminated, in the center field joint at 120 degrees, 3/4-inch diameter; and at 270 degrees, 1-inch diameter. A 0.6-inch hairline crack in the RH center FJPS was visible at 205 degrees. A 9.6-inch unbond occurred on the aft edge of the RFC factory joint weather seal at 93-101 degrees. The unbond extended to the pin retainer band for the full length of the unbond. There was no evidence of sooting or heating affects in the unbond area.

Separation of the aft struts appeared nominal. The stiffener rings/K5NA closeouts were damaged by water impact. There was no structural damage to the ETA ring or IEA.

The phenolic material on the kick ring delaminated in several locations. K5NA protective domes on the aft side of the phenolic kick ring were missing in 6 places (220-270 degrees) prior to water impact. All four Debris Containment System (DCS) plungers were properly seated (Figure 7).

FIGURE 5. RIGHT SRB FRUSTUM



MISSING TPS

NONE

DEBONDS

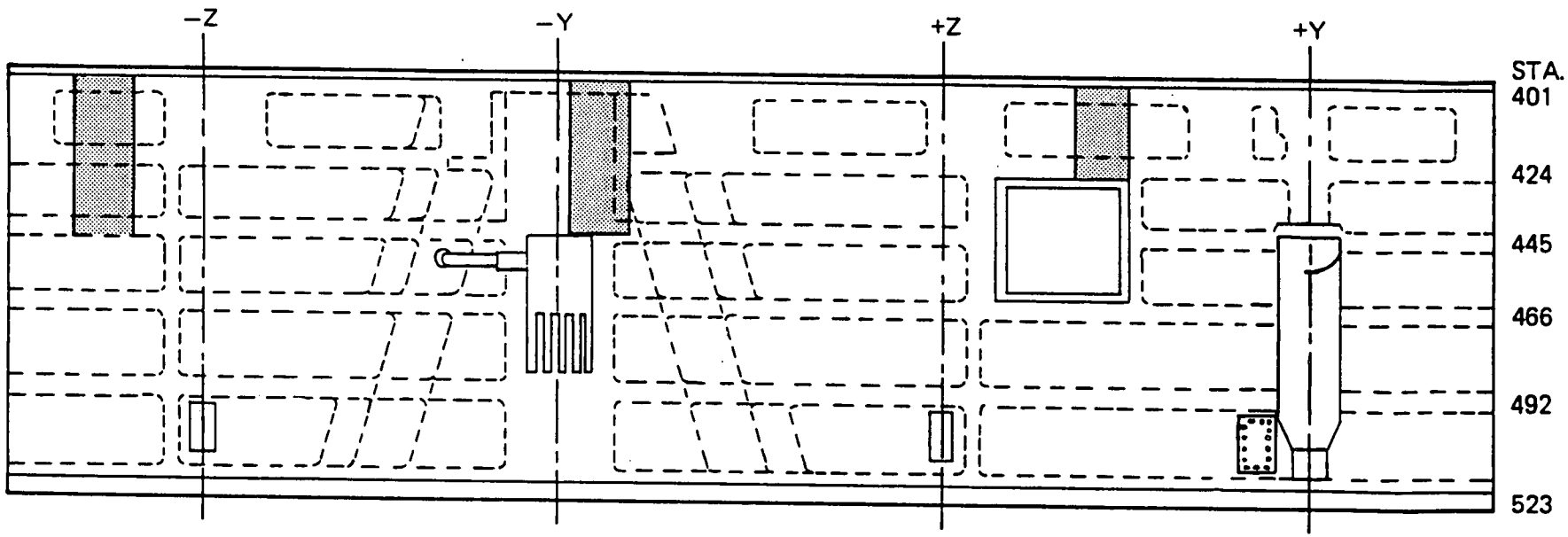
- 38 DEBONDS OVER FASTENERS

NOTES:

1. RH UPPER BSM COVER BENT BACK TO 135° POSITION
2. RH LOWER BSM COVER BENT BACK TO 100° POSITION
3. BLISTERING OF HYPALON PAINT. VARYING DEGREES OF CHARRING ALONG 395 RING

EGG/V-326

FIGURE 6. **RIGHT SRB FWD SKIRT**



TPS MISSING

NONE

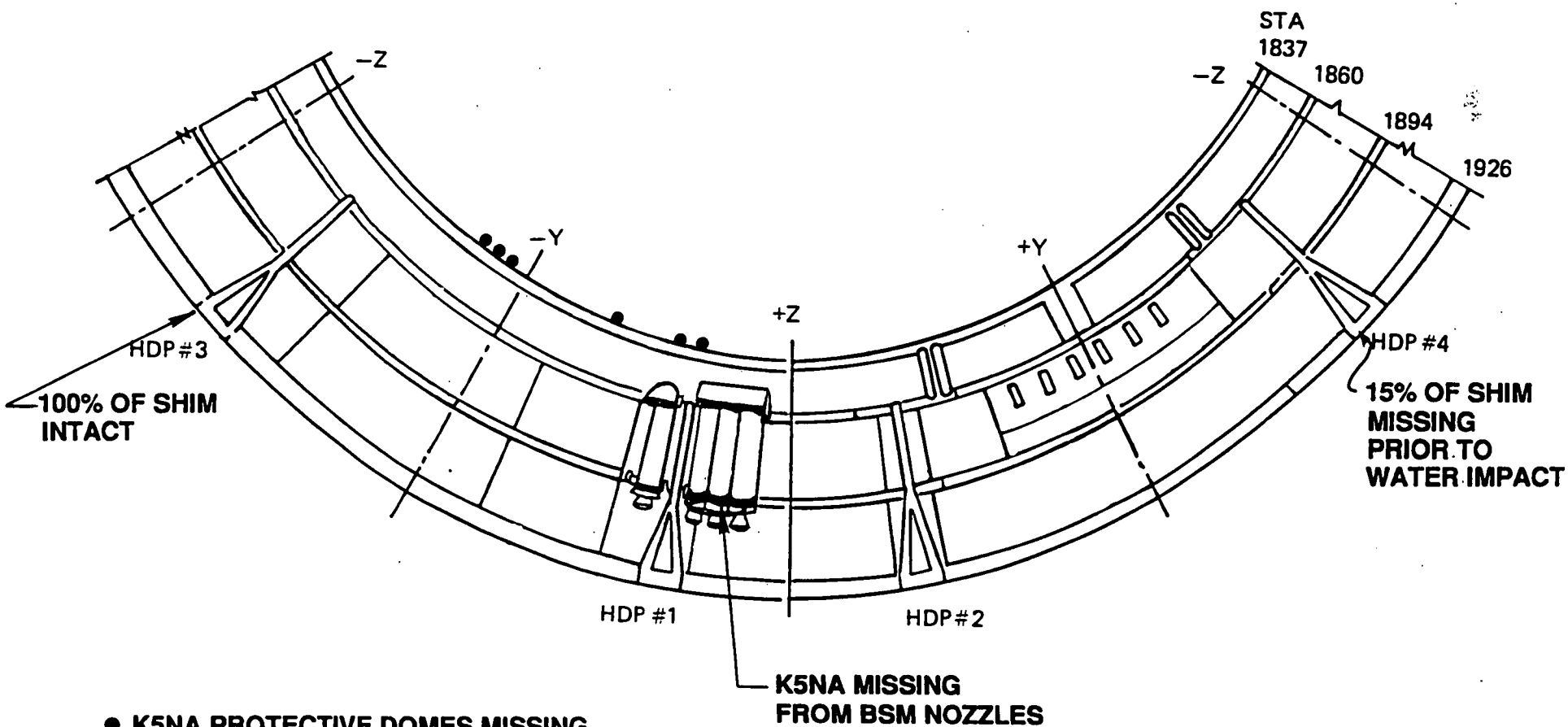
DEBONDS

NONE

NOTES:

1. **BLISTERING OF HYPALON PAINT OCCURRED IN GENERAL AREA OF THE THRUST POST.**

FIGURE 7. RIGHT SRB AFT SKIRT EXTERIOR TPS



- K5NA PROTECTIVE DOMES MISSING PRIOR TO WATER IMPACT (6 PLACES). SUBSTRATE CHARRED

EGG/V 326C

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum exhibited no missing TPS but had 40 debonds over fasteners. A 3"x3" debond over a cluster of fasteners occurred near the +Y side of the BSM's (Figure 8). Three of the BSM covers were fully opened and locked in the 180 degree position. One BSM cover was locked but bent back to approximately 135 degrees.

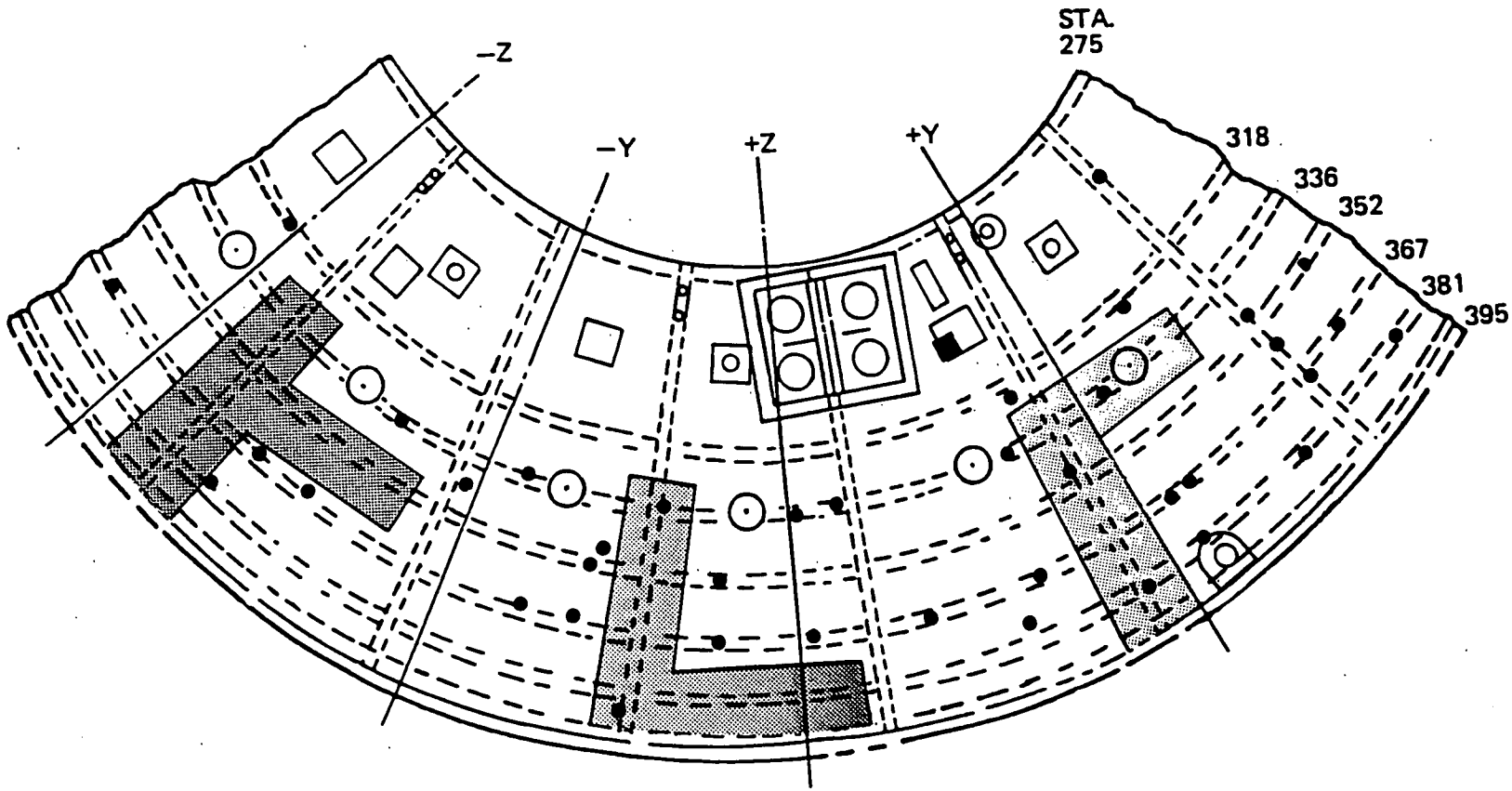
The LH forward skirt exhibited no debonds, but was missing TPS due to nozzle severance debris hits. The phenolic block on the +Z RSS antenna was delaminated (Figure 9). The frustum severance ring, which utilized the new pin retainer clips, was missing no pins. Separation of the forward attach bolt appeared normal.

Generally, the new Field Joint Protection System (FJPS) closeouts were in good condition. Small pieces of K5NA were missing from the center field joint heater closeout. A 0.6-inch hairline crack occurred in the LH center FJPS at 320 degrees.

Separation of the aft struts appeared nominal. There was no structural damage to the stiffener rings, ETA ring, or IEA.

The phenolic material on the kick ring delaminated in several locations. HDP #5, 7, and 8 DCS plungers were properly seated. The HDP #6 plunger was jammed open by a frangible nut half. Aft skirt HDP #7 was missing Epon shim from the inboard side of the foot and the substrate was sooted (Figure 10).

FIGURE 8. LEFT SRB FRUSTUM



MISSING TPS

NONE

DEBONDS

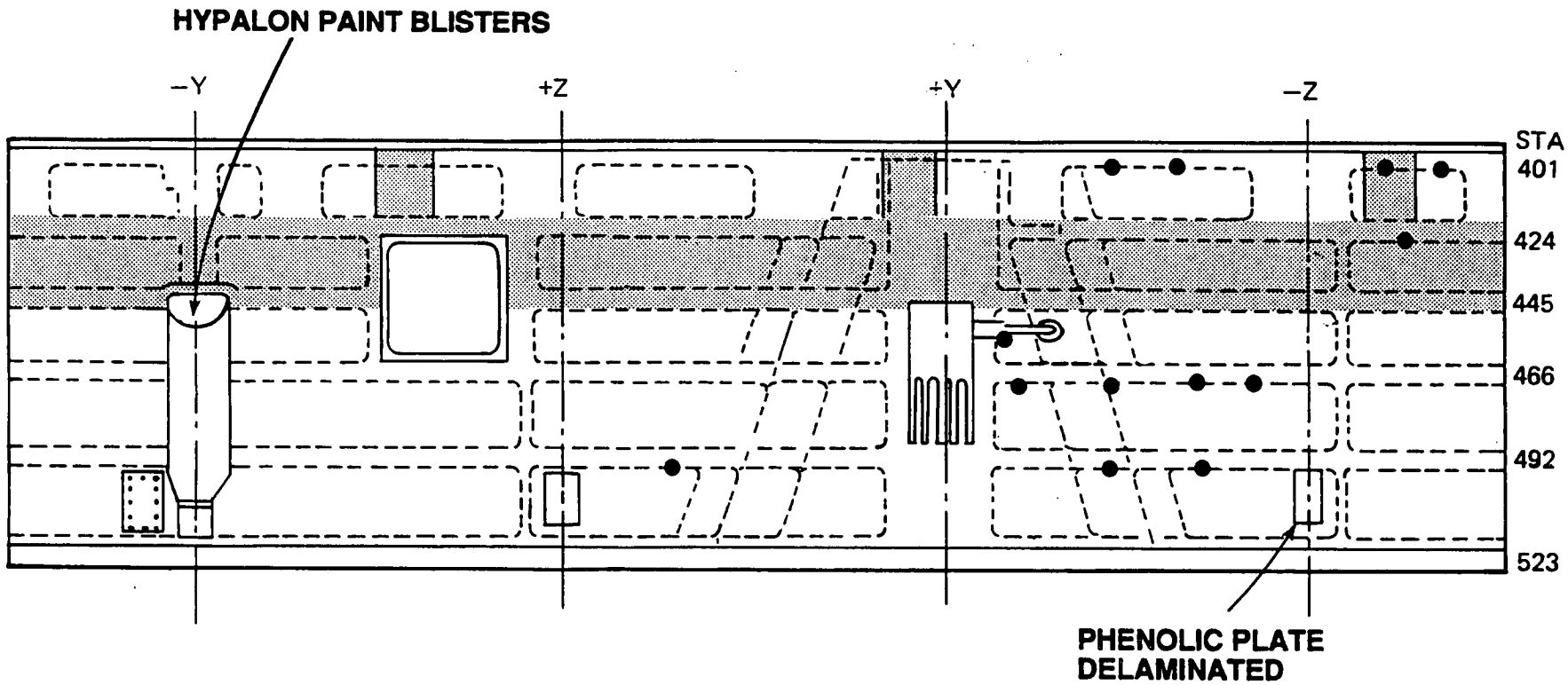
- 40 DEBONDS OVER FASTENERS
- ■ 3" X 3" DEBOND OVER CLUSTER OF FASTENERS

NOTES:

1. VERY LITTLE BLISTERING/AERO HEATING EFFECTS
2. RH LOWER BSM COVER BENT BACK TO 90° POSN

EGG/V-326E

FIGURE 9. LEFT SRB FWD SKIRT



TPS MISSING	DEBONDS
• 13 AREAS OF MISSING MSA-2 DUE TO NOZZLE SEVERANCE DEBRIS	NONE

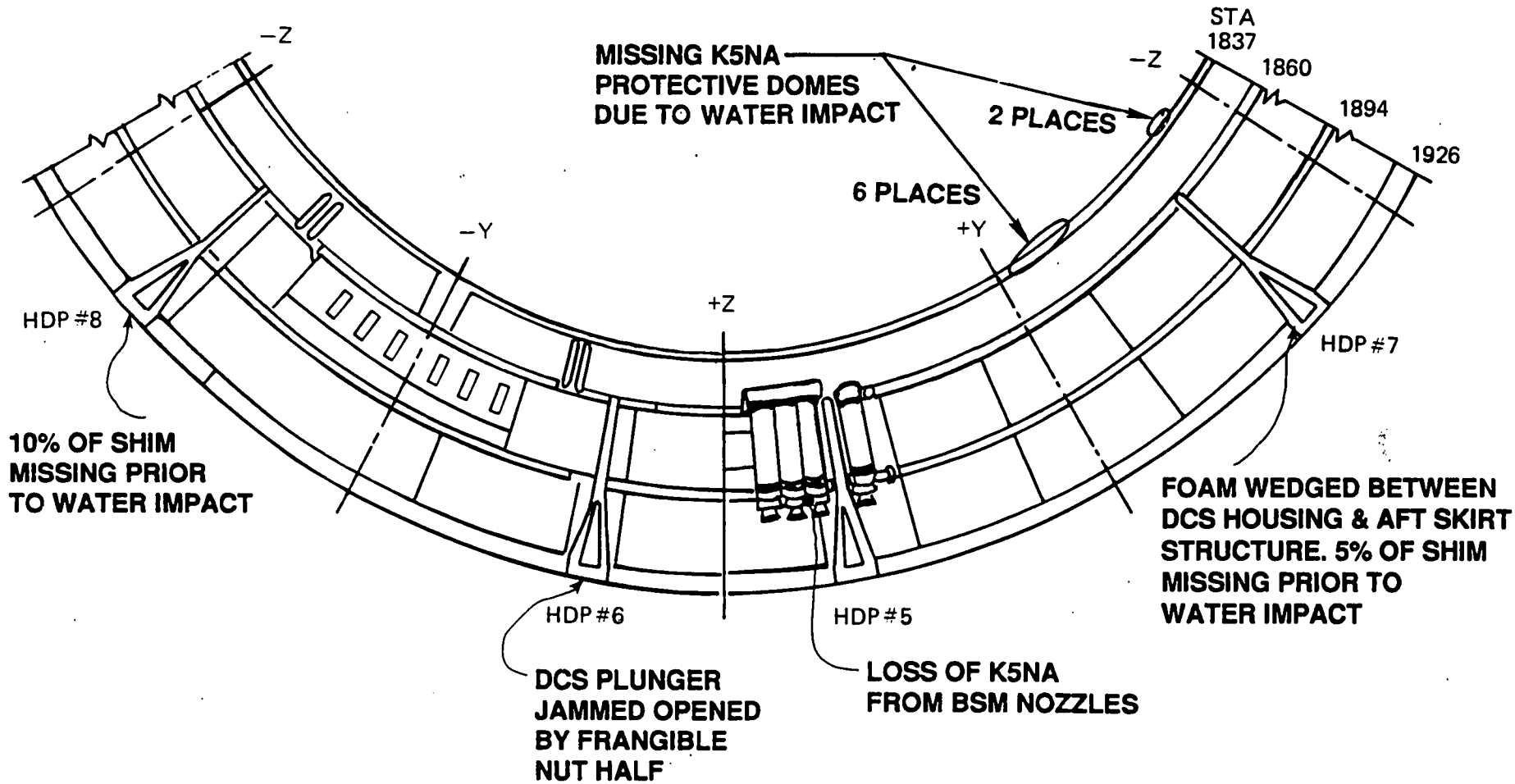
NOTES:

1. MINIMAL SIGNS OF AEROHEATING EFFECTS & BLISTERING OF HYPALON PAINT

FIGURE 10. LEFT SRB AFT SKIRT EXTERIOR TPS

NOTES:

1. TYPICAL BLISTERING & SOOTING OF HYPALON PAINT



EGG/V-326F

7.3 RECOVERED SRB DISASSEMBLY FINDINGS

Water impact damage included a snubbed nozzle on the RH SRB and bent stiffener rings at the aft and center ring locations. The TVC rock actuator on the LH SRB nozzle was broken. The clevis attached to the nozzle exit cone extension had separated at the actuator attach point.

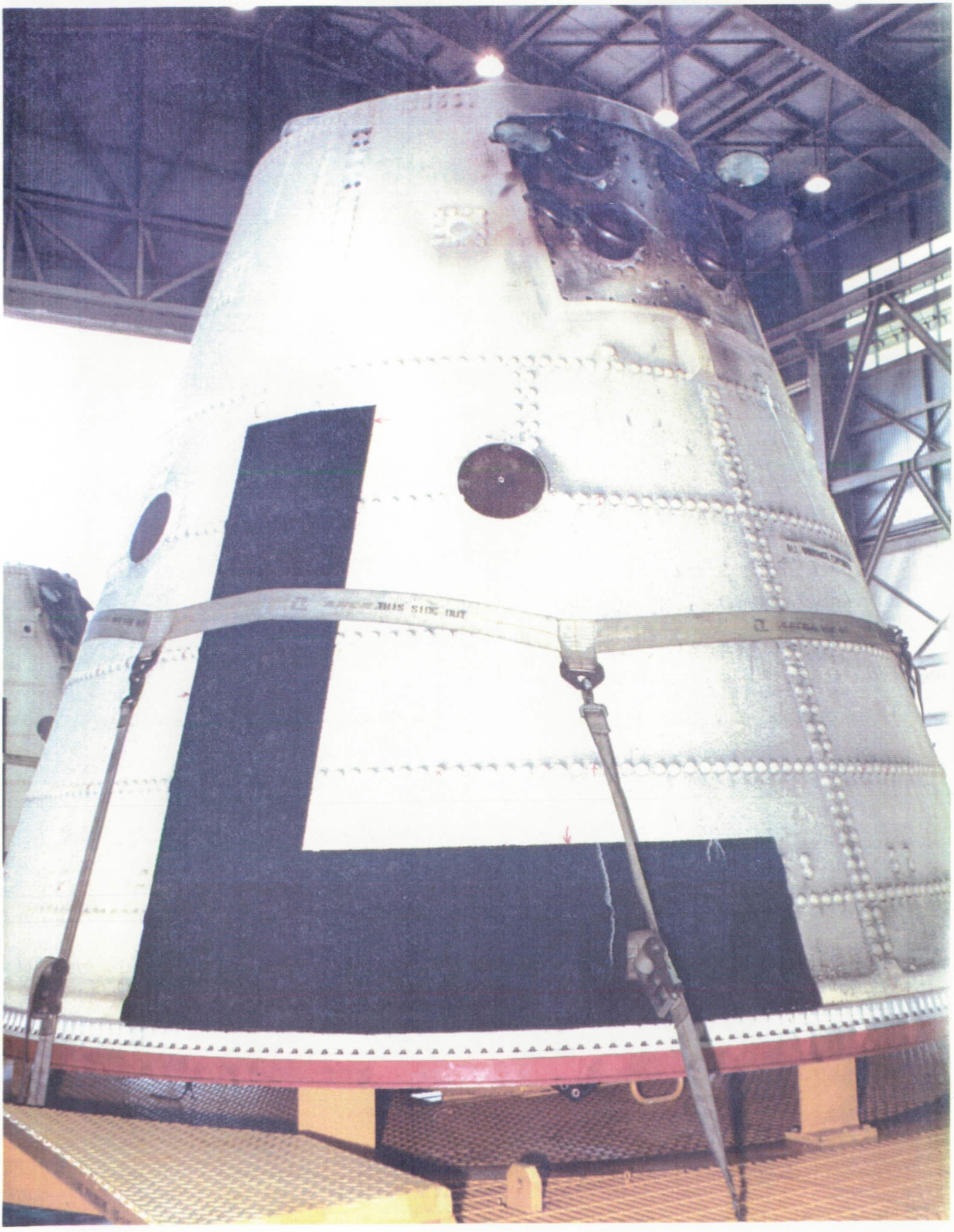
A blowhole occurred in the LH ignitor outer joint putty at 165 degrees. Cadmium plating was missing on the forward face of the outer gasket to the primary seal inner cushion. Heavy soot was present up to the primary seal cushion. Cad plating damage indicates a larger area of the gasket was exposed to hot gas impingement. Similarly, a blowhole occurred in the RH ignitor outer joint putty at 268 degrees. Cad plating was not missing up to the seal cushion like on the LH outer gasket. A redesign of the ignitor joint is continuing at Thiokol.

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 75% and individual holddown post retention percentages as listed:

HDP #	Overall %	% of Nut without 2 large halves	% of Ordnance
1	88	99	70
2	99	100	99
3	89	97	70
4	94	100	76
5	92	100	70
6	27	37	2
7	91	100	69
8	22	25	16

Loss of a 3"x1/2" ordnance fragment from the HDP #6 DCS was visible in the film review. However, the film review did not show the loss of debris from HDP #8 DCS after T-0. The plunger appeared to be seated properly during the post flight inspection. Although HDP #7 DCS debris plunger seated properly, the blast container and plunger assembly were incorrectly assembled and aligned at the pad before launch.

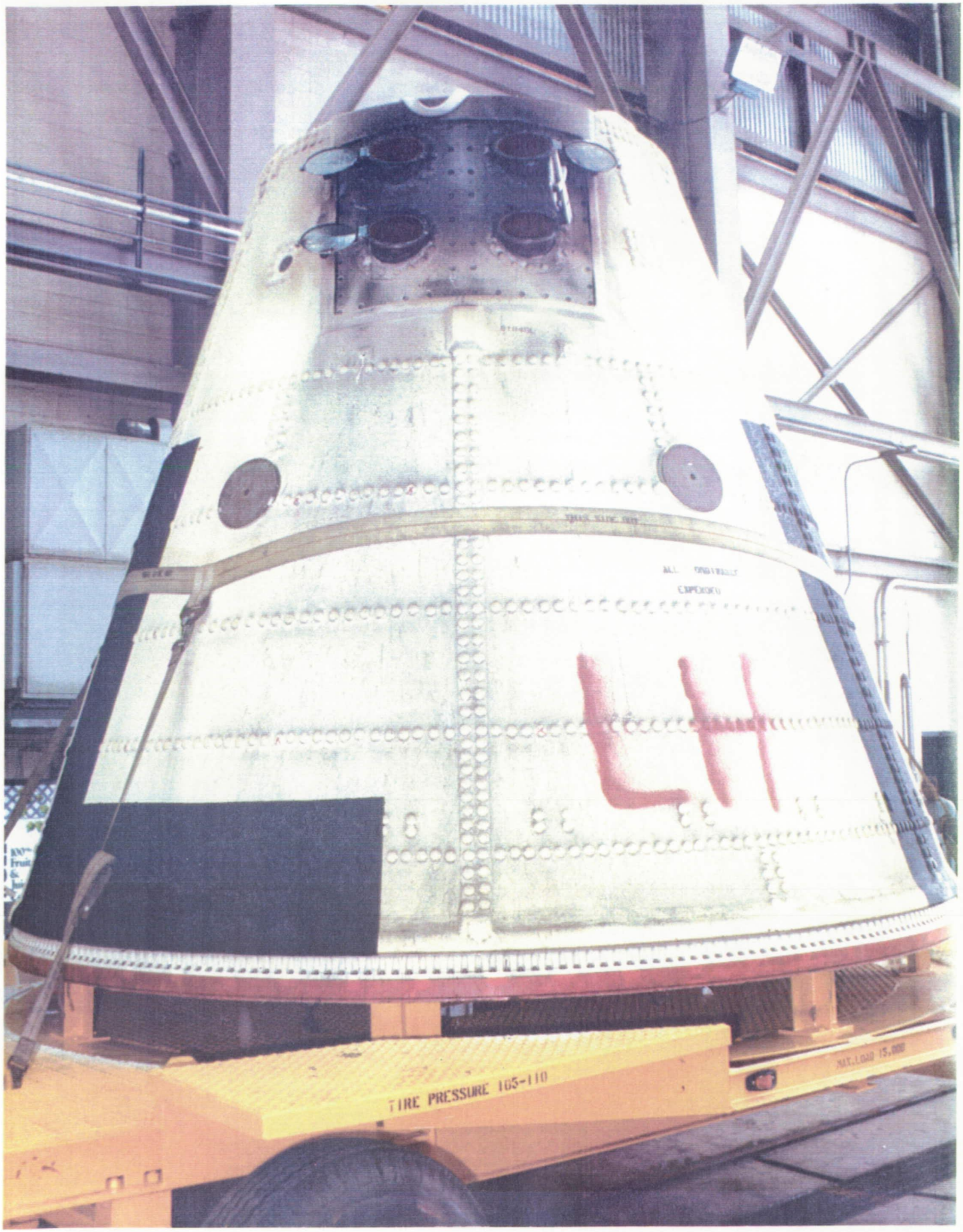
SRB post flight/retrieval debris anomalies are listed in Section 10.3.



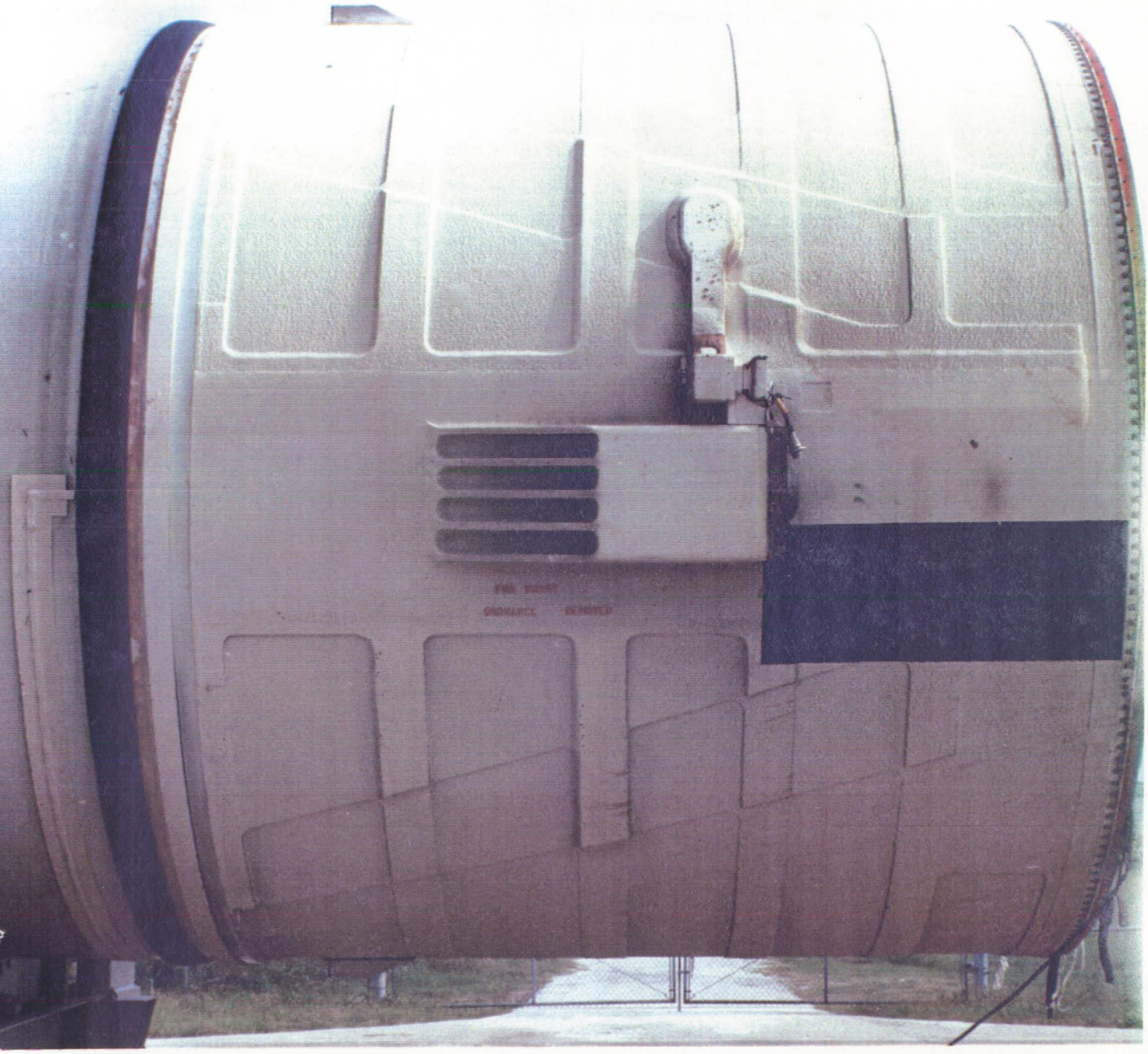
Post flight condition of RH frustum. Although no MSA-2 was missing, debonds over fasteners continue to occur.

C-2

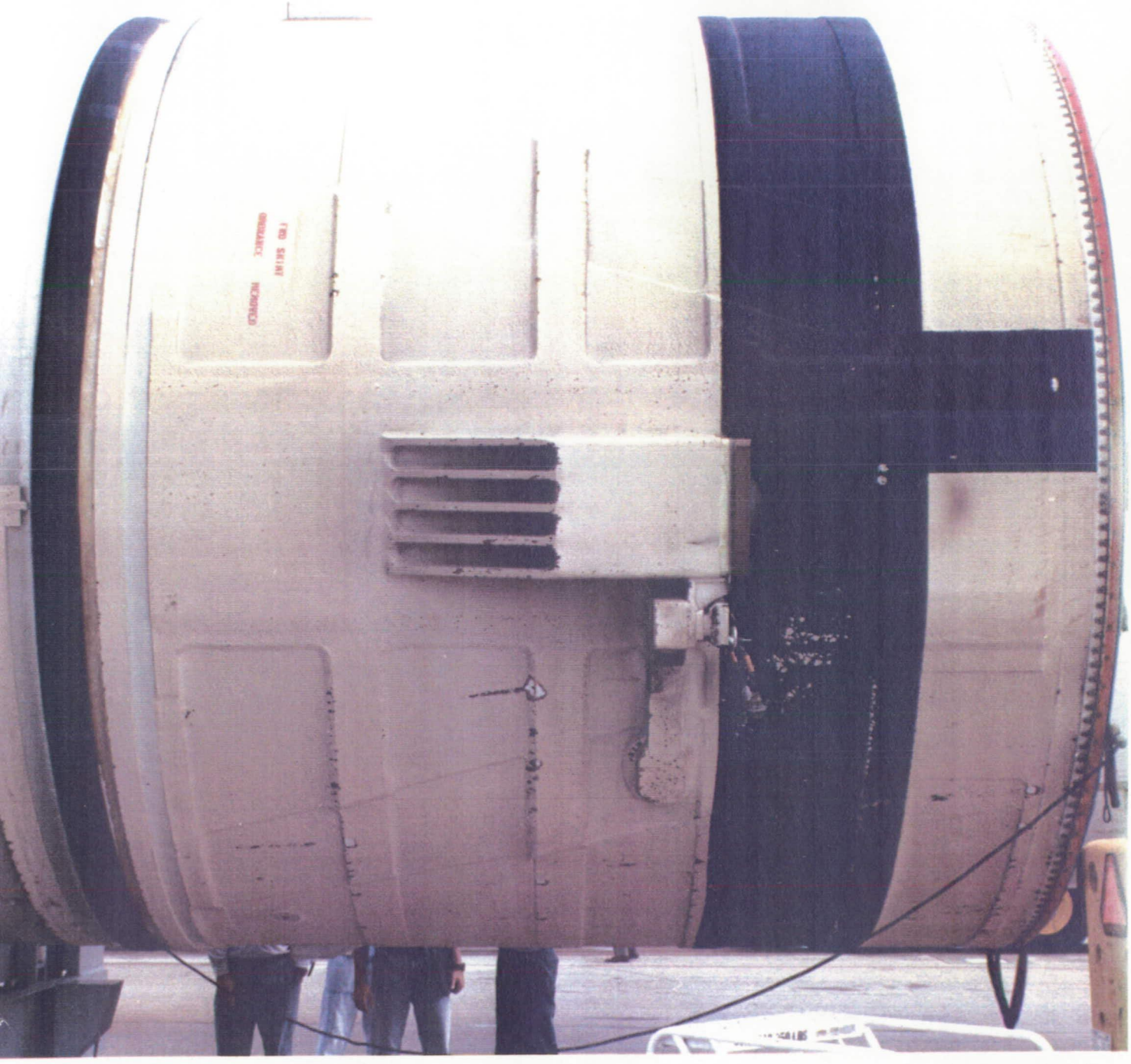
ORIGINAL PAGE
COLOR PHOTOGRAPH



Post flight condition of LH frustum. Although no MSA-2 was missing, debonds over fasteners continue to occur.

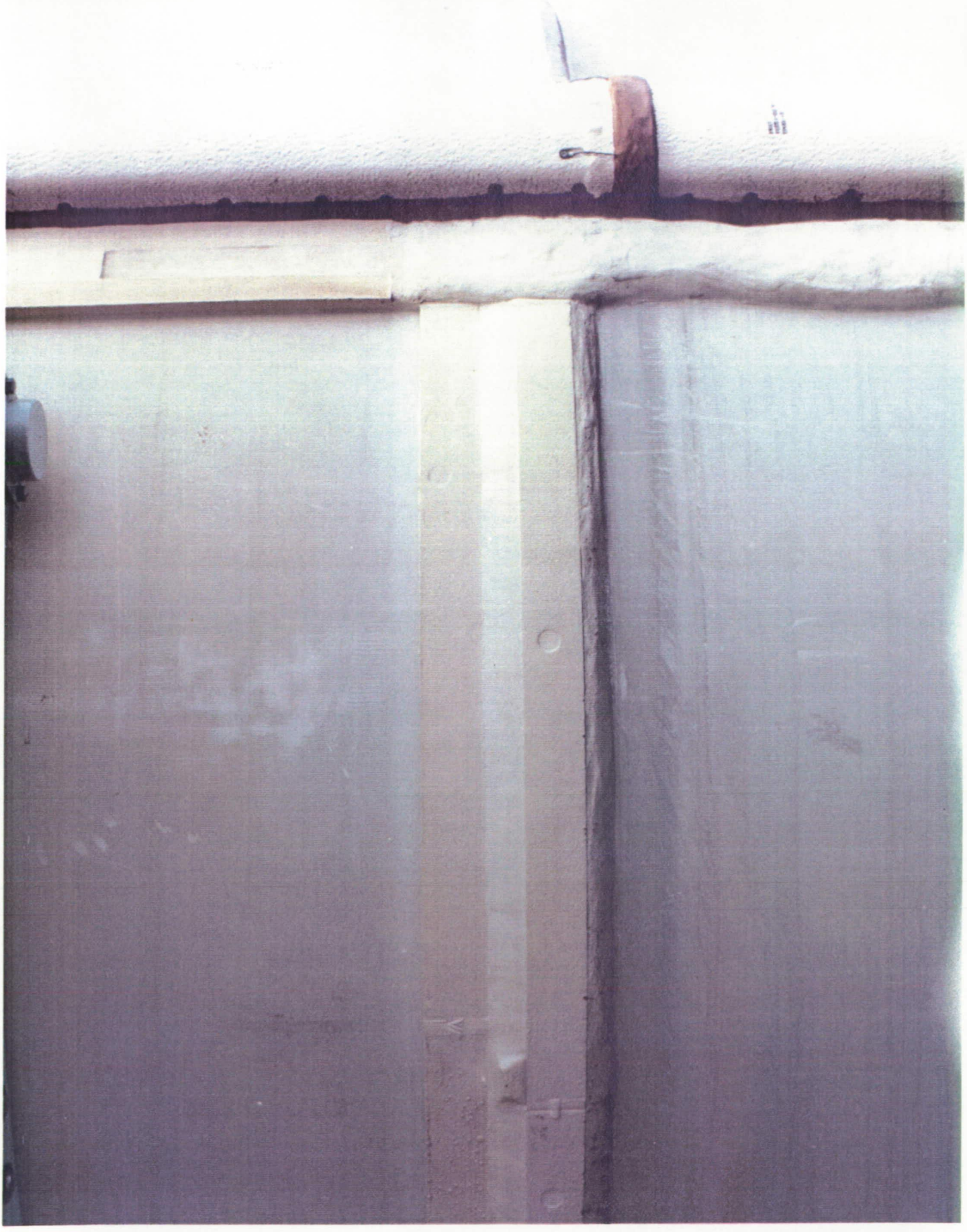


Post flight condition of RH forward skirt. There were no debonds or missing TPS.



Post flight condition of LH forward skirt. Missing TPS was caused by nozzle severance debris impacts.

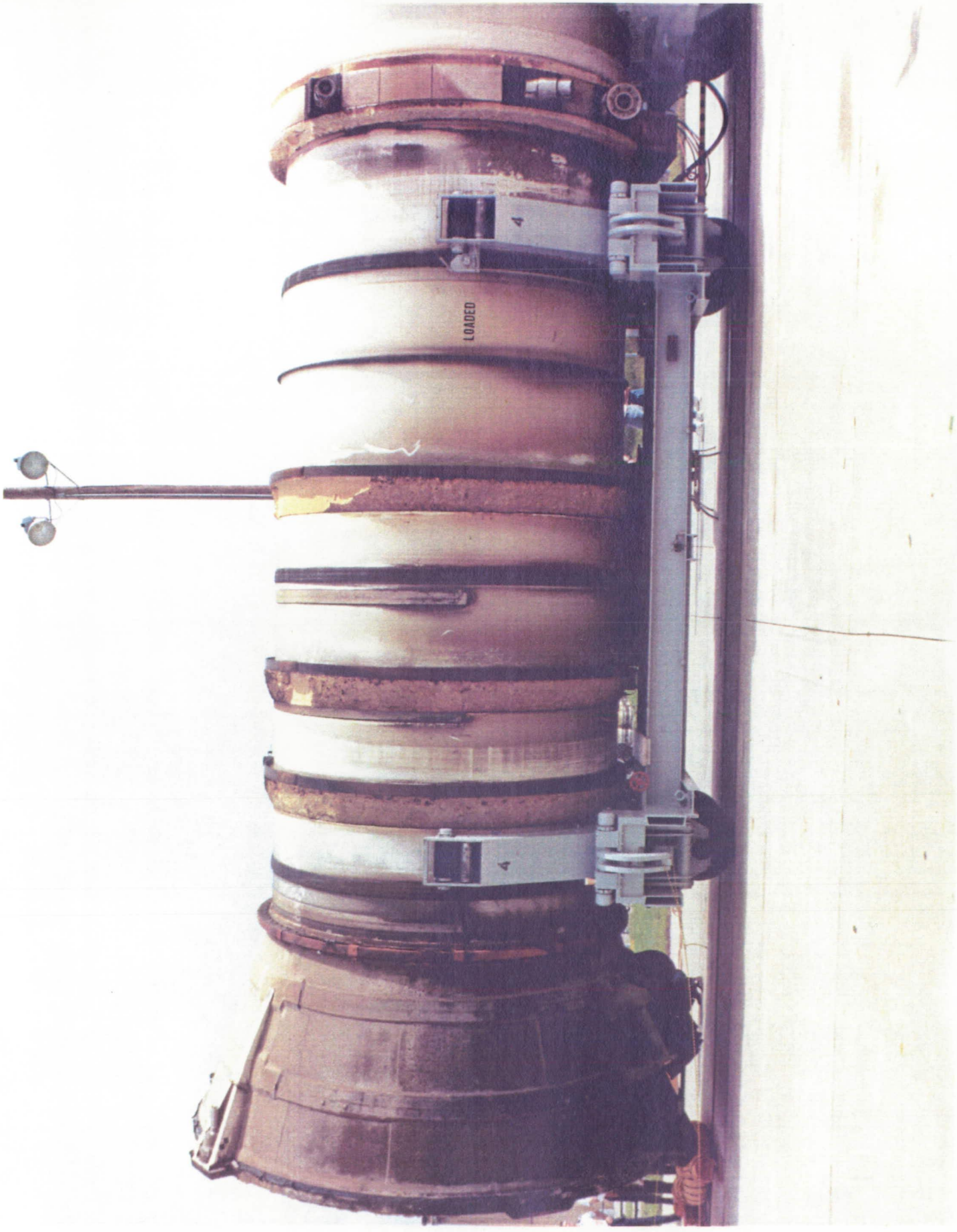
Phenolic plate on LH RSS antenna cover was delaminated



New Field Joint Protection System (FJPS) closeouts were in generally good condition

K5NA closeout blistered, or delaminated, in the center field joint

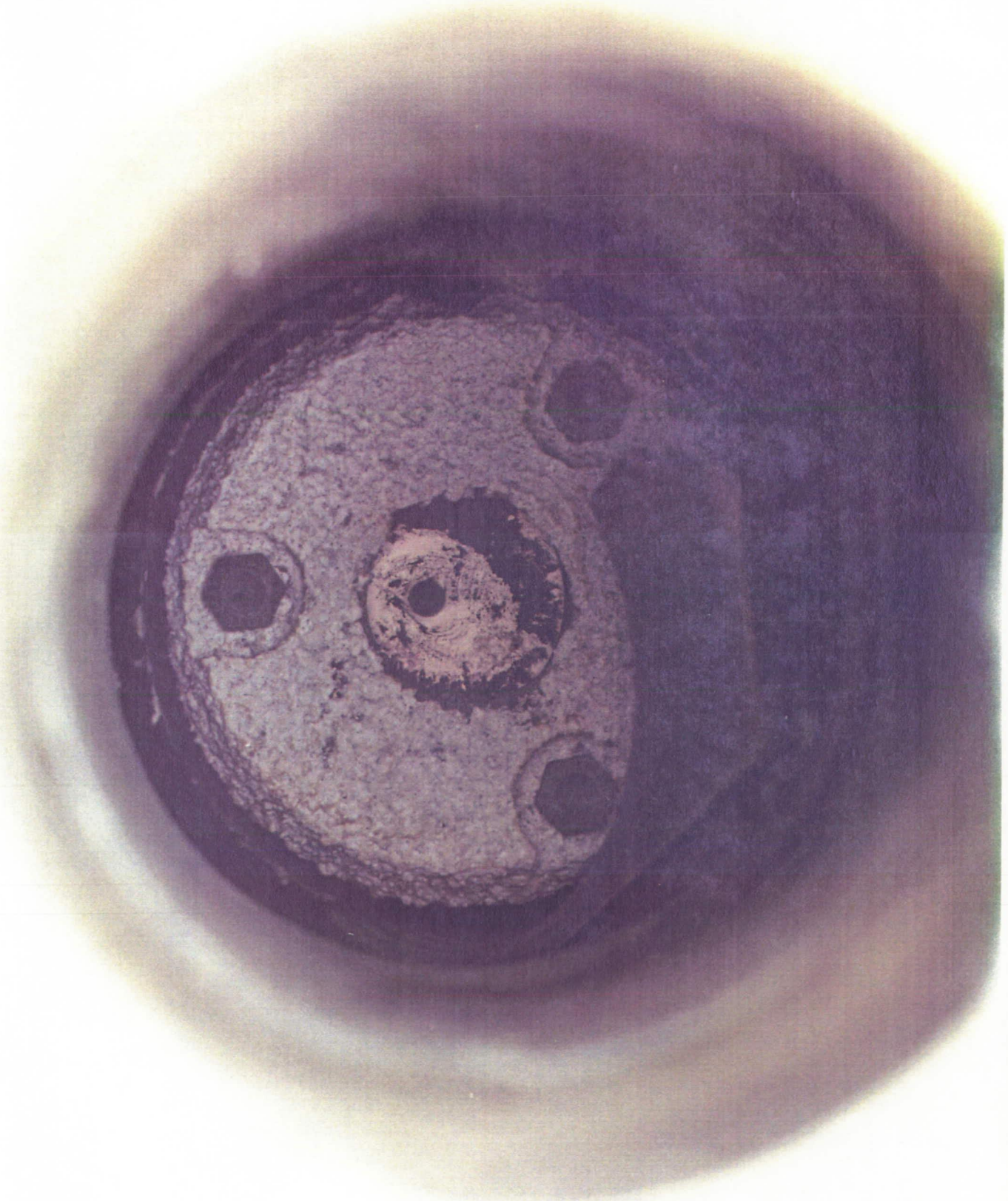
A 9.6-inch unbond occurred on the aft edge of the RFC factory joint weather seal



Post flight condition of RH aft booster. Loss of ETA ring and stiffener ring foam was caused by water impact.

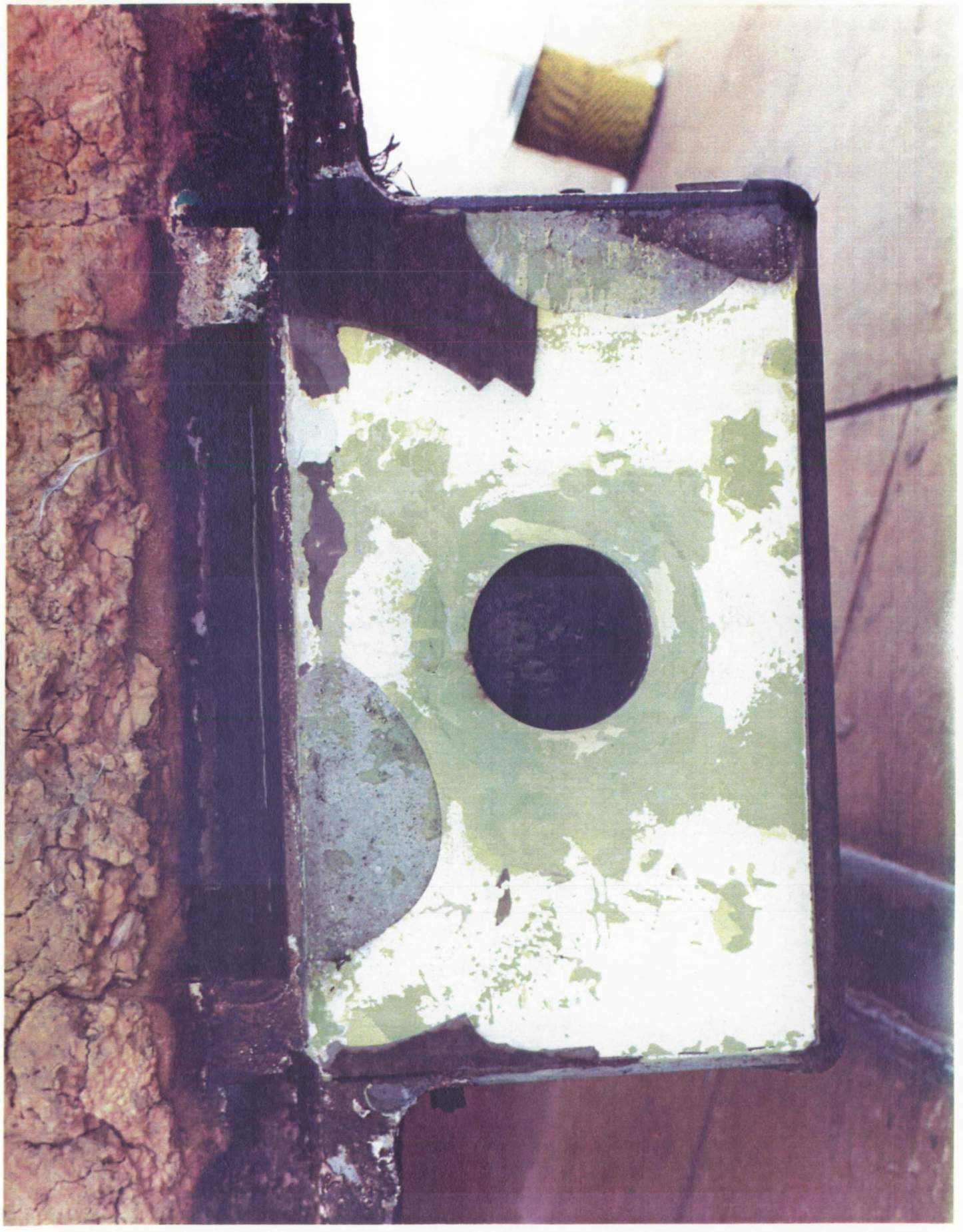
Post flight condition of LH aft booster

Phenolic material has delaminated from the kick ring. Note loss of K5NA protective domes prior to water impact.



ORIGINAL PAGE
COLOR PHOTOGRAPH

The HDP #6 DCS plunger was jammed open by a frangible nut half



Sooted substrate indicates portions of the EPON shim material was lost prior to water impact.

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A detailed post landing inspection of OV-103 Discovery was conducted on October 10-11, 1990, at Ames-Dryden (EAFB) on Runway 22 and in the Mate/Demate Device (MDD) to identify debris impact damage, and if possible, debris sources. The Orbiter TPS sustained a total of 76 hits, of which 16 had a major dimension of one inch or greater. This total does not include the approximately 150 hits on the base heat shield.

The Orbiter lower surface had a total of 64 hits, of which 13 had a major dimension of one inch or greater. A comparison of these numbers to statistics from 22 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 less than average. Figures 11-14 show the TPS debris damage assessment for STS-41.

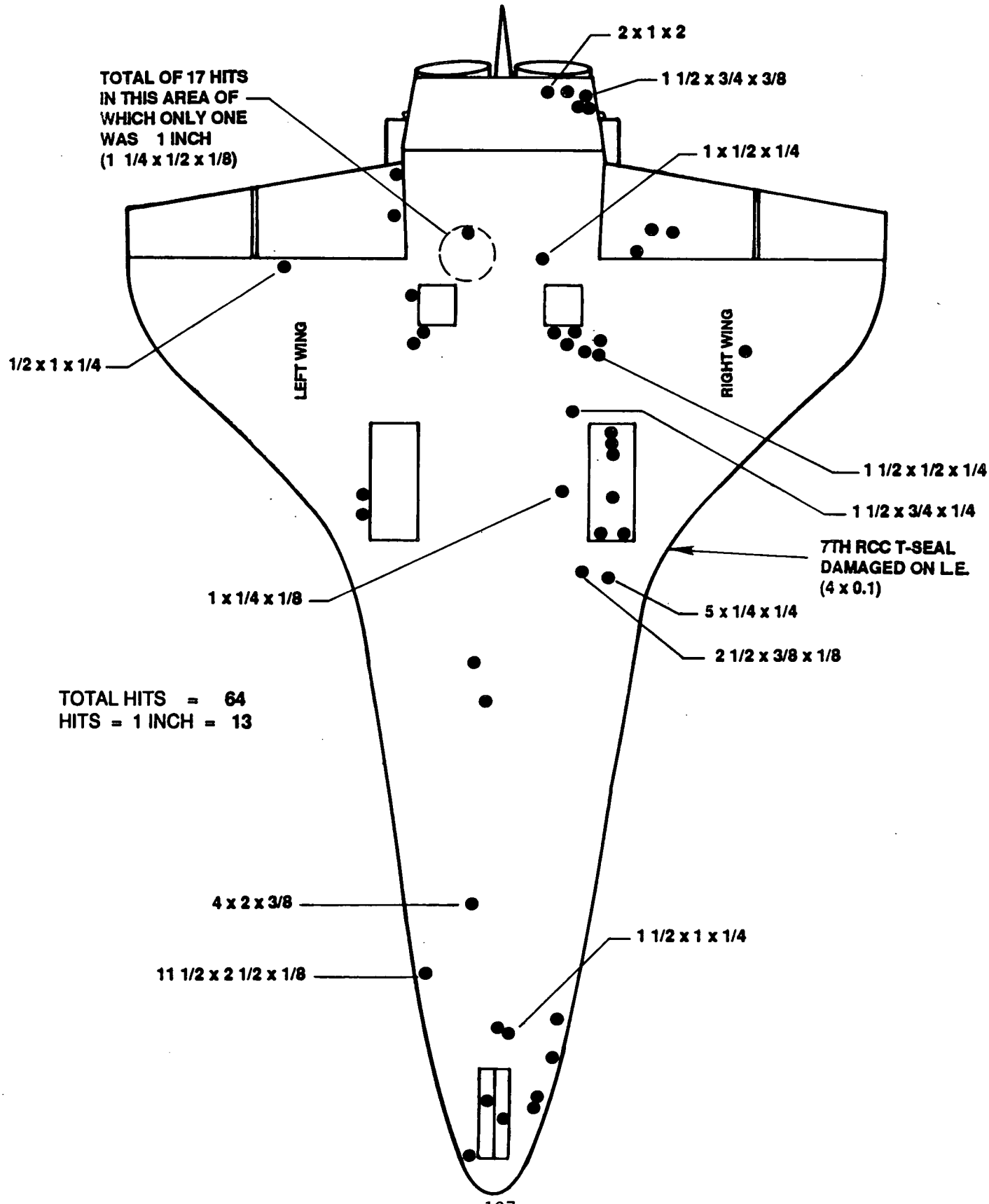
The Orbiter lower surface tile damage sites had an approximate equal distribution about the vehicle centerline. A cluster of 17 hits (one larger than one-inch) occurred just aft and inboard of the LH2 ET/ORB umbilical cavity. Similar clusters of hits have occurred in this area on previous flights and are attributed to ice/debris impacts during ET separation. A total of 5 hits occurred on the body flap lower surface. One of these damage sites exhibited significant thermal erosion to a depth of 2 inches with melting of the adjacent tile coating material.

The debris plunger in the EO-2 (LH2) separation fitting debris container was obstructed by the frangible nut halves and failed to seat properly. Three pieces of spent ordnance assembly (detonator, booster fragment, and connector piece) were found on the runway beneath the LH2 ET/ORB umbilical cavity and were attributed to this failure. This anomaly was documented on PR PYR-3-12-0153. The debris plunger had been modified prior to return-to-flight, but has experienced failures in approximately 33% of the Shuttle flights. In addition, a 2-1/4 inch long piece of what appeared to be lockwire was found on the runway beneath the LO2 ET/ORB umbilical cavity (ref PR LAF-3-12-0242). The origin of this wire is unknown. EO-3 separation ordnance device plunger appeared to have functioned properly.

The RH connector on the forward separation pyro bolt (EO-1) was loose at the locking ring. There were no anomalies with the LH connector. A forward separation support bearing plate insert was backed out (during forward separation bolt removal) and a TCS blanket was pinched between the structure and the forward separation bolt bearing plate.

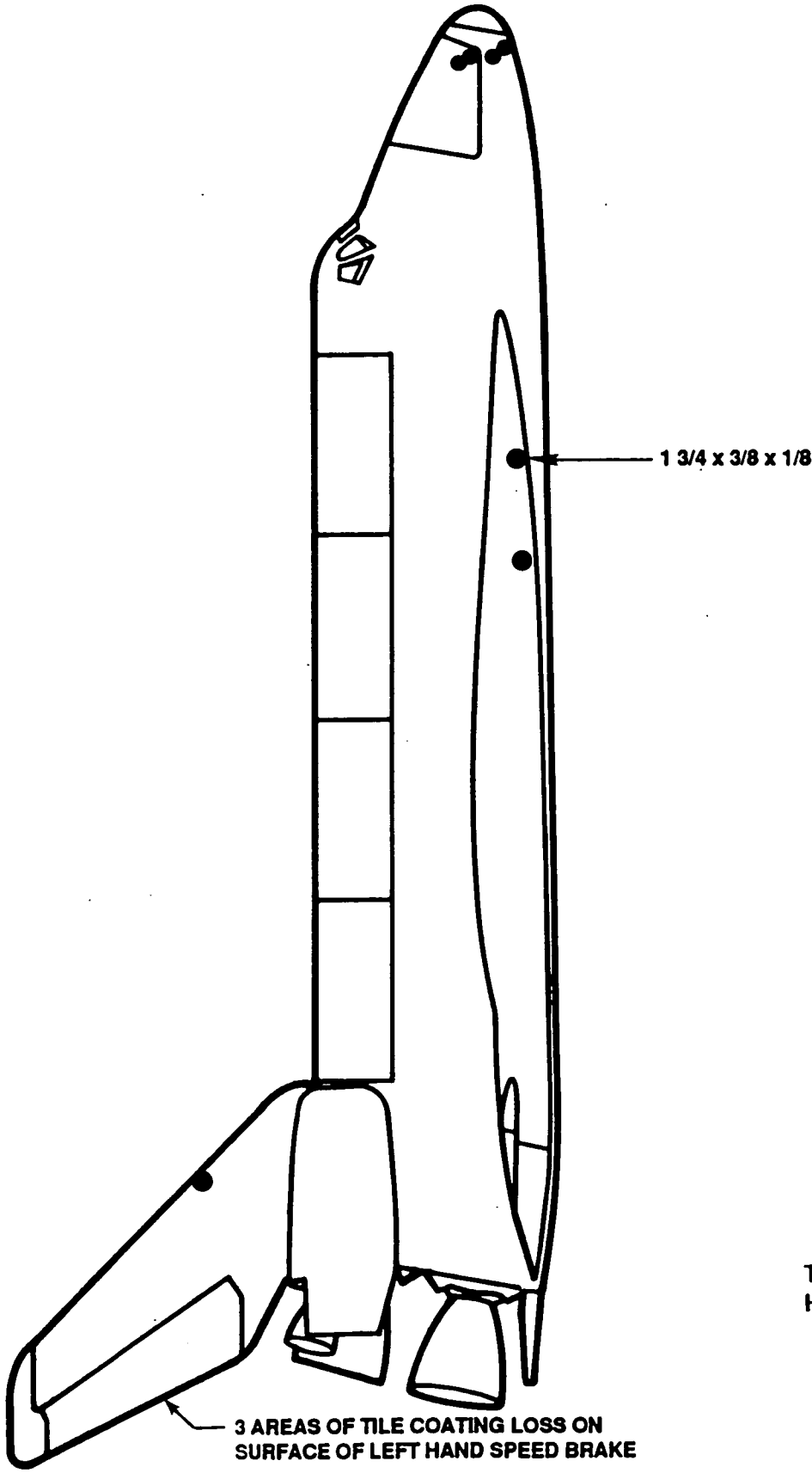
Damage to the base heatshield tiles was average with approximately 150 sites. The main engine closeout beta blankets were in excellent condition.

FIGURE 11. **DEBRIS DAMAGE LOCATIONS**



EGG/V-088B

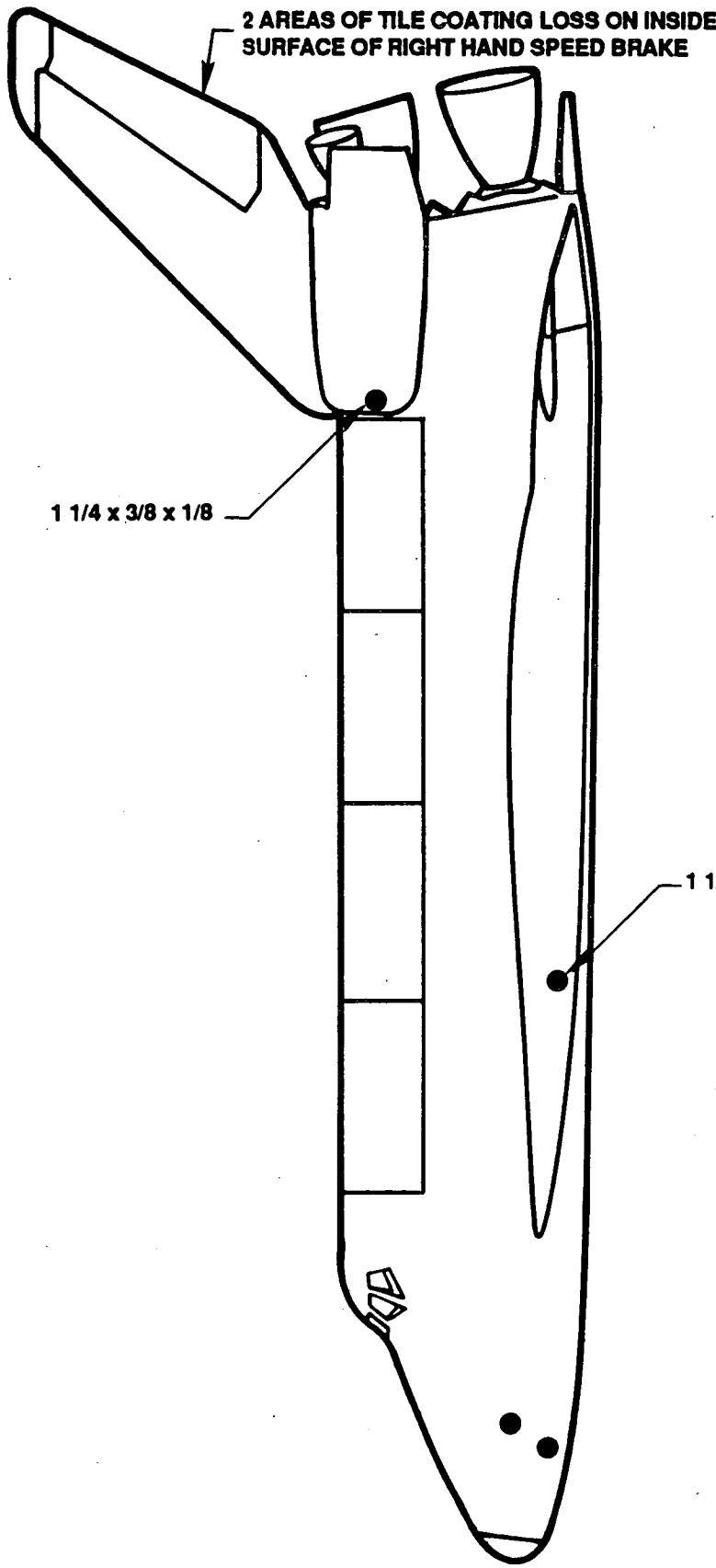
FIGURE 12. **DEBRIS DAMAGE LOCATIONS**



TOTAL HITS = 7
HITS ≧ 1 INCH = 1

EGG/V-088/

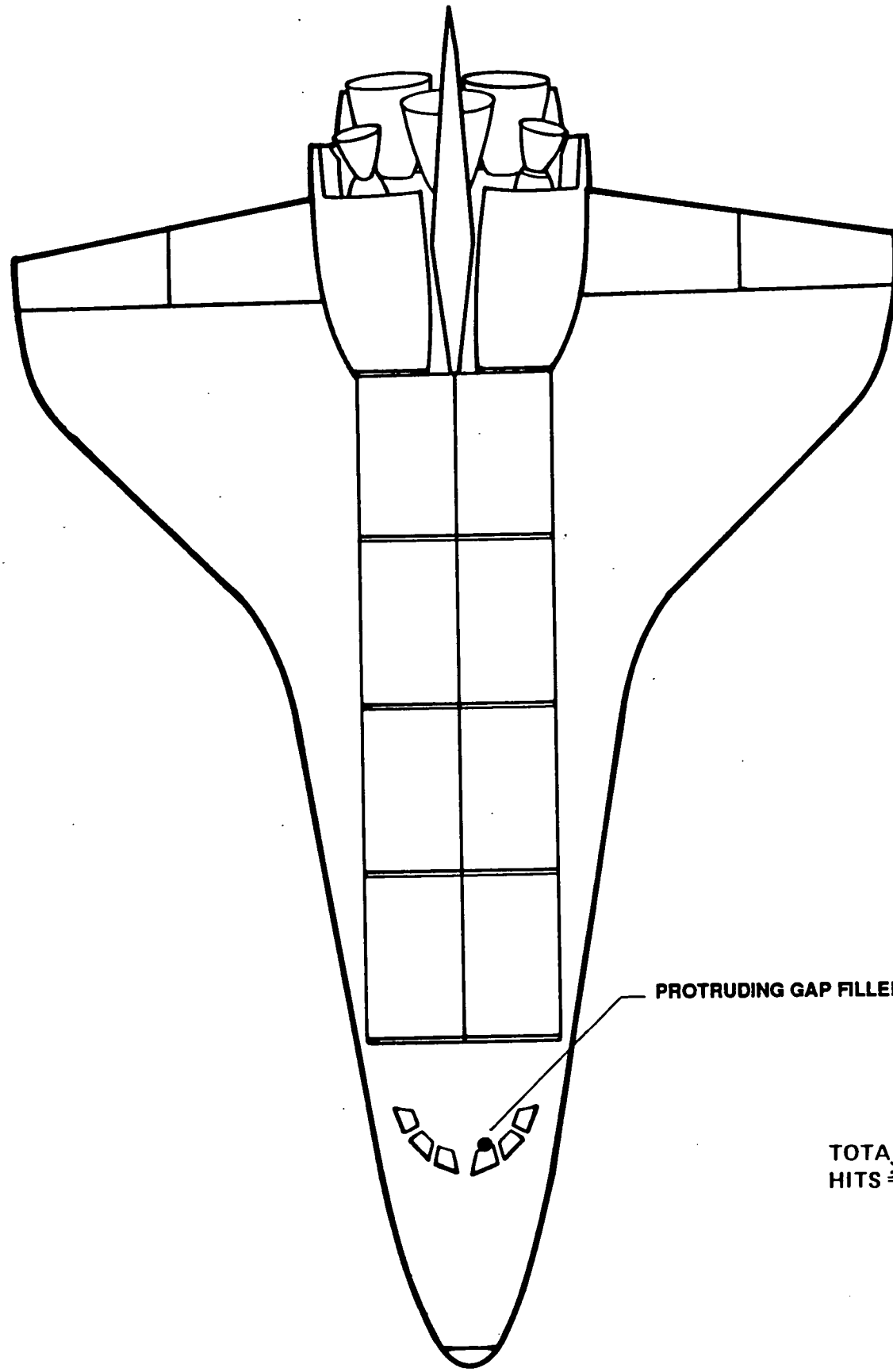
FIGURE 13. **DEBRIS DAMAGE LOCATIONS**



TOTAL HITS = **4**
HITS ≧ 1 INCH = **2**

EGG/V

FIGURE 14. **DEBRIS DAMAGE LOCATIONS**



Several small pieces of gap filler sleeving material were protruding slightly on the leading edges of both RH and LH OMS pods. No apparent damage to adjacent tiles resulted from these gap fillers. The overall condition of the OMS pods was better than usual with only one debris damage site on the LH OMS pod.

The MMH tank relief vent on the LH side of the FRCS module sustained what appeared to be a high velocity impact. The aft-facing edge of the vent pipe was missing a 3 mm diameter semi-circle of material. A hole approximately 2 mm in diameter by 3.5 mm deep was present in the tile immediately aft of the vent. This damage is believed to have been caused by either orbital debris or a micrometeroid. The tile has been sent to JSC for detailed analysis, and as of the printing of this document, no results have been released.

Orbiter windows #3 and #4 were moderately hazed with some minor streaking. Windows #2 and #5 were lightly hazed. Samples were taken from all the windows for laboratory analysis.

Samples were also taken from selected damage sites, as shown in Figures 15 and 16, for laboratory analysis.

The KSC Shuttle Thermal Imager (STI) was used to measure the surface temperatures of several areas. Twenty minutes after landing, the Orbiter nosecap RCC was 152 degrees F and the RH wind leading edge RCC panels #9 and #17 were 73 degrees F (ref Figure 17).

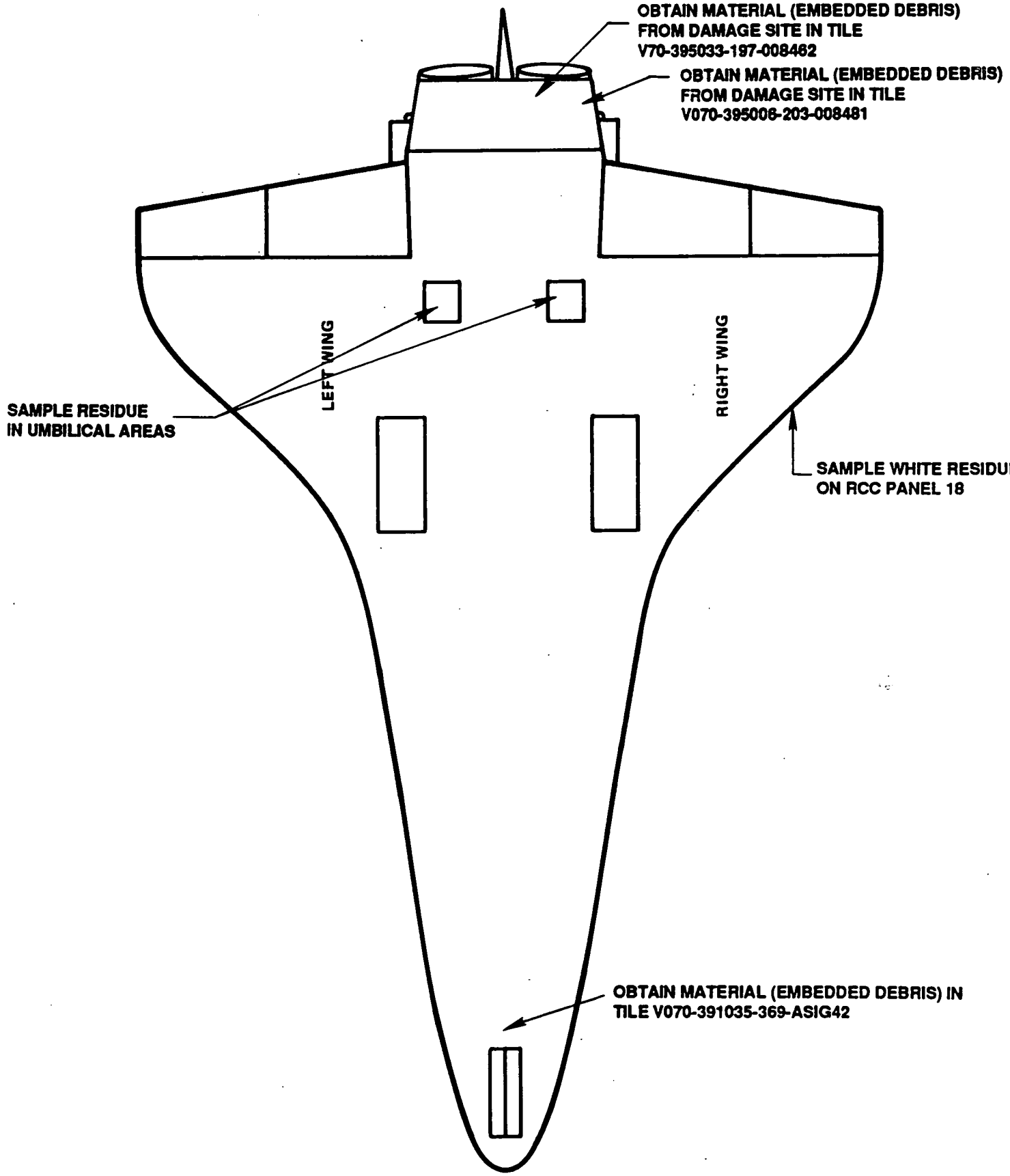
Runway 17L was inspected by the Debris Team on 9 October 1990 and all potentially damaging debris was removed. Runway 22 was inspected and swept by Air Force personnel. Both runways were found to be in good condition.

The post landing inspection of Runway 22 was performed 30 minutes after landing. No flight hardware was found.

In summary, the total number of lower surface Orbiter TPS debris hits was less than average when compared to previous flights as shown in the comparison charts (Figures 18-19). 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. The potential identification of sources of debris for mission STS-41 will be based on the laboratory analysis of TPS damage sites, inspection of the recovered SRB components, and photographic analysis.

Orbiter post landing anomalies are listed in Section 10.4.

FIGURE 15. **STS-41 DEBRIS DAMAGE CHEMICAL SAMPLE LOCATIONS**



EGG/V-088

FIGURE 16. **STS-41 DEBRIS DAMAGE CHEMICAL SAMPLE LOCATIONS**

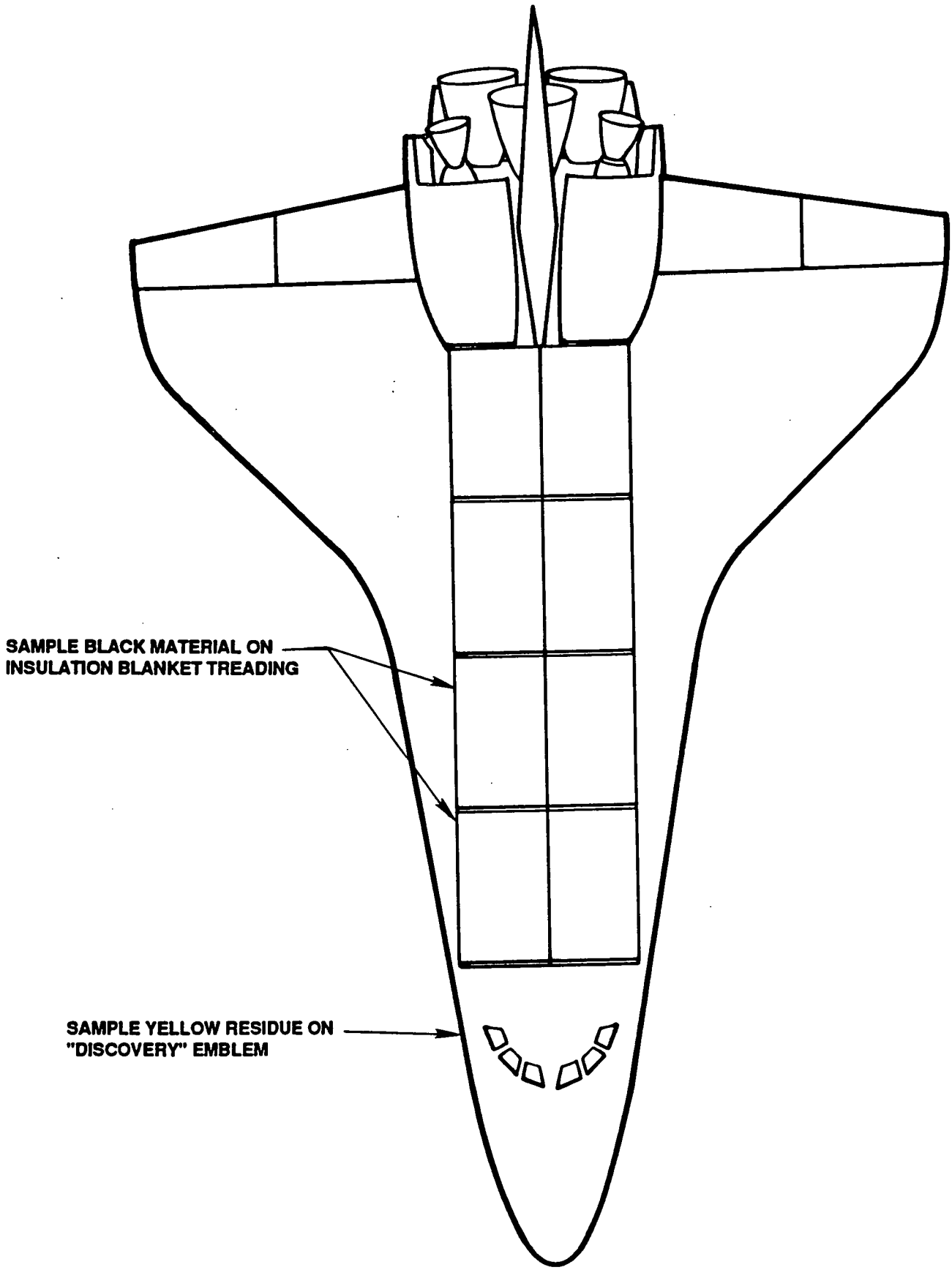


FIGURE 17. **TEMPERATURE MEASUREMENTS**

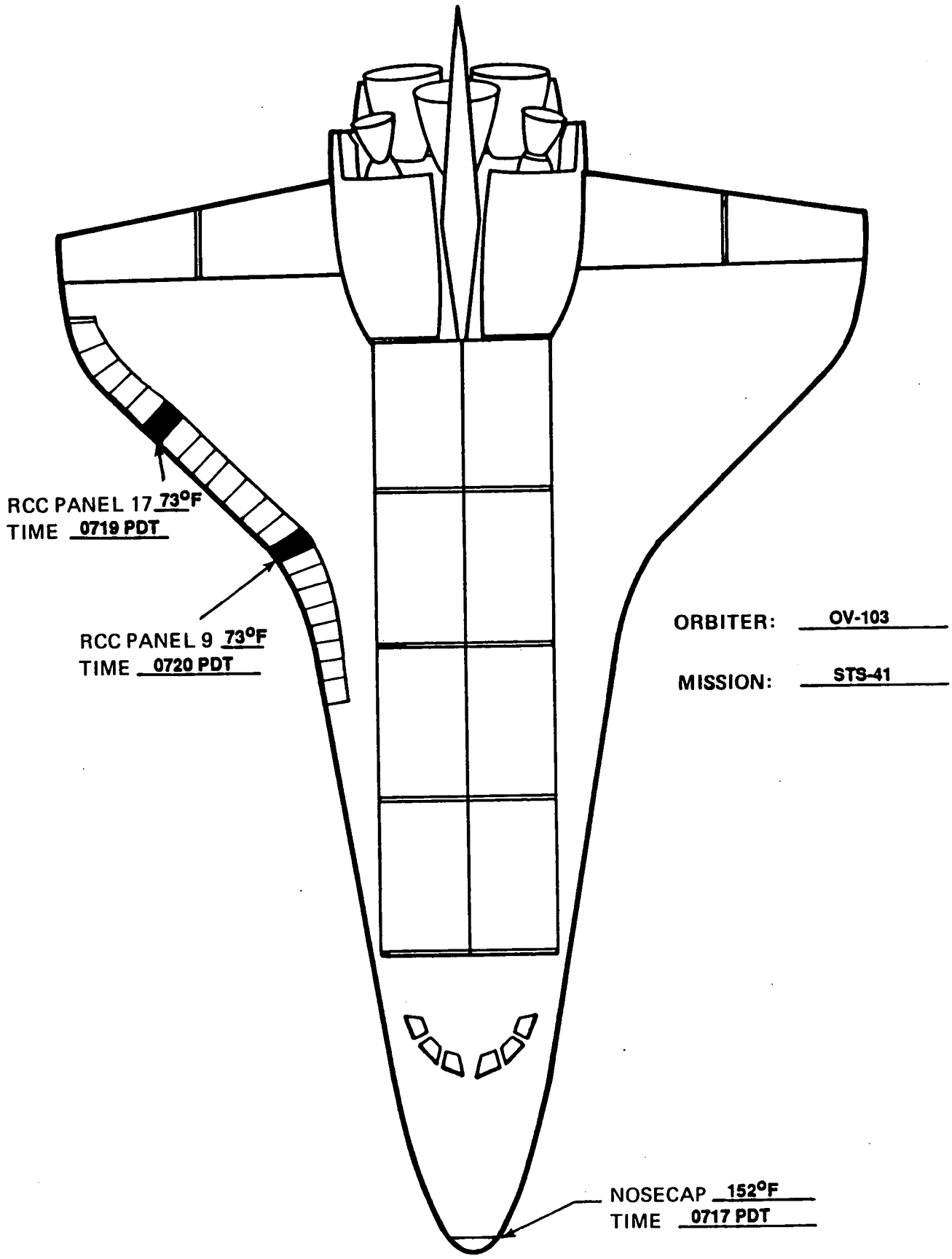


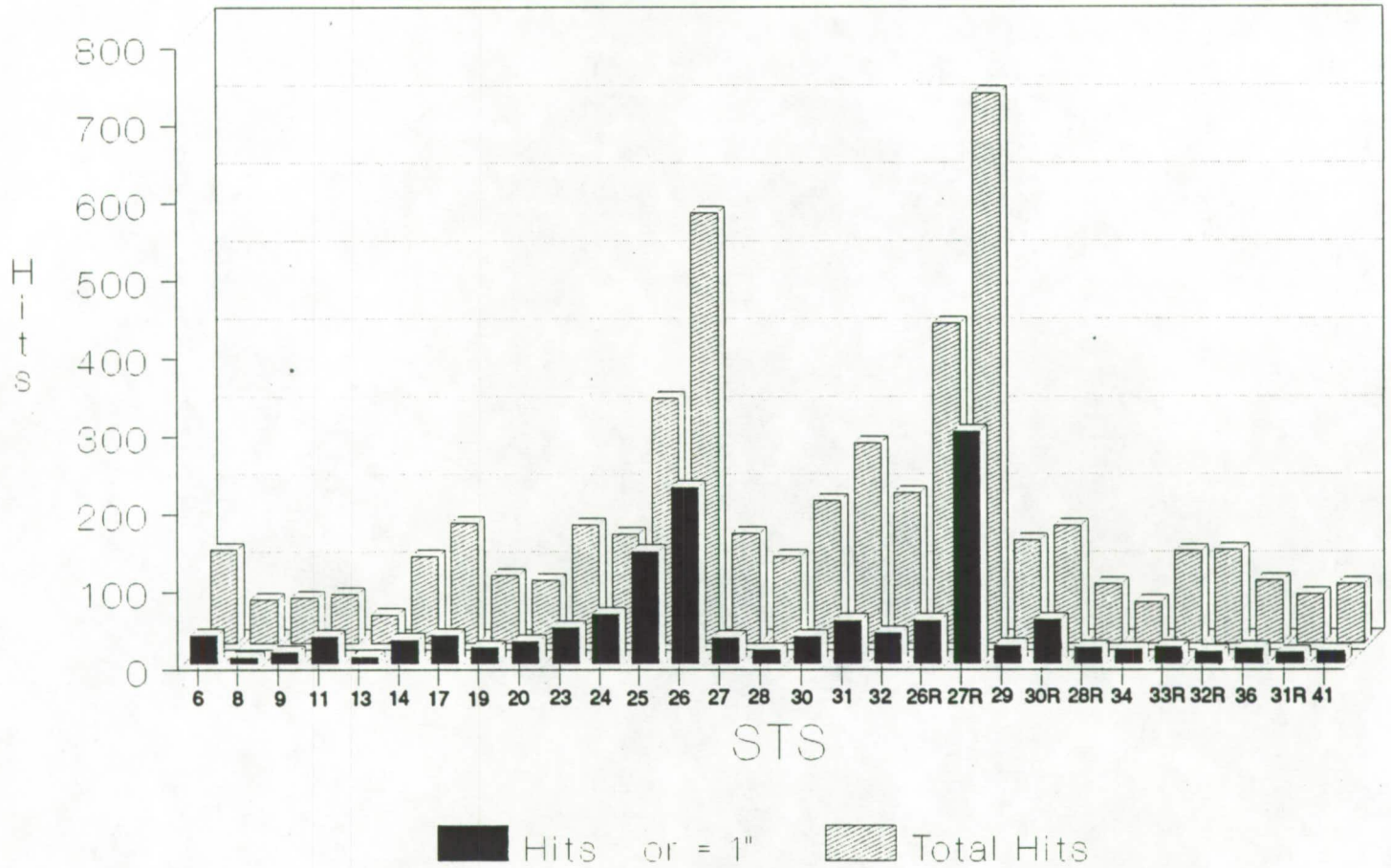
FIGURE 18. STS-41 DEBRIS DAMAGE ASSESSMENT SUMMARY

	Hits > or = 1"	Total Hits
Lower Surface	13	64
Upper Surface	0	1
Right Side	1	7
Left Side	1	3
Right OMS Pod	0	0
Left OMS Pod	1	1
TOTALS	16	76

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

FIGURE 19. # COMPARISON TABLE



ORIGINAL PAGE
COLOR PHOTOGRAPH

Overall view of OV-103 RH side after landing

Overall view of OV-103 LH side after landing

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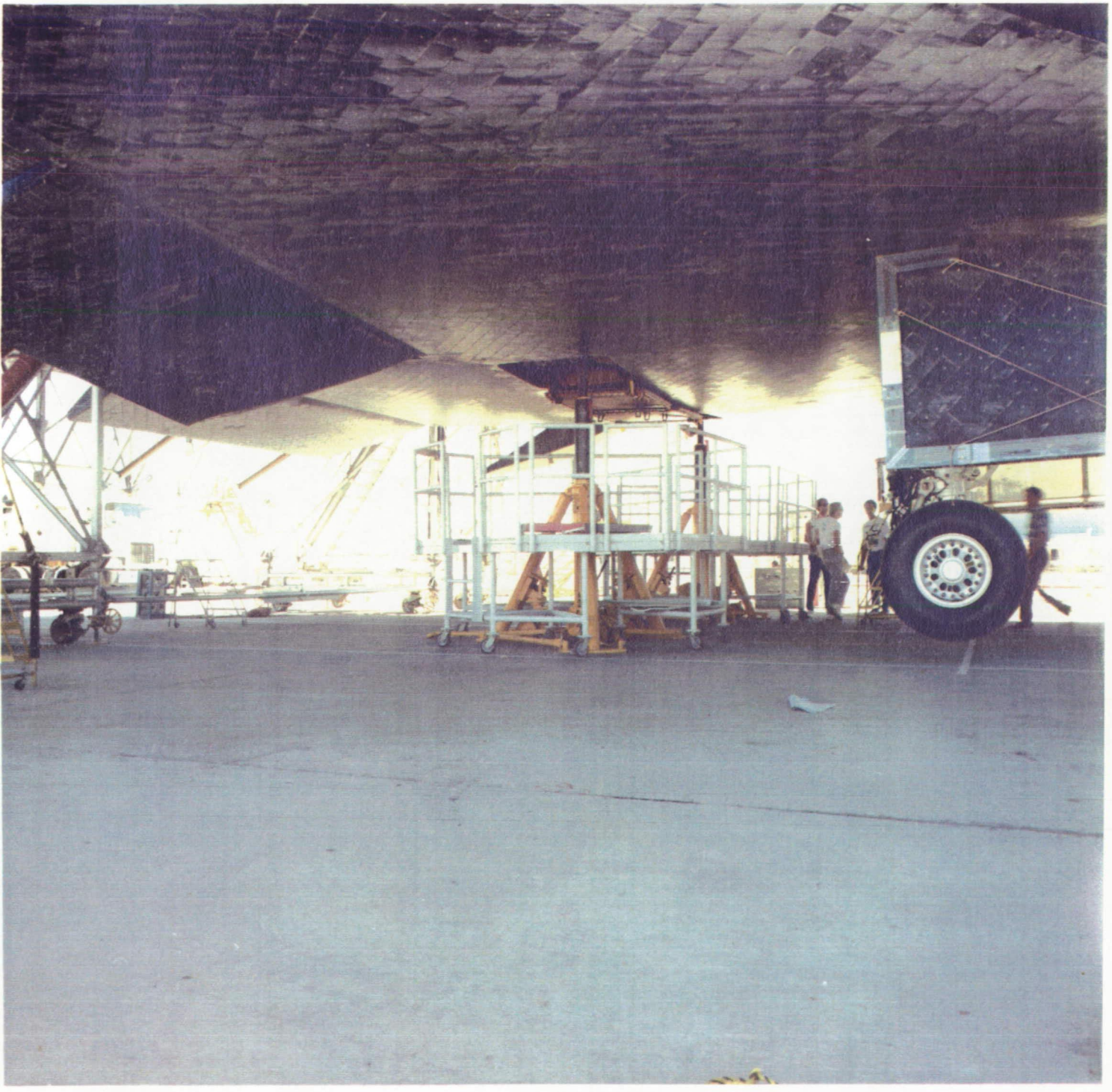
COLOR PHOTOGRAPH

Post landing condition of OV-103 nose tiles and windows



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Overall view of Orbiter RH wing lower surface/elevons

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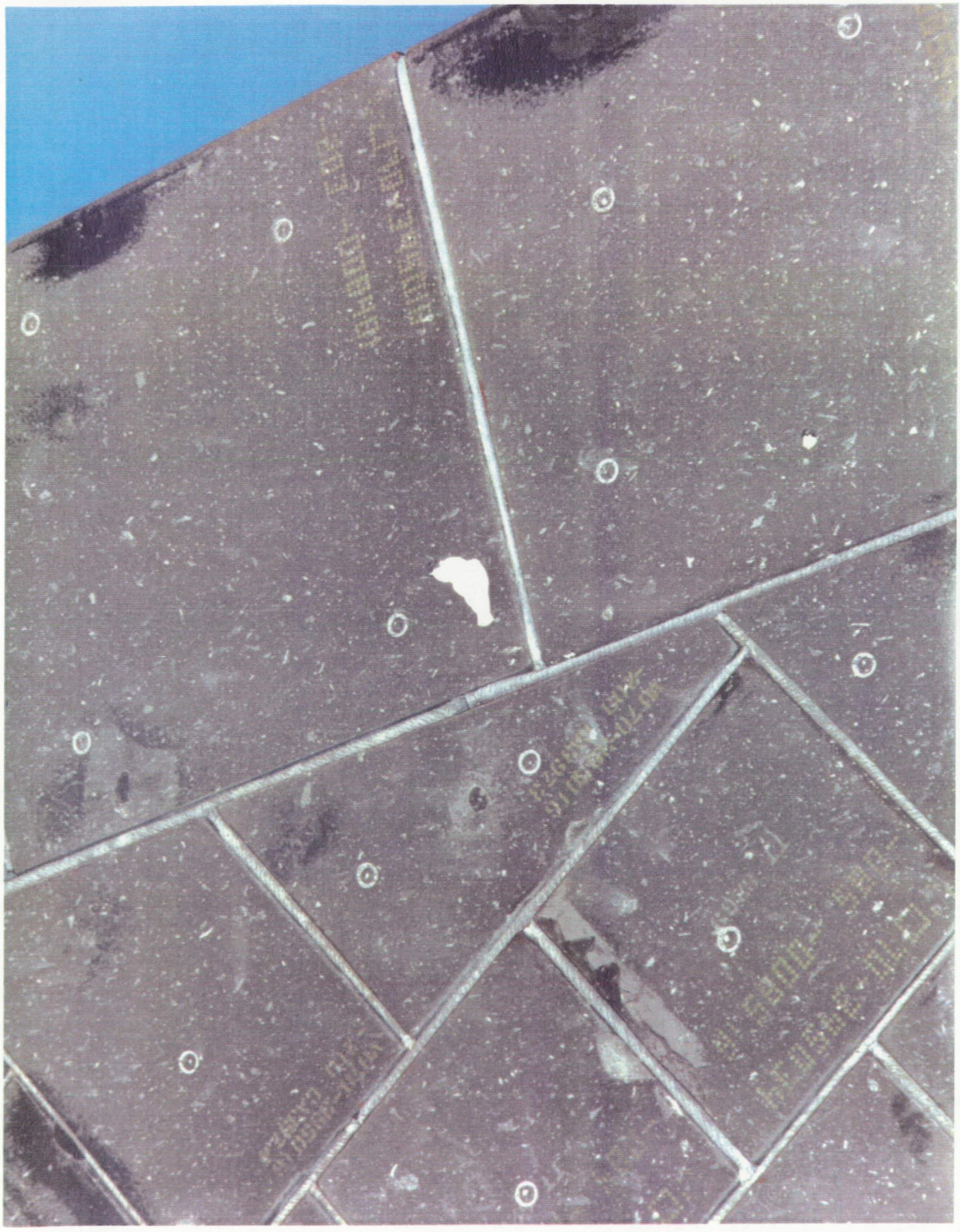
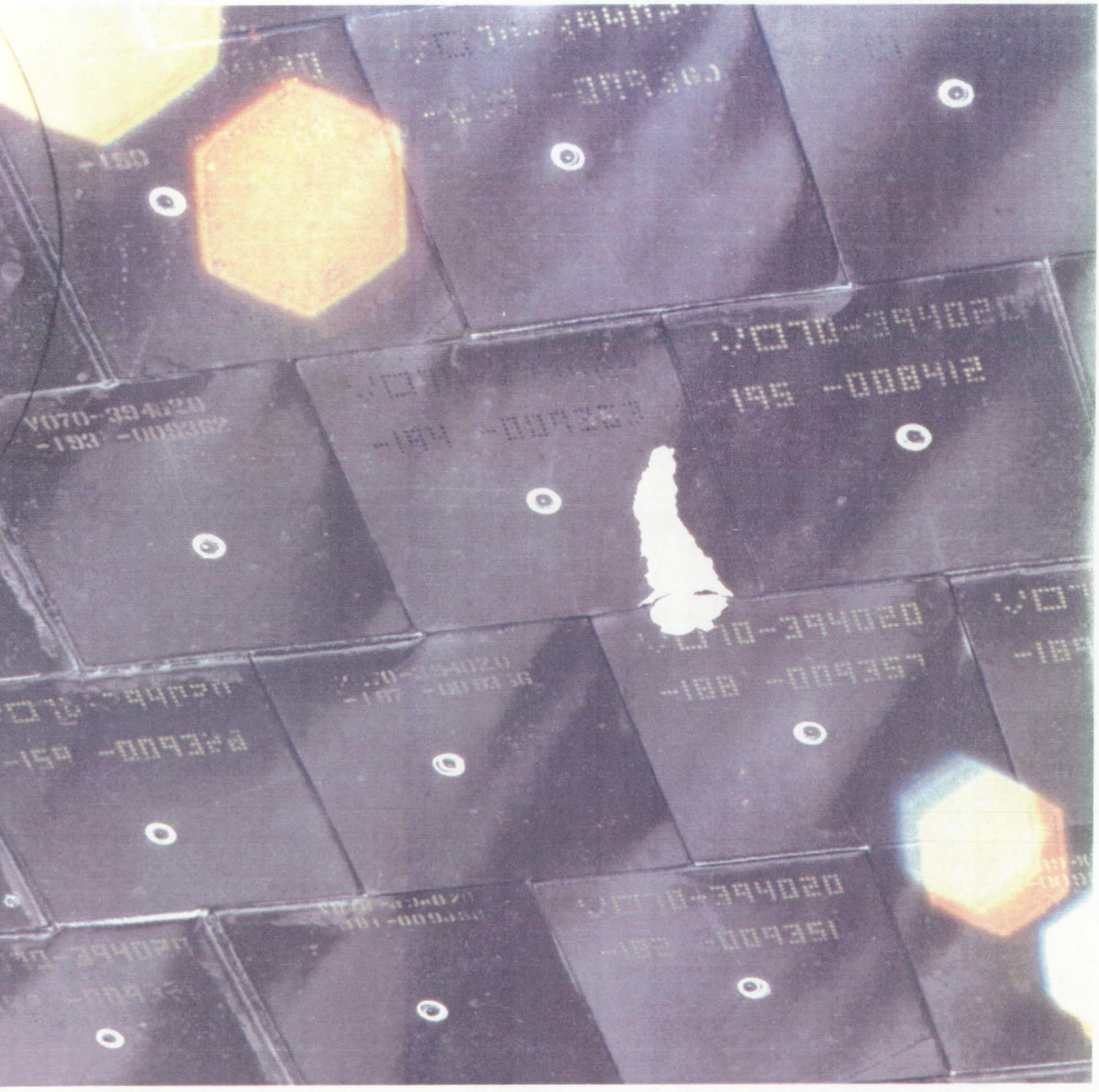
COLOR PHOTOGRAPH

Surface coating material loss on four tiles below
the crew module hatch



Typical tile damage from a debris impact on the body flap



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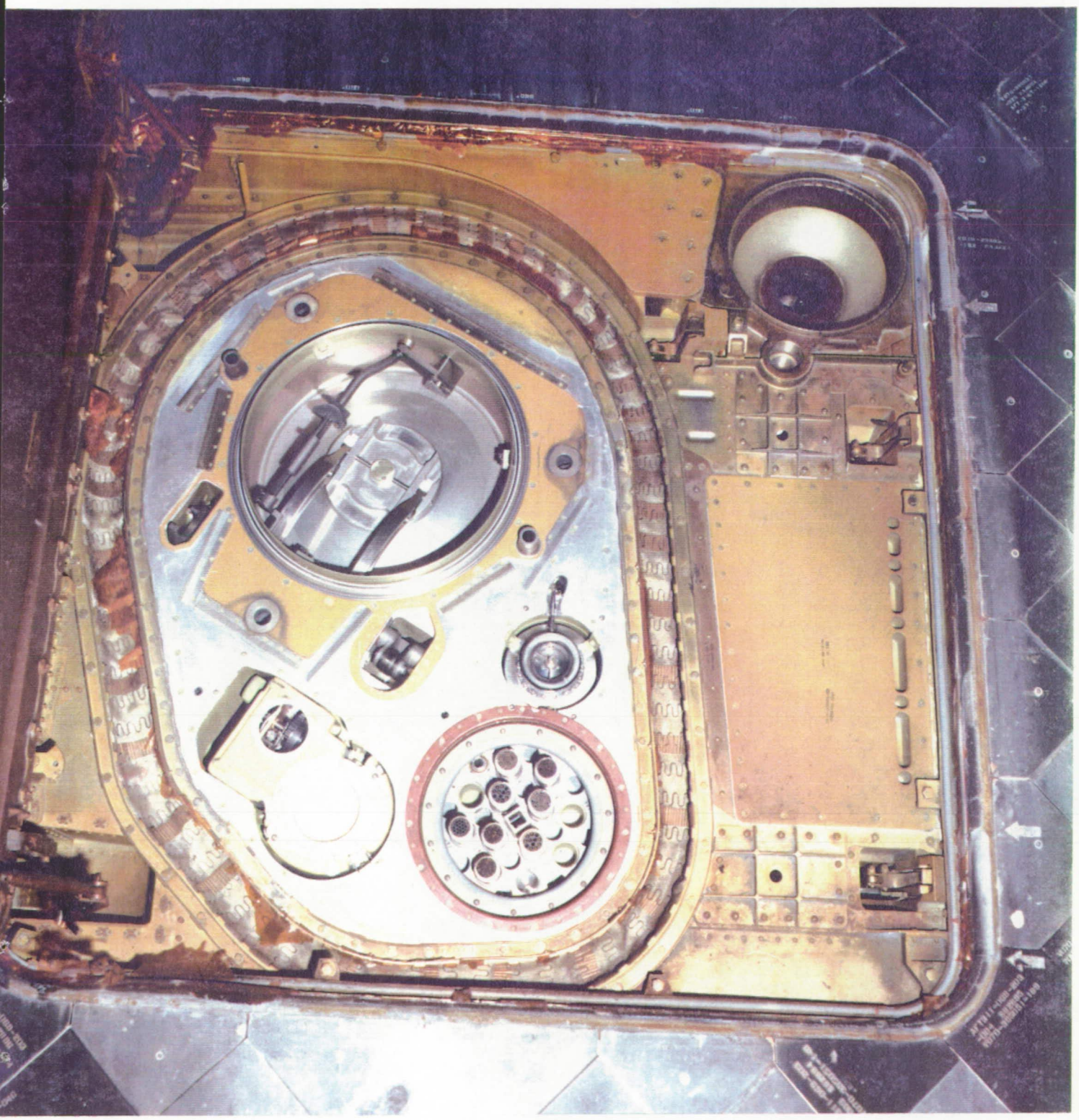
COLOR PHOTOGRAPH

Typical lower surface tile damage from a debris impact



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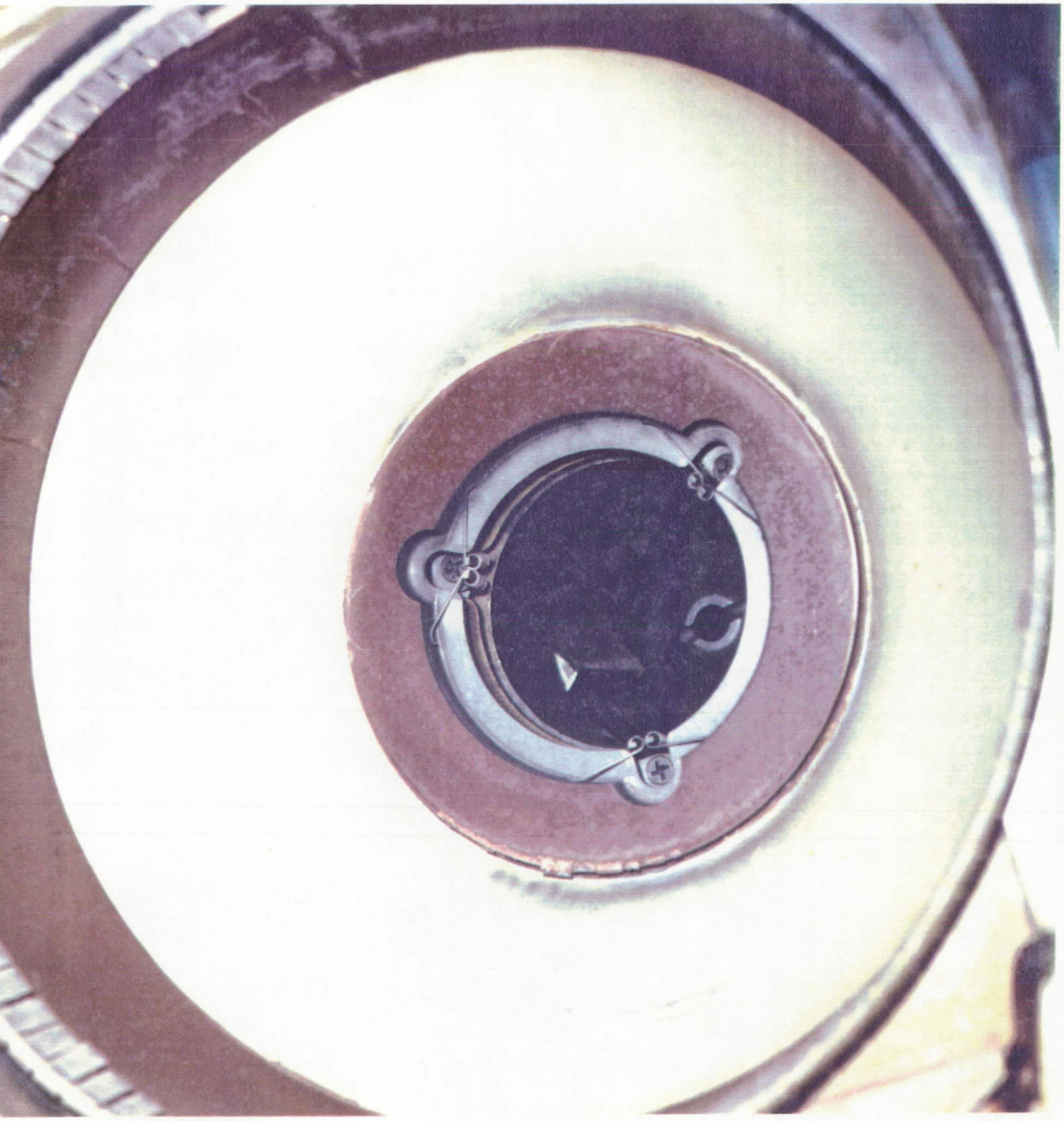
View of ET/ORB LH2 umbilical. Note presence of frangible nut piece obstructing EO-2 debris hole plugger.



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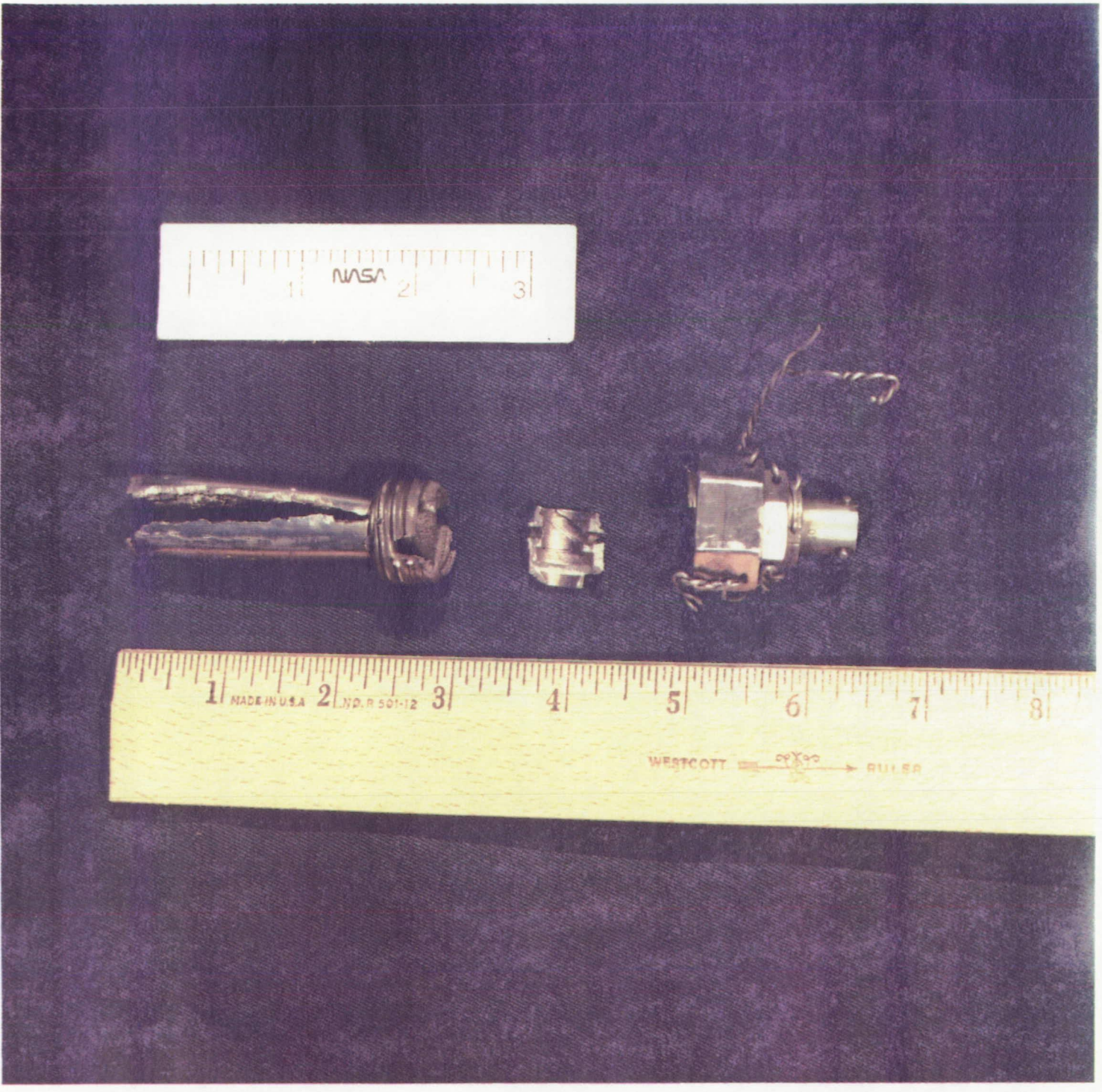
EO-2 separation fitting debris container plunger was jammed open by frangible nut half



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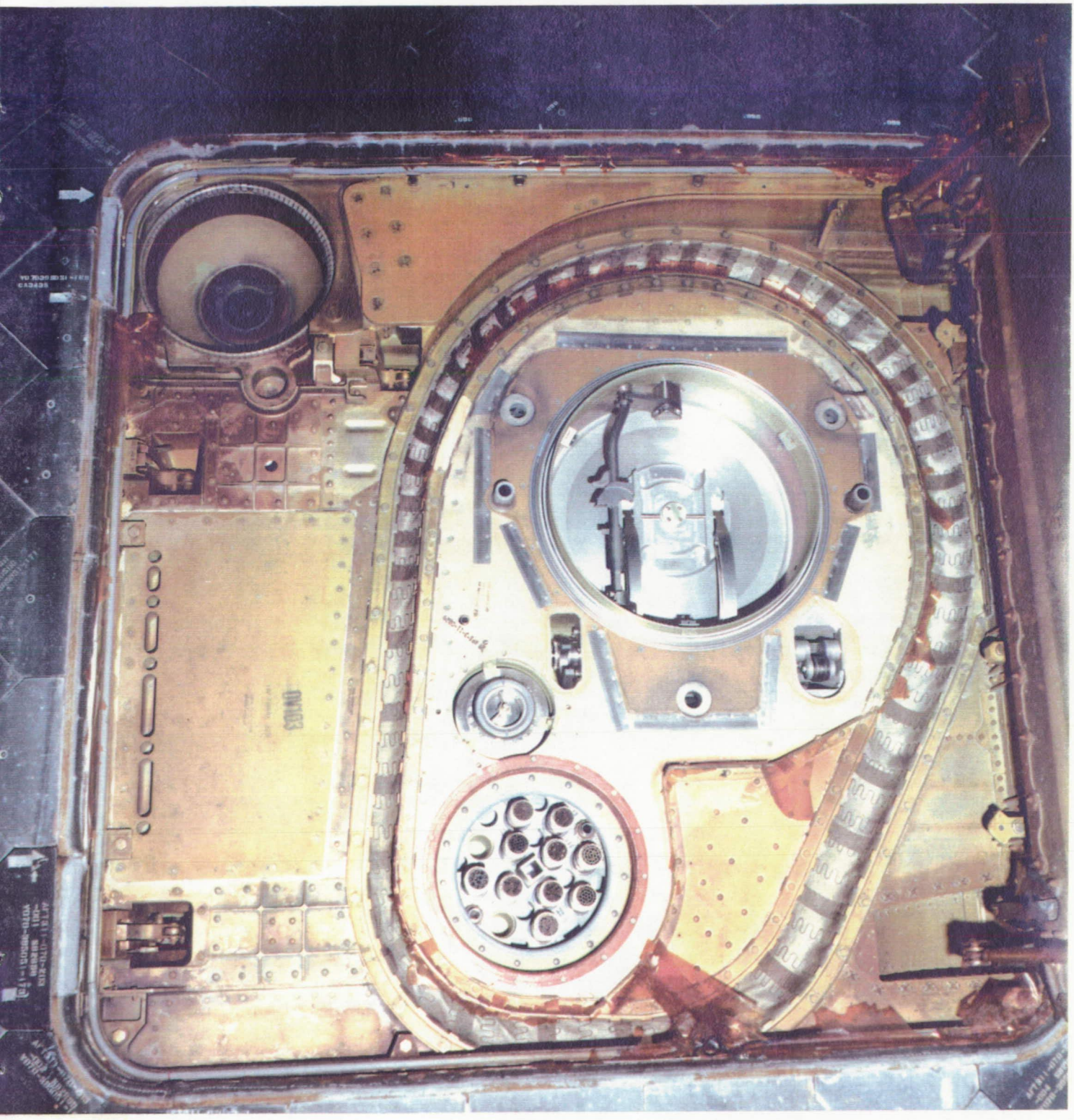
Three pieces of spent ordnance (detonator, booster fragment, connector piece) lay on the runway below the EO-2 attach point



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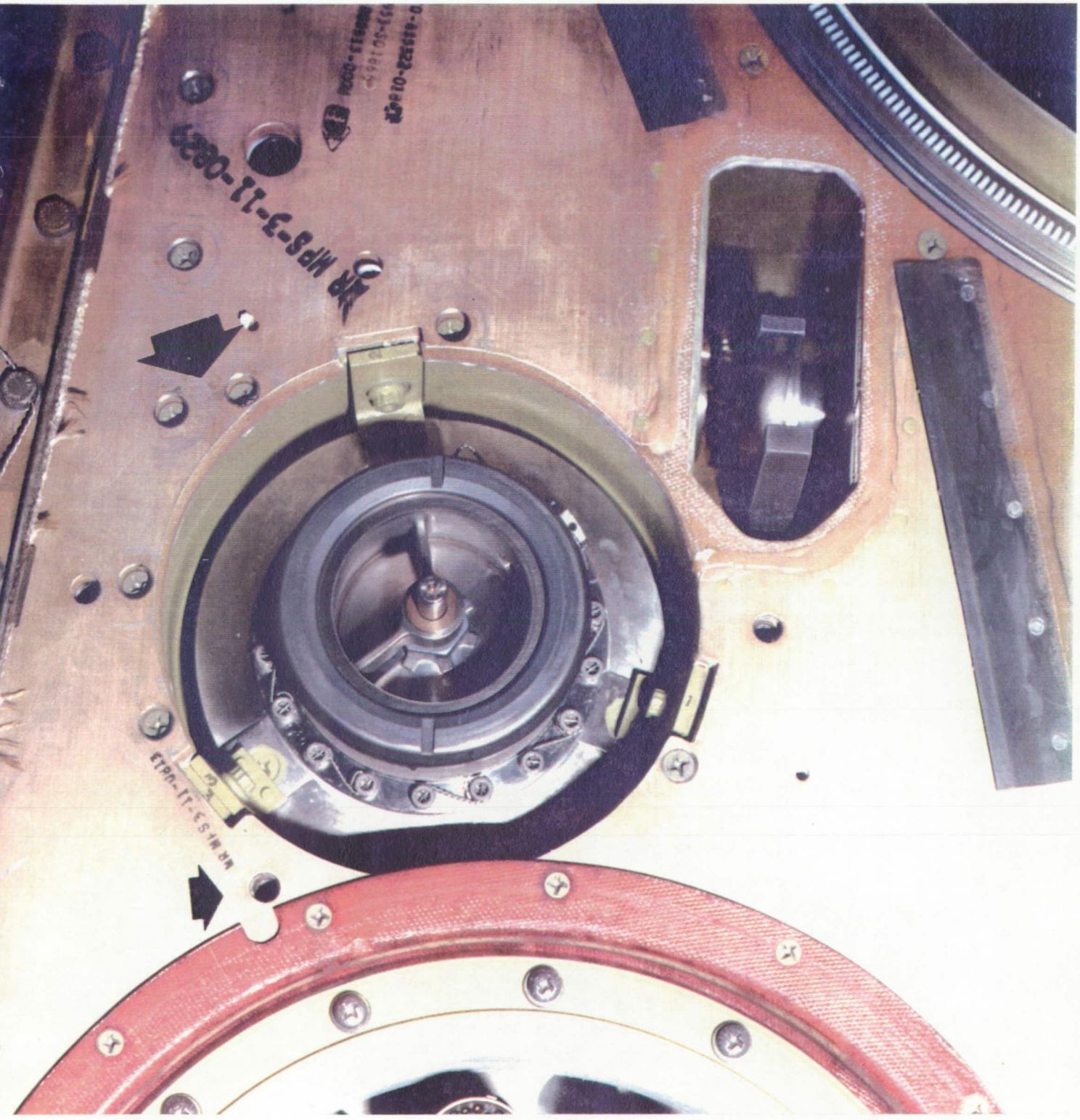
View of ET/ORB LO2 umbilical



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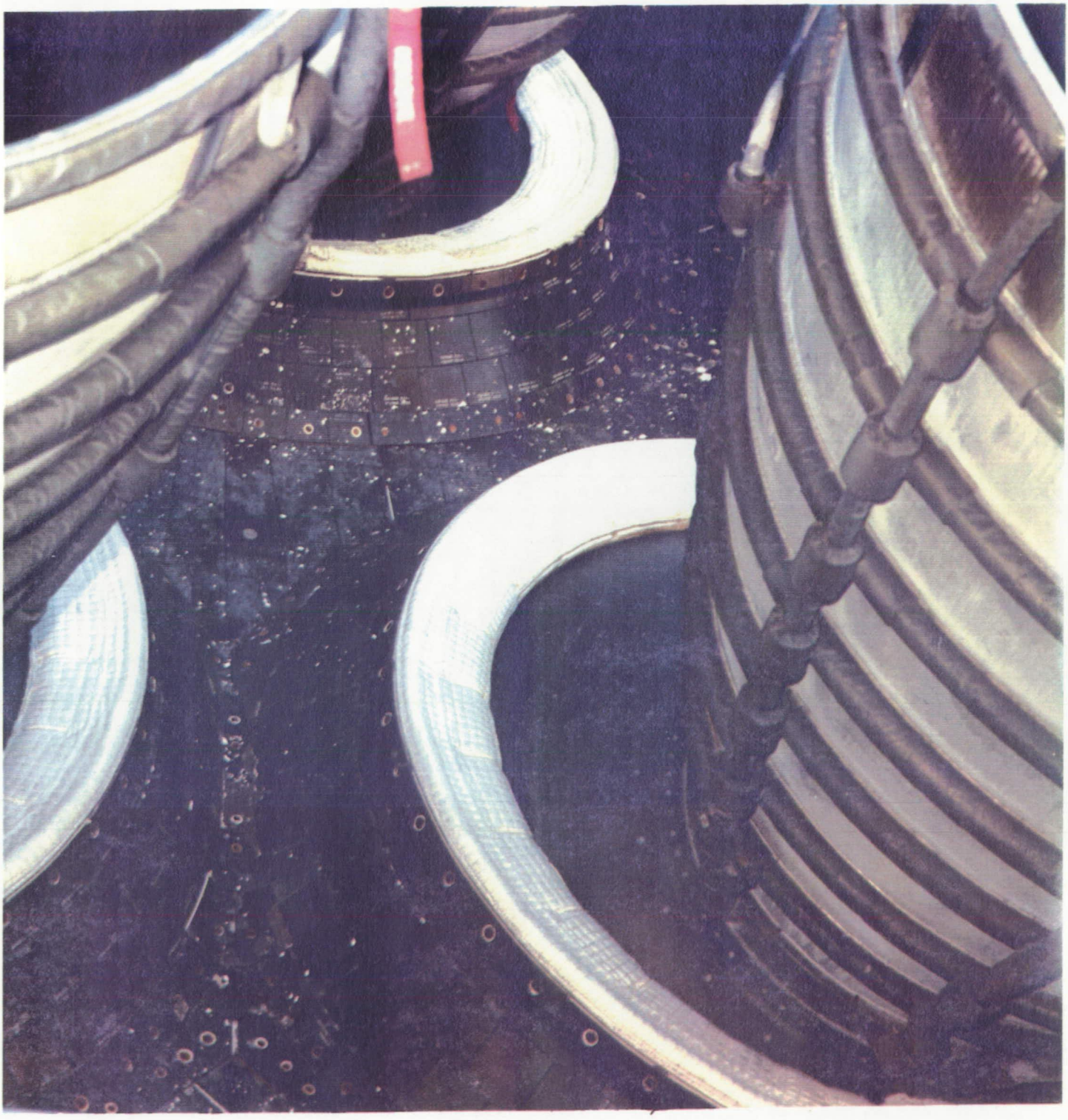
LO2 2-inch press line and attaching fasteners had been pulled away from the umbilical plate. Some fasteners were missing.



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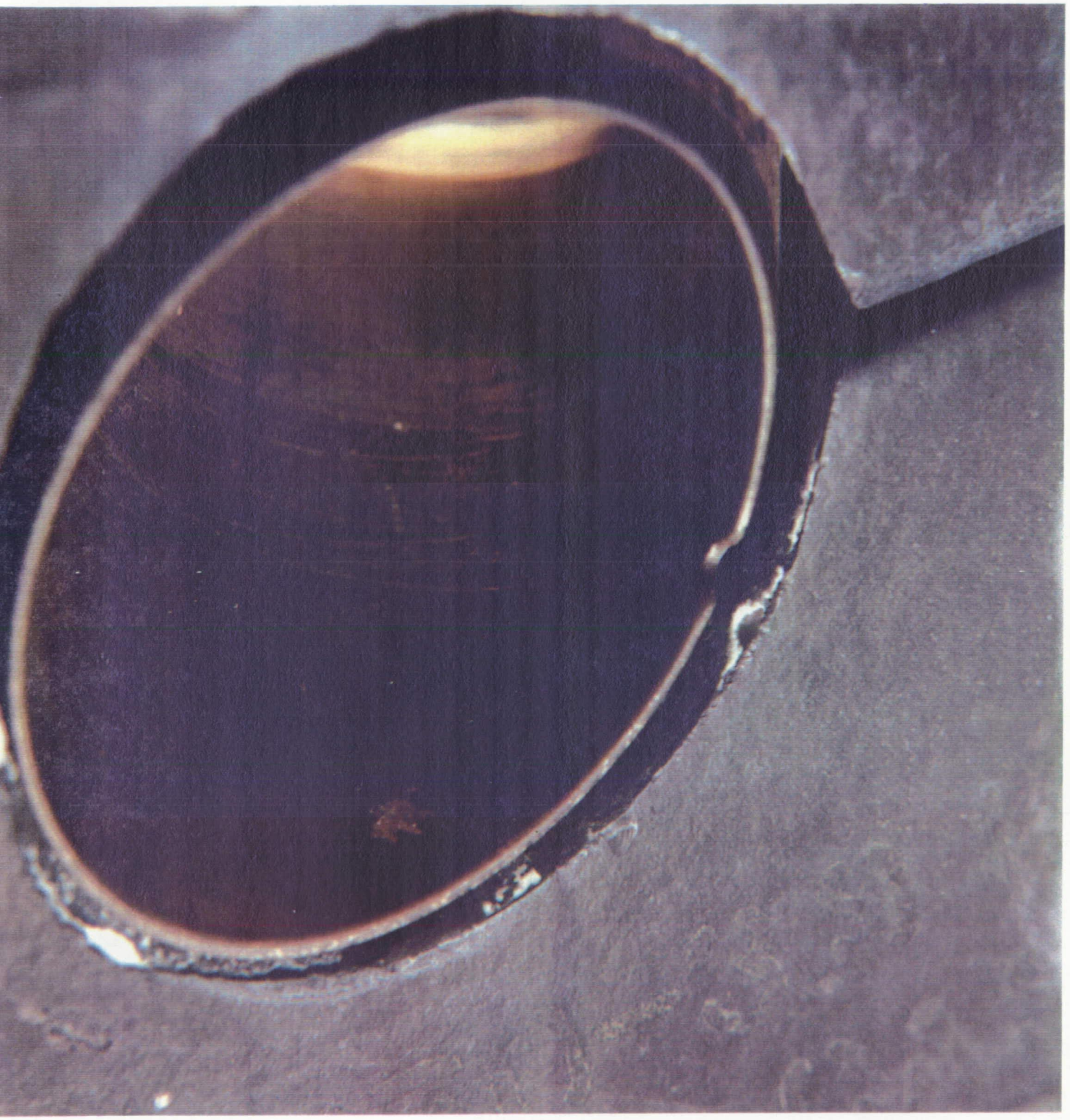
SSME beta blankets were in excellent condition after flight
Note typical 'peppering' of base heat shield tiles

ORIGINAL PAGE
COLOR PHOTOGRAPH

MMH tank relief vent on the LH side of the Forward RCS module sustained an on-orbit high velocity impact



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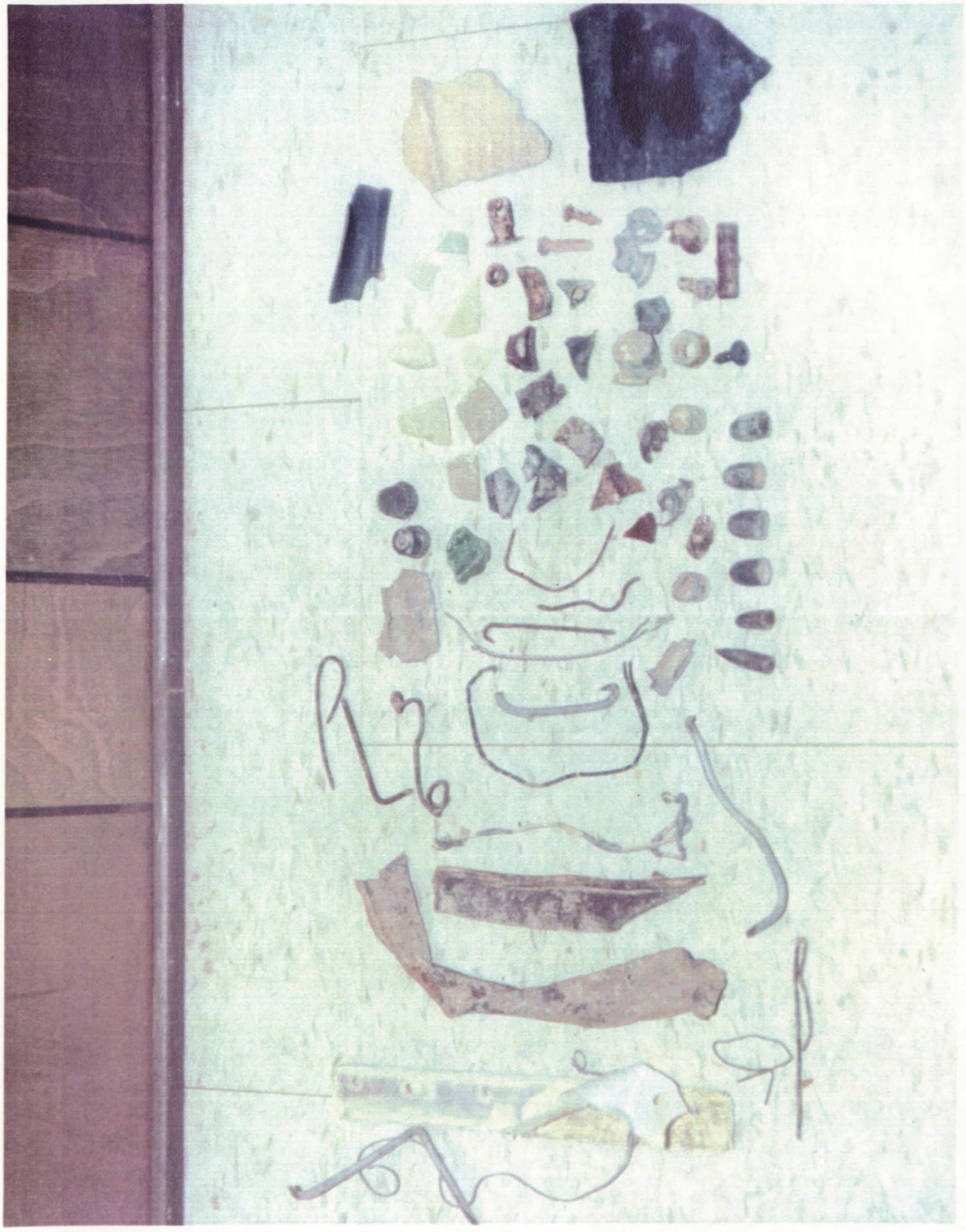
Close-in view of 3mm diameter area of missing material on MMH tank relief vent. Hole in adjacent tile measured 2mm x 3.5mm.



Typical debris collected during pre-landing runway walkdown

9.0 DEBRIS SAMPLE LAB REPORTS

A total of 17 samples were obtained from Orbiter OV-103 during the STS-41 post-landing debris assessment at Ames-Dryden Flight Research Facility, California (Figure 15-16). The 17 submitted samples consisted of 8 Orbiter window wipes, 2 samples from the ET/ORB umbilical area, 2 FRCS area samples, 2 wing leading edge RCC wipes (RH), 2 tile samples, and a spatula wipe (ref). 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 sample results and analyses are provided by Orbiter location in the following summaries.

Orbiter Windows

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

1. Metallic particles
2. Rust
3. Dust and salt
4. Muscovite, calcite, plagioclase, hematite
5. Tile and insulation glass fibers
6. Organics and organic fibers
7. Alpha-Quartz

Debris analysis provides the following correlations:

1. Metallic particles (zinc, aluminum, carbon steel, brass, stainless steel) 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. Rust is common to SRB/BSM residue and the landing site.
3. Dust and salt are landing site products.
4. Muscovite, calcite, plagioclase, and hematite are naturally-occurring landing site products.
5. Tile and insulation glass fibers originate from Orbiter thermal protection system (TPS).
6. Organic materials are probably insect/animal remains and deposits, or tile waterproofing.
7. Alpha-Quartz is one of the purest forms of the earth mineral silica and tile base component.

ET-Orbiter Umbilicals

Chemical analysis of samples from the ET/Orbiter umbilicals revealed the following materials:

1. Calcite
2. Fluorocarbon with inorganic filler
3. Polyurethane foam

Debris analysis provides the following correlations:

1. Calcite is a naturally-occurring landing site product.
2. Fluorocarbon with inorganic filler is probably Viton rubber from umbilical seals.
3. Polyurethane foam is used as a closeout material for the umbilicals. The presence of a "polyurecoat" is also indicative of umbilical closeout material.

Insulation Adjacent to FRCS

Results of the FRCS area samples indicated the presence of the following material:

1. Silicon-rich TPS material

Debris analysis provides the following correlation:

1. Silicon-rich TPS materials are used on the Orbiter thermal protection system.

Orbiter wing RCC panels

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

1. Black and white silicon-rich materials
2. Dust and salt

Debris analysis provides the following correlations:

1. Black and white silicon-rich materials originate from Orbiter thermal protection system (TPS).
2. Dust and salt are of naturally-occurring landing site origin.

Orbiter Tile

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

1.Silicon-rich TPS materials (Black and white)

Debris analysis provides the following correlation:

1. Silicon-rich TPS materials (Black and white) are used on the Orbiter thermal protection system (TPS).

Spatula wipe

The reference spatula wipe provided no evidence of chemical sample for comparison.

Conclusions

The STS-41 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 analysis 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.

Samples from the ET/Orbiter umbilical area indicated only closeout-type materials and landing site products. The presence of fluorocarbon with inorganic filler is similar to that for mission STS-34.

The FRCS area samples provided indication of Orbiter thermal protection system materials only.

The Orbiter wing RCC sampling indicated thermal protection system materials and landing site products.

The Orbiter tile damage site samples provided indication of Orbiter thermal protection system (TPS) materials only. This data suggests that damage debris was not retained at the damage site or was Orbiter thermal protection system material.

The spatula wipe sample, intended to eliminate sampling method material from chemical results, provided no indication of sample method contamination.

This mission provided evidence of an orbital debris impact in the area of FRCS dump nozzle. No KSC chemical sampling was performed for this impact.

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
NOVEMBER 5, 1990

SUBJECT: ORBITER Debris Samples From STS-41 Landing At DFRF

LABORATORY REQUEST NO: MCB0820-90

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 OV-103, STS-41 landing at DFRF, California, and were identified as follows:

RESIDUE/SWAB
#1. Orbiter window W-1.
#2. Orbiter window W-2.
#3. Orbiter window W-3.
#4. Orbiter window W-4.
#5. Orbiter window W-5.
#6. Orbiter window W-6.
#7. Orbiter window W-7.
#8. Orbiter window W-8.
RESIDUE/ET/ORB
#9. LOX Umbilical Plate.
#10. LH2 Umbilical Plate.
RESIDUE/STAIN
#11. LH FRCS Thermal Blanket and Thruster Cover Residue.
#12. RH FRCS Stain from Fiber Insulation Blanket (FIB)
WING RCC
#13. RH RCC Panel 18 Residue.
#14. RH RCC Panel 19 White Streak.
TILE DEBRIS
#15. AFT of NLGD 391035-369
#16. Body Flap 395006-203.
#17. Spatula Wipe (REF).

1.3 REQUESTED: Perform chemical/material identification and compare results to known STS materials.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

The submitted samples were analyzed by means of optical microscopy (OM), infrared spectrometry (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 classified into components on the basis of color and texture by OM. The classified components from all samples are listed in Table 1 with the possible identification of each component and elemental analysis.

Table 1 RESIDUE/SWAB, WINDOW

Component ID	Possible Ident.	Elemental Analysis byEDS*	
		Major	Minor
1. Metallics	Zn-Metal,Al-Metal C-Steel,Brass,SS	Zn,Fe,Al,Cu,Cr	Ni
2. Black Mtls	Dust,Rust,Salt	Fe,Si,Al,Cl,K	Zn,Cr,S,Ca
3. Red Mtls	Rust,Dust	Fe,Cl,Si,Al	S,Ca,K
4. Lgt. Brn Mtls	Dust,Salt	Si,Al,K,Ca,Fe	Cl,S,Zn
5. Amber Flake	Muscovite	Fe,K,Si,Al	Ti,Ca,Mg
6. Glass Fiber	Tile Insulation	Si,Al	
7. Organics			
8. Organic Fibers	ND		
9. Wht-Fine Mtls	Si-Al Rich	Si,Al	Fe,Ca,K,Ce

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

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

Table 2

Sample No. Components	#1	#2	#3	#4	#5	#6	#7	#8
1. Metallics	T (Zn-Fe)	T,(Al C-Fe)	T (Al)	T (Al,Zn)	X	Brass T(Al)	X	(Al) T(SS)
2. Black Mtls	20	5	15	10	3	8	4	10
3. Red Mtls	3	T	2	3	2	10	T	3
4. Lgt Brn Mtls	72	23	43	69	80	74	66	69
5. Muscovite	5	7	40	18	10	8	30	18
6. Glass Fiber	T	T	T	T	T	T	T	T
7. Organics	T	T	T	T	T	T	T	T
8. Organic Fiber	T	T	T	T	T	T	T	T
9. Si-Al Mtls	X	63	X	T	5	X	X	X
Part.Size um	1-85	1-100	1-100	1-110	1-60	1-110	1-130	1-120

20: Estimated Volume Percent.
X: Not detected.
T: Trace.
Zn-Fe: Zn-Fe metal, Al: Al-alloy.
C-Fe: Carbon Steel, Zn: Zinc Metal.
SS: Stainless Steel (300 series).

2.2.3 Table 3 lists estimated volume percent, elemental analysis of each classified component, and identification of organic components.

Table 3

Component ID	Elemental Analysis By EDS*		Part Size um
	Major	Minor	
RESIDUE/ET/ORB			
#9. LOX Umb Plate			
a. White Powder (T)	Ca		1-120
b. Foam (40)	Urethane (PDL), Polyurecoat		L
c. Black Mtls (60)	Fluorocarbon w/Inorganic Filler		L
#10. LH2 Umb Plate			
a. Foam (2)	Urethane (PDL)		L
b. Black Mtls (98)	Fluorocarbon w/Inorganic Filler		
RESIDUE/STAIN			
#11. LH, FRCS			
a. Lgt-Yel Mtls(30)	Si	Cr	1-300
b. Wht-GreyMtls(55)	Si		1-250
c. Fiber (15)	Si,Al		10
#12. RH, FRCS, STAIN			
a. Lgt-YelMtls(100)	Si		1-250
#13. RH RCC,18(T)			
a. White Mtls (90)	Ca,Cl,S	P,Al,Si,Na,C	1- 60
b. Black Mtls (10)	Si	Al,Ca,Ti	1- 35
#14. RH RCC,19(No)			
NO SAMPLE			
TILE DEBRIS			
#15. AFT OF NLGD			
a. Black Mtls (T)	Si		1-200
b. Wht-Fib Mtl(100)	Si		1-300
#16. BODY FLAP			
a. Black Mtls (1)	Si		1-1000
b. Wht-Fib Mtl (99)	Si		1-2000
#17. SPATULA WIPE			
NO SAMPLE			

(40): Estimated Volume Percent.
T: Trace.
L: Large Piece (20 or 30 mm in diameter).

3.0 CONCLUSIONS:

3.1 RESIDUE/SWAB--WINDOW (TABLES 1 AND 2)

3.1.1 The sample numbers 1, 2, 3, 4, 6, and 8 contained trace amounts of metallics. The metallics were composed of a combination of Al-metal, Zn-metal, Zn-Fe alloy, carbon steel, brass, and a 300-series stainless steel.

3.1.2 All samples contained black materials and the black materials were composed of dust, rust, and salt components.

3.1.3 All samples contained red materials and the red materials were composed mainly of rust with small amounts of dust and salt components.

3.1.4 All samples contained light-brown colored materials. The OM and XRD data suggested that the light-brown materials were composed of calcite ($CaCO_3$), Alpha-Quartz (Alpha-SiO_2), plagiodase ($NaAlSi_3O_8$-$CaAl_2Si_2O_8$), hematite (Fe_2O_3), opaque, and clay minerals.

3.1.5 All samples contained muscovite [$KAl_2(AlSi_3O_{10})(OH)_2$].

3.1.6 All samples contained trace amounts of tile fiber, insulation glass fibers, organics and organic fibers. The organics and organic fibers were not analyzed at this time due to small amounts of sample.

3.1.7 The sample numbers 2, 4, and 5 contained white fine-grained materials. The fine-grained materials appeared to be composed of cryptocrystalline Si-Al-rich materials which might be the components of insulation materials.

3.1.8 The particle sizes were estimated to be in the range of 1 to 120 micrometer.

3.1.9 The black materials, red materials, light-brown materials and amber flake appeared to be very similar in composition to those of lakebed soil {MCB097-89} in California.

3.2 RESIDUE ET/ORB (TABLE 3)

3.2.1 The sample #9 contained white powder, foam and charred black materials, and the sample #10 contained foam and black materials.

3.2.2 The white powder materials appeared to be composed of calcite ($CaCO_3$) by OM examination.

3.2.3 The yellowish foam in the sample #9(LOX) gave IRS spectra characteristic of a urethane foam such as PDL, but on the underside of the same foam there was a polymeric looking materials which gave matches of a polyurethan foam such as polyurecoat, but not PDL. The foam from the sample #10 (LH_2) was identified to be the PDL foam.

3.2.4 The charred black materials had an adhesive type of constituent present which gave IRS spectra characteristic of a fluorocarbon which appears to be filled with inorganic fillers such as possibly magnesium silicate.

3.3 RESIDUE/STAIN (TABLE 3)

3.3.1 The sample #11 contained light-yellow dense materials, white-grey dense materials and fibrous materials. The sample #12 contained fibrous materials. All particles appeared to be the TPS materials.

3.4 WING RCC AND TILE DEBRIS

3.4.1 All samples contained black materials, white materials and white fibrous materials. All particles appeared to be the TPS materials except sample #13. The white materials in sample #13 appeared to be composed of dust and salt components.

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

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

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
NOVEMBER 6, 1990

SUBJECT: Orbiter Debris Sample from STS-41 Landing

LABORATORY REQUEST NO: MCB-0851-90

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 sample was from OV-103, STS-41, TPS, Orbiter, and was identified as "body flap tile V070-395033-197-008962, that was sustained hit, entire tile removed for analysis."

1.3 REQUESTED: Perform measurement/dimensional analysis of damage site (the major damage site) and perform chemical/material identification of possible entrapped debris, and compare results to known STS materials.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

The sample was analyzed by means of optical microscopy (OM) and electron microprobe with energy dispersive spectrometry (EDS). The dimensional analysis of damage site was performed by metrological analysis.

2.2 Results:

The entrapped debris from damage site were classified into components on the basis of color and texture by OM and the analytical results are listed in Table 1.

Table 1

Component ID		Elemental Analysis By EDS*	
		Major	Minor
a.	Black Dense Mtls	Si	
b.	Red Mtls	Si,Fe	S,Cl,Ca,Ti
c.	Brown Mtls	K,Cl,Ca	Na,Al,Mg,Si,P,S,Fe

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

2.2.2 Figures 1 through 4 are OM photomacrographs of damage site to show the morphological feature of the damaged area.

2.2.3 The length, width and depth by metrological analysis are as follows:

Length = 2.800"
Width = 0.950"
Depth = 2.000"

3.0 CONCLUSIONS:

3.1 The damage site contained trace amounts of entrapped debris. The entrapped debris were composed of black dense tile, RTV, dust, and salt components (Table 1).

3.2 The dimensional measurements of damage site are: length = 2.800", width = 0.950", and depth = 2.000".

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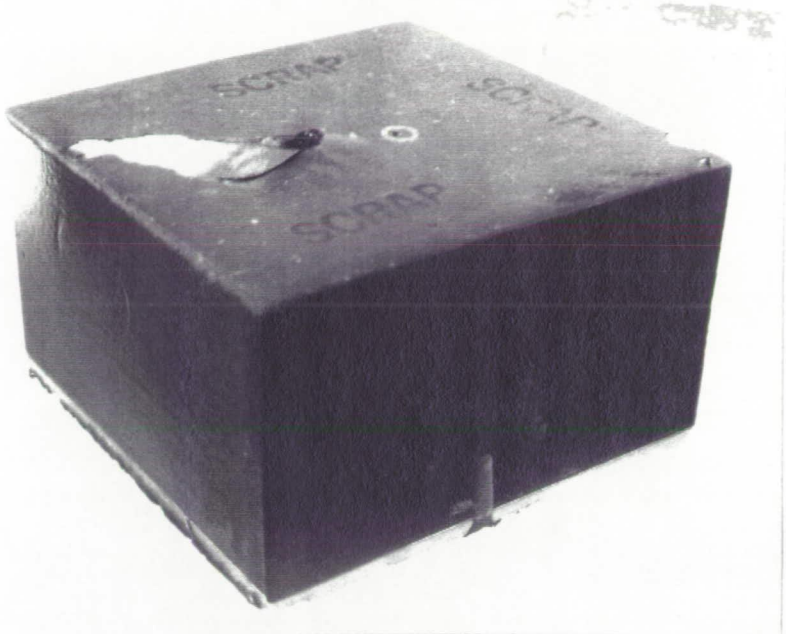

Figure 1. Low magnification OM photomacrograph of tile materials. 0.44X

Figure 2. Low magnification OM photomacrograph of damaged tile surface. 0.5X

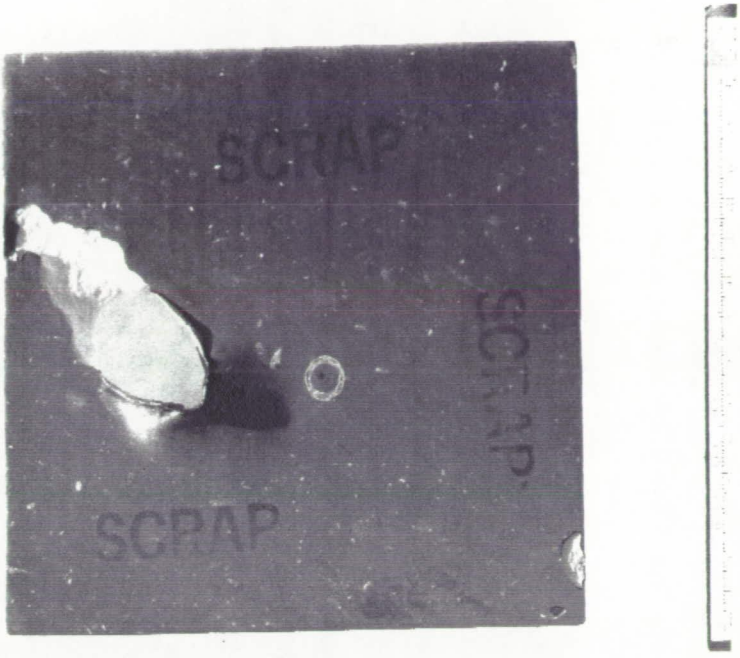

Figure 3. Low magnification OM photomacrograph of damaged tile surface. 0.5X

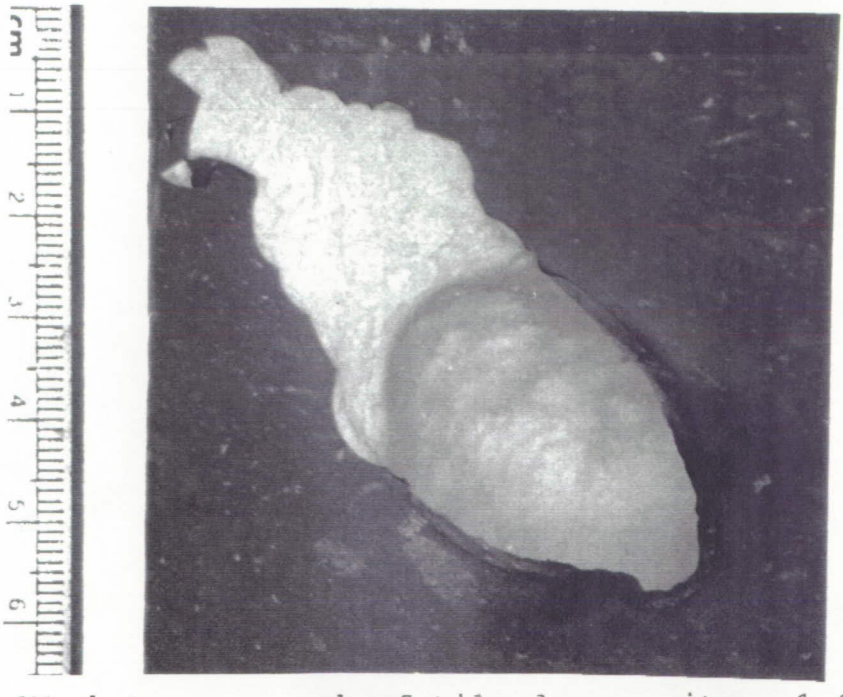

Figure 4. OM photomacrograph of tile damage site. 1.6X

10.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 11 Post Launch Anomalies were observed for STS-41.

10.1 POST LAUNCH PAD DEBRIS INSPECTION

1. Seven FSS/RSS cable tray covers were found scattered around the pad. Numerous other covers on the facility were loose.

2. Shim sidewall material had debonded from HDP #2 and #5 shoes

10.2 FILM REVIEW

1. Ordnance debris 3"x1/2" fell from the LH aft skirt HDP #6 stud hole shortly after liftoff. Loss of debris during ascent was caused by failure of the debris plunger to seat properly.

2. At least 6 light-colored particles fell out of the SRB plume during ascent and may be pieces of SRB aft skirt instafoam.

10.3 SRB POST FLIGHT/RETRIEVAL INSPECTION

1. There were 38 MSA-2 debonds over fasteners on the RH frustum and 41 debonds over fasteners on the LH frustum.

2. The phenolic block on the +Z RSS antenna was delaminated.

3. Delaminations occurred in the RH center segment new Field Joint Protection System (FJPS) at 120 degrees, 3/4-inch diameter; and at 270 degrees, 1-inch diameter.

4. A 9.6-inch unbond occurred on the aft edge of the RFC factory joint at 93-101 degrees.

5. K5NA protective domes on the RH phenolic kick ring were missing in 6 places prior to water impact.

6. The HDP #6 DCS plunger was jammed by a frangible nut half and failed to seat properly resulting in loss of debris during ascent.

10.4 ORBITER POST LANDING INSPECTION

1. The debris plunger in the EO-2 (LH2) separation fitting debris container was caught by the frangible nut halves and failed to seat properly. Three pieces of spent ordnance assembly were found on the runway beneath the LH2 ET/ORB umbilical opening and were attributed to this failure. (IFA candidate due to possible obstruction of ET door on orbit).

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Report Documentation Page

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15. Supplementary Notes

Thermal Protection System (TPS)

16. Abstract

A Debris/Ice/TPS assessment and photographic analysis was conducted for Space Shuttle Mission STS-41. Debris inspections of the flight elements and launch pad were performed before and after launch. Ice/frost conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography was analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and photographic analysis of Mission STS-41, and their overall effect on the Space Shuttle Program.

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