NASA Technical Memorandum TM 102152

Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-28R

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National Aeronautics and
Space Administration

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Charles G. Stevenson
NASA/Kennedy Space Center

Gregory N. Katnik
NASA/Kennedy Space Center

Scott A. Higginbotham
NASA/Kennedy Space Center

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DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-28R

AUGUST 8, 1989

Prepared By:

Gregory N. Katnik
NASA/Kennedy Space Center
TV-MSD-22

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

Approved:
September 22, 1989

Charles G. Stevenson
Lead, Ice/Debris Assessment Team
Chief, ET Mechanical Systems
TV-MSD-22

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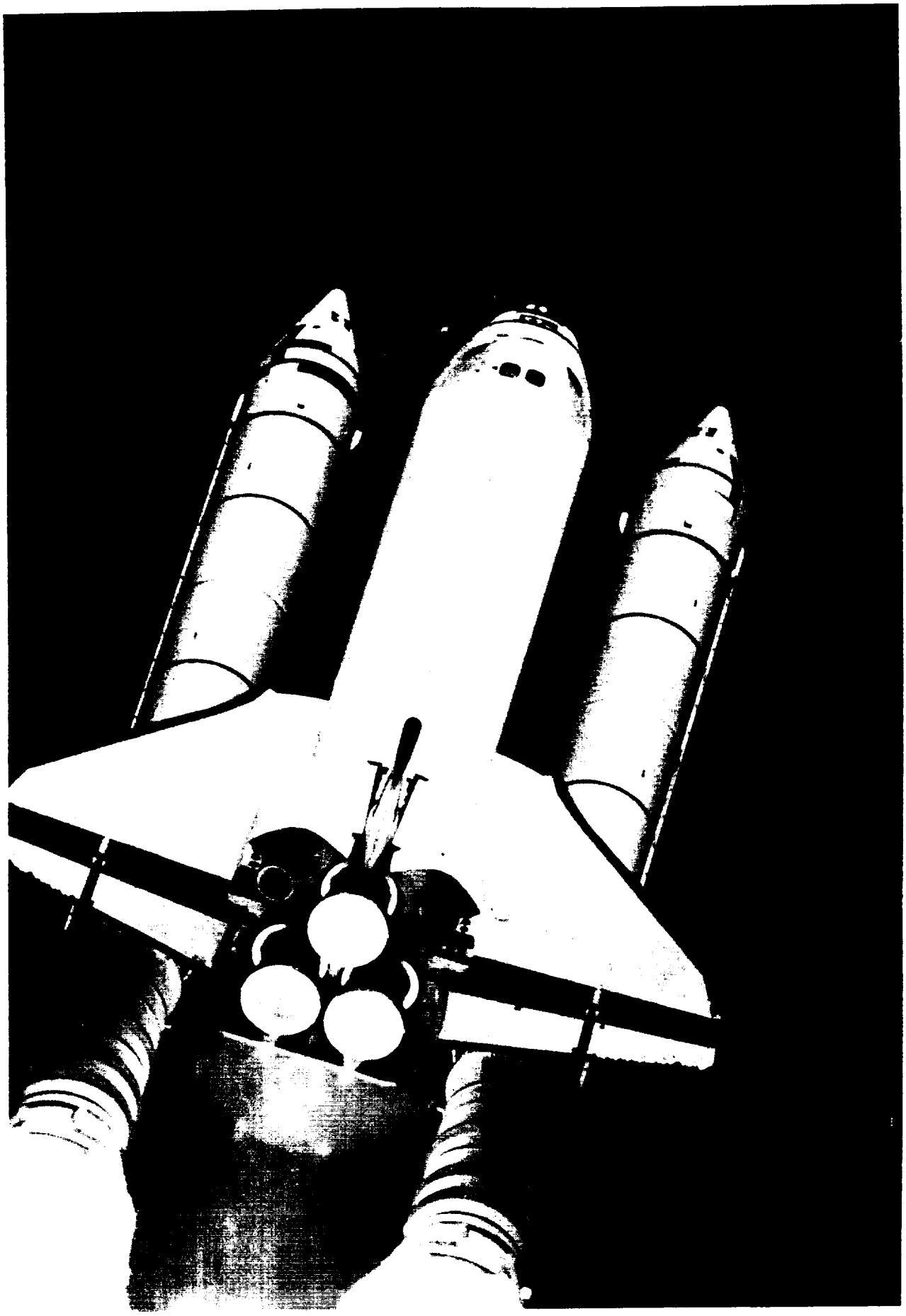
FORWARD

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.



LAUNCH OF SHUTTLE MISSION STS-28R ON 8/8/89 AT 8:37 a.m. EST

1.0 Summary

Debris and Photo Analysis Team activities for Mission STS-28R began with the pre-launch debris inspection of the launch pad and Shuttle vehicle on 7 August 1989. No major anomalies were observed on OV-102 Columbia, BIO-28, or ET-31. Minor facility discrepancies, which included loose MLP deck bolts, were corrected prior to cryoloading the vehicle.

No Orbiter or SRB anomalies were detected during the Ice Inspection. Condensate, but no ice or frost, was present on all acreage areas of the External Tank. The IR scanner measured an average surface temperature of 70-72 degrees F on these areas. Slightly less than usual amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets. The LH2 and LO2 ET/ORB umbilicals exhibited less ice but normal amounts of frost on both the inboard and outboard sides. There were no unusual vapors emanating from the umbilicals, other then the normal purge gases, and no evidence of cryogenic leakage. Five ice/frost console observation anomalies were documented and found acceptable for launch per the LCC and NSTS-08303. At launch, the ET ice condition was well within the database for ice formation. The hydrogen umbilical leak sensor detected no significant hydrogen during the cryo load and was removed by the Ice Inspection Team during the T-3 hour hold.

After the successful launch at 12:37:00 GMT, a post launch debris inspection of Pad 39B was performed. No significant flight hardware, except for 3 Orbiter Q-felt plugs, or TPS material was found. Shim material on all south holddown posts showed signs of debonding. No fragments from HDP debris containers were found. Pieces of a GOX vent hood plastic window were recovered at the pad perimeter. The GH2 vent arm was latched but captured off-center. Overall, the facility sustained minimal damage.

A total of 133 film and video items were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. However, numerous small pieces of white tile material were shaken loose from the upper surface of the RH elevons during SSME ignition. Many tile GSE shims/spacers were not removed and several fell from the vehicle during SSME startup. One was found embedded in a RH OMS pod white tile after landing. Movement of the HDP #1 and #5 blast container/plunger housing occurred at T-0 and consisted of 2 oscillations. Many film items showed the FSS water deluge system did not operate. Numerous pieces of debris fell from the vehicle during ascent. Most have been identified as ice/frost particles from the ET/ORB umbilicals, RCS paper covers, instafoam particles from the SRB aft skirts, and pieces of foam from the External Tank.

Movement of the Orbiter body flap was visible from the roll maneuver through early ascent. Maximum body flap deflections occurred during Max Q. The amplitude of the deflection as measured from E-207 averaged 5.5 +/- 2 inches with a frequency of 7.7-8.7 Hz.

Orbiter umbilical cameras recorded nominal separations of the LH SRB and ET. Missing/damaged TPS was visible on the ET/ORB LH2 cable tray, along the top surface of the LO2 umbilical, and on the intertank-to-LH2 tank flange near the PAL ramp. A large 23x15x1 inch divot occurred in the intertank acreage TPS just above the RH bipod. This divot was located in the vented SOFI area. The shallow depth indicates a cohesive failure internal to the CPR net spray material. This is a first for such a large shallow divot and may be indicative of damaged SOFI during ET processing.

The Solid Rocket Boosters were inspected at Hangar AF after retrieval. The BSM aero heat shield cover in the lower right corner of the LH SRB forward BSM cluster was missing. The cover, hinge, and a section of the attachment ring were broken off. Impact marks on the BSM nozzle indicate the cover oscillated through three cycles most probably in the time frame between BSM firing and parachute deployment. All the evidence does not support the hypothesis that the cover separated at or after water impact. While the cause of the failure is still under investigation, the continued bending observed in many attach ring assemblies may suggest a redesign is needed.

Both forward skirts and frustums exhibited a total of 2 debonds and no missing TPS. However, blistering and cratering of the Hypalon paint continues to be a problem. A subsurface delamination was detected in the LH SRB -Z RSS antenna. Cork thickness was measured and found to be excessive at the forward EB attach points. Although a 2.5 inch crack occurred in the LH SRB aft field joint K5NA, all other field joint closeouts were undamaged. The LH IEA case was cracked at the corners and the covers damaged. All 3 stiffener rings on the RH aft booster sustained water impact damage. K5NA was missing from all aft BSM nozzles and several bolt heads on both aft phenolic kick rings. Both skirt aft rings were missing foam around the holddown post shoes, HPU exhaust horns, and joint heater umbilicals. HDP #3, 4, 7, and 8's epon shims were missing material prior to water impact.

Prior to Orbiter landing at Edwards AFB, film review showed the LH MLG door extended 0.25-0.50 seconds before the right door. The MLG wheels lagged similarly. The elevons oscillated at a high rate prior to landing. A review of flight data showed that the elevon movement matched control stick inputs and was pilot induced.

Several pieces of the outboard forward corner tile from the RH MLG door and 10 pieces of Ames gap filler material were found on runway 17L after landing. Overall, the Orbiter TPS sustained a total of 76 hits, of which 20 had a dimension of 1-inch or greater. The lower surface tiles had a total of 60 hits, of which 13 had a major dimension of 1-inch or greater. The majority of lower surface damage was concentrated around the ET/ORB umbilicals, inboard elevons, and body flap. 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.

Three gap fillers on the lower surface, 14 on the LH OMS pod, and 7 on the RH OMS pod were protruding. Gap filler sleeving material was loose on the forward areas of both pods, and in one case caused severed damage to an adjacent white tile. An 18-inch long section of sleeving was missing entirely from the RH pod.

White tiles on the upper orbiter surfaces showed considerable degradation. The most significant damage occurred on the wing upper surface forward and aft of the elevon hinge line. This damage was not caused by debris impacts.

Window #3 was heavily hazed; window #4 was less hazed. Window #5 exhibited a 6x1 inch deposit. Other deposits on the vehicle after landing consisted of 4 white streaks on the RH wing RCC and 3 black streaks with residual particles on the LH wing RCC.

A total of 45 Post Launch Anomalies are listed in Section 10.0.

2.0 KSC ICE/FROST/DEBRIS TEAM ACTIVITIES

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

Team Activities:

1) Prelaunch Pad Debris Inspection

Objective:	Identify and evaluate potential debris material/sources. Baseline debris and debris sources existing from previous launches.
Areas:	MLP deck, ORB and SRB flame exhaust holes, FSS, Shuttle 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/resolve potential debris sources. The prelaunch vehicle/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 drainback
Requirements:	OMRSD S00FB0.005 - Monitor and video tape record ET TPS surfaces during loading through prepressurization.
Documents:	OMI S0007, OMI S6444
Report:	OIS call to NTD, Launch Director, and Shuttle managers. Generate IPR's.

3) Ice/Frost TPS and Debris Inspection

Objective:	Evaluate any ice formation as potential debris material. Identify and evaluate any ORB, ET, or SRB TPS anomaly which may be a debris source or safety of flight concern. Identify and evaluate any other possible facility or vehicle anomaly.
Areas:	MLP deck, FSS, Shuttle 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. The ET/ORB LH2 umbilical leak detector system is removed during this activity
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 Playlinda 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/photographed.
Documents:	OMI S0007, OMI S6444
Report:	Initial report to LTD 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 space shuttle vehicle. 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/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 and in the MDD.

Requirements: OMRSD S00U00.040 - An engineering debris inspection team shall perform a prelanding runway inspection to identify, document, and collect debris that could result in orbiter damage. Runway debris and any facility anomalies which cannot be removed/corrected by the Team shall be documented and photographed; the proper management authority shall be notified and corrective actions taken.

Requirements: OMRSD S00U00.050 - An engineering debris inspection team shall perform a post landing runway inspection to identify and resolve potential debris sources that may have caused vehicle damage but was not present or was not identified during pre-launch runway inspection. Obtain photo-graphic 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 MMT 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 7 August 1989 at 0830 hours with the following key personnel present:

C. Stevenson	NASA - KSC	Chief, ET Mechanical Systems Lead, Ice/Debris Assess Team
G. Katnik	NASA - KSC	ET Mech/TPS, Ice/Debris Assessment, STI
S. Higginbotham	NASA - KSC	STI, Debris Assessment
B. Speece	NASA - KSC	ET Processing, Ice Assess
B. Bowen	NASA - KSC	ET Processing, "SURFICE"
J. Rivera	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	"SURFICE", Debris Assess
M. Bassignani	NASA - KSC	ET Processing, Ice Assess
J. Hoffman	LSOC - SPC	ET Processing, Ice Assess
M. Young	LSOC - SPC	ET Processing, Ice Assess
J. Cawby	LSOC - SPC	ET Processing, Ice Assess
F. Huneidi	NASA - MSFC	TPS & Ice Assessment
D. Andrews	NASA - MSFC	Debris Assessment
Z. Byrns	NASA - JSC	Level II Integration
C. Gray	MMC - MAF	ET TPS & Materials Design
S. Copsey	MMC - MAF	ET TPS Testing/Certif
B. Fleming	MMC - KSC	ET Processing, LSS
J. McClymonds	RI - Downey	Debris Assess, LVL II Integ
A. Fazio	RI - KSC	Debris Assessment, LSS
H. Novak	USBI - PSE	SRB Processing
J. Maw	MTI - Utah	SRM Plant Representative
G. Meeks	NASA - SSC	STI Operations
C. Thurman	NASA - SSC	STI Operations

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 7 August 1989 from 1000 - 1230 hours. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-102 Columbia (8th flight), ET-31 (LWT-24), and BIO-28. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and new vehicle configurations.

There were no major vehicle anomalies. However, paper covers on the Orbiter forward RCS pitch nozzles (total of 3) were joined together with mylar tape. These particular covers usually pull free during ascent and contact the Orbiter windows. The effect of mylar tape on window hazing is unknown.

Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during the cryoload/launch of STS-28R, a temporary hydrogen detector was installed at the umbilical. The temporary detector consists of two tygon tubes that run from the LH2 umbilical area to the hazardous gas detection equipment located on the FSS. 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 cryo loading and will be removed by the Ice Inspection Team during the T-3 hour hold.

A recurring problem is loose MLP deck bolts. This inspection revealed one loose and two missing bolts on the junction box cover plate between the cameras west of the LH SRB near the water pipe, loose handrail access and grounding bolts southwest of the LH SRB and southeast of the RH SRB, a missing bolt on the east hypergolic fuel access plate, loose fasteners on the SSME flame hole north water pipe, one loose bolt on the raised deck area between the SRB's, loose grounding bolts on the inboard side of both right and left SRB exhaust holes, two missing and two bent bolts out of a total of six on the Portable Purge Unit electrical interface cover plate in the northwest corner of the MLP. Only putty held one bolt in place on an access plate near the northwest corner of the LH2 TSM. Two deck plates adjacent to the SSME exhaust hole north side were loose.

Trash and debris included a metal washer in a LH SRB secondary sound suppression water trough, a pip pin in the holddown post #1 haunch area, two ziplock bags in the holddown post #6 well area, tape/plastic between the RH SRB joint heater umbilical and instafoam closeout.

Excessive RTV was again applied to the instrumentation bands at the base of the SRB holddown posts. This condition is acceptable for this launch only.

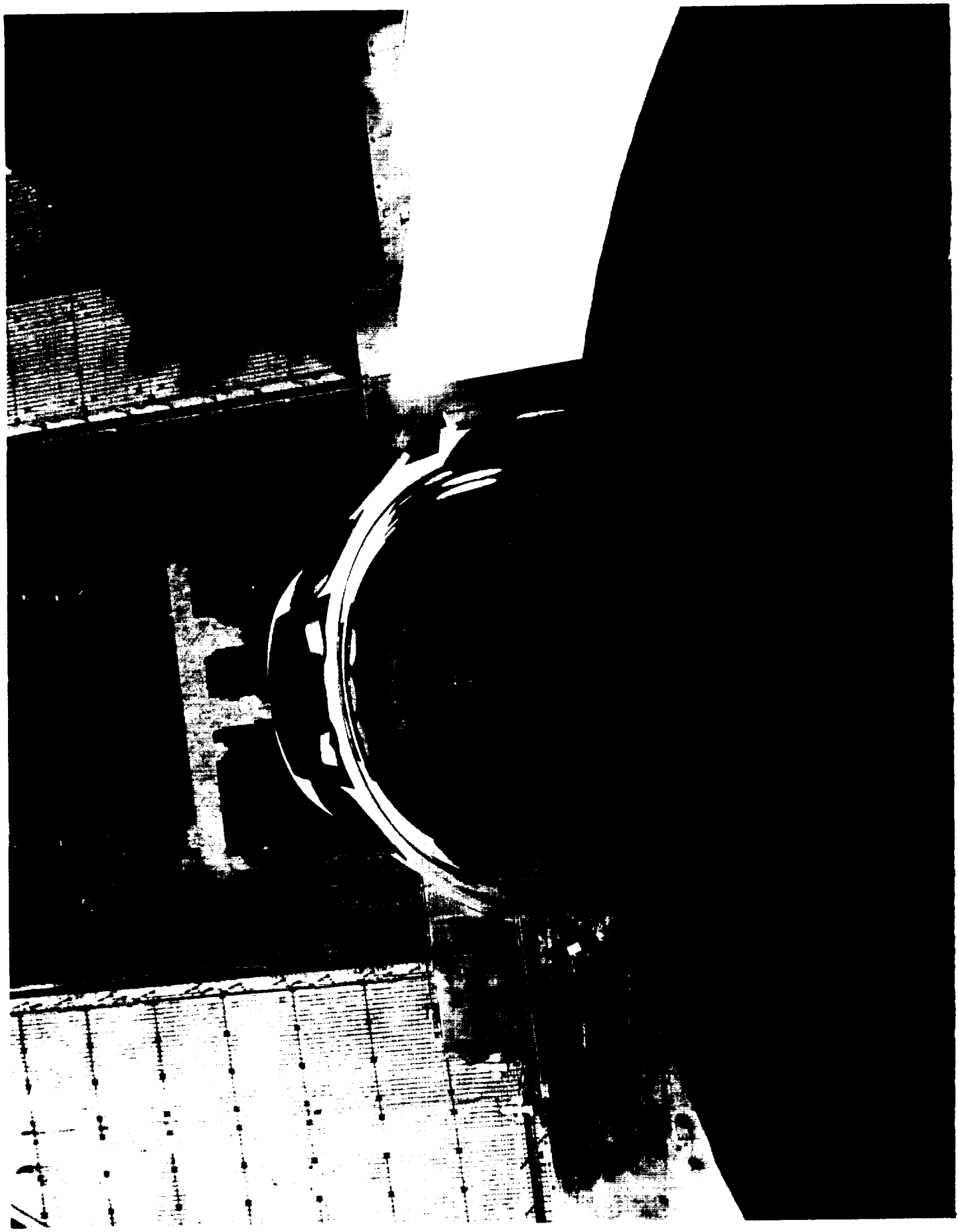
Cleanup of the MLP deck and pad surface was in progress at the time of the inspection. The facility discrepancies listed above were transferred to the pad leader for resolution prior to vehicle tanking.

OVERALL VIEW OF ET-31 (LWT 24) -Z SIDE TPS ACREAGE

PRE-LAUNCH CONFIGURATION OF LH SRB FORWARD BSM COVERS

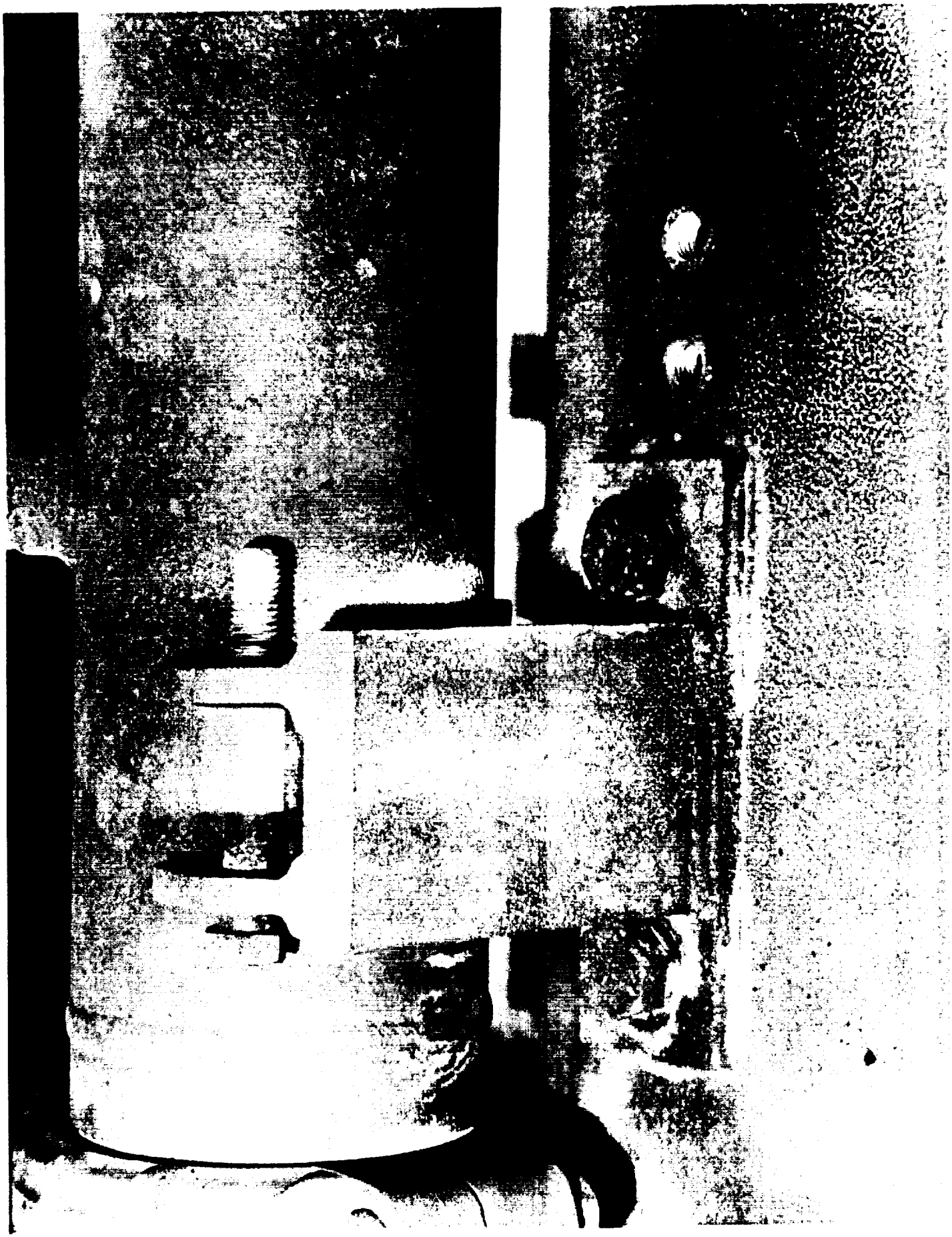
FLIGHT CONFIGURATION OF THE ET/ORB LH2 UMBILICAL BAGGIE. TWO 16mm MOTION PICTURE CAMERAS RECORD SRB AND ET SEPARATION

BUTCHER PAPER WAS TAPED TOGETHER TO COMPLETE INSTALLATION OF THE ORBITER FORWARD RCS COVERS



LOOSE PAPER COVER ON THE ORBITER LH FORWARD RCS WAS DOCUMENTED PRIOR TO LAUNCH

HYDROGEN DETECTOR/TUBING IS ATTACHED TO ET/SRB UPPER STRUT FAIRING, ET THRUST FITTING, AND LH2 TANK PRESS LINE



LOOSE SOUND SUPPRESSION BOLT NEAR THE SSME EXHAUST HOLE

LOOSE BOLT IN A MOBILE LAUNCH PLATFORM ACCESS COVER

4.0 LAUNCH

STS-28R was launched at 0837 EST on 8 August 1989.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 8 August 1989 from 0245 to 0430 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no violations of NSTS-08303 or the Launch Commit Criteria. Ambient weather conditions at the time of the inspection were:

Temperature:	78 F
Relative Humidity:	82 %
Wind Speed:	6 Knots
Wind Direction:	274 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

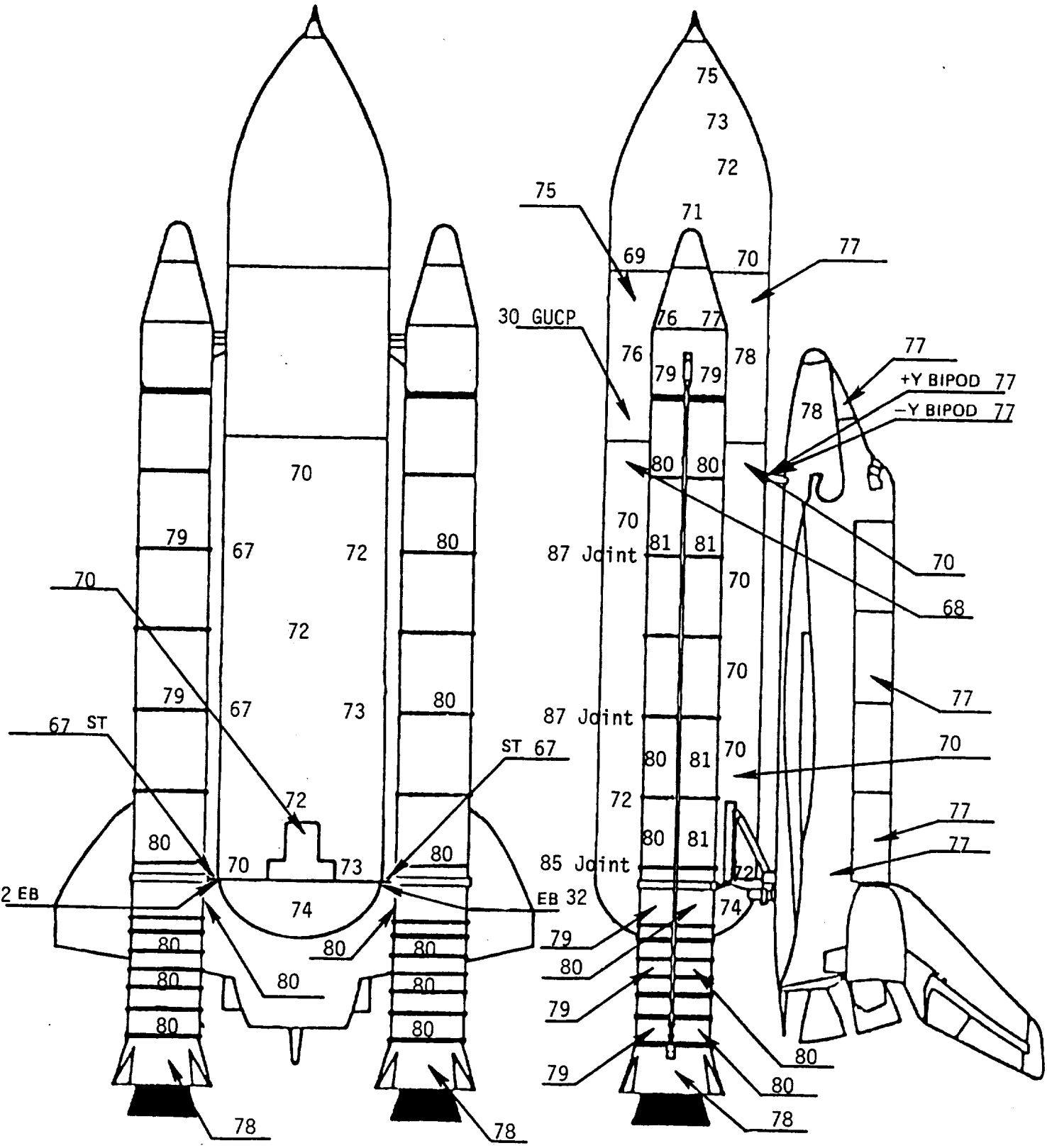
No Orbiter tile anomalies were observed. A paper cover missing from the LH forward RCS had been detected shortly after the pre-launch inspection and documented on a PR. This condition was no constraint to launch. The average Orbiter surface temperature was recorded as 77 degrees F. The surface temperatures of the SSME engine mounted heat shields were measured at 43 degrees F for SSME #1 (at the interface), 32-35 degrees F for SSME #2 (across the engine mounted heat shield to the thermal barrier), and 56 degrees F for SSME #3 (at the interface). Some frost was visible on the nozzle to heatshield interface on SSME #1 and #2 with a small amount of ice on SSME #2. Condensate, but no ice or frost, was present on the SSME #3 heatshield.

4.3 SRB OBSERVATIONS

No SRB anomalies were observed. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 79 to 81 degrees F. Temperatures in the area of the SRB field joint heaters ranged from 85 to 87 degrees F. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 82 degrees F.

FIGURE 1. **INFRA RED SCANNER SSV SUMMARY DATA**

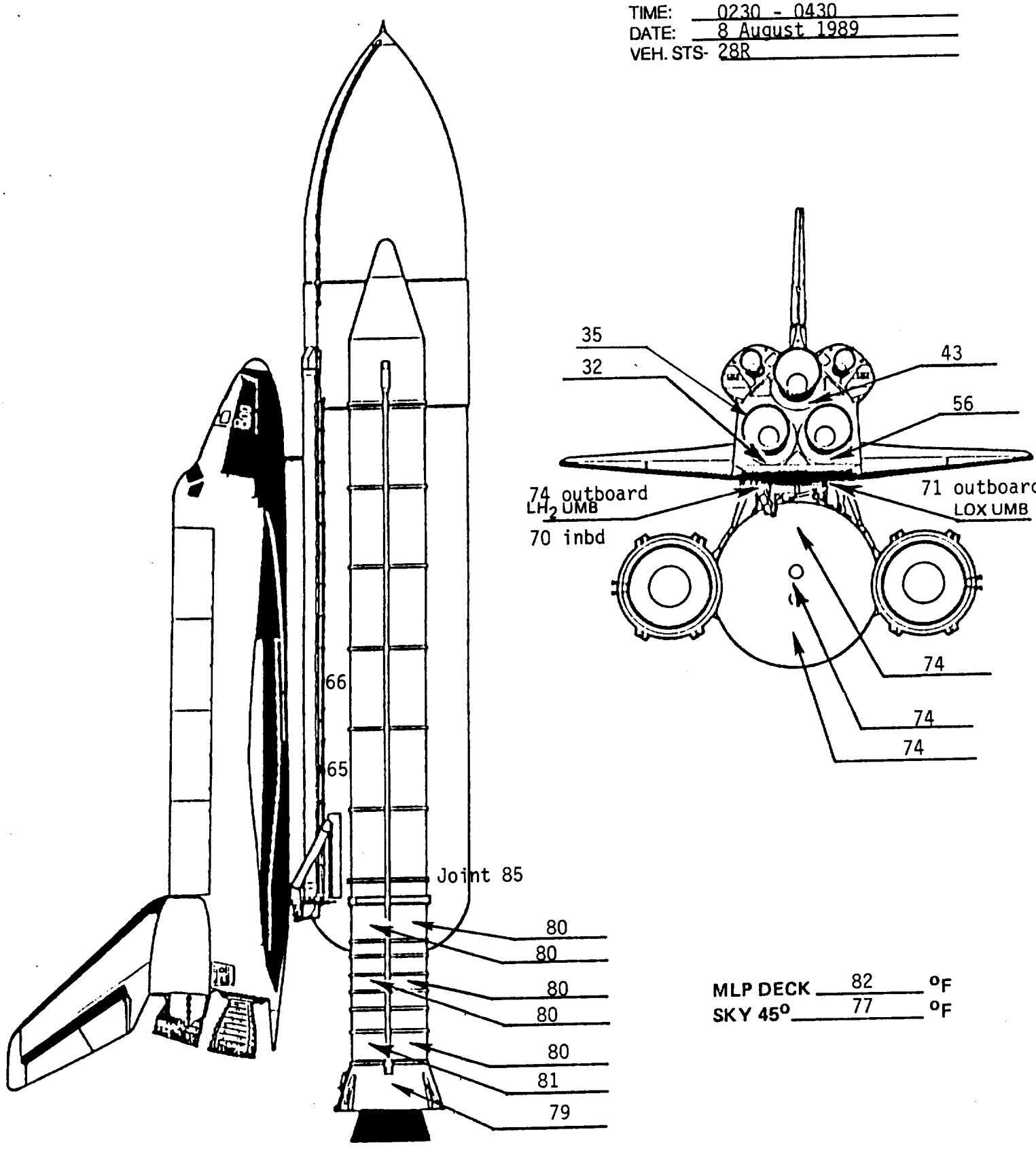
TIME: 0230 - 0430
DATE: 8 August 1989
VEH. STS- 28R



EGG/V−343C

FIGURE 2. **INFRA RED SCANNER SSV SUMMARY DATA**

TIME: 0230 - 0430
DATE: 8 August 1989
VEH. STS- 28R



MLP DECK 82 °F
SKY 45° 77 °F

EGG/V-343D

4.4 EXTERNAL TANK OBSERVATIONS

The ice/frost prediction computer program was run from 2330 to 0837 hours and the results tabulated in Figures 3, 4, and 5. The program predicted condensate with no ice accumulation on all TPS acreage surfaces.

Acreage condensate, but no ice or frost, was present on the LO2 tank, Intertank (run on), and LH2 tank. The IR scanner measured an average surface temperature of 72 degrees F on the LO2 tank, 77 degrees F on the Intertank, and 70 degrees F on the upper and lower LH2 tank.

An above average amount of condensate trickled down the LH2 tank and ran off the aft dome. There was no acreage ice or frost.

Ice/Frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The EB struts were dry and were not covered by ice.

Slightly less than normal amounts of ice/frost were present in the LO2 feedline bellows and support brackets. Four LH2 tank cable tray ice/frost ramps exhibited minor amounts of frost, which is not unusual. These conditions are acceptable per NSTS-08303.

There was no ice in on the LH2 feedline or in the bellows. Minor amounts of frost had formed in the LH2 recirculation line bellows.

The LH2 and LO2 ET/ORB umbilicals exhibited less ice but normal frost accumulations on both the inboard and outboard sides. Frost fingers had formed on the purge vents and normal venting was occurring. There was no unusual vapors emanating from the umbilicals or any evidence of cryogenic leakage.

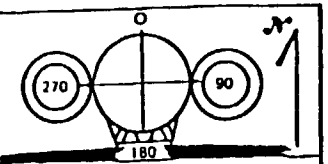
Run-on condensate from the LO2 tank was present on the intertank. Small amounts of frost had accumulated in 3 LO2 tank to intertank interface stringers roots in the -Y+Z and -Y-Z quadrants near the thrust panel. Minor amounts of frost had formed around the GUCP, but there was no sign of leakage.

The tumble valve cover was properly installed and intact.

The ET/ORB umbilical hydrogen detection sensor tygon tubing was removed with no damage to the vehicle.

The summary of ice/frost team observation anomalies consists of 5 OTV recorded items:

STS- 28R	TEST: S0007 Launch					DATE: 8/7/89	T-0 TIME: 0837 DATE: 8/8/89	
ORBITER	ET	SRB	MLP	PAD	LO_2 CHILLDOWN TIME: 2320 SLOW FILL TIME: 2358 FAST FILL TIME: 1207 REPLENISH TIME: 0216		LH_2 CHILLDOWN TIME: 2320 SLOW FILL TIME: 2331 FAST FILL TIME: 0000 REPLENISH TIME: 0208	
OV- 102	31	B1028	2	39B				



LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
2330	83.6	74.0	74.94	9	205	II	5.31	72.63	+.0018	-.2752	II	5.31	69.15	+.0040	-.2420	II	2.88	63.58	+.0042	-.1335	II	12.24	72.75	+.0034	-.5164
2345	82.6	72.8	73.49	9	207	II	5.31	71.25	+.0016	-.2622	II	5.31	67.72	+.0038	-.2294	II	2.88	62.05	+.0041	-.1255	II	12.24	71.39	+.0031	-.4916
0000	82.4	71.6	72.82	9	211	II	5.31	70.72	+.0015	-.2571	II	5.31	67.16	+.0037	-.2246	II	2.88	61.47	+.0039	-.1225	II	12.24	70.84	+.0029	-.4818
0015	82.4	70.6	72.42	10	222	II	5.90	70.80	+.0013	-.2777	II	5.90	67.51	+.0035	-.2448	II	3.20	62.17	+.0039	-.1338	II	13.60	70.94	+.0024	-.5267
0030	81.8	68.6	71.02	12	224	II	7.08	70.18	+.0007	-.3099	II	7.08	67.31	+.0030	-.2767	II	3.84	62.47	+.0038	-.1512	II	16.32	70.36	+.0012	-.5997
0045	80.8	70.0	70.61	10	238	II	5.90	68.98	+.0012	-.2599	II	5.90	65.62	+.0033	-.2276	II	3.20	60.13	+.0038	-.1228	II	13.60	69.15	+.0022	-.4931
0100	80.6	72.8	71.53	10	247	II	5.90	69.53	+.0015	-.2654	II	5.90	66.18	+.0037	-.2328	II	3.20	60.65	+.0040	-.1258	II	13.60	69.73	+.0028	-.5042
0115	80.0	75.0	71.78	8	248	II	4.72	68.67	+.0019	-.2204	II	4.72	64.66	-.0039	-.1886	II	3.44	61.21	+.0042	-.1345	II	9.68	68.30	+.0039	-.3644
0130	80.0	77.6	72.75	7	242	II	4.13	68.80	+.0022	-.2027	II	4.13	64.38	+.0042	-.1712	II	2.24	57.62	+.0040	-.0927	II	9.52	68.92	+.0043	-.3685
0215	79.6	77.8	72.43	8	233	II	4.72	68.96	+.0021	-.2229	II	4.72	64.96	-.0042	-.1909	II	2.56	58.60	+.0041	-.1016	II	10.88	69.16	+.0041	-.4129
0230	79.0	78.4	72.05	8	242	II	4.72	68.47	+.0022	-.2189	II	4.72	64.44	-.0042	-.1871	II	2.56	58.02	+.0041	-.0989	II	10.88	68.69	+.0042	-.4057
0245	78.6	79.2	71.94	8	242	II	4.72	68.24	+.0022	-.2171	II	4.72	64.19	+.0043	-.1854	II	2.56	57.73	+.0042	-.0977	II	10.88	68.48	+.0043	-.4026
0300	78.2	80.6	72.05	6	260	II	3.54	66.88	+.0024	-.1713	II	3.54	61.83	+.0042	-.1404	II	2.58	57.69	+.0042	-.0979	II	7.26	66.30	+.0048	-.2721
0315	78.2	81.4	72.33	5	269	II	2.95	66.17	+.0024	-.1493	II	2.95	60.41	+.0041	-.1189	II	2.15	55.87	+.0041	-.0861	II	6.05	65.34	+.0049	-.2299
0330	77.6	82.0	71.94	6	274	II	3.54	66.56	+.0025	-.1692	II	3.54	61.48	+.0043	-.1384	II	2.58	57.29	+.0043	-.0961	II	7.26	66.00	+.0049	-.2960

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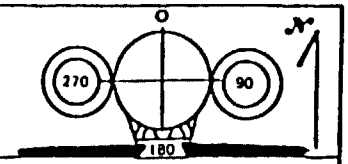
FIGURE 3. Ice/Frost Computer Predictions

STS- 28R	TEST: S0007 Launch					DATE: 8/8/89	T-0 TIME: 0837 DATE: 8/8/89
ORBITER	ET	SRB	MLP	PAD	LO_2		LH_2	
OV- 102	31	B1028	2	39B	CHILLDOWN TIME: 2320 SLOW FILL TIME: 2358	FAST FILL TIME: 1207 REPLENISH TIME: 0216	CHILLDOWN TIME: 2320 SLOW FILL TIME: 2331	FAST FILL TIME: 0000 REPLENISH TIME: 0208



LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL. HUM. %	DEW PT °F	WIND VEL. KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0345	76.8	83.4	71.63	7	260	II	4.13	66.73	+.0026	-.1879	II	4.13	62.17	+.0045	-.1568	II	3.01	58.26	+.0045	-.1095	II	8.47	66.37	+.0050	-.3062
0400	77.4	84.0	72.43	6	264	II	3.54	66.81	+.0026	-.1709	II	3.54	61.74	+.0044	-.1400	II	2.58	57.52	+.0044	-.0973	II	7.26	66.29	+.0052	-.2721
0415	77.0	84.4	72.17	6	262	II	3.54	66.46	+.0026	-.1687	II	3.54	61.36	+.0044	-.1379	II	2.58	57.12	+.0044	-.0955	II	7.26	65.94	+.0052	-.2685
0430	75.8	84.2	70.91	7	256	II	4.13	65.83	+.0026	-.1815	II	4.13	61.20	+.0045	-.1506	II	3.01	57.23	+.0045	-.1044	II	8.47	65.48	+.0050	-.2957
0445	76.2	84.6	71.44	5	242	II	2.95	64.66	+.0026	-.1405	II	2.95	58.79	+.0042	-.1109	II	1.60	51.69	+.0038	-.0775	II	6.80	64.68	+.0051	-.2437
0545	75.8	87.4	71.97	4	222	II	2.36	63.56	+.0026	-.1191	II	2.36	56.72	+.0041	-.0895	II	1.28	51.73	+.0039	-.0779	II	5.44	63.34	+.0053	-.1975
0600	75.6	87.8	71.90	6	243	II	3.54	65.68	+.0028	-.1638	II	3.54	60.52	+.0046	-.1335	II	1.92	52.74	+.0041	-.0771	II	8.16	65.92	+.0055	-.2928
0615	75.4	88.4	71.89	6	240	II	3.54	65.59	+.0029	-.1632	II	3.54	60.42	+.0046	-.1325	II	1.92	52.63	+.0041	-.0765	II	8.16	65.84	+.0056	-.2920
0630	75.6	88.6	72.15	5	246	II	2.95	64.90	+.0028	-.1423	II	2.95	59.02	+.0045	-.1121	II	1.60	51.70	+.0039	-.0778	II	6.80	64.98	+.0056	-.2468
0645	75.4	88.8	72.02	6	249	II	3.54	65.68	+.0028	-.1638	II	3.54	60.57	+.0046	-.1331	II	2.58	56.16	+.0046	-.0913	II	7.26	65.23	+.0056	-.2614
0700	76.0	89.2	72.74	6	271	II	3.54	66.45	+.0029	-.1687	II	3.54	61.33	+.0047	-.1378	II	2.58	57.01	+.0047	-.0951	II	7.26	66.00	+.0057	-.2694
0715	76.2	89.2	72.94	6	276	II	3.54	66.68	+.0029	-.1702	II	3.54	61.57	+.0048	-.1392	II	2.58	57.26	+.0047	-.0962	II	7.26	66.22	+.0057	-.2718
0730	76.4	89.4	73.20	5	278	II	2.95	65.99	+.0029	-.1485	II	2.95	60.19	+.0046	-.1179	II	2.15	55.51	+.0044	-.0833	II	6.05	65.29	+.0056	-.2299
0745	76.6	89.6	73.47	5	274	II	2.95	66.27	+.0029	-.1500	II	2.95	60.48	+.0046	-.1195	II	2.15	55.81	+.0045	-.0847	II	6.05	65.57	+.0057	-.2323
0800	77.2	89.4	74.00	5	259	II	2.95	66.91	+.0029	-.1537	II	2.95	61.16	+.0046	-.1230	II	2.15	56.53	+.0045	-.0882	II	6.05	66.21	+.0057	-.2382

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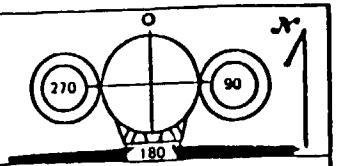
FIGURE 4. Ice/Frost Computer Predictions

STS – 28R	TEST: S0007 Launch					DATE: 8/8/89	T-0 TIME: 0837 DATE: 8/8/89	
ORBITER	ET	SRB	MLP	PAD	LO_2 CHILLDOWN TIME: 2320 SLOW FILL TIME: 2358	LO_2 FAST FILL TIME: 1207 REPLENISH TIME: 0216	LH_2 CHILLDOWN TIME: 2320 SLOW FILL TIME: 2331	LH_2 FAST FILL TIME: 0000 REPLENISH TIME: 0208
OV– 102	31	B1028	2	39B				



LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0815	78.8	88.2	75.20	5	252	II	2.95	68.46	+.0029	-.1627	II	2.95	62.83	+.0047	-.1317	II	2.15	58.30	+.0046	-.0969	II	6.05	67.74	+.0057	-.2525
0830	80.6	83.2	75.52	7	261	II	4.13	71.07	+.0027	-.2202	II	4.13	66.77	+.0048	-.1879	II	3.01	63.08	+.0048	-.1346	II	8.47	70.68	+.0053	-.3598
T-0 0837	81.4	81.0	73.35	7	262	II	4.13	71.17	+.0025	-.2209	II	4.13	66.89	+.0046	-.1887	II	3.01	63.23	+.0047	-.1353	II	8.47	70.75	+.0050	-.3605
AVG.	78.5	82.0	72.58	7	S.W.			67.73					63.04					57.88					67.54		

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FIGURE 5. Ice/Frost Computer Predictions

Anomaly 001 recorded torn hydrogen fire detection system butcher paper on the thrust strut lower position. The condition was documented on IPR 28RV-412, upgraded to PR ET-31-TS-0113, and dispositioned by MRB to use-as-is.

Anomaly 002 documented frost spots at the LO2 tank to intertank splice in the stringer roots near the -Y thrust panel. These spots were acceptable per the NSTS-08303 criteria.

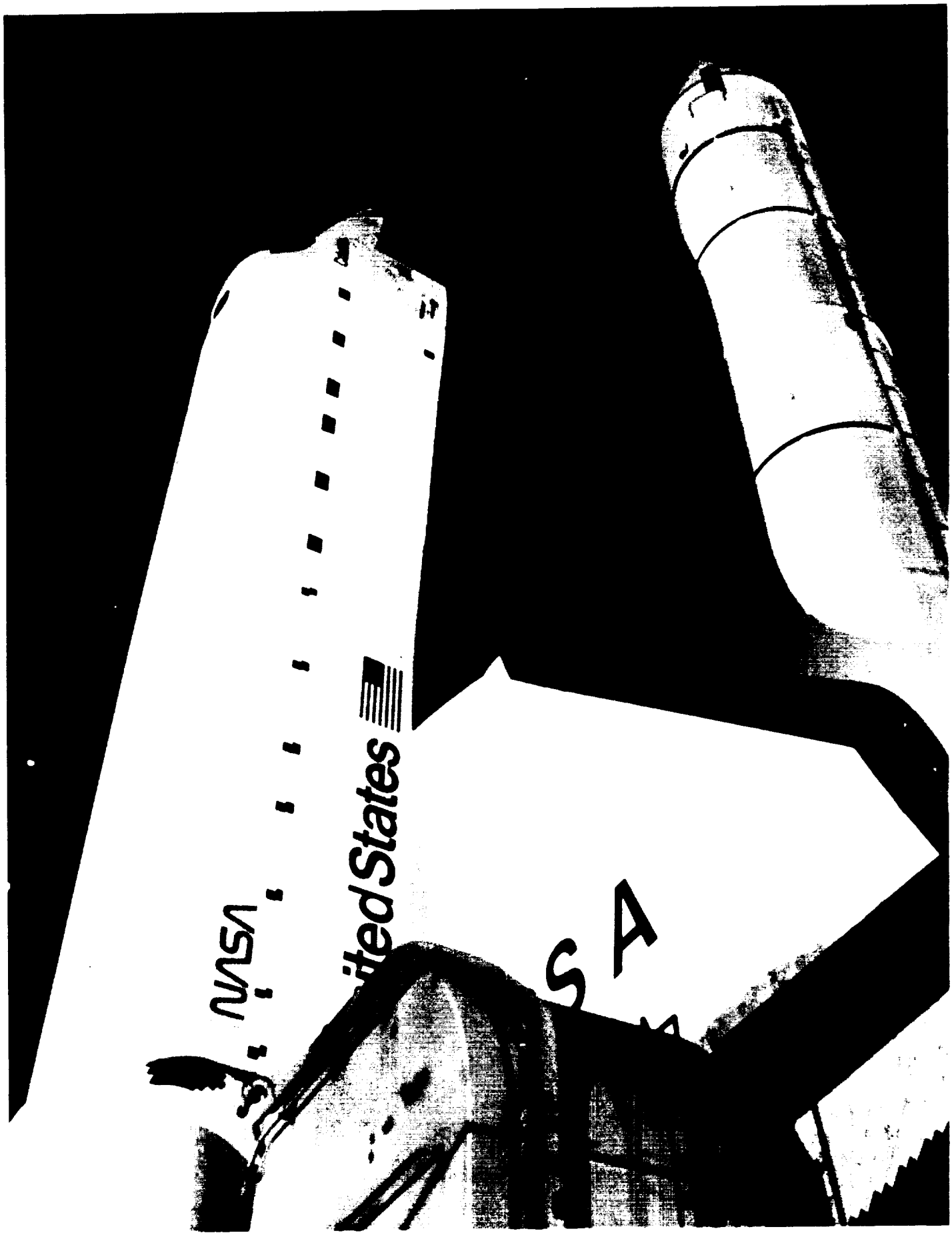
A small amount of ice/frost in the LO2 feedline bellows and brackets was documented on Anomaly 003. These amounts were less than normally observed during cryoloadings and were acceptable per NSTS-08303.

Anomaly 004 recorded pronounced frost fingers on the ET/ORB LH2 and LO2 purge vents. No leakage or unusual vapors emanated from the umbilicals. The condition was acceptable per NSTS-08303.

Anomaly 005 documented small amounts of frost on four LH2 tank cable tray ice/frost ramps. The frost accumulation was acceptable per NSTS-08303.

4.5 FACILITY OBSERVATIONS

All debris concerns previously identified had been resolved prior to cryoloading and no new items were noted during the walkdown. No leaks were observed on either the LO2 or LH2 ORB T-0 umbilicals, though small amounts of ice had formed. There was also no apparent leakage from the GH2 vent line or GUCP. The modification to the GH2 vent line successfully precluded ice formation but some ice/frost, which was expected, had accumulated on the GUCP legs. Visual and infrared observations of the GOX seals confirmed no leakage. The ends of the GOX vent ducts exhibited no icicles.



OVERALL VIEW OF OV-102 COLUMBIA, ET-31, AND RH SRB BIO-28

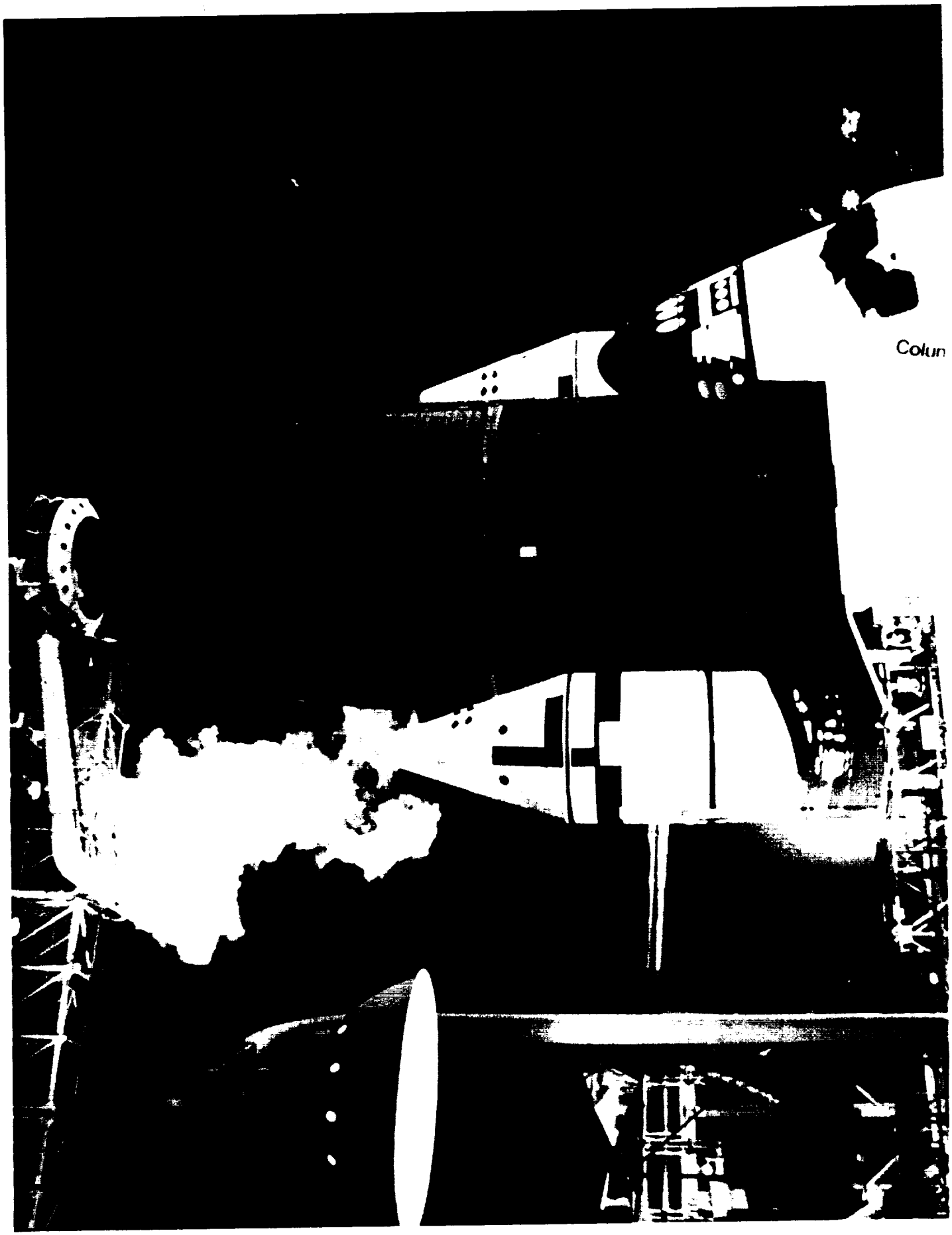
ORIGINAL PAGE
COLOR PHOTOGRAPH

NO TPS ACREAGE ANOMALIES DURING CRYOLOAD. NOTE RH SOLID ROCKET BOOSTER GEI INSTALLATIONS AND CABLE RUNS.

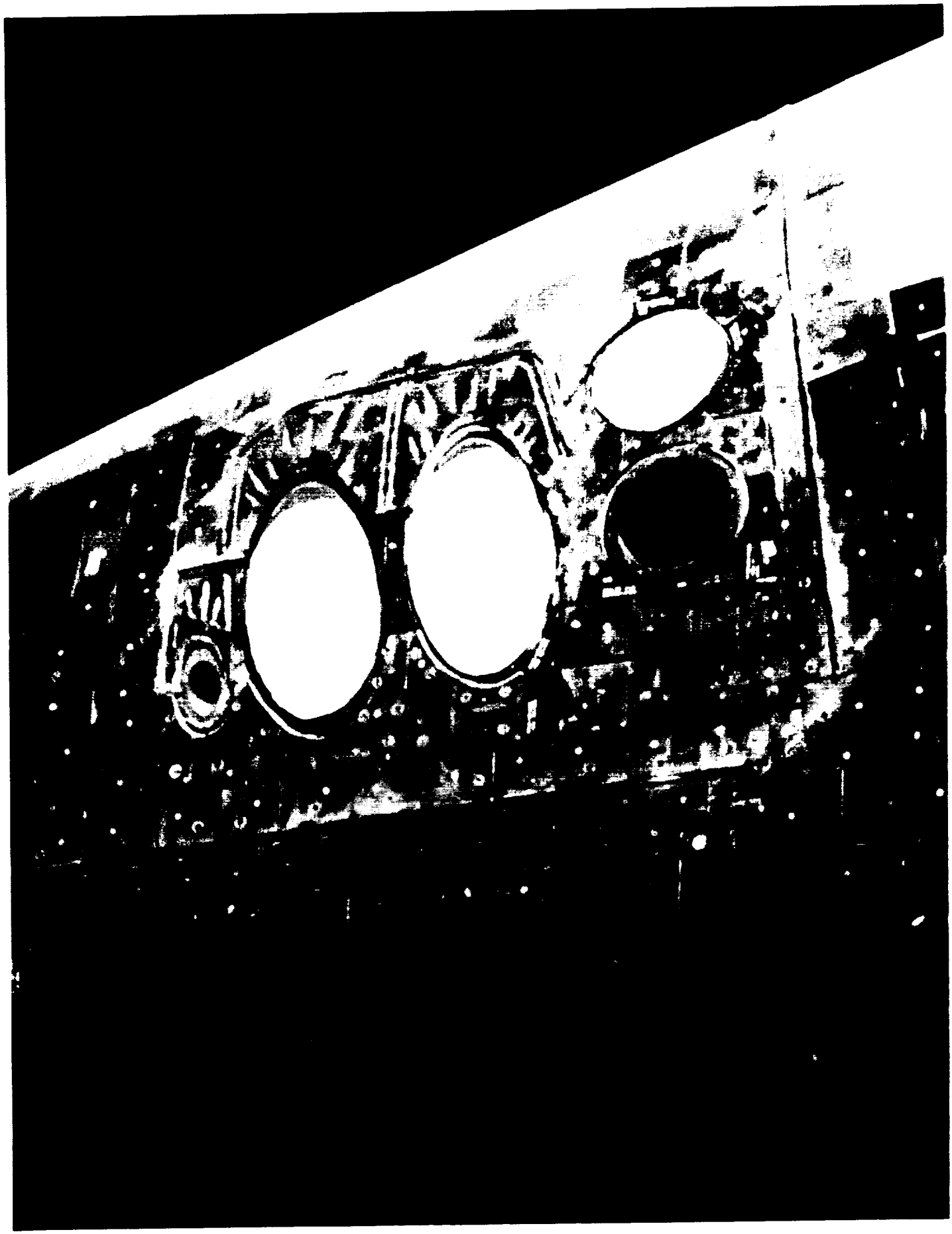
ORIGINAL PAGE
COLOR PHOTOGRAPH

OVERALL VIEW OF -Z SIDE TPS ACREAGE AFTER CRYOLOAD

NO ICE/FROST ACCUMULATION ON +Z SIDE TPS ACREAGE



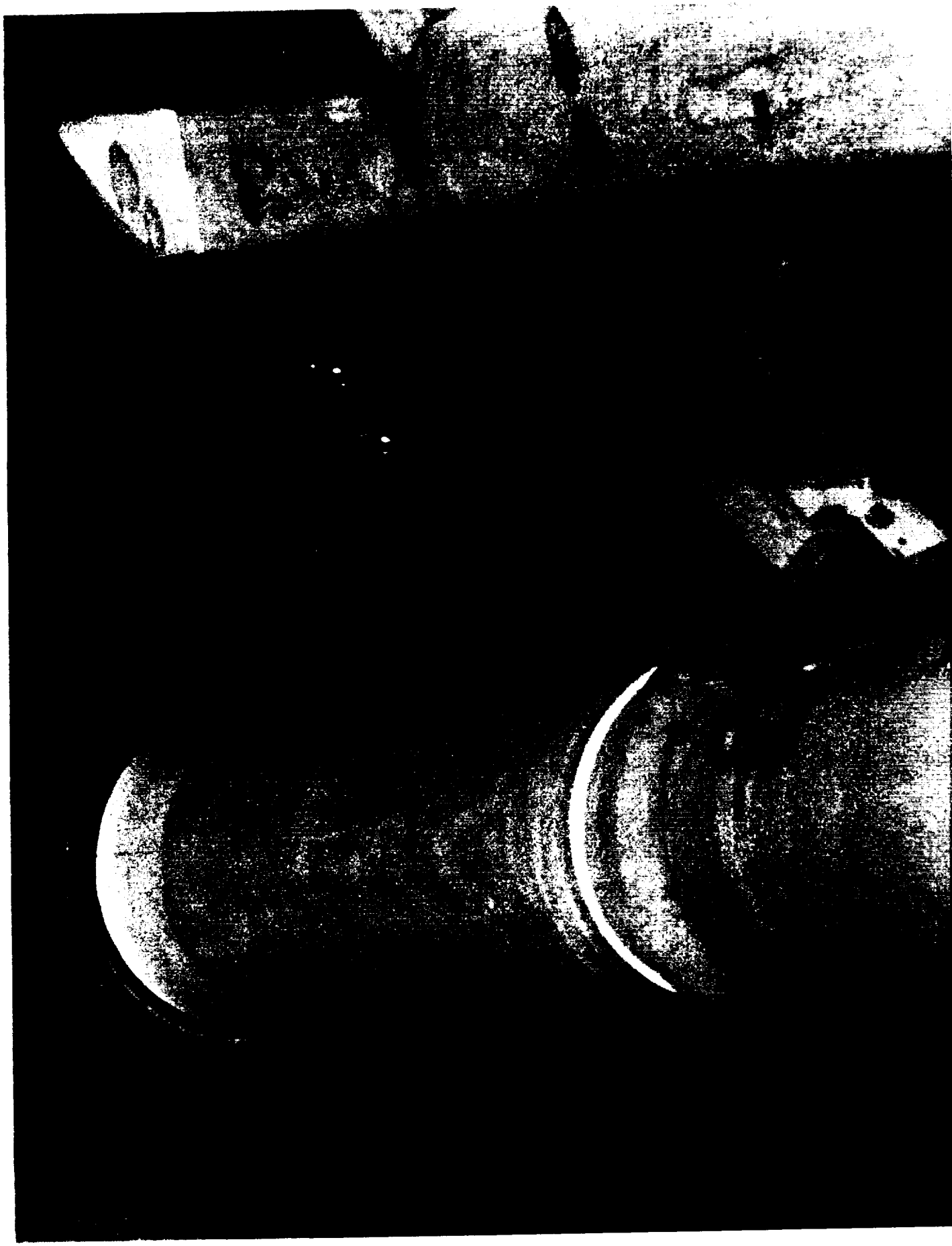
CONDENSATE, BUT NO ICE/FROST ACCUMULATION, WAS PRESENT ON LO2 TANK AFTER CRYOLOAD



FORWARD RCS PAPER COVER THAT HAD BEEN LOOSE THE DAY BEFORE LAUNCH WAS MISSING COMPLETELY AT THE TIME OF THE ICE INSPECTION

FROST FORMED ON SSME #1 AND #2 ENGINE MOUNTED HEAT SHIELDS

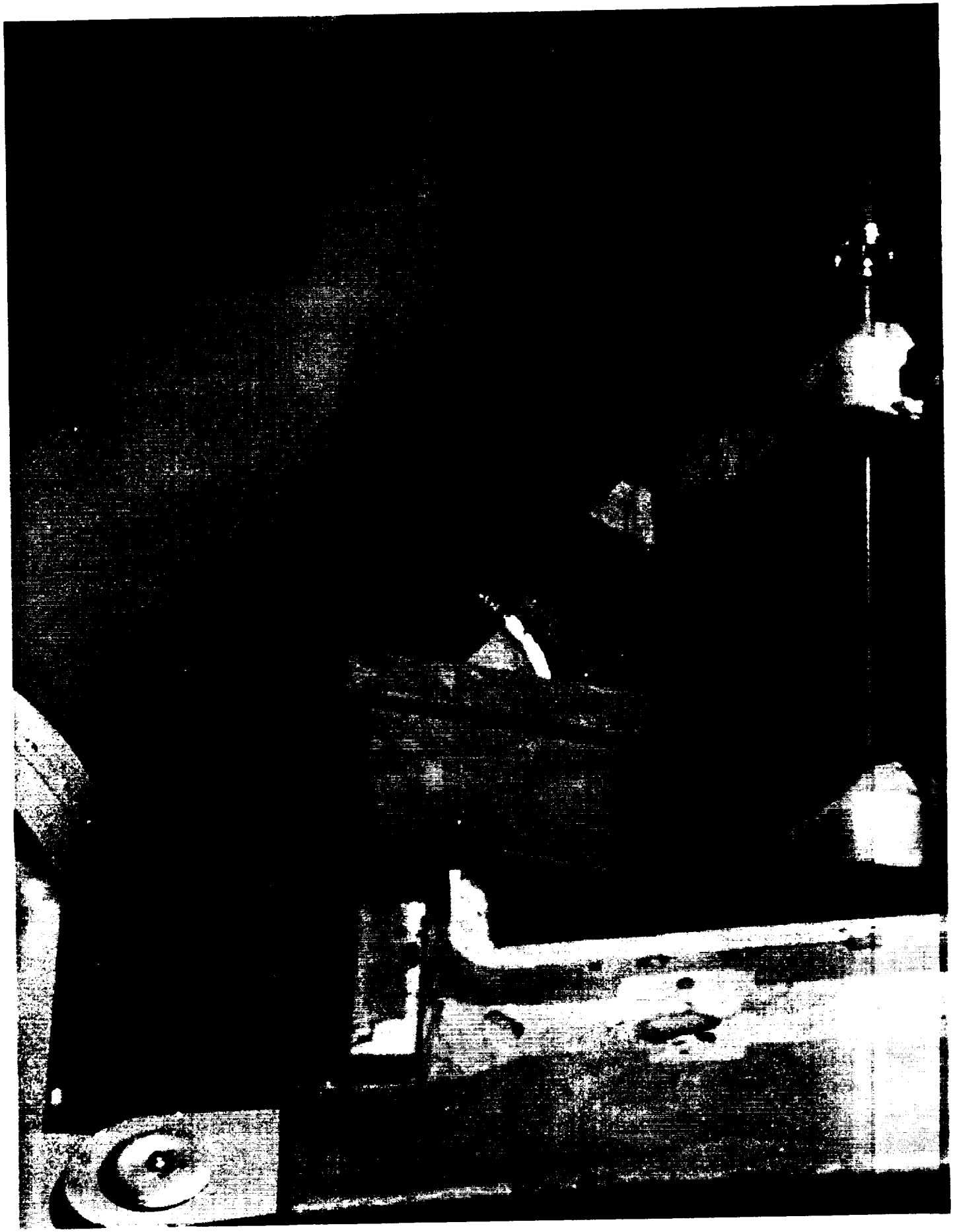
ET TUMBLE VALVE COVER WAS CONFIGURED FOR FLIGHT. NO LEAKAGE FROM THE GOX VENT SEAL WAS OBSERVED.



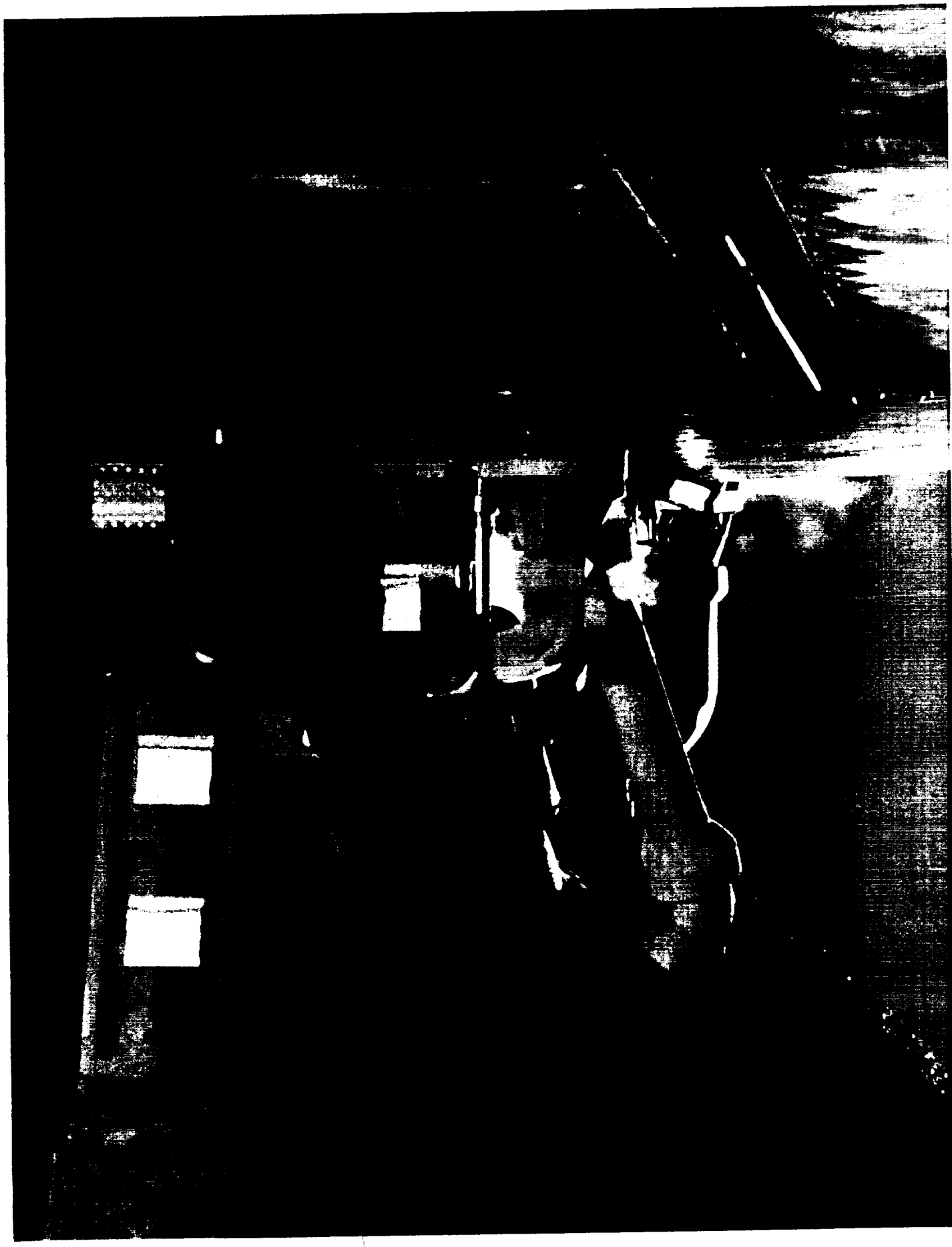
ICE/FROST HAS ACCUMULATED IN THE FEEDLINE SUPPORT BRACKET AND FEEDLINE FORWARD BELLOWS AT STATION XT-1106

COLOR PHOTOGRAPH

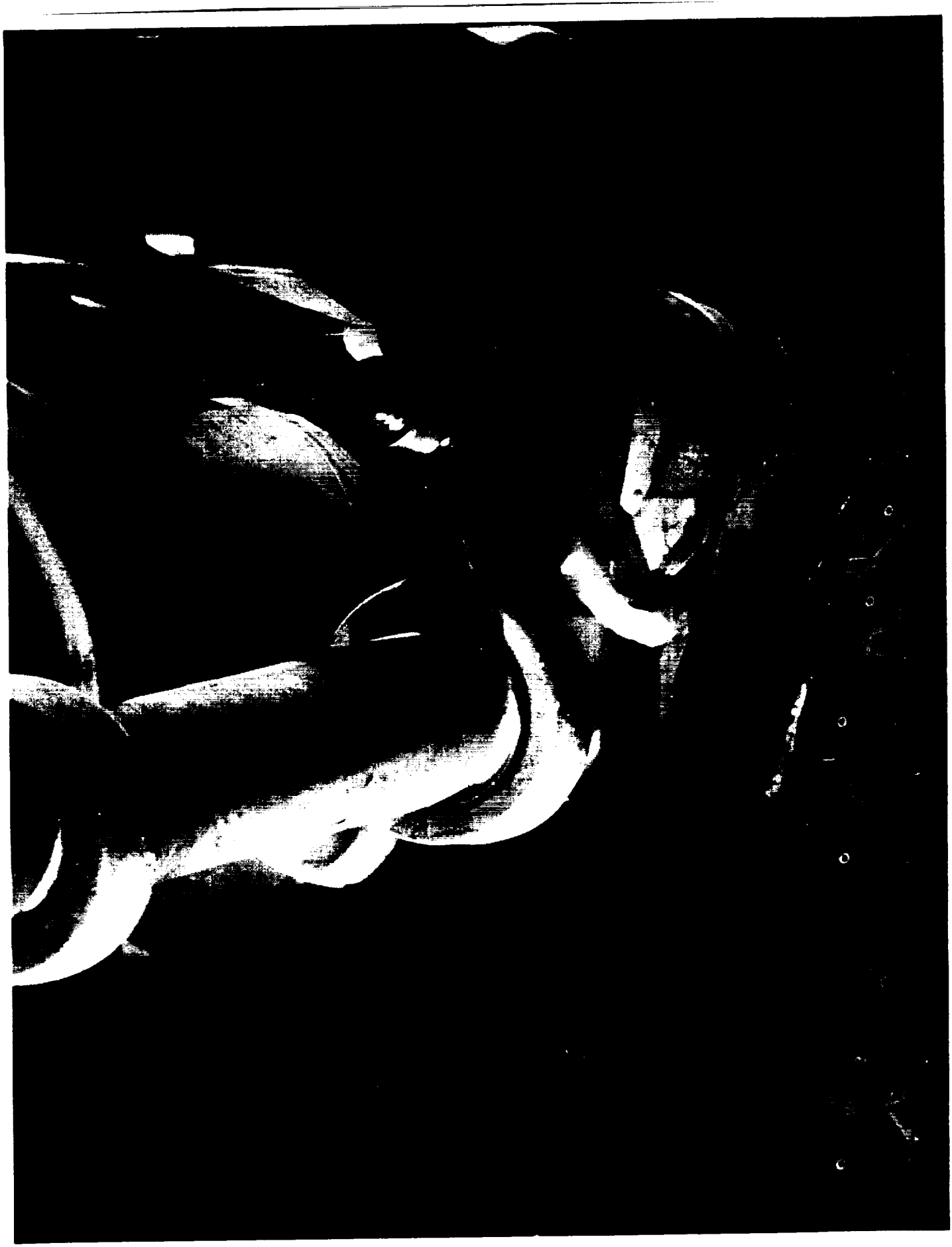
TYPICAL ICE/FROST ACCUMULATION IN THE FEEDLINE SUPPORT BRACKET



HARD ICE HAS ACCUMULATED IN THE FEEDLINE BELLOWS AT XT-1973



NORMAL PURGE GAS IS VENTED AND CONDENSATE DRIPPED FROM THE LH2 ET/ORB UMBILICAL. FROST FINGERS FORMED ON THE PURGE VENTS



ICE/FROST ACCUMULATED IN THE LH2 ET/ORB UMBILICAL CAVITIES, INBOARD SIDE OF THE BAGGIE MATERIAL, AND RECIRC LINE BELLOWS

ICE/FROST ACCUMULATION ON LO2 ET/ORB UMBILICAL BAGGIE AND LO2 FEEDLINE INTERFACE. NOTE FROST FINGER ON AFT PURGE VENT

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the pad and surrounding area was conducted on 8 August 1989 from launch +2.0 to 5.5 hours. The MLP, FSS, pad apron, and acreage areas were inspected. No significant flight hardware or TPS materials was found with the exception of three Q-felt plugs and a portion of another. In addition, a small piece of SSME insulation screen material was found on the crawlerway adjacent to the stowed position of the engine service platform. The usual amount of SRB throat plug material (foam and RTV) was present on the pad. Water trough material from the SRB exhaust holes was scattered throughout the field and on the pad apron.

SRB holddown post erosion was negligible for this launch. Shim material for all south holddown posts showed evidence of debonding. Holddown post #2 shim material was displaced from the shoe sidewall. No shrapnel from holddown post debris containers was found. All of the doghouse blast covers on the north holddown posts were in the closed position, exhibited no apparent damage, and did not appear to be missing any parts. The SRB aft skirt purge lines were in place, but damaged. The SRB joint heater umbilicals showed typical plume effects after separation.

Several pieces of typical facility debris were found at the pad perimeter. Emergency egress slidewire baskets #4 and #7 had been released sometime during launch. The other five baskets were secured on the FSS 195 foot level and sustained no launch damage.

The GOX vent arm, Orbiter Access Arm, and Tail Service Masts showed slight but normal launch damage except for a broken window on the southwest side of the GOX vent hood. The pieces of the plastic window were found at the pad perimeter. The GH2 vent arm was latched. However, the north saddle stabilizer rod had lodged between the latches due to a misalignment. Although PR PV6-136757 was written against the vent line latching off-center, this was not an anomalous condition and PR disposition consisted of taking alignment measurements and checking bushings.

The Shuttle Thermal Image (STI) units located at Camera Site 2 and on the roof of the RSS sustained no launch damage and were operational after launch. Both housings were coated with SRB residue.

Overall, there was very little damage to the pad.

Patrick AFB and MILA radars had been reconfigured again for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent. Although the signals were very weak, a total of 45 objects were detected in the time frame T+137 (180,000 feet altitude) through 296 seconds

(381,860 feet altitude). 31 of the objects were detected by the MILA radar, 42 by the 014 radar, and only 28 objects were imaged by the 28-14 radar. Seventy percent of all these objects were imaged in the 137-170 second time frame. Since the lower right BSM cover was missing from the LH SRB at the time of recovery, particular attention was focused on the time of SRB separation. However, all objects exhibited very low reflectivity and none were metallic. The radar data cannot provide specific object characteristics of the low reflectivity objects, such as size and material type.

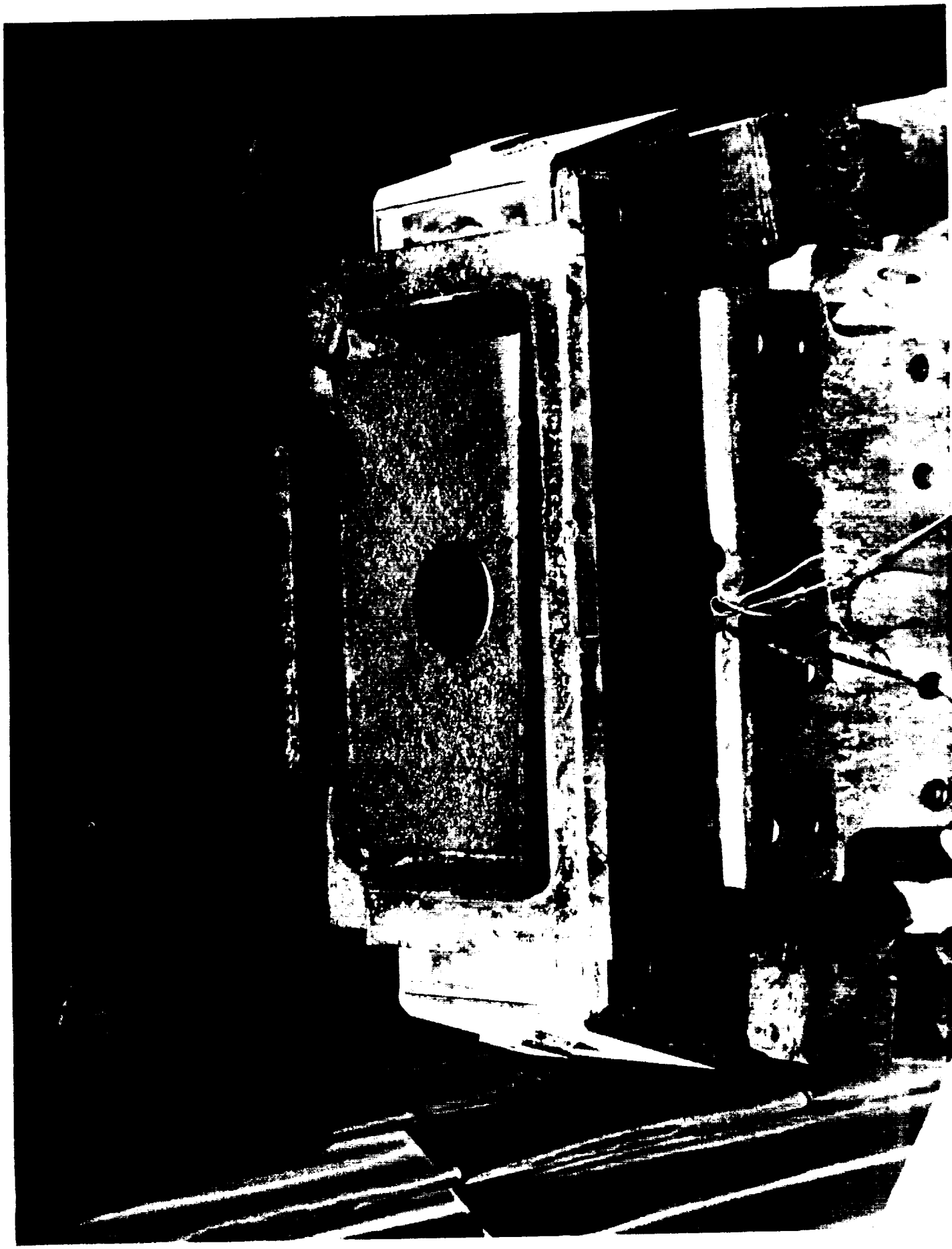
The debris inspection continued on 9 August 1989 and was expanded to include areas outside the perimeter fence. Ground teams searched the beach, railroad tracks, and beach access road from the northern KSC boundary to the Titan complex. The NASA helicopter was utilized to cover the water areas around the pad, the beach from the Cape lighthouse to a point 10 miles north of the pad, and the ocean area under the flight path. The only flight hardware found consisted of an base heatshield Q-felt on the railroad tracks east of the beach road.

Observed Post Launch Anomalies are listed in Section 10.0.

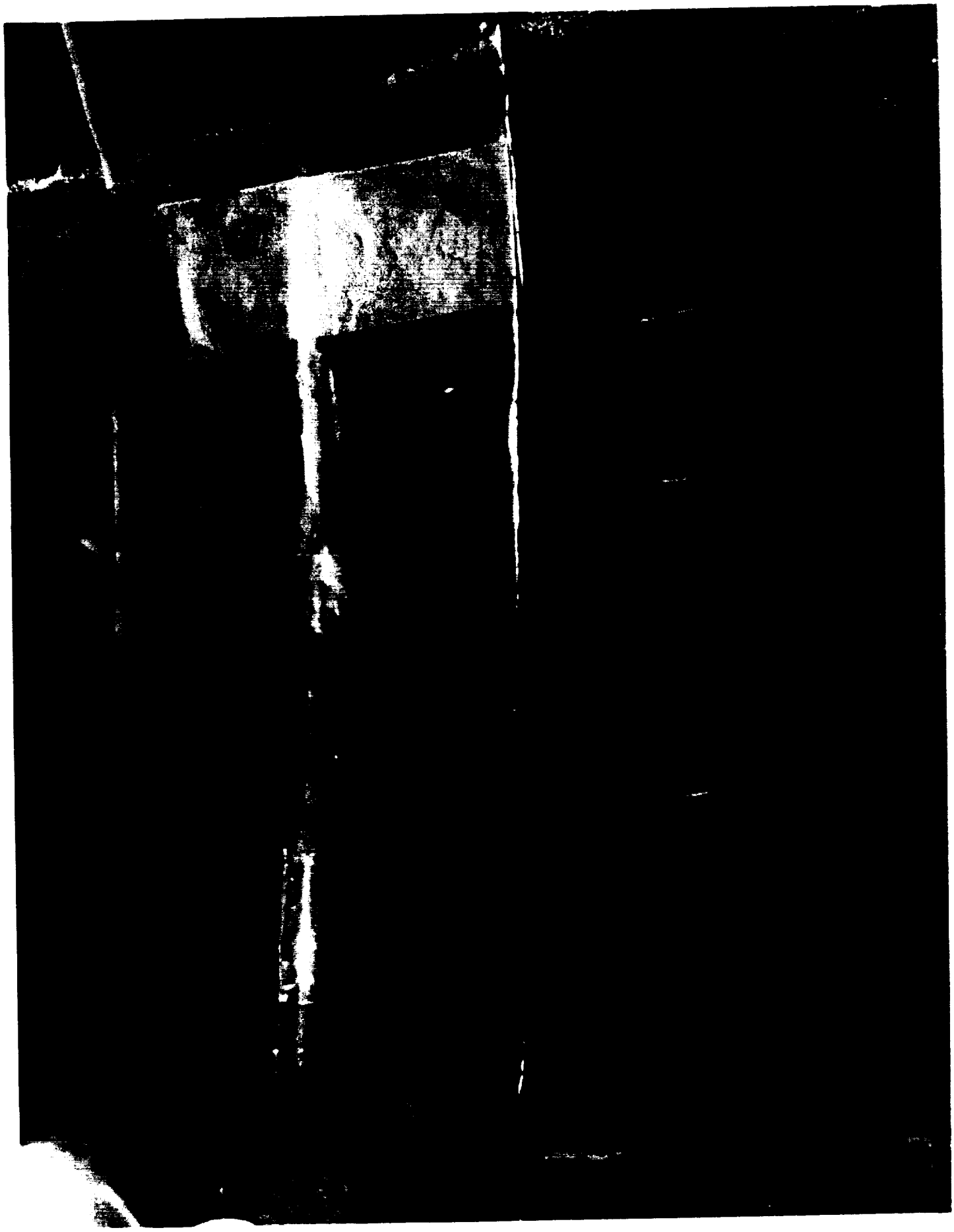
TYPICAL ORBITER Q-FELT PLUGS, SSME INSULATION TRIMMINGS, AND SRB THROAT PLUG MATERIAL RECOVERED AFTER LAUNCH

POST LAUNCH CONDITION OF LH SRB HOLDDOWN POSTS

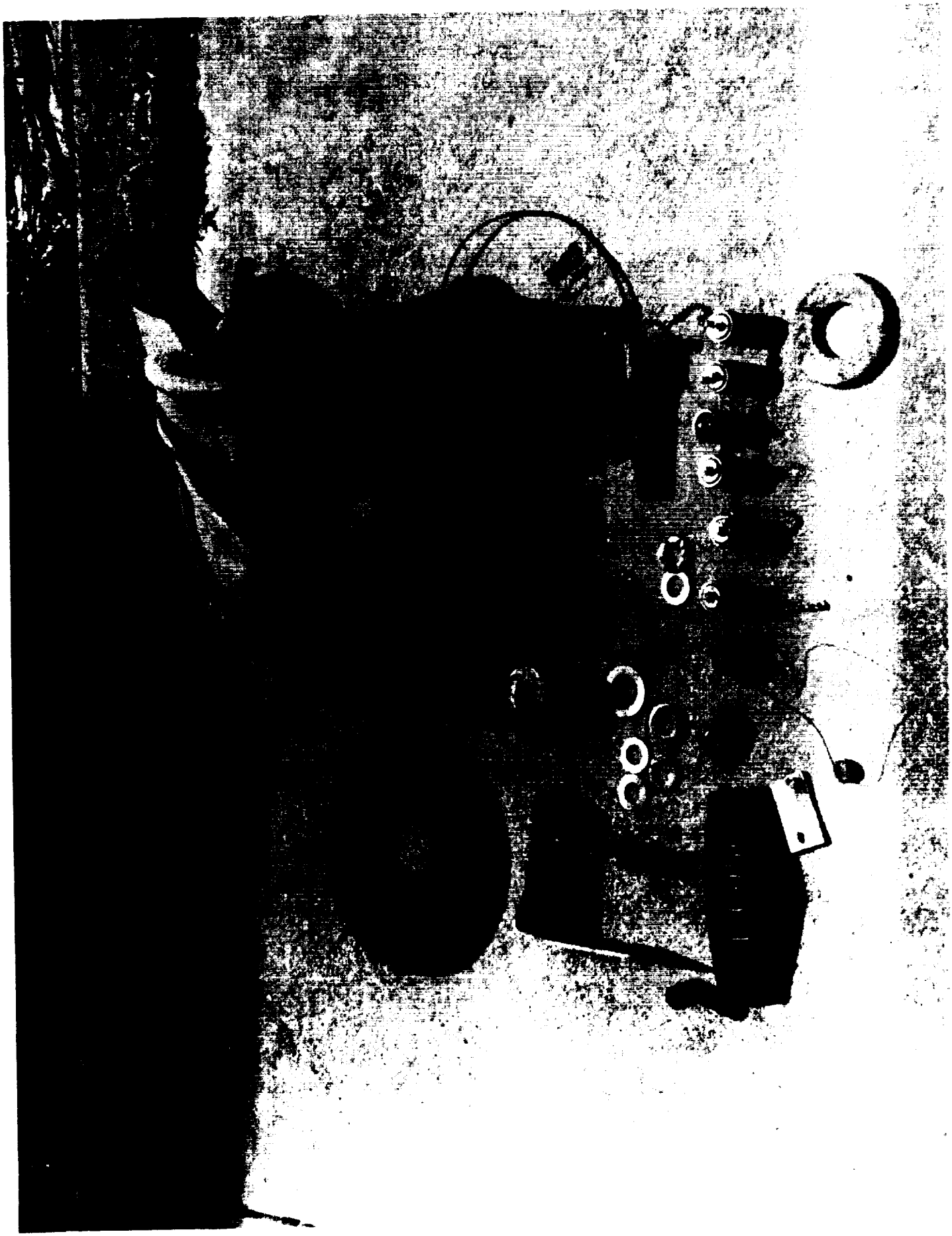
NORTH HOLDDOWN POSTS SUSTAINED NEGLIGIBLE EROSION. DOGHOUSE BLAST COVERS HAD CLOSED PROPERLY



SOUTH HDP SHIM SIDEWALL MATERIAL DEBONDED FROM THE HDP SHOE



PLUNGER FRANGIBLE ATTACH STUDS RECOVERED FROM THE SRB SOUTH HOLDDOWN POST STUDS



TYPICAL TYPES OF FACILITY DEBRIS COLLECTED AFTER LAUNCH

MATERIAL FOUND ON THE MLP DECK MAY HAVE ORIGINATED FROM THE HAMMERHEAD CRANE LEVEL OF THE FSS

GH2 VENT ARM LATCHED, BUT WAS CAPTURED 'OFF-CENTER'

6.0 FILM REVIEW SUMMARY/PROBLEM REPORT DISPOSITION

A total of 133 film and video data items, which included 39 videos, 59 16mm films, 28 35mm films, six 70mm films, and one special film were reviewed starting on launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission. There were no unusual vapors emanating from the ET/ORB umbilicals. However, some tiles on the base heatshield and both aft RCS stingers were chipped by main engine acoustics (E-17, 19, 20, 23). Numerous, small particles of white tile material are shaken loose from the upper surface of the RH elevons during SSME ignition (E-5, 6, 17, 23, 25, 26). During liftoff, a piece of tile gap filler came off the right side of the vertical stabilizer at the interface line between AFRSI blankets and leading edge black tiles (E-34, 76).

One blue and 4 orange tile shims fell from the base heatshield and aft fuselage area during SSME startup (E-5, 6, 18, 19, 20).

A heavy shower of ice and frost particles from the ET/ORB LH2 and LO2 umbilicals fell past the body flap during SSME ignition, but no Orbiter tile damage was visible (E-5, 6, 18, 40).

Movement of the HDP #1 and #5 blast container/plunger housing occurred at T-0 and consisted of two oscillations (EX1, EX4). HDP shim putty material pulled loose (EX1) and HDP #7 shim sidewall lost a piece of material (E-16) as the vehicle rises. Aft skirt instafoam particles and K5NA fragments also shook loose (EX3, EX4, 7, 8, 9, 10, 12). The HDP #7 plunger rubber retainer fell out of the aft skirt stud hole (E-16).

There were no major facility anomalies. No swing arms or other pad structures contacted the vehicle during liftoff. The GUCP leg latched, but was captured off-center. The deceleration cable twisted and the stabilizer rod was caught between the latches. The "S" pulley appeared to have excessive friction (E-39). The two emergency egress slidewire baskets found in the landing zone did not release from the FSS 195 foot level during the time period from SSME ignition through tower clear (E-57, 58, 63, 64, OTV 171).

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

Numerous pieces of debris from the vehicle were visible during ascent. Most have been identified as ice/frost particles from the ET/ORB umbilicals, RCS paper covers from the Orbiter, instafoam particles from the SRB aft skirt, and pieces of foam from the External Tank.

The vehicle overshot the heading during the roll maneuver, but made two course corrections. This is a normal occurrence when the roll angle is high (TV-4).

Movement of the Orbiter body flap was visible during the roll maneuver through most of the ascent (E-59, 207, 221, 222, 223). Maximum body flap deflections occurred between GMT 12:37:49.21 - 12:37:52.83 (Max Q 12:37:49.76). The amplitude of the deflections as measured from E-207 averaged 5.5 +/- 2 inches. The deflection frequency averaged 7.7 - 8.7 Hz (Figure 6).

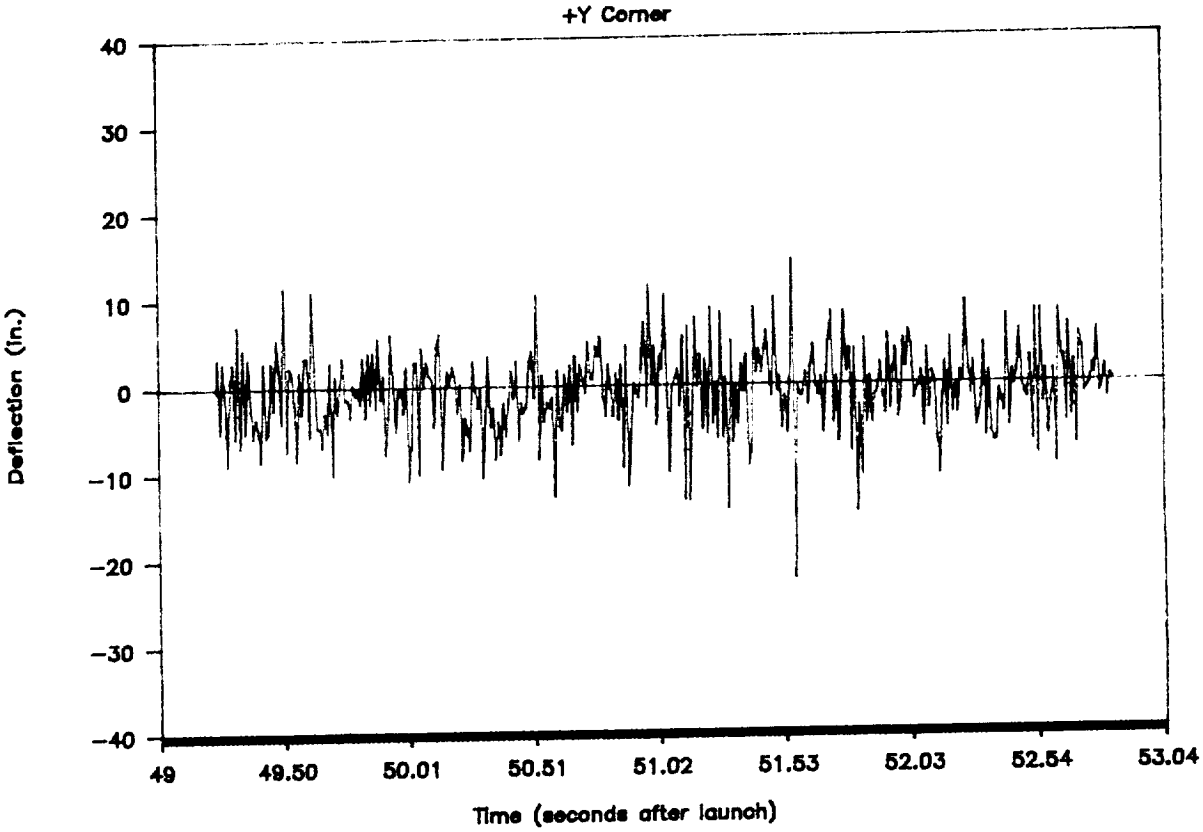
A particle appeared from or behind the LH SRB plume (E-220, TV-4) traveling at a high angle to the plume and falling away from the vehicle. The particle was moving rapidly and appeared to tumble. Size estimate is 24x10x6 inches and is probably foam from the LH SRB aft ring.

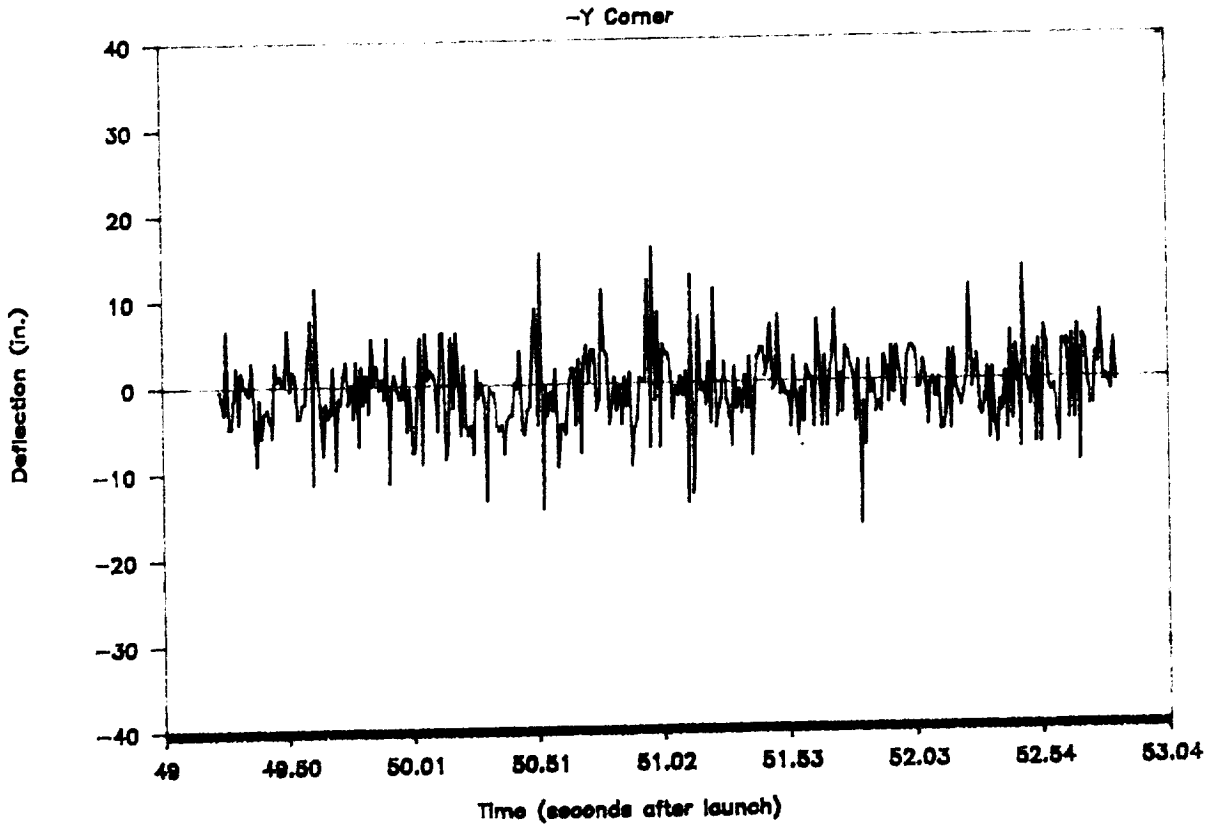
Separation of the SRB frustums and deployment of the parachutes appeared nominal (E-233, 234, 301, 302). However, the presence of the LH SRB forward BSM covers could not be verified from these film items.

Umbilical cameras showed a nominal separation of the LH SRB, but image enhancement could not determine if the missing BSM cover had been intact and in the latched position. The LH2 umbilical cable tray was missing a 4"Wx10"Lx1"deep piece of close out TPS. ET separation was also nominal. The LH2 umbilical flapper valve was totally covered by frozen hydrogen. Although the red RTV seal appeared intact, several pieces of frozen hydrogen adhered to the umbilical face above and below the 17-inch valve and could have formed during umbilical separation. An anomalous condition would exist if the frozen hydrogen had formed before umbilical separation. The TPS along the entire top of the LO2 umbilical was displaced with a loose chunk (18"Wx8"Lx2"deep) in the center and missing pieces at the 11 and 2 o'clock positions. A large 23"Lx15"Wx1"max depth divot occurred in the intertank acreage TPS just above the RH bipod ramp. This divot was located in the vented SOFI area. The shallow depth indicates a cohesive failure internal to the CPR net spray material. The failure occurred prior to L+90 seconds and exhibits a continuation of an intertank char line from ascent heating. This is a first for such a large shallow divot and may be indicative of damaged SOFI during ET processing. The bipods had not rotated or folded away from the Orbiter during ET separation. One 4"x8" divot was visible on the intertank-to-LH2 tank flange right of the PAL ramp (16mm and 35mm umbilical cameras).

LH MLG door extended 0.25 to 0.50 seconds before the right door. Extension of the LH MLG wheel lagged similarly. Elevons oscillated at a high rate prior to and just after main landing gear touchdown. Elevon movement matched control stick inputs and was pilot-induced. Flare angle was greater than usual. At

FIGURE 6. Body Flap Deflection

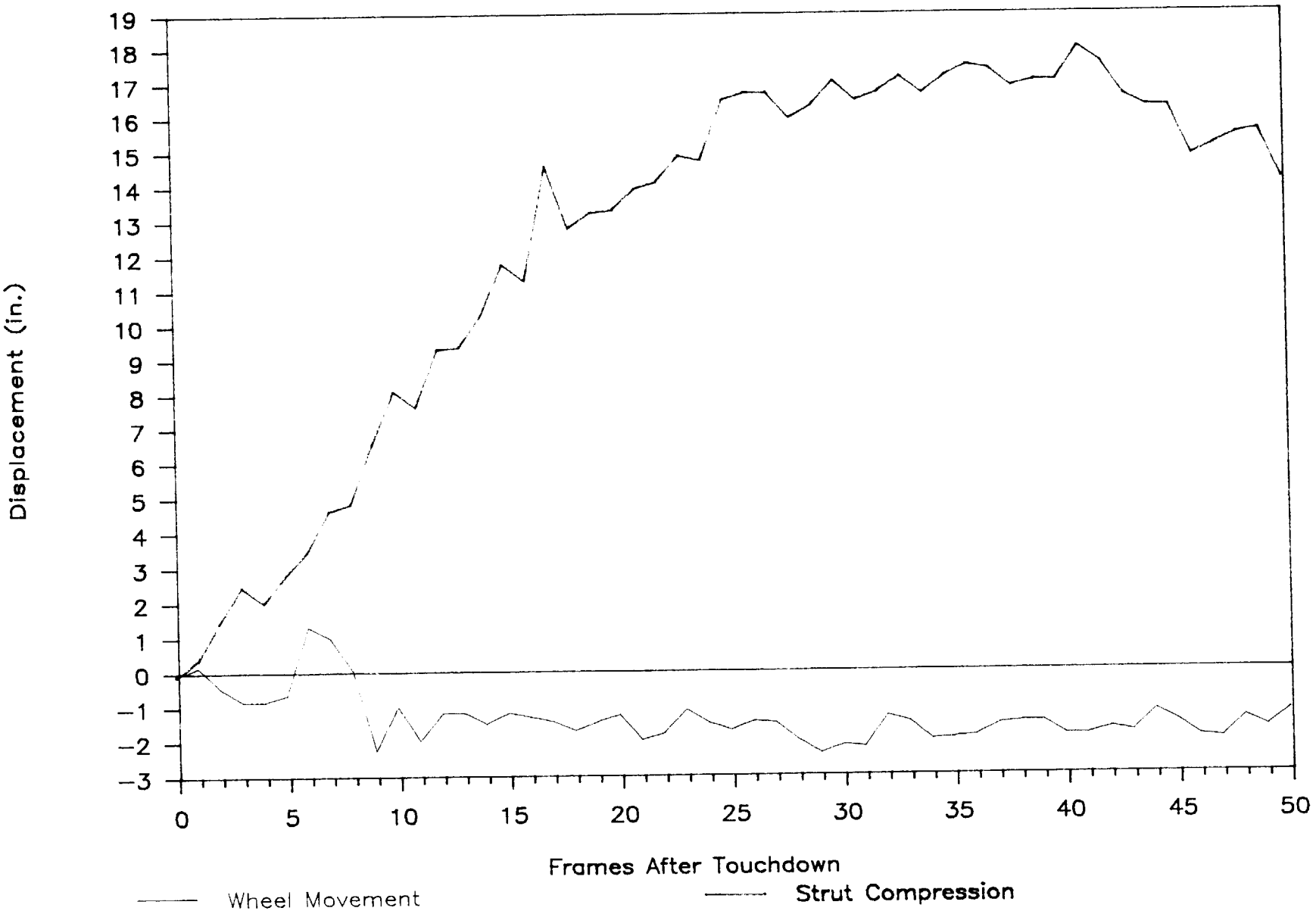




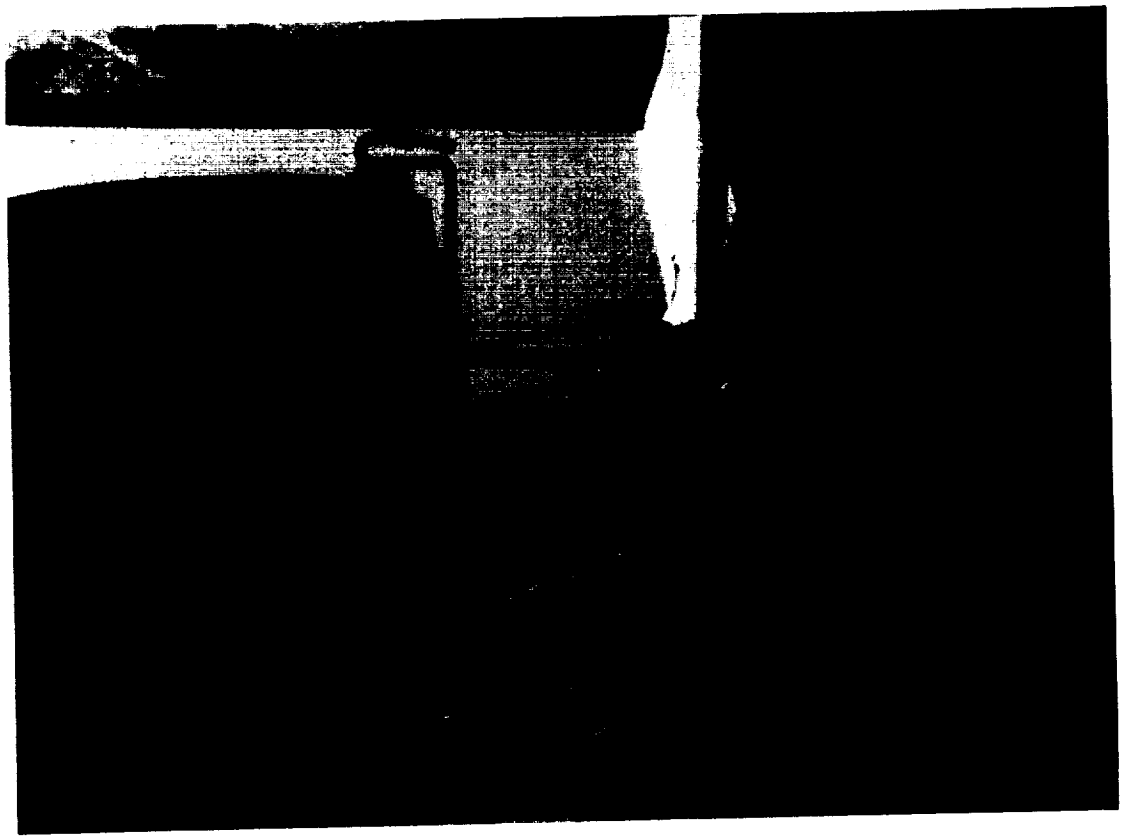
one point, the body flap came within two feet of the runway surface. Due to low airspeed (154 mph) at main gear touchdown, nose sink rate was high and nose gear strut experienced significant forward/aft flex at first contact with the runway. The strut forward/aft flexure as measured on film item E-1001 was 1-2 inches and is graphically illustrated in Figure 7. The strut hydraulic stroke of 21.82 inches was close to the full or maximum stroke of 22 +/- 1 inch (all landing film items).

No PR's or IPR's were generated as a result of the film and video data review. However, photo imagery/data of the roll maneuver, body flap movement, and Orbiter landing were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. Observed Post Launch Anomalies are listed in Section 10.0.

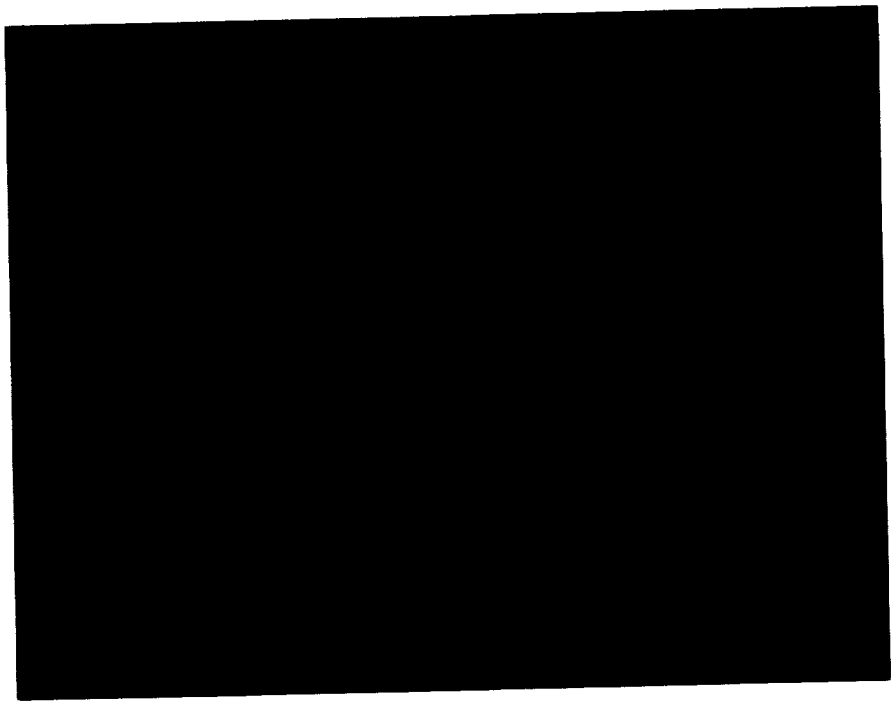
FIGURE 7. STS-28R Nosegear Deflection Study

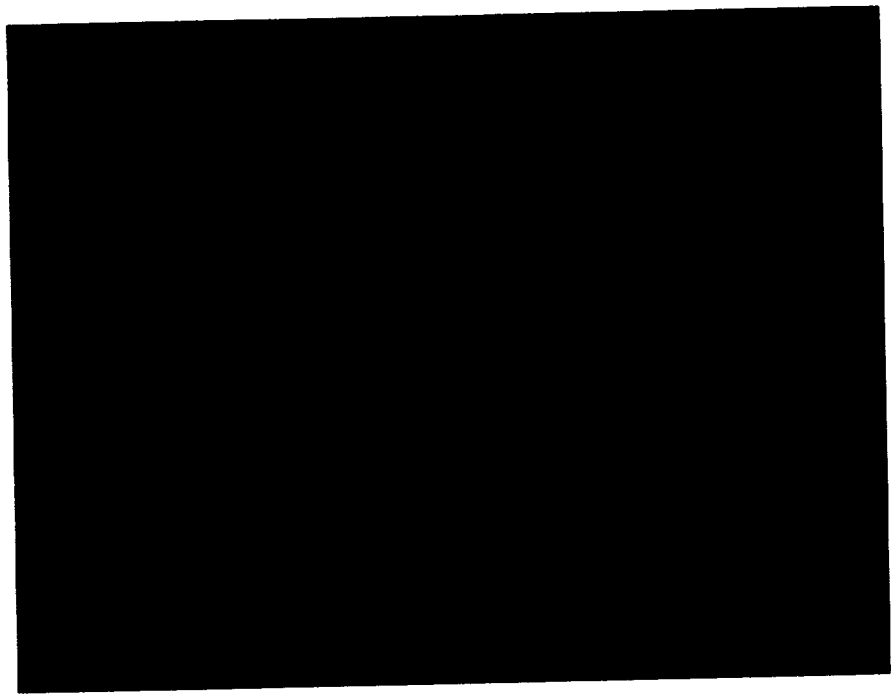


ORIGINAL PAGE
COLOR PHOTOGRAPH



SSME IGNITION CAUSES WHITE TILE MATERIAL TO SHAKE LOOSE FROM THE UPPER SURFACE OF THE RH INBOARD ELEVON

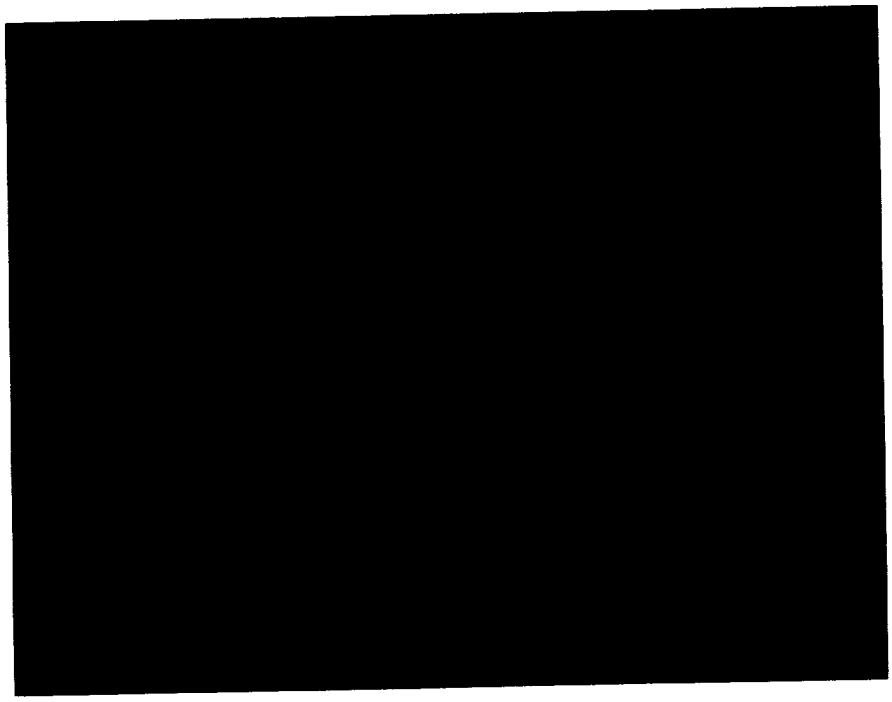


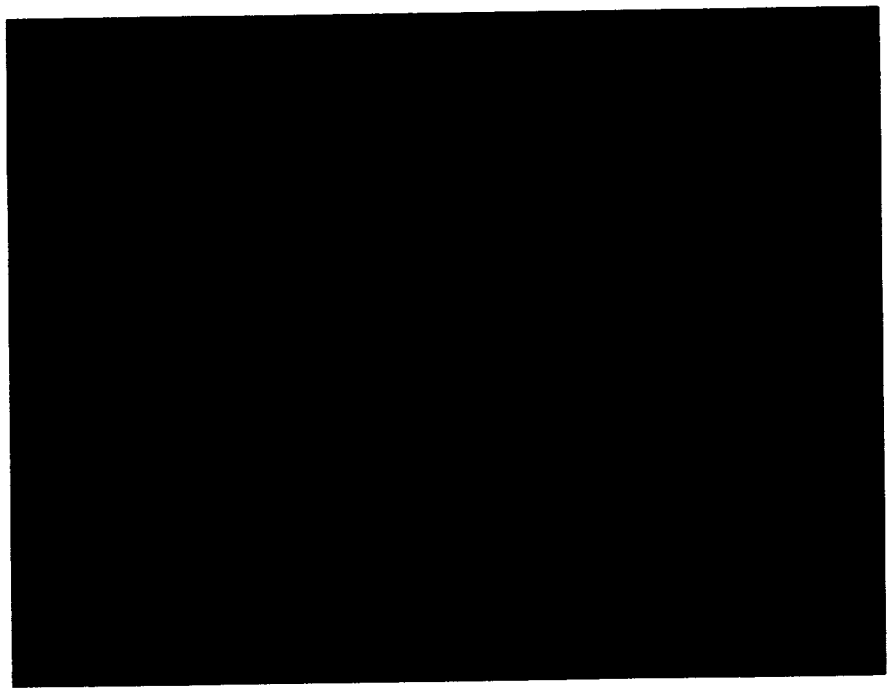


ORIGINAL PAGE
COLOR PHOTOGRAPH

STI INFRARED SCANNER SHOWS BURNING HYDROGEN BLOWN EASTWARD DURING SSME IGNITION

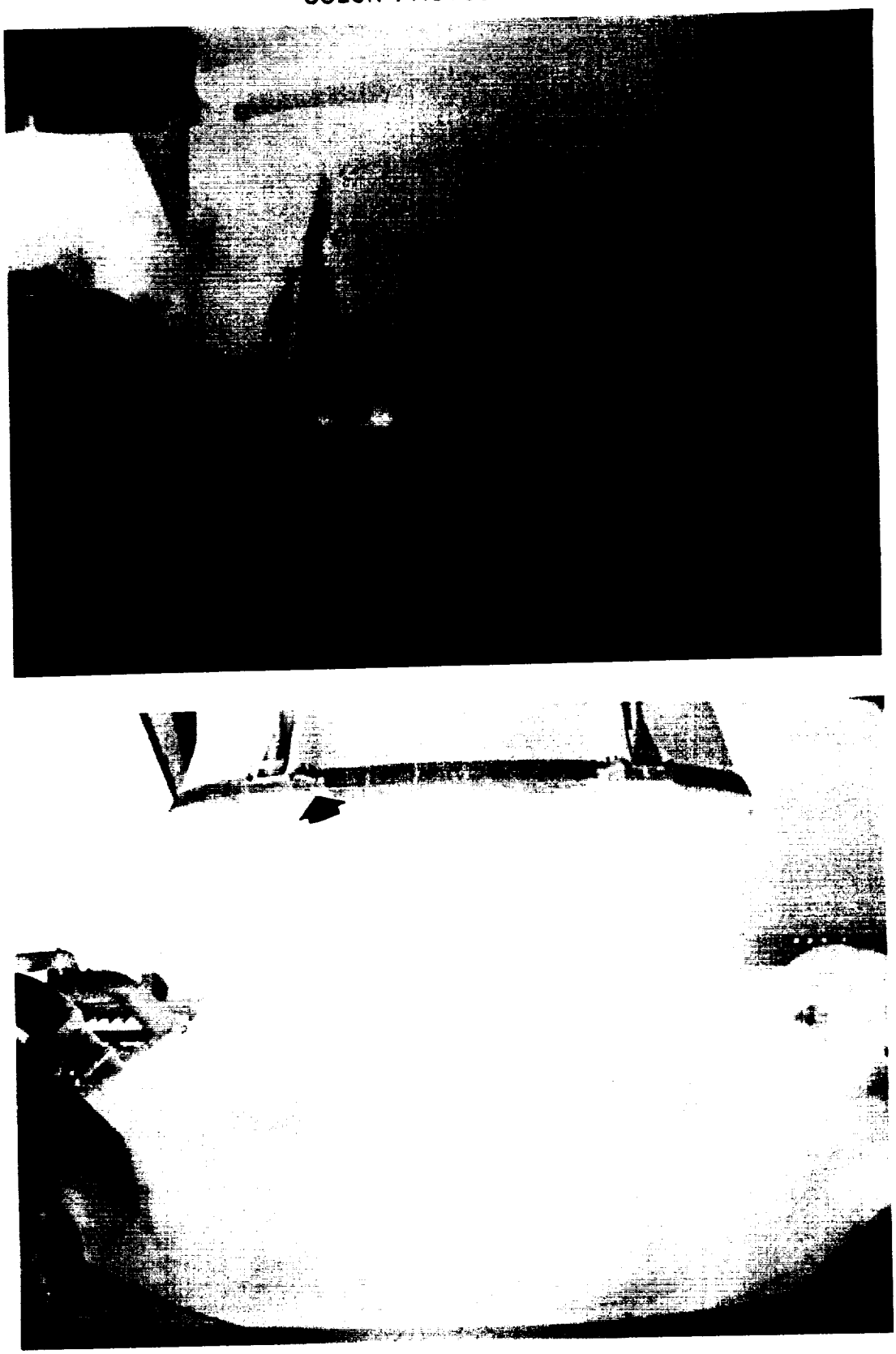
ORIGINAL PAGE
COLOR PHOTOGRAPH



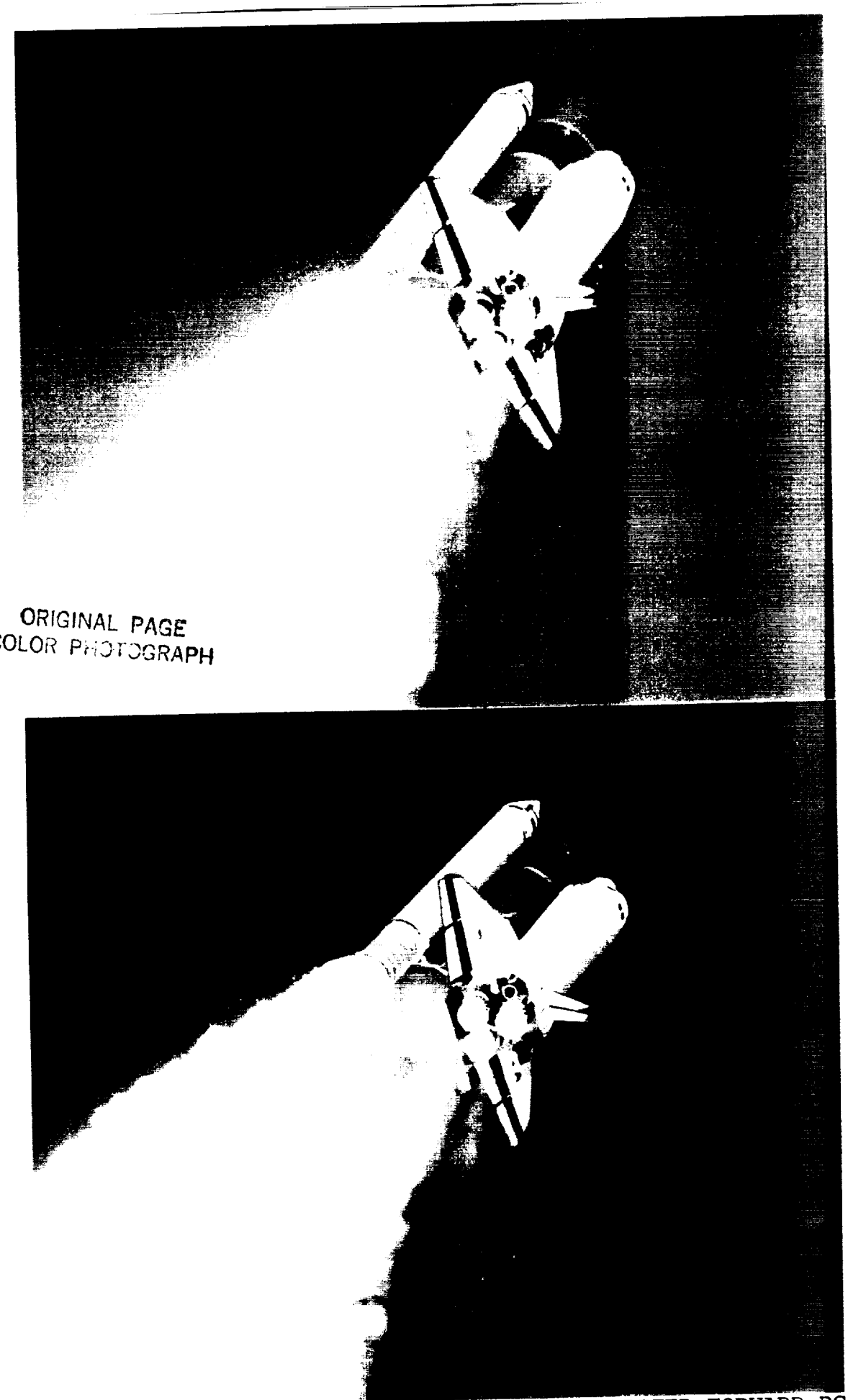


POCKETS OF BURNING HYDROGEN ARE DRAWN BACK INTO SSME EXHAUST PLUME BY ASPIRATION

ORIGINAL PAGE
COLOR PHOTOGRAPH

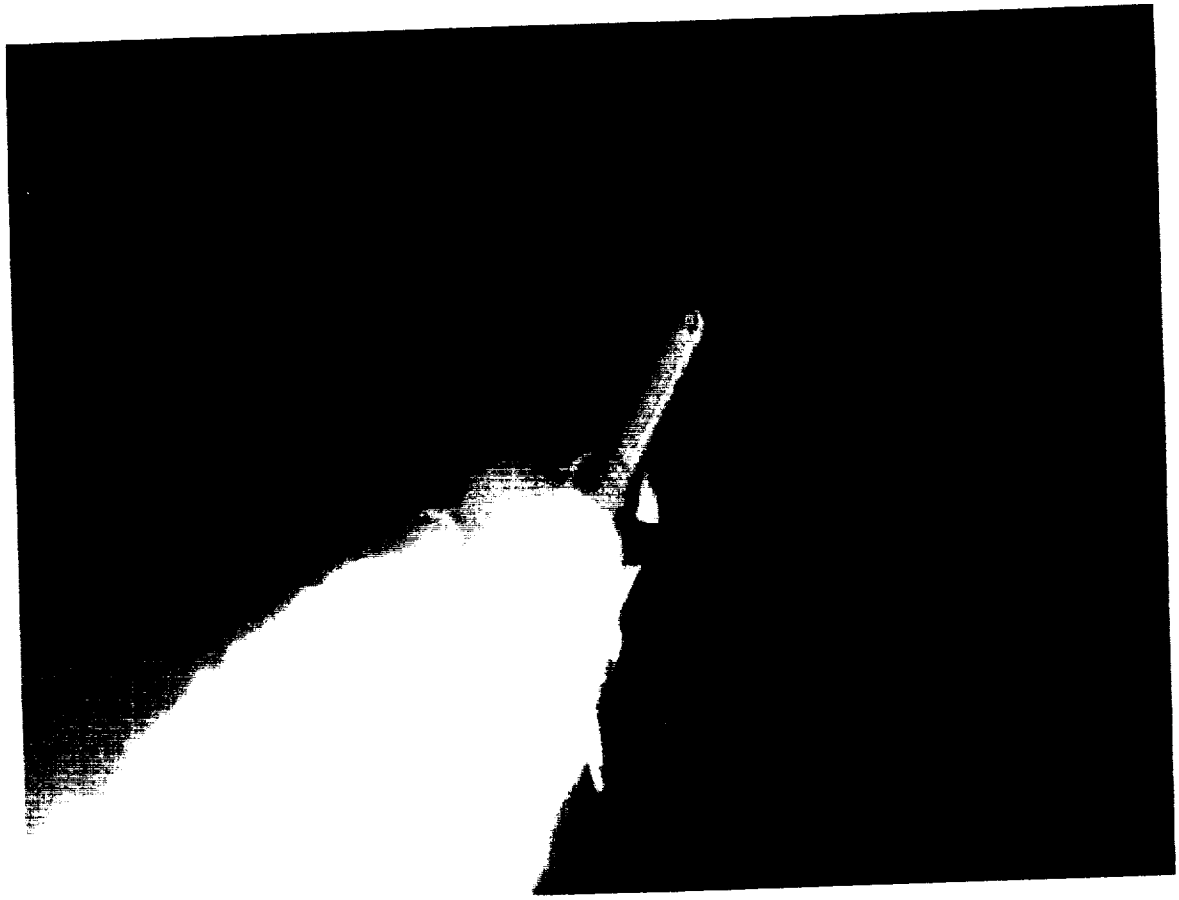


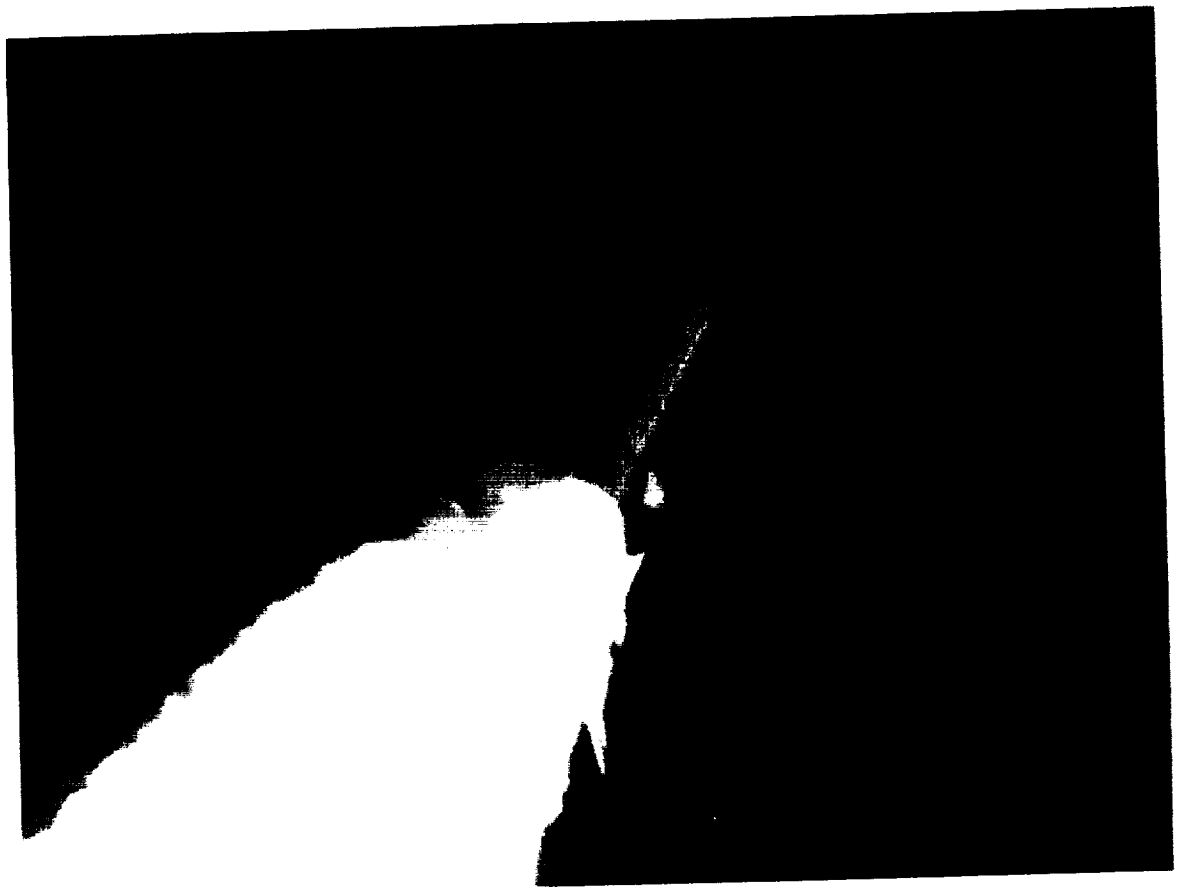
PIECE OF SHIM SIDEWALL MATERIAL FALLS FROM THE HDP #7 FOOT JUST AFTER LIFTOFF



ORIGINAL PAGE
COLOR PHOTOGRAPH

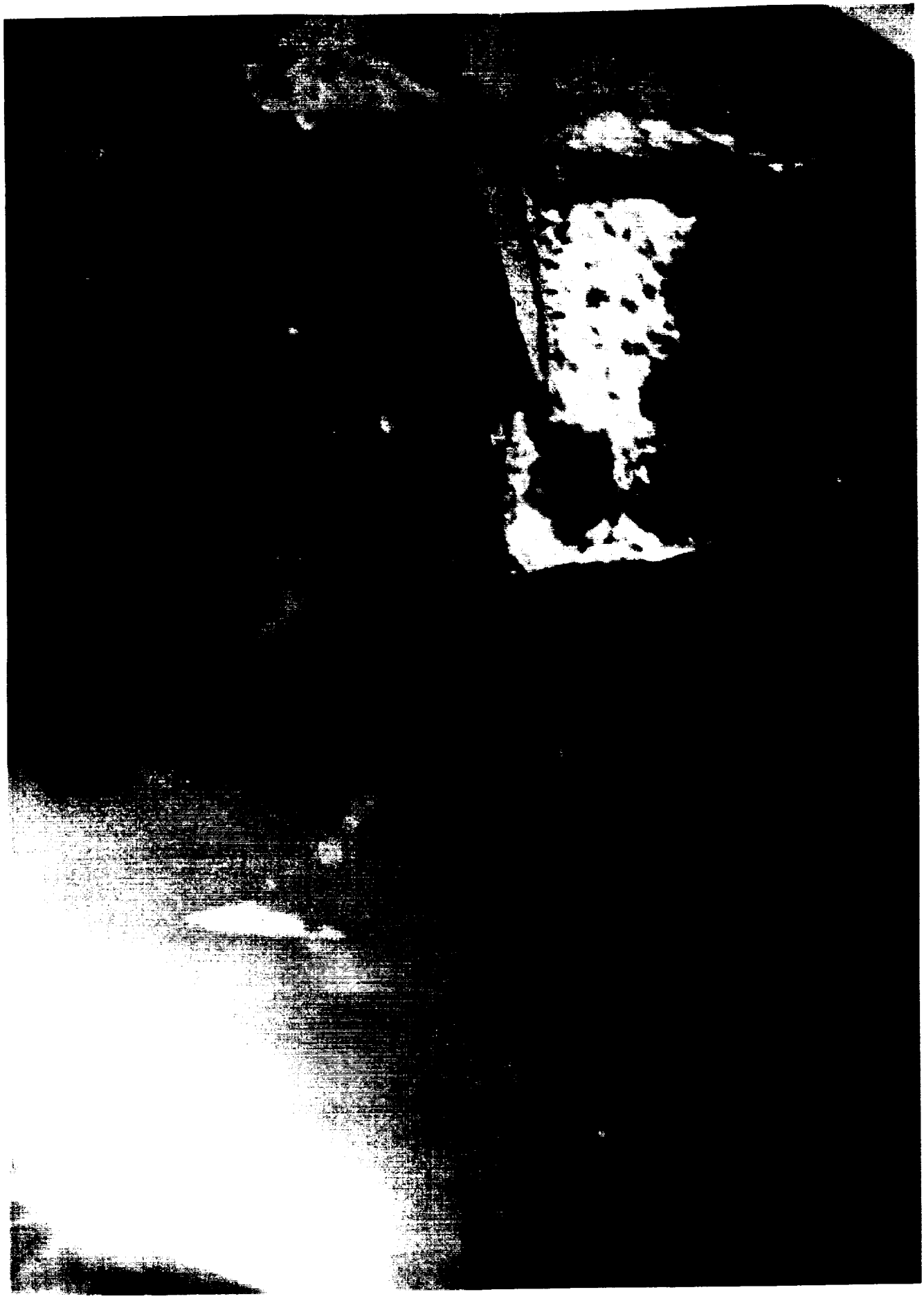
RED & WHITE COLORED PAPER COVERS FROM THE ORBITER FORWARD RCS FALL PAST THE RH WING AND AFT OF THE VEHICLE





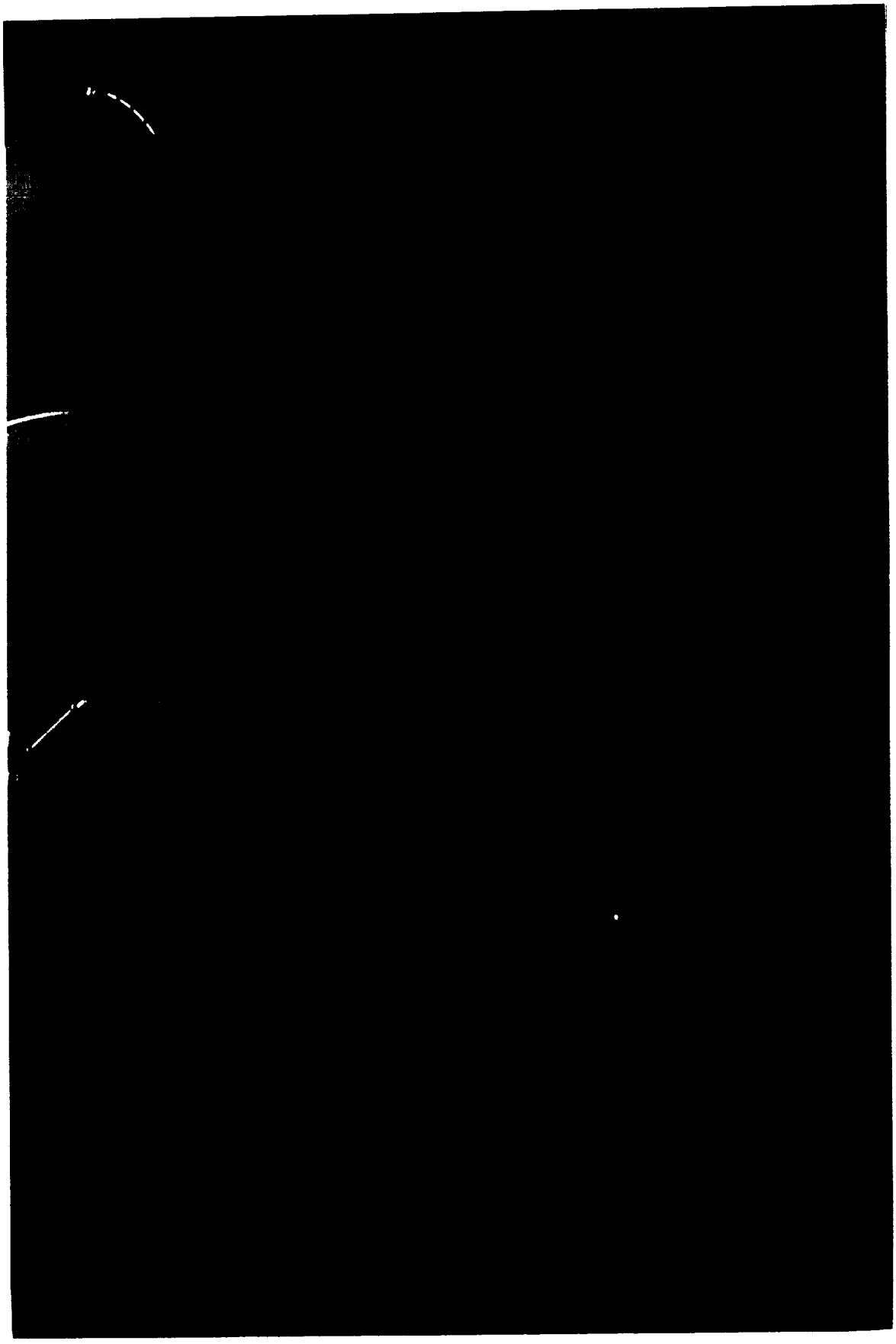
TPS-COLORED OBJECT, PROBABLY INSTAFOAM FROM THE LH SRB AFT RING, FALLS AWAY FROM THE VEHICLE

INDETERMINATE CONDITION OF THE LH SRB FORWARD BSM COVERS.
NOTE EROSION OF THE TPS ON THE LH2 ET/ORB CABLE TRAY

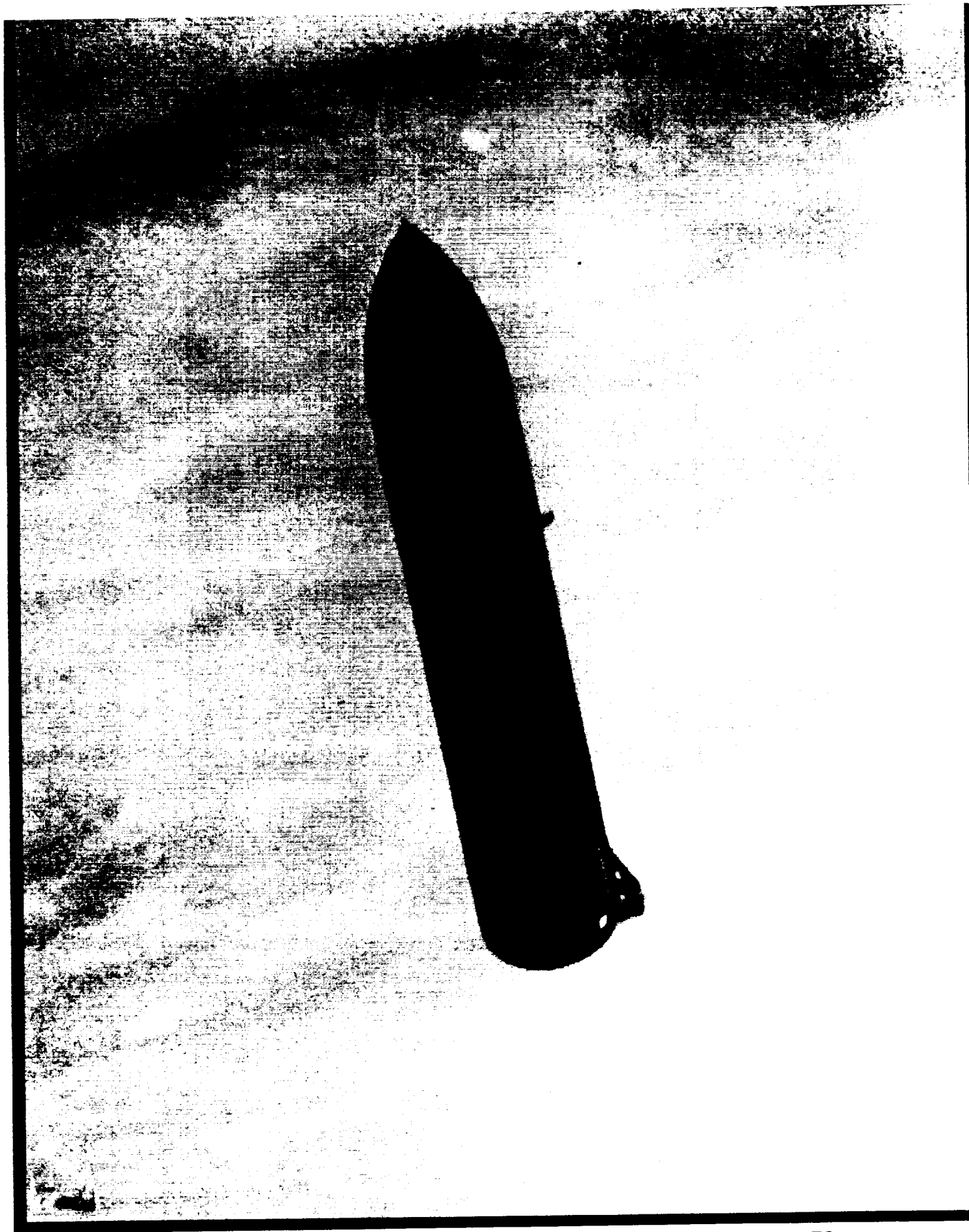


PLUME OF LH2/GH2 INDICATES SEPARATION OF THE LH2 UMBILICAL CARRIER PLATES. EROSION OF CABLE TRAY TPS HAS NOT EXPOSED SLA

TPS IS DAMAGED/MISSING ALONG THE ENTIRE TOP SURFACE OF THE LO2 UMBILICAL. NOTE DIVOTS IN THRUST STRUT FLANGE & ICE IN BELLOWS



TPS DIVOT FORWARD OF RH BIPOD RAMP INDICATES COHESIVE FAILURE IN THE NET SOFI MATERIAL. NOTE SPRAY PATTERN IN THE BSM SCAR.



TPS IS CHARRED FORWARD OF THE LH SRB ATTACH POINTS DUE TO AERO HEATING. BIPODS HAVE NOT ROTATED/FOLDED BACK AGAINST ET.

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 north to view RH SRB Heater Umbilical during ignition and liftoff.

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

Comments: T-0 OCCURS AT FRAME 4158. HDP #1 IS LOCATED AT THE CENTER FOV. SEVERAL PIECES OF DEBRIS APPEAR BEHIND THE HDP PLUNGER HOUSING DURING SSME START-UP. MANY PIECES OF DEBRIS IMPACT THE MLP DECK DURING SSME IGNITION. HDP PLUNGER SPRING HOUSING MOVEMENT OCCURS AT T-0 AND CONSISTS OF 1-2 OSCILLATIONS. HDP SHIM PUTTY MATERIAL PULLS LOOSE AS THE VEHICLE LEAVES THE FOV.

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

Comments: T-0 OCCURS AT FRAME 4216. THE SRB JOINT HEATER UMBILICAL SEPARATION APPEARS NOMINAL. AS THE UMBILICAL AND SRB SEPARATE, SEVERAL PIECES OF DEBRIS COME INTO VIEW FROM THE SRB/ UMBILICAL INTERFACE AREA.

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

Comments: T-0 OCCURS AT FRAME 4194. PIECES OF AFT SKIRT INSTAFOAM COME INTO VIEW FROM AROUND THE HEATER UMBILICAL & SRB INTERFACE DURING SSME STARTUP AND T-0. THE SRB JOINT HEATER UMBILICAL SEPARATION APPEARS NOMINAL.

EX4
400 FPS
16mm

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

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

Comments: T-0 OCCURS AT FRAME 4050. HDP #5 IS IN THE CENTER FOV. SEVERAL PIECES OF DEBRIS APPEAR DURING SSME STARTUP. MOVEMENT OF THE BLAST CONTAINER AND PLUNGER HOUSING OCCURS AT T-0 AND CONSISTS OF TWO OSCILLATIONS. A PIECE OF RUBBER FALLS OUT OF THE AFT SKIRT STUD HOLE (FRAME 4253). SEVERAL PIECES OF SRB AFT SKIRT INSTAFOAM APPEAR AFTER T-0. SEVERAL PIECES OF CORK AND K5NA ORIGINATE FROM THE SRB HDP STRUCTURE FOLLOWING T-0.

E-1
400 FPS
16mm

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

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

Comments: NUMEROUS PIECES OF ICE FALL FROM LH2 AND LO2 ET/ORB UMBILICALS. ROFI AND SSME IGNITION APPEAR NOMINAL. AT FRAME 2020, A BIRD MOVES FROM LEFT TO RIGHT IN BETWEEN THE CAMERA AND THE VEHICLE. SMALL CYLINDRICAL PIECE OF DEBRIS, APPROXIMATELY 1/4 INCH DIAMETER AND 1.5 INCHES LONG, MOVES CLOSE TO CAMERA (PROBABLY LENS TORQUE PIN). T-0 OCCURS AT FRAME 3713. PIECE OF WATER TROUGH NYLON CORD APPEARS FROM THE RH SRB PRIMARY WATER TROUGH AREA AND MOVES UPWARD APPROXIMATELY 35 FEET. AT FRAME 4128, A PIECE OF RCS PAPER COVER FALLS AFT OF SSME #2. LAST EVIDENCE OF ICE FALLING FROM LH2 ET/ORB UMBILICAL IS AT FRAME 4470.

E-2

400 FPS
16mm

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

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

Comments: SSME #3 IGNITION OCCURS AT FRAME 2994. RCS PAPER COVERS ON RH STINGER TEAR AT FRAME 3223. T-0 OCCURS AT FRAME 5136. PIECE OF WATER TROUGH NYLON ROPE EXITS PRIMARY WATER

TROUGH AREA. PARTICLE STRIKES LO2 TSM (FILM ITEM E-1). LH2 TSM UMBILICAL DOOR IS CLOSED BY FRAME 5565. WATER FROM RH SRB STIFFENER RINGS VAPORIZES DURING ASCENT.

E-3
400 FPS
16mm

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

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

Comments: SSME IGNITION OCCURS AT FRAME #1955. RCS PAPER PAPER FROM LH STINGER BEGINS TO TEAR AT FRAME 2264. AT FRAME 3630, A PIECE OF ROPE FALLS BETWEEN CAMERA AND LH2 TSM. T-0 OCCURS AT FRAME 4142. OBJECT (FLAT AND RECTANGULAR) MOVES EASTERLY BETWEEN CAMERA AND LH2 TSM AT FRAME 4363. LO2 TSM UMBILICAL DOOR IS CLOSED BY FRAME 4576.

E-4
400 FPS
16mm

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

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

Comments: SSME IGNITION OCCURS AT FRAME 3000. SEVERAL PIECES OF ICE FALL FROM LH2 AND LO2 ET/ORB UMBILICALS. WATER FROM THE RH AND LH SRB STIFFENER RINGS VAPORIZES. LO2 TSM UMBILICAL DOOR IS CLOSED BY FRAME 5601. AT FRAME 5624, ICE PARTICLE FALLS OUTBOARD OF THE VEHICLE NEAR THE LH SRB. OBJECT, POSSIBLY BIRD, MOVES FROM RIGHT TO LEFT AWAY FROM THE VEHICLE BEGINNING AT FRAME 5772. AT FRAME 6012, FIVE PARTICLES OF GUCP ICE FALL IN THE VICINITY OF THE LH ET/SRB STRUT.

E-5
400 FPS
16mm

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

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

Comments: SSME IGNITION OCCURS AT FRAME 1986. GAP FILLER FROM RH ELEVON PROTRUDES. ONE ORANGE TILE SHIM AND SEVERAL SMALL PIECES OF WHITE TILE MATERIAL FALL FROM UPPER SIDE OF THE RH WING, POSSIBLY FROM THE ELEVONS. T-0 OCCURS AT FRAME 4047. NUMEROUS PIECES OF ICE FALL FROM ET/ORB UMBILICALS. WATER TROUGH NYLON ROPE APPEARS IN FRONT OF RH SRB. PIECE OF GAP FILLER FROM UPPER SURFACE OF BODY FLAP APPEARS AT FRAME 4427. AT FRAME 4362, OBJECT COMING FROM RH SRB MOVES SOUTH AND STRIKES THE LO2 TSM (FILM ITEM E-1).

E-6
200 FPS
16mm

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

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

Comments: SSME IGNITION OCCURS AT FRAME 1312. ICE FALLS FROM ET/ORB LH2 AND LO2 UMBILICALS. RH ELEVON MOVEMENT OCCURS AT T-0. NUMEROUS, SMALL WHITE PARTICLES OF TILE MATERIAL APPEAR FROM +Z SIDE OF WING. A GAP FILLER ORIGINATES FROM ABOVE THE RH WING (FRAME 1694) AND APPEARS AT TOP OF FRAME. A PARTICLE FALLS FROM THE RH INBOARD ELEVON HINGE AREA (FRAME 1710). ICE AND ACLAR BAG MATERIAL FALL FROM ET/ORB LH2 UMBILICAL AS VEHICLE RISES FROM PAD (FRAME 1947). PIECE OF DEBRIS CROSSES FOV (FRAME 2377) FROM RIGHT TO LEFT. PARTICLE ORIGIN IS UNKNOWN, BUT IS FIRST VISIBLE ABOVE THE +Y ET/SRB FAIRING. AS VEHICLE RISES, A RECTANGULAR OBJECT CROSSES FOV TO EAST SIDE OF LO2 TSM. ICE FALLS FROM THE LO2 UMBILICAL AND 3 PARTICLES CONTACT THE ORBITER BODY FLAP, BUT NO TILE DAMAGE IS VISIBLE. WATER VAPORS VENT FROM THE +Y ET/SRB CABLE TRAY DRAIN HOLE.

E-7
400 FPS
16mm

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

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

Comments: T-0 OCCURS AT FRAME 4077. MANY PIECES OF DEBRIS ARE EJECTED FROM SRB EXHAUST HOLE T-0. FOUR SMALL PARTICLES APPEAR AFT OF HDP COVER. A VERY LONG PIECE OF WATER TROUGH MATERIAL APPEARS ABOVE THE MLP DECK. HDP DOGHOUSE BLAST COVER CLOSURE APPEARS NOMINAL. INSTAFOAM OVERSPRAY BREAKS LOOSE FROM AFT SKIRT CLOSEOUT AS VEHICLE RISES.

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

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

Comments: T-0 OCCURS AT FRAME 4163. SMALL PIECES OF HYPALON PAINT AND K5NA FALL FROM THE HDP SHOE DURING LIFT-OFF. SEVERAL SMALL PIECES OF THROAT PLUG MATERIAL ARE PROPELLED OUT OF THE FLAME TRENCH AT T-0. NO DEBRIS FALLS FROM THE AFT SKIRT STUD HOLE AND NO THERMAL CURTAIN TAPE IS LOOSE.

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

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

Comments: CONSIDERABLE CAMERA SHAKE DURING SSME STARTUP. WATER DELUGE SPRAY BLOWS ACROSS FOV. LARGE PIECES OF ICE FROM THE ET/ORB UMBILICALS FALL ONTO MLP DECK DURING SSME IGNITION. WHAT APPEARS TO BE A BIRD IS PULLED INTO THE SSME PLUME BY ASPIRATION (FRAME 2330). T-0 OCCURS AT FRAME 4222. TWO PARTICLES ARE VISIBLE IN THE VICINITY OF HDP #1 AT FRAME 4515.

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

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

Comments: T-0 OCCURS AT FRAME 4232. FACILITY DEBRIS IS VISIBLE ON THE MLP DECK DURING SSME START-UP. A VERY LONG PIECE OF WATER TROUGH CHORD RISES ABOVE THE MLP DECK AS VEHICLE LEAVES THE FOV. NO PARTICLES FALL FROM THE AFT SKIRT STUD HOLE. TWO PIECES OF AFT SKIRT CLOSEOUT FOAM FALL ADJACENT TO HDP SHOE DURING LIFT-OFF. THE DOGHOUSE BLAST COVER APPEARS TO CLOSE NOMINALLY.

E-11
400 FPS
16mm

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

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

Comments: T-0 OCCURS AT FRAME 4236. MANY PIECES OF FACILITY DEBRIS ARE VISIBLE ON THE MLP DECK DURING SSME START-UP. A PIECE OF AFT SKIRT CLOSEOUT FOAM HITS THE MLP DECK AT T-0 (FRAME 4375). A PIECE OF FOAM APPEARS IN FOV AS VEHICLE RISES FROM PAD (FRAME 4565). THE HDP DOGHOUSE BLAST COVER CLOSURE APPEARS NOMINAL. NO PARTICLES FALL FROM THE AFT SKIRT HDP STUD HOLE.

E-12
400 FPS
16mm

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

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

Comments: K5NA FRAGMENTS FROM THE BSM CLOSEOUTS COME INTO VIEW FROM BETWEEN THE NOZZLES AT FRAMES 2019 AND 2475. TWO PIECES OF HARD ICE FROM THE ET/ORB LH2 UMBILICAL IMPACT THE MLP DECK. PIECES OF INSTAFOAM ARE PROPELLED OUT OF THE SRB EXHAUST HOLE BY SRB IGNITION. NO FRAGMENTS DROP FROM THE AFT SKIRT HDP STUD HOLE. A SOFI-COLORED OBJECT WITH A RED SPOT COMES INTO VIEW AT FRAME 4423. ORIGIN IS UNKNOWN, BUT MAY BE A BIRD.

E-13
400 FPS
16mm

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

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

Comments: SOME OF THE FREE BURNING HYDROGEN COMES INTO VIEW AFTER BEING BLOWN UNDER THE BODY FLAP BY THE PREVAILING WIND DURING SSME STARTUP. T-0 OCCURS AT FRAME 4124 AND A SMALL DARK OBJECT APPEARS FROM BEHIND THE BLAST CONTAINER. SEVERAL PIECES OF DEBRIS ARE PROPELLED OUT OF THE EXHAUST HOLE DURING LIFT-OFF. AN OBJECT APPROX. 1 INCH IN DIAMETER, POSSIBLY THE RUBBER BOOT FROM THE PLUNGER, FALLS FROM THE AFT SKIRT HDP STUD HOLE (FRAME 4484).

E-14
400 FPS
16mm

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

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

Comments: SEVERAL PIECES OF DEBRIS ARE EJECTED OUT OF EXHAUST HOLE ADJACENT TO HDP DURING LIFT-OFF. HDP DOGHOUSE COVER CLOSURE APPEARS NOMINAL. NO DEBRIS FALLS FROM AFT SKIRT HDP STUD HOLE.

E-15
400 FPS
16mm

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

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

Comments: SSME IGNITION BEGINS AT FRAME 2224. HPU EXHAUST IS VISIBLE. ICE FROM THE SSME OVERBOARD VENT PORTS BREAKS OFF AT SSME IGNITION. AT FRAME 3874, A SMALL OBJECT ENTERS THE FOV FROM THE RIGHT, MOVES UNDER THE SSME, THEN FALLS FROM THE FOV. T-0 OCCURS AT FRAME 4342. AT LIFTOFF, ICE FALLS FROM THE LO2 ET/ORBITER UMBILICAL AND THE LO2 T-0 UMBILICAL. THE SRB THERMAL CURTAIN TAPE IS INTACT. THE USUAL AMOUNT OF SRB WATER TROUGH AND THROAT PLUG MATERIAL IS VISIBLE AFTER SRB IGNITION. IN FRAME 4701 A PIECE OF RTV CROSSES FROM LEFT TO RIGHT THROUGH THE FOV. IN FRAME 4713, WATER TROUGH ROPE APPEARS IN THE LEFT CENTER FOV. A PARTICLE IS VISIBLE ABOVE HDP #4 IN FRAME 4732. THE HDP DOGHOUSE BLAST COVERS APPEAR TO CLOSE NORMALLY (FRAME 4780).

E-16

400 FPS
16mm

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

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

Comments: SSME IGNITION BEGINS IN FRAME 2200. EXHAUST FROM THE SRB HPU IS VISIBLE. ICE FROM THE SSME OVERBOARD VENT PORTS BREAKS LOOSE AT SSME IGNITION. T-0 OCCURS AT FRAME 4232. AT T-0, ICE FALLS FROM THE LH2 ET/ORBITER UMBILICAL AND THE LH2 T-0 UMBILICAL. THE USUAL AMOUNT OF SRB WATER TROUGH AND THROAT PLUG MATERIAL APPEARS AFTER SRM IGNITION AND THE THERMAL CURTAIN TAPE

IS INTACT. SHIM MATERIAL FROM THE FOOT OF HDP #7 COMES LOOSE IN FRAME 4437. THE HDP DOGHOUSE BLAST COVERS APPEAR TO CLOSE NORMALLY.

E-17
400 FPS
16mm

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

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

Comments: FREE HYDROGEN BURNS AND CAUSES HEAT WAVES TO RISE PAST THE LO2 T-0 UMBILICAL. RCS PAPER COVERS TEAR AND THE BODY FLAP MOVES DURING SSME STARTUP. ICE FALL FROM THE ET/ORB LO2 UMBILICAL AND THE LO2 T-0 UMBILICAL/TSM. A SHOWER OF WHITE TILE PARTICLES APPEARS FROM THE +Z SIDE OF THE INBOARD ELEVON. RETRACTION OF THE LO2 T-0 UMBILICAL IS NOMINAL. TWO CHIPS ON LH RCS STINGER TILES ARE VISIBLE AS THE VEHICLE RISES.

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

Comments: HEAT WAVES FROM BURNING HYDROGEN RISE TO THE LH2 T-0 CONNECTIONS. RCS PAPER COVERS TEAR AND THE ORBITER BODY FLAP MOVES DURING SSME STARTUP. TWO ORANGE TILE SHIMS, ONE OF WHICH ORIGINATES FROM THE BASE HEAT SHIELD, APPEAR AT FRAME 2836. ONE BLUE TILE SHIM AND ONE PARTICLE ORIGINATE FROM THE SIDE OF THE ORBITER NEAR THE LOWER LEFT CORNER OF THE LH2 T-0 CARRIER PLATE (FRAME 3180). THE BLUE SHIM EVENTUALLY BOUNCES OFF SSME #2 NOZZLE. LARGE PIECES OF ICE FROM THE ET/ORB LH2 UMBILICAL FALL PAST THE BODY FLAP WITHOUT CONTACTING OR DAMAGING TILES. RETRACTION OF THE LH2 T-0 UMBILICAL IS NOMINAL.

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

Comments: DURING SSME STARTUP, RCS PAPER COVERS TEAR AND A TILE CHIPS ON THE RH STINGER. ICE PARTICLES FALL FROM THE LO2 T-0 UMBILICAL. SSME IGNITION APPEARS NOMINAL. AN ORANGE TILE SHIM APPEARS FROM BEHIND SSME #1 AT FRAME 6075. LO2 T-0 RETRACTION IS NORMAL.

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

Comments: RCS PAPER COVERS TEAR AND ONE TILE CHIP APPEARS ON THE LH STINGER DURING SSME IGNITION. A SECOND TILE CHIP IS VISIBLE ON THE SSME #3 HEATSHIELD INTERFACE. TWO ORANGE TILE SHIMS FALL FROM BEHIND THE LH STINGER AND ARE PULLED INTO SSME PLUME (FRAME 3012). A THIRD ORANGE TILE SHIM ORIGINATES FROM THE BASE HEAT-SHIELD (FRAME 3242) WHILE A FOURTH APPEARS FROM BEHIND SSME #1 (FRAME 4679). SSME IGNITION IS NORMAL. RCS PAPER COVER PIECES CONTINUE TO FALL THROUGHOUT IGNITION SEQUENCE. RETRACTION OF LH2 T-0 UMBILICAL IS NOMINAL.

E-21
200 FPS
16mm

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

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

Comments: CLOSING OF THE LO2 TSM DOOR APPEARS NOMINAL. FOLLOWING DOOR CLOSURE, SEVERAL PIECES OF DEBRIS APPEAR INSIDE THE TSM.

E-22
200 FPS
16mm

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

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

Comments: CLOSURE OF THE LH2 TSM DOOR APPEARS NOMINAL. FOLLOWING DOOR CLOSURE, SEVERAL PIECES OF DEBRIS AND THE PURGE BAGGIE APPEAR INSIDE THE TSM.

E-23
400 FPS
16mm

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

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

Comments: SSME STARTUP OCCURS AT FRAME 2249. TILE CHIP FALLS FROM +Y STINGER AFT EDGE DURING SSME IGNITION (FRAME 2557). ICE FALLS FROM LO2 TSM AND TRAVERSES FOV AFT OF STINGER DURING SSME START. THREE PARTICLES FALL AFT OF RH INBOARD ELEVON +Z SURFACE DURING LIFT-OFF. LO2 TSM DOOR CLOSURE APPEARS NOMINAL.

E-24
400 FPS
16mm

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

Comments: CAMERA MALFUNCTION

E-25
400 FPS
16mm

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

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

Comments: ET/ORBITER UMBILICAL ICE AND WHITE TILE MATERIAL FROM THE +Z SIDE OF THE ORBITER WING FALL DURING SSME IGNITION. NORMAL ELEVON MOTION OCCURS. IN FRAME 3977, A PARTICLE APPEARS FROM THE +Z SIDE OF THE ORBITER WING AT MID-SPAN. THE USUAL THROAT PLUG MATERIAL AND WATER TROUGH PIECES ARE EJECTED FROM THE SRB FLAME HOLE AREA. AFTER LIFTOFF, SOME PIECES OF SRB THROAT PLUG MATERIAL ARE PROPELLED UPWARD OUT OF THE SRB EXHAUST HOLE AND FALL BACK FROM THE ET/SRB STRUT AREA (FRAME 5653). SRB THERMAL CURTAIN TAPE IS INTACT. STARTING AT FRAME 6055, THREE THROAT PLUG PARTICLES APPEAR IN THE TOP OF THE FOV AND FALL TOWARDS THE LEFT.

E-26
400 FPS
16mm

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

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

Comments: ET/ORBITER UMBILICAL ICE AND WHITE TILE MATERIAL FROM THE +Z SIDE OF THE ORBITER WING FALL DURING SSME IGNITION. NORMAL ELEVON MOTION OCCURS. ICE FALLS FROM THE LH2 T-0 UMBILICAL AT LIFTOFF. GH2 VENT LINE RETRACTION IS NORMAL.

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

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

Comments: T-0 OCCURS AT FRAME 4160. MANY PIECES OF DEBRIS ARE EJECTED OUT OF THE EXHAUST HOLE DURING LIFTOFF. SMALL DARK FACILITY DEBRIS ORIGINATED FROM THE HDP #4 AREA AFTER T-0. HDP 3 AND 4 DOGHOUSE BLAST COVERS APPEAR TO CLOSE NOMINALLY.

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

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

Comments: T-0 OCCURS AT FRAME 4154. SEVERAL PIECES OF DEBRIS, INCLUDING DARK FACILITY DEBRIS, ARE EJECTED FROM SRB EXHAUST HOLE AT T-0. HOLDDOWN POSTS #7 AND 8 DOGHOUSE BLAST COVERS APPEAR TO CLOSE NOMINALLY. NO DEBRIS FALLS FROM AFT SKIRT HDP 7 AND 8 STUD HOLES.

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

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

Comments: SSME START-UP OCCURS AT FRAME 1912. T-0 OCCURS AT FRAME 4026. FREE BURNING HYDROGEN IS VISIBLE ADJACENT TO THE ORBITER BODY FLAP -Z SIDE DURING SSME IGNITION (FRAME 1727). ICE FALLS FROM THE LO2 AND LH2 UMBILICALS DURING SSME STARTUP. ICE FALLS FROM THE GUCP AT T-0. DARK FACILITY DEBRIS APPEARS ALONGSIDE THE LH SRB OUTBOARD SIDE DURING SSME IGNITION.

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

Comments: T-0 OCCURS AT FRAME 644. ICE/FROST PARTICLES FALL FROM THE LH2 AND LO2 UMBILICALS DURING SSME START-UP AND T-0. LH ELEVON MOVES DURING SSME STARTUP. NORMAL AMOUNT OF VAPOR (PURGE GAS) IS VENTED AT THE LH2 UMBILICAL DURING SSME IGNITION. WATER VAPOR ORIGINATES FROM THE ORBITER TILES. CONDENSATE ON THE ET AFT DOME VAPORIZES. A PIECE OF LOOSE WATER TROUGH CHORD APPEARS AS THE VEHICLE RISES FROM THE PAD. THIRTEEN PIECES OF DEBRIS ARE VISIBLE DURING LIFT-OFF. A BIRD TRAVERSES FOV FROM LEFT TO RIGHT AND DOES NOT APPEAR TO STRIKE THE VEHICLE. A SMALL LIGHT COLORED OBJECT FALLS AFT OF THE LH2 TSM AT LIFT-OFF (FRAME 1269).

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

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

Comments: T-0 OCCURS AT FRAME 3434. ICE PARTICLES FALL FROM THE GUCP DURING SSME START-UP AND T-0. THE GUCP/ET SEPARATION IS NOMINAL.

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

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

Comments: TWO ICE PARTICLES FROM THE GUCP FALL ALONG SIDE OF THE LH SRB DURING SSME IGNITION. GH2 VENT LINE DISCONNECT AND RETRACTION IS NOMINAL. NO VEHICLE ANOMALIES ARE VISIBLE. ICE/FROST PARTICLES FROM ET/ORB UMBILICALS AND PIECES OF RCS PAPER COVERS CONTINUE TO FALL WHILE VEHICLE RISES. CONDENSATE DRIPS FROM VERTICAL STABILIZER. A WHITE PARTICLE, POSSIBLY A TILE CHIP, IS FIRST VISIBLE NEAR THE VERTICAL STABILIZER, CROSSES THE BLACK

RUDDER HINGE (FRAME 5868), AND EVENTUALLY IS PULLED INTO THE SSME PLUME (FRAME 6002). A FACILITY CABLE TRAY COVER ENTERS FOV AT FRAME 7288.

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

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

Comments: TWO ICE PARTICLES FROM THE GUCP FALL ALONG SIDE THE LH SRB DURING SSME IGNITION. T-0 OCCURS AT FRAME 2709. GH2 VENT LINE DISCONNECT AND RETRACTION IS NOMINAL. NO VEHICLE ANOMALIES ARE VISIBLE. WELL AFTER VEHICLE CLEARS FRAME, A CONSIDERABLE AMOUNT OF FACILITY DEBRIS APPEARS AND IS BELIEVED TO BE SCALE FROM THE HAMMERHEAD CRANE LEVEL.

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

Comments: ICE/FROST PARTICLES, BACKLIT BY SSME IGNITION, FALL FROM THE ET/ORB UMBILICALS TO THE MLP DECK. NO DAMAGE TO ORBITER TILES IS VISIBLE. T-0 OCCURS AT FRAME 2490. WELL AFTER VEHICLE CLEARS TOWER, A CONSIDERABLE AMOUNT OF FACILITY DEBRIS IS VISIBLE AND IS BELIEVED TO BE SCALE FROM THE HAMMERHEAD CRANE LEVEL. A FACILITY CABLE TRAY COVER APPEARS AT FRAME 7043.

E-39 Camera is located on the FSS 185 foot level and
400 FPS views GH2 vent line latchback.
16mm

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

Comments: ICE AND FACILITY DEBRIS APPEAR AT T-0. THE GUCP LEG CAPTURE APPEARS TO HAVE OCCURRED "OFF CENTER". THIS MAY HAVE BEEN CAUSED BY THE DECELERATION CABLE TWISTING TO THE SOUTH. THE STABILIZER ROD APPEARS TO BE CAUGHT BETWEEN THE LATCHES. ALSO,

THE "S" PULLEY APPEARS TO HAVE EXCESSIVE FRICTION. IN CONCLUSION, THE GH2 VENT LINE WAS SECURED, EVEN THOUGH THE LATCHBACK MECHANISM FAILED TO WORK PROPERLY.

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

Comments: VEHICLE 'TWANG' APPEARS NORMAL. T-0 OCCURS AT FRAME 2825. MISSING PAPER COVER FROM LH FWD RCS WAS NOTED DURING CRYOGENIC LOADING INSPECTION. NO VEHICLE ANOMALIES ARE VISIBLE. WATER FROM SRB STIFFENER RINGS AND CONDENSATE FROM ET AFT DOME VAPORIZE. NO UNUSUAL VAPORS EMANATE FROM ET/ORB UMBILICALS. ICE/FROST PARTICLES CONTINUE TO FALL FROM THE ET/ORB UMBILICALS, BUT NO DAMAGE TO ORBITER TILES IS VISIBLE. TWO PIECES OF RCS PAPER COVERS FALL AFT OF VEHICLE NEAR SSME #2. RESIDUALS VAPORIZE AT THE ORBITER LH2 T-0 UMBILICAL. AS VEHICLE CLEARS TOP OF FRAME, A PIECE OF DEBRIS WELL AFT OF THE VEHICLE IS PULLED UPWARD. STARTING AT FRAME 5400, A CONSIDERABLE AMOUNT OF FACILITY DEBRIS IS VISIBLE WELL AFTER THE VEHICLE HAS CLEARED THE TOWER. THIS DEBRIS IS BELIEVED TO BE SCALE FROM THE HAMMERHEAD CRANE LEVEL OF THE FSS.

E-41 Camera is located on the FSS 255 foot level and
400 FPS views the GH2 vent line during rotation. Also
16mm shows clearance between structure and SRB aft
skirt.

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

Comments: T-0 OCCURS AT FRAME 2681. THE GH2 VENT ARM RETRACTION APPEARS NOMINAL. CONDENSATE FROM THE ET AFT DOME AND WATER FROM THE LH SRB STIFFENER RINGS VAPORIZES. A DEBRIS PARTICLE FALLS ALONG THE LH SIDE OF THE VEHICLE (FRAME 3124). FACILITY DEBRIS APPEARS AFTER THE VEHICLE LEAVES THE FOV.

E-42 Camera is located on the FSS 185 foot level and
400 FPS views the GH2 vent line drop, deceleration, and
16mm latchback.

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

Comments: A RECTANGULAR PIECE OF FACILITY DEBRIS APPEARS PRIOR TO T-0 (FRAME 1885 TO 1955). TWO PIECES OF FACILITY DEBRIS FALL FROM THE HAUNCH SOUTH SIDE AS THE VENT LINE RETRACTED. THE GH2 VENT LINE RETRACTION AND LATCHBACK APPEAR NOMINAL. SEVERAL PIECES OF ICE FALL FROM THE VENT LINE AFTER LATCHBACK.

E-43 Camera is located on pad surface and views sound
200 FPS suppression water flow distribution beneath MLP.
16mm

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

Comments: VEHICLE PLUME QUICKLY OBSCURES FIELD OF VIEW. THE SOUND SUPPRESSION WATER SYSTEM APPEARS TO FUNCTION NOMINALLY.

E-44 Camera is located on the FSS 155 foot level and
400 FPS views the LH OMS Pod leading edge tiles during
16mm ignition and liftoff.

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

Comments: T-0 OCCURS AT FRAME 4098. THE LO2 TSM UMBILICAL DOOR CLOSES NORMALLY. VAPOR IS VISIBLE NEAR THE ORBITER VERTICAL STABILIZER. A PARTICLE FALLS AFTER THE VERTICAL STABILIZER LEAVES FOV (FRAME 5044). TWO PARTICLES FALL AFT OF THE LH STINGER (FRAME 4640 AND 4811). RESIDUALS FROM THE LH2 T-0 UMBILICAL VAPORIZE AS THE VEHICLE LEAVES FOV.

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

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

Comments: ICE FALLS FROM THE GUCP PRIOR TO T-O AND AS VEHICLE RISES FROM THE PAD. VAPOR DISCHARGES FROM THE GH2 VENT LINE SHORTLY AFTER T-0. A LARGE PIECE OF FACILITY DEBRIS APPEARS AS THE VEHICLE LEAVES THE FOV (FRAME 3807). THE CLEARANCE BETWEEN THE GH2 VENT LINE AND LH SRB WAS NOMINAL.

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

Comments: EARLY RUN - NO DATA

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

Focus : GOOD
F. O. V.: GOOD
Exposure: GOOD

Comments: CONDENSATE FROM ET AFT DOME AND WATER FROM RH SRB STIFFENER RINGS VAPORIZE AS VEHICLE CLEARS TOWER. NO VAPORS ARE VISIBLE AT ET/ORB UMBILICALS. ICE PARTICLES CONTINUE TO FALL FROM ET/ORB UMBILICALS THROUGH TOWER CLEAR. THREE BIRDS IN LOWER FRAME FLY TOWARD CAMERA AWAY FROM VEHICLE. PAPER COVERS FROM RCS NOZZLES FALL OFF VEHICLE FROM TOWER CLEAR THROUGH ROLL MANEUVER. VEHICLE TRACKING IS LOST AFTER ROLL MANEUVER.

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

Focus : GOOD
F. O. V.: GOOD
Exposure: GOOD

Comments: CONDENSATE FROM ET AFT DOME AND WATER FROM RH SRB STIFFENER RINGS VAPORIZE AS VEHICLE CLEARS TOWER. NO VAPORS EMANATE FROM ET/ORB UMBILICALS. ICE PARTICLES CONTINUE TO FALL FROM ET/ORB UMBILICALS THROUGH TOWER CLEAR. THREE BIRDS FLY TOWARD CAMERA AWAY FROM VEHICLE. PAPER COVERS FROM RCS NOZZLES ARE CLEARLY VISIBLE COMING OFF DURING ROLL MANEUVER AND PASSING ALONG VEHICLE RIGHT SIDE INTO PLUME. AFTER ROLL MANEUVER, VIEW OF VEHICLE IS OBSCURED BY SRB PLUME.

E-54 Camera is located at camera site 2 on the east pad
100 FPS perimeter. Remote tracking of upper one-third of
35mm launch vehicle from ignition to 1200 feet.

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

Comments: FRCS PAPER COVERS BEGIN TO FALL OFF DURING ROLL MANEUVER. AT FRAME 2262, NUMEROUS PARTICLES APPEAR FROM LH SRB PLUME, PROBABLY AFT SKIRT INSTAFOAM. AT FRAME 2307, 3 PARTICLES FIRST APPEAR NEAR THE RH WING TIP. SEVERAL PARTICLES ARE VISIBLE AFT OF THE ET AFT DOME AREA.

E-57 Camera is located at camera site 6 on the NW pad
96 FPS perimeter. Remote tracking of lower one-third of
35mm launch vehicle from ignition to 1200 feet.

Focus : GOOD
F. O. V.: GOOD, BUT TRACKING IS ERRATIC
Exposure: GOOD

Comments: CONDENSATE FROM ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE DURING TOWER CLEAR AND EARLY ASCENT. DARK OBJECT IS FIRST VISIBLE AT FRAME 1350 IN SHADED AREA OF -Z SIDE OF ET AND MOVES FROM VEHICLE TO LOWER LEFT FIELD-OF-VIEW. OBJECT HAS CHARACTERISTICS OF FLYING BIRD. TWO PIECES OF RCS PAPER COVER FALL AS VEHICLE ROLLS. NO SIGN OF SLIDEWIRE BASKET RELEASE FROM T-0 THROUGH TOWER CLEAR.

E-58 Camera is located at camera site 6 on the NW pad
96 FPS perimeter. Remote tracking of center one-third of
35mm launch vehicle from ignition to 1200 feet.

Focus : GOOD
F. O. V.: GOOD
Exposure: GOOD

Comments: CONDENSATE FROM ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE FROM TOWER CLEAR THROUGH EARLY ASCENT. NEAR ROLL MANEUVER COMPLETION, MANY RCS PAPER COVERS ARE CLEARLY VISIBLE SEPARATING FROM THE RCS NOZZLES, PASSING ALONGSIDE ORBITER FUSELAGE, AND FALLING INTO PLUME AREA. SRB PLUME BLOCKS VIEW OF VEHICLE IN LATE ASCENT. NO SIGN OF SLIDEWIRE BASKET RELEASE FROM T-0 THROUGH TOWER CLEAR.

E-59 Camera is located at camera site 6 on the NW pad
100 FPS perimeter. Remote tracking of upper one-third of
35mm launch vehicle from ignition to 1200 feet.

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

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE. PAPER COVERS FROM FRCS BEGIN TO FALL OFF AT T+14.42 SECONDS. MOVEMENT OF ORBITER BODY FLAP OCCURS JUST AFTER ROLL MANEUVER (T+17 THROUGH 22 SECONDS).

E-60 Camera is located on north pad perimeter at camera 96 FPS site 1 and views the entire launch vehicle, FSS, 35mm and MLP zero level.

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

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE. RH STINGER PAPER COVERS COME OFF AT FRAME 7510. AT FRAME 8311, PARTICLES ARE VISIBLE AFT OF VERTICAL STABILIZER - MOST LIKELY RCS PAPER COVERS.

E-61 Camera is located at camera site 2 on the east pad
100 FPS perimeter and views the launch vehicle, FSS, and
35mm MLP.

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

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE. AT T+2.2 SECONDS, PARTICLES COME OUT OF RH SRB. PAPER COVERS FROM RH STINGER COME OFF AT T+3.31 SECONDS. AT T+ 3.78 SECONDS, PARTICLE APPEARS AFT OF TAIL (E-34).

E-62 Camera is located on the SE pad perimeter at
96 FPS camera site 3 and views entire vehicle, FSS, and
35mm MLP.

Focus : OK
F. O. V.: OK
Exposure: OK
Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE. AT FRAME 990, A PIECE OF WATER TROUGH MATERIAL MOVES NORTHEAST FROM RH SRB.

E-63 Camera is located on SW pad perimeter at camera
96 FPS site 4 and views entire launch vehicle, FSS, and
35mm MLP.

Focus : VERY GOOD
F. O. V.: VERY GOOD
Exposure: VERY GOOD

Comments: SSME IGNITION IS NORMAL. NO SIGN OF SLIDEWIRE BASKET RELEASE FROM T-0 THROUGH TOWER CLEAR. AT FRAME 1170, A BIRD PASSES FROM BOTTOM TO RIGHT MIDDLE FRAME AND IS NOT NEAR VEHICLE. AT FRAME 1530, DRAGONFLY ENTERS FOV. TWO MORE BIRDS APPEAR AFTER TOWER CLEAR.

E-64 Camera is located on NW pad perimeter at camera
96 FPS site 6 and views entire launch vehicle, FSS, and
35mm MLP.

Focus : GOOD
F. O. V.: GOOD
Exposure: GOOD

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB AFT SKIRTS VAPORIZE AS VEHICLE CLEARS TOWER. AFT DOWNWARD-FIRING RCS PAPER COVER COMES OFF AND PASSES BY LH SRB AFT SKIRT AT TOWER CLEAR.

E-65 Camera is located on east pad perimeter at camera
100 FPS site 2 and views ET LO2 feedline, ET intertank,
16mm and RH SRB as vehicle passes through the frame.

Focus : OK
F. O. V.: TOO HIGH, TOO FAR RIGHT, TOO TIGHT
Exposure: OK

Comments: A SMALL PIECE OF ICE FROM THE STATION 1106 LO2 FEED-LINE BELLOWS FALLS BETWEEN THE ORBITER AND ET. NUMEROUS PARTICLES TRAIL THE ET, THEN FALL BACK. CONDENSATE VAPOR COMES OFF THE ET AFT DOME.

E-76 Camera is located on SE pad perimeter at camera
96 FPS site 3 and views SSME engines #1 and #3 and the RH
35mm OMS engine nozzle.

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

Comments: SSME IGNITION IS NOMINAL. DURING LIFTOFF, A PIECE OF TILE OR TILE SHIM COMES OFF THE RIGHT SIDE OF THE VERTICAL STABILIZER (FRAME 550) AT THE INTERFACE LINE BETWEEN AFRSI BLANKETS AND LEADING EDGE BLACK TILES APPROXIMATELY MIDWAY UP THE VERTICAL STABILIZER. AS THE VEHICLE LIFTS OFF, ICE PARTICLES FROM THE ET/ORB LO2 UMBILICAL APPEAR FROM BEHIND THE BODY FLAP.

E-77 Camera is located on SW pad perimeter at camera
96 FPS site 4 and views SSME engines #1 and #2 and the LH
35mm OMS engine nozzle.

Focus : GOOD
F. O. V.: GOOD
Exposure: GOOD

Comments: SSME IGNITION SEQUENCE APPEARS NORMAL. LH RCS PAPER COVERS COME OFF DURING SSME START-UP. LH2 TSM T-0 RETRACTION IS NORMAL. ICE PARTICLES FALL FROM LO2 TSM T-0 IN RIGHT SIDE OF FRAME.

E-78 Camera is located on SE pad perimeter at camera
400 FPS site 3 and views RH OMS Pod leading edge.
16mm

Focus : SOFT
F. O. V.: PLUME OBSTRUCTS FOV
Exposure: OK

Comments: NORMAL AMOUNT OF GASEOUS OXYGEN VAPOR IS PRESENT AT THE LO2 T-0 AS THE VEHICLE RISES. ET/ORB LO2 UMBILICAL ICE FALLS AFT OF THE ORBITER BODY FLAP.

E-79 Camera is located on east pad perimeter at
100 FPS camera site 2 and views the ET nosecone, louver,
16mm and ogive.

Focus : SOFT
F. O. V.: SLIGHTLY UNDEREXPOSED
Exposure: SLIGHTLY LOW
Comments: VENT LOUVER LIGHTLY COVERED BY FROST ON SIDES AND BOTTOM. GOX VAPORS ARE VENTED FROM THE NORTHEAST DUCT. ET 'TWANG' IS APPROXIMATELY 34 INCHES. ICE PARTICLES FALL FROM ET/ORB LH2 AND LO2 UMBILICALS AS VEHICLE RISES. RCS PAPER COVER PIECES FALL AFT OF THE SSME'S AS VEHICLE LEAVES FOV.

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

Comments: CAMERA MALFUNCTION

E-202 UCS-15 IFLOT tracking of launch vehicle from
30 FPS ignition and early flight through LOV.
70mm

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

Comments: WATER FROM SRB STIFFENER RINGS AND CONDENSATE FROM ET AFT DOME VAPORIZES DURING ASCENT. PARTICLES NEAR AFT END OF VEHICLE ARE RCS PAPER COVERS (FRAMES 515, 560, 584, 603). SRB SEPARATION IS NOMINAL. VIEW IS SIMILAR TO E-220.

E-203 UCS-6 IFLOT tracking of launch vehicle from
30 FPS ignition and early flight through LOV.
70mm

Focus : OK
F. O. V.: OK
Exposure: OK, THOUGH ITEM IS UNDEREXPOSED FOR PLUME STUDY

Comments: NO 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 : OK
F. O. V.: OK, BUT IMAGE IS INVERTED
Exposure: SLIGHTLY UNDEREXPOSED

Comments: HAZE OBSCURES DETAIL. SRB SEPARATION APPEARS NOMINAL WITH NO DEBRIS VISIBLE NEAR ORBITER.

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 : OK, BUT SOME CAMERA SHAKE DEGRADES IMAGE
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED

Comments: HAZE OBSCURES DETAILS. EXHAUST PLUME RECIRCULATION IS NORMAL IN ET AFT DOME AREA. SRB SEPARATION OCCURS AT FRAME 8008 AND APPEARS NORMAL WITH NO VISIBLE DEBRIS NEAR ORBITER.

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 : OK
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED

Comments: HAZE OBSCURES DETAIL. EXHAUST PLUME RECIRCULATION BECOMES VISIBLE AT FRAME 2589. SRB SEPARATION OCCURS AT FRAME 3865 AND APPEARS NORMAL WITH NO VISIBLE DEBRIS NEAR ORBITER.

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 : GOOD
F. O. V.: GOOD, BUT IMAGE IS REVERSED
Exposure: SLIGHTLY UNDEREXPOSED

Comments: AT FRAMES 2700-3450, THE ORBITER BODY FLAP APPEARED TO MOVE IN AMPLITUDES THAT WERE GREATER THAN EXPECTED. MAXIMUM DEFLECTION OCCURRED BETWEEN GMT 12:37:49.21 - 12:37:52.83 (MAX Q 12:37:49.76). MEASUREMENTS FROM THE FILM INDICATE THE AVERAGE AMPLITUDE WAS 5.5 +/- 2 INCHES. THE DEFLECTION FREQUENCY AVERAGED 7.7 TO 8.7 HZ.

(BASED ON THESE OBSERVATIONS, A TEST PROGRAM CONSISTING OF A STATIC FREE-PLAY, MODAL (VIBRATION) ANALYSIS, AND VISUAL INSPECTION/BORESCOPING WAS INITIATED. THE STATIC FREE-PLAY TEST APPLIED A 1265 POUND MAXIMUM LOAD INCREMENTALLY WHILE MEASURING THE TRAILING EDGE DISPLACEMENT. THE FREE-PLAY TEST OF OV-102 PRODUCED A MAXIMUM DISPLACEMENT OF 0.479 INCHES COMPARED TO THE MAXIMUM ALLOWABLE DISPLACEMENT OF 0.625 INCHES. HOWEVER, THE MODAL ANALYSIS RESULTED IN A MEASURED FREQUENCY OF 7.5 HZ, WHICH IS BELOW THE DESIGN FREQUENCY OF 9 HZ IN THE FIRST MODE (CANTILEVER). IN ADDITION, A LOUD 'BANGING', CYCLICAL NOISE ORIGINATED FROM THE ACTUATOR AREA DURING THE TEST. THIS RESULTED IN THE REMOVAL OF THE OV-102 BODY FLAP FOR DISASSEMBLY AND VISUAL INSPECTION OF THE ATTACH HARDWARE AND ACTUATORS. STRUCTURALLY, SOME OF THE HOLES FOR THE ATTACH HARDWARE WERE SLIGHTLY WORN AND WERE CONSIDERED TO BE THE CAUSE OF THE CYCLICAL NOISES. THE ACTUATORS HAVE BEEN RETURNED TO THE VENDOR FOR INSPECTION.

TESTING OF THE OV-103 BODY FLAP REVEALED A FREQUENCY OF 8.12 HZ IN THE MODAL ANALYSIS AND A FREE-PLAY DISPLACEMENT OF 0.880 INCHES, WHICH EXCEEDED THE MAXIMUM ALLOWABLE DISPLACEMENT OF 0.625 INCHES. ROCKWELL-DOWNEY HAS SINCE RECALCULATED THE MAXIMUM ALLOWABLE DISPLACEMENT TO BE 0.970 INCHES.

A FREE-PLAY TEST WAS CONDUCTED ON THE BODY FLAP OF OV-104 WITH A MAXIMUM DISPLACEMENT OF 0.28 INCHES FOR AN APPLIED LOAD OF 100 POUNDS. HOWEVER, THE LOAD WAS NOT HIGH ENOUGH TO REMOVE THE SYSTEM 'SLOP' OR LOOSENESS. NO MODAL ANALYSIS WILL BE PERFORMED.

ET AFT DOME CHARRING IS LESS THAN AVERAGE AS VEHICLE ASCENDS. OPTICAL PHENOMENON IN THE FORM OF BRIGHT SPOTS IS VISIBLE NEAR AFT END OF VEHICLE DURING ASCENT. SRB SEPARATION APPEARS NORMAL WITH NO EVIDENCE OF DEBRIS. AT FRAME 9778, TWO PARTICLES ARE VISIBLE IN SEPARATED LH SRB'S PLUME. SRB'S HAVE SEVERAL GLOWING "CINDERS" (SLAG) AFTER SEPARATION.

E-208
48 FPS
35mm

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

Comments: TRACKING OF VEHICLE OCCURRED TOO LATE (AFTER SRB SEPARATION) TO DISCERN DETAIL.

E-209
30 FPS
70mm

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

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

Comments: ATMOSPHERIC HAZE OBSCURES VEHICLE - ONLY PLUME IS VISIBLE.

E-210
30 FPS
70mm

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

Focus : OK
F. O. V.: OK
Exposure: BEGINS DARK (SET FOR PLUME), BUT IMPROVES LATER
Comments: VEHICLE NOT ACQUIRED UNTIL FRAME 700. SRB SEPARATION IS NOMINAL. VIEW IS SIMILAR TO E-218.

E-211 UCS-13 IFLOT intermediate tracking of forward
96 FPS portion of ORB and ET from acquisition to LOV.
35mm

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

Comments: NO VEHICLE DETAIL VISIBLE DURING FIRST PART OF FILM DUE TO ATMOSPHERIC HAZE. VEHICLE IS MOSTLY OBSCURED BY SRB PLUME DURING SECOND PART OF FILM. SRB SEPARATION IS NOMINAL.

E-212 UCS-23 MIGOR tracking of launch vehicle
96 FPS from acquisition to LOV.
35mm

Focus : OK
F. O. V.: OK, BUT IMAGE IS INVERTED AND TRACKING IS ERRATIC
Exposure: SLIGHTLY UNDEREXPOSED

Comments: HAZE OBSCURES DETAIL. SRB SEPARATION OCCURS AT FRAME 10314 AND APPEARS NORMAL WITH NO SIGNS OF DEBRIS/ANOMALIES.

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

Comments: CAMERA MALFUNCTION

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

Comments: VEHICLE ROLL MANEUVER APPEARS TO BE GREATER THAN REQUIRED AS VEHICLE MAKES AN AZIMUTH CORRECTION BACK TO THE EAST FOLLOWED BY ANOTHER SMALLER CORRECTION. OTHER EVENTS ARE SIMILAR TO THOSE DESCRIBED IN E-222.

C-2

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

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

Comments: HAZE OBSCURES DETAIL. NO DEBRIS OR ANOMALIES ARE VISIBLE IN ACQUISITION VIEW AND EARLY ASCENT. SRB PLUME BLOCKS VIEW OF VEHICLE IN LATE ASCENT PRIOR TO SRB SEPARATION. SRB SEPARATION OCCURS AT FRAME 9225 AND APPEARS NORMAL WITH NO INDICATIONS OF DEBRIS OR VEHICLE ANOMALIES.

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 : UNKNOWN
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: WATER FROM SRB STIFFENER RINGS AND CONDENSATE FROM ET AFT DOME VAPORIZE DURING ASCENT. PARTICLES, WHICH ARE MOST LIKELY THE RCS PAPER COVERS FALLING FROM THE VEHICLE, ARE VISIBLE IN FRAMES 395, 436, 466, 485, 553, 568, 586, 641-652, AND 734. SRB SEPARATION IS NOMINAL. VIEW IS SIMILAR TO E-221.

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 : OK
F. O. V.: GOOD
Exposure: SLIGHTLY UNDEREXPOSED

Comments: HAZE OBSCURES DETAIL. WATER FROM SRB STIFFENER RINGS VAPORIZES. NUMEROUS PIECES OF RCS PAPER COVERS FALL DURING AND AFTER ROLL MANEUVER. CONDENSATE ON ET AFT DOME VAPORIZES. SEVERAL SMALL PARTICLES APPEAR AFT OF ET AFT DOME AREA BETWEEN SRB PLUMES. SLIGHT ET AFT DOME CHARRING IS VISIBLE. SHOCK WAVES ARE VISIBLE ON SRB FRUSTRUM AND ORBITER FUSELAGE. A PARTICLE, FROM OR BEHIND THE LH SRB PLUME, APPEARS AT FRAME 5175 TRAVELING AT AN OBLIQUE ANGLE TO THE PLUME. THE PARTICLE IS MOVING RAPIDLY AND APPEARS TO TUMBLE. SIZE ESTIMATE IS 24X10X6 INCHES AND IS PROBABLY INSTAFOAM FROM THE LH SRB AFT RING. NO ANOMALIES WERE DETECTED DURING ET/SRB SEPARATION.

E-221
96 FPS
35mm

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

Focus : GOOD
F. O. V.: GOOD
Exposure: GOOD

Comments: WATER FROM SRB STIFFENER RINGS AND CONDENSATE ON ET AFT DOME VAPORIZE DURING ASCENT. AT FRAME 1174, PIECE OF PAPER COVER FROM THE FORWARD-FIRING RCS THRUSTER PASSES THE ORBITER TAIL. AT FRAME 1311, GLARE FROM SUN IS REFLECTED ON ORBITER LH COCKPIT WINDOW. AT FRAME 1383, A SECOND PIECE OF RCS PAPER PASSES ORBITER TAIL. THREE PARTICLES ARE ILLUMINATED AFT OF ORBITER TAIL (FRAME 1441). AT FRAME 1631, A PARTICLE FALLS BY SSME #2 AND 3. AT FRAME 1650, A PARTICLE FALLS AFT OF ORBITER. AT FRAME 1706, ANOTHER PARTICLE IS VISIBLE AFT OF SSME #2 AND 3. AT FRAME 1767, PARTICLE PASSES BOTTOM OF VERTICAL STABILIZER. AT FRAME 1920, PARTICLE IS VISIBLE AFT OF SSME #1. AT FRAME 1937, A PARTICLE FALLS AFT OF SSME #3, FOLLOWED BY ANOTHER PARTICLE AT FRAME 1939. AT FRAME 1950, TWO PARTICLES ARE VISIBLE AFT OF SSME #3 AND STILL TWO MORE PARTICLES AT FRAME 2190. AT FRAME 2750, PARTICLE PASSES BY SSME #1. MOVEMENT OF THE ORBITER BODY FLAP IS VISIBLE JUST AFTER ROLL MANEUVER AND DURING FLIGHT THROUGH MAX Q.

E-222
96 FPS
35mm

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

Focus : OK, THOUGH CAMERA SHAKES THROUGH MOST OF ASCENT
F. O. V.: OK
Exposure: OK

Comments: WATER FROM SRB STIFFENER RINGS AND CONDENSATE FROM ET AFT DOME VAPORIZES. NUMEROUS PIECES OF RCS NOZZLE PAPER COVERS FALL DURING AND AFTER ROLL MANEUVER. SEVERAL PARTICLES ARE VISIBLE AFT OF THE VEHICLE IN THE PLUME AREA. AN OBJECT PASSES CLOSE TO THE CAMERA LENS MOVING FROM TOP TO BOTTOM AT GMT 12:37:15.6. APPARENT MOVEMENT OF THE ORBITER BODY FLAP OCCURS AT GMT 12:37:16 THROUGH 12:37:21 WITH A PARTICULARLY LARGE DEFLECTION AT T+20 SECONDS. MORE MOVEMENT IS VISIBLE AT GMT 12:37:29 AND 12:37:40 THROUGH 41 SECONDS. A FLASH IN THE SSME PLUME OCCURS AT 12:37:51.60.

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

Comments: BAGGIE MATERIAL FALLS IN FRAME 2963. ALTHOUGH THE ORBITER BODY FLAP IS VIEWED PREDOMINANTLY THROUGH THE SSME PLUME, APPARENT MOVEMENT OF THE BODY FLAP IS VISIBLE AT MAX Q. A PARTICLE IS CAUGHT IN THE PLUME RECIRCULATION EFFECT IN THE ET AFT DOME AREA (FRAME 3960). PARTICLE IS LAST SEEN IN FRAME 4001.

E-233 Castglance airborne tracking
35mm

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

Comments: SEPARATION OF LH FRUSTUM FROM FORWARD SKIRT APPEARS NOMINAL. ALL THREE PARACHUTES OPEN FULLY. TRACKING WAS LOST SOON AFTER PARACHUTE DEPLOYMENT. LH SRB WAS RE-ACQUIRED AFTER SPLASH DOWN.

E-234 Castglance airborne tracking
16mm

Focus : OK
F. O. V.: INCONSISTENT TRACKING
Exposure: UNDEREXPOSED

Comments: DUPLICATION OF E-233 WITH TRACKING OF LH SRB.

E-301 RH SRB parachute deployment
200 FPS
16mm

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

Comments: FRUSTUM SEPARATION APPEARS NORMAL. MANY LOOSE RESTRAINING CORDS FLY BY CAMERA. ALL 3 PARACHUTES FULLY DEPLOY AND INFLATE. HUNDREDS OF SMALL DEBRIS PIECES AND THICK SMOKE MARK NOZZLE SEVERANCE, BUT NO MAJOR PARACHUTE DAMAGE IS VISIBLE.

E-302 LH SRB parachute deployment
200 FPS
16mm

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

Comments: FRUSTUM SEPARATION APPEARS NORMAL. MANY LOOSE RESTRAINING CORDS FLY BY CAMERA. ALL 3 PARACHUTES FULLY DEPLOY AND INFLATE. HUNDREDS OF SMALL DEBRIS PIECES AND THICK SMOKE MARK NOZZLE SEVERANCE, BUT NO MAJOR PARACHUTE DAMAGE IS VISIBLE.

HIGH ALT Co-altitude view of vehicle.

Focus : IMAGE BLURRED BY CAMERA SHAKE
F. O. V.: DISTANT
Exposure: OK

Comments: FINE DETAIL WAS NOT DISCERNIBLE DUE TO CAMERA MOVEMENT

VIDEO ITEMS

OTV 101 Views Orbiter LH2 T-0 Umbilical from the FSS 255
B/W M-II foot level.

Comments: CAMERA LIGHT INSIDE TSM COMES ON AND ILLUMINATES FUSELAGE OF ORBITER. SSME IGNITION AND GIMBAL PROFILE IS NORMAL. NO FREE HYDROGEN RISES ALONG LH2 TSM DUE TO PREVAILING WINDS. T-0 UMBILICAL DISCONNECT AND RETRACTION IS NOMINAL.

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

Comments: NORMAL VENTING OF PURGE GASES. ICE/FROST PARTICLES FALL FROM GUCP DURING SSME IGNITION. UMBILICAL DISCONNECT AND RETRACTION ARE NOMINAL. NO VEHICLE ANOMALIES.

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

Comments: CAMERA IS POINTED AT LH SRB - AN UNUSUAL ORIENTATION DUE TO SUN GLARE. ICE/FROST FALLS FROM ET/ORB UMBILICALS, BUT NO TILE DAMAGE IS VISIBLE. NO SRB ANOMALIES.

OTV 111 Views GUCP and GH2 vent line with new Insight IR
B/W IR camera.

Comments: CAMERA IS POINTED AWAY FROM VEHICLE DURING LAUNCH

OTV 119 Views LH2 umbilical with new Insight IR camera.
B/W IR

Comments: CAMERA IS POINTED AWAY FROM VEHICLE DURING LAUNCH

OTV 130 Views SSMEs and Orbiter aft end from SE pad apron
B/W IR with new Insight IR camera.

Comments: CAMERA IS POINTED AWAY FROM VEHICLE DURING LAUNCH

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

Comments: VEHICLE TWANG IS VISIBLE AGAINST FSS IN BACKGROUND. A BIRD PASSES CAMERA LENS JUST AFTER LIFTOFF. PAPER COVERS FROM THE FORWARD RCS FALL AFT PAST VERTICAL STABILIZER. NO VEHICLE ANOMALIES.

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

Comments: SSME AND SRB IGNITION IS NOMINAL.

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

Comments: VEHICLE TWANG IS TYPICAL. PAPER COVERS FROM FWD RCS FALL AFT PAST VERTICAL STABILIZER. CAMERA LENS OPTICAL PHENOMENA IN THE FORM OF PIN POINTS OF LIGHT OCCUR NEAR THE FORWARD FUSELAGE JUST AFTER ROLL MANEUVER. TRACKING IS ERRATIC.

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

Comments: T-0 UMBILICAL DISCONNECT AND RETRACTION FROM THE ORBITER IS NOMINAL. NO VEHICLE ANOMALIES.

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

Comments: T-0 UMBILICAL DISCONNECT AND RETRACTION FROM THE ORBITER IS NOMINAL. RESIDUAL VAPORS VENT FROM THE UMBILICAL. NO VEHICLE ANOMALIES.

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

Comments: SSME STARTUP AND GIMBALLING IS NORMAL. RCS PAPER COVERS TEAR DURING IGNITION. NO ANOMALIES DURING LO2 T-0 DISCONNECT AND RETRACTION.

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

Comments: LARGE SHOWER OF ICE/FROST PARTICLES FROM ET/ORB UMBILICALS DURING SSME IGNITION, BUT NO TILE DAMAGE IS VISIBLE. ELEVONS SHAKE DURING STARTUP. NO UNUSUAL VAPORS EMANATE FROM ET/ORB UMBILICALS THOUGH NORMAL PURGE GAS IS VENTING FROM THE PURGE VENTS. NO SSME ANOMALIES AS VEHICLE PASSES THROUGH FOV.

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

Comments: ICE/FROST PARTICLES FALL FROM BOTH ET/ORB LH2 AND LO2 UMBILICALS DURING SSME IGNITION, BUT NO TILE DAMAGE IS VISIBLE. NO SRB ANOMALIES.

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

Comments: ICE/FROST PARTICLES FALL FROM BOTH ET/ORB LH2 AND LO2 UMBILICALS DURING SSME IGNITION, BUT NO TILE DAMAGE IS VISIBLE. NO SRB ANOMALIES. OUTPOURING OF WATER FROM RAINBIRD IS IMPRESSIVE.

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

Comments: VEHICLE 'TWANG' IS VERY NOTICEABLE. GH2 VENT LINE DISCONNECT AND RETRACTION APPEARS NORMAL. NO VEHICLE ANOMALIES.

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

Comments: LOUVERS ARE LIGHTLY COATED BY FROST, BUT NO ICE IS PRESENT. TWANG CAUSES VEHICLE TO MOVE ACROSS FRAME. NO MISSING TPS FROM OGIVE OR GOX FOOTPRINT AREAS.

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

Comments: GOX VAPORS ARE BLOWN NORTHWARD BY PREVAILING WIND. CAMERA LIGHT IN LH2 TSM IS ACTIVATED AND SHINES ON ORBITER AFT FUSELAGE. FREE BURNING HYDROGEN FROM SSME STARTUP UP IS BLOWN NORTH UNDER THE BODY FLAP AND IS THEN PULLED BACK INTO THE SSME FLAME HOLE BY ENGINE PLUME ASPIRATION. SSME IGNITION CAUSES A SHOWER OF ICE/FROST PARTICLES TO FALL FROM BOTH ET/ORB UMBILICALS BUT NO TILE DAMAGE IS VISIBLE. VIBRATION CAUSES A GAP FILLER TO FALL FROM THE LH WING TILES. LH2 T-0 UMBILICAL DISCONNECT AND RETRACTION IS NORMAL THOUGH RESIDUAL VAPORS ARE STILL IN THE VICINITY. LH WING MOTION IS TYPICAL AT LIFTOFF. NO UNUSUAL VAPORS EMANATE FROM THE ET/ORB UMBILICALS EXCEPT NORMAL PURGE GASES.

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

Comments: SSME STARTUP AND GIMBAL PROFILE IS NORMAL. VEHICLE IS QUICKLY OBSCURED BY SSME PLUME. AFT RCS PAPER COVERS TEAR ALMOST IMMEDIATELY.

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

Comments: SSME IGNITION IS NOMINAL. GH2 VENT LINE RETRACTS, LATCHES, AND DOES NOT REBOUND FROM THE ET INTERTANK ACCESS ARM HAUNCH.

OTV 172 Views SSMEs with new Insight IR camera from SW
B/W IR corner of MLP deck.

Comments: CAMERA WAS POINTED AWAY FROM VEHICLE DURING LAUNCH

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

Comments: SEQUENCE OF IGNITION IS CLEARLY VISIBLE. FREE BURNING HYDROGEN IS BLOWN NORTH UNDER BODY FLAP AND EASTWARD AWAY FROM VEHICLE AND LO2 TSM, BUT IS QUICKLY DRAWN BACK INTO SSME EXHAUST HOLE BY PLUME ASPIRATION. STEADY-STATE PLUME OF ALL SSME'S IS NOMINAL.

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

Comments: SOME FREE BURNING HYDROGEN RISES ALONG SIDE OF SSME #2 AND #1 NOZZLES, BUT PREVAILING WIND PREVENTS ANY RISE TO LH2 TSM OR LH AFT FUSELAGE. STEADY-STATE PLUME OF ALL SSME'S IS NOMINAL. JUST AFTER VEHICLE CLEARS FRAME, A PIECE OF SOUND SUPPRESSION WATER TROUGH CORD MOVES THROUGH FIELD OF VIEW TRAVELING SOUTH.

TV-1 View from UCS-9 northwest of Pad-B.
Color M-II

Comments: VISIBILITY TO PAD IS NOT GOOD DUE TO ATMOSPHERIC HAZE. NO ANOMALIES THROUGH TOWER CLEAR.

TV-2 View from convoy at SLF.
Color M-II

Comments: VIEW TOO DISTANT FOR DETAIL. NO PLUME ANOMALIES. SRB SEPARATION APPEARS NORMAL.

TV-11 Views entire launch vehicle from TV Tower 1 SLF.
Color M-II

Comments: DISTANT VIEW TO PAD WITH VISIBILITY AFFECTED BY ATMOSPHERIC HAZE. VISIBILITY GETS WORSE AS VEHICLE IS BACKLIT BY SUN AND LATER OBSCURED BY SRB PLUME.

TV-4 Views entire vehicle from Beach Road IFLOT Site.
Color M-II

Comments: SEVERAL BIRDS ARE IN THE VICINITY, BUT NONE ARE NEAR THE VEHICLE. SSME IGNITION AND LIFTOFF ARE NOMINAL. VEHICLE APPEARS TO OVERSHOOT HEADING DURING ROLL MANEUVER. PAPER COVERS FROM FORWARD RCS FALL ALONG FUSELAGE, PAST VERTICAL STABILIZER,

AND INTO THE PLUME. SHOCK WAVES FORM ON FORWARD FUSELAGE AND ET/ SRB ATTACH POINTS. LIGHT-COLORED OBJECT 'POPS' UP OUT OF PLUME MOMENTARILY BEFORE BEING LOST TO VIEW AGAINST PLUME. MAY BE THE PIECE OF SUSPECTED AFT RING INSTAFOAM VISIBLE IN THE FILM ITEMS. SRB SEPARATION IS NORMAL AND NO DEBRIS IS VISIBLE NEAR THE ORBITER.

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

Comments: VISIBILITY TO PAD IS POOR DUE TO ATMOSPHERIC HAZE. VIEW IS TOO DISTANT FOR FINE DETAIL.

TV-21 Views entire launch vehicle from DLTR-3 site
Color M-II directly south of Pad B.

Comments: SSME IGNITION IS NORMAL. INITIAL LIFTOFF IS OBSCURED BY SSME PLUME. NO SRB PLUME ANOMALIES.

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

Comments: NOT AVAILABLE.

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

Comments: CLOSE-IN, TIGHT VIEW IS STILL SOMEWHAT OBSCURED BY ATMOSPHERIC HAZE. OPTICAL PHENOMENA IN THE FORM OF A DIAGONAL LINE STARTS NEAR SSME AREA AND MOVES AFT INTO THE PLUME. THIS OCCURS TWICE. NO DIVOTS ON ET -Z ACREAGE ARE VISIBLE. SRB SEPARATION IS NORMAL WITH NO DEBRIS NEAR THE ORBITER. PARTICLES RECORDED ON RADAR AFTER SRB SEPARATION ARE NOT VISIBLE.

TV-16 View from helicopter orbiting west of pad and VAB.
Color M-II

Comments: NO VEHICLE ANOMALIES.

TV-18 Malabar ITEC video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: CLOSE-IN, TIGHT VIEW IS MOSTLY OBSCURED BY ATMOSPHERIC HAZE. SRB SEPARATION IS NORMAL WITH NO DEBRIS VISIBLE NEAR ORBITER.

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

Comments: HAZE OBSCURES DETAIL. SRB SEPARATION APPEARS NORMAL. NO SLAG/DEBRIS IS VISIBLE AFTER SEPARATION. NO VEHICLE ANOMALIES.

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

Comments: HAZE OBSCURES DETAIL. SRB SEPARATION APPEARS NORMAL WITH NO VISIBLE DEBRIS PARTICLES. NO VEHICLE ANOMALIES.

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

Comments: HAZE OBSCURES DETAIL. CONDENSATE ON THE ET AFT DOME VAPORIZES DURING THE ROLL MANEUVER. SHORTLY AFTER SHOCK WAVES BECOME VISIBLE, VEHICLE IS TOTALLY OBSCURED BY SUN GLARE AND HAZE. ANY KIND OF DETAIL IS NOT REGAINED UNTIL WELL AFTER SRB SEPARATION. NO VEHICLE ANOMALIES.

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

Comments: HAZY. UNABLE TO SEE PARTICLES DURING ROLL THAT WERE PREVIOUSLY NOTED IN OTHER VIEWS. CORRECTION FOR ROLL OVERSHOOT IS VISIBLE. IMAGE QUALITY (HAZE) IMPROVES AS THE VEHICLE ASCENDS. SRB SEPARATION APPEARS NORMAL WITH NO SLAG/DEBRIS VISIBLE. NO VEHICLE ANOMALIES.

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

Comments: ATMOSPHERIC CLARITY IS MUCH BETTER FOR THIS ITEM. IGNITION SEQUENCE AND LIFTOFF APPEAR NORMAL. SHOCK WAVES ARE VISIBLE NEAR BOTH THE ORBITER AND SRB NOSES BEGINNING AT T+41 SECONDS. SRB SEPARATION APPEARS NORMAL. NO VEHICLE ANOMALIES.

ET-213 UCS-7 MOTS video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: INITIAL ACQUISITION IS LATE AND TRACKING IS ERRATIC. IMAGE IS VERY HAZY INITIALLY, BUT IMPROVES SOMEWHAT AS VEHICLE ASCENDS. "STRAIGHT LINE" OPTICAL EFFECT PASSES THROUGH THE IMAGE. LITTLE AFT DOME CHARRING IS EVIDENT. SRB SEPARATION APPEARS NORMAL. NO VEHICLE ANOMALIES.

6.2 ON-ORBIT FILM DATA REVIEW

ON-ORBIT View of LH SRB and External Tank separation from 16mm ET/ORB LH2 umbilical

Comments: SEPARATION OF THE LH SRB FROM THE EXTERNAL TANK WAS NOMINAL. NO BOOSTER CASE OR FIELD JOINT ANOMALIES WERE VISIBLE. ETA COVERS AND THE ET/SRB UPPER STRUT FAIRING WERE INTACT. TAILOFF FROM THE FORWARD BSM'S WAS STILL OCCURRING AS THE BOOSTER PASSED THROUGH THE FOV. THE COVERS WERE IN SUN/SHADOW. ADDITIONAL ENHANCEMENT COULD NOT DETERMINE WHETHER THE RIGHT LOWER COVER REMAINED INTACT AND IN THE LATCHED POSITION.

THE NORMAL, BUT LARGE, NUMBER OF SMALL TPS PARTICLES WERE VISIBLE UNDER THE ET AFT DOME AND CAUGHT IN THE PLUME RECIRCULATION. THE NUMBER OF THESE PARTICLES LESSENED AFTER SRB SEPARATION. CHARRING OF THE ET TPS ACREAGE OCCURRED FORWARD OF THE 2058 RING. AFT DOME NCFI WAS INTACT. THE EB CABLE TRAY AFT FACING TPS EXHIBITED THE EXPECTED CHARRING AND 'POPCORNING'. THE LH2 UMBILICAL CABLE TRAY WAS MISSING A SIGNIFICANT AREA (4"Wx10"Lx1"D) OF CLOSEOUT TPS, BUT HAD NOT ERODED DOWN TO THE SLA. A 6"X4" PIECE OF TPS BROKE OFF THE FEEDLINE ATTACH STRUCTURE, BOUNCED AGAINST THE UMBILICAL, AND FELL AFT.

THE WHITE PLUMES IN THE UPPER PART OF THE FRAME AND BELOW THE UMBILICAL CABLE TRAY BEGIN 7 SECONDS PRIOR TO ET SEPARATION (FIRST MOVEMENT). THESE PLUMES, CAUSED BY LH2/GH2 UNDER PRESSURE ESCAPING FROM THE SEPARATED UMBILICAL, CAUSE A CHUNK OF TPS TO BREAK OFF NEAR THE FORWARD OUTBOARD BOLT AND FRAGMENT INTO SEVERAL PIECES BEFORE FALLING PAST THE CAMERA. THE PLUMES WERE VISIBLE FOR 246 FRAMES (APPROXIMATELY 1 SECOND) AND FIRST MOTION OF THE TANK OCCURRED 1540 FRAMES LATER. SEPARATION OF THE EXTERNAL TANK FROM THE ORBITER WAS NOMINAL AT GMT 12:45:53.8 FOLLOWED BY RCS FIRING AT 12:45:54.0. THE LH2 UMBILICAL FLAPPER VALVE WAS TOTALLY COVERED BY FROZEN HYDROGEN. ALTHOUGH THE RED RTV SEAL APPEARED INTACT AROUND THE UMBILICAL, SEVERAL PIECES OF FROZEN HYDROGEN ADHERED TO THE UMBILICAL FACE ABOVE AND BELOW THE 17-INCH VALVE AND COULD HAVE FORMED DURING UMBILICAL SEPARATION. AN ANOMALOUS CONDITION WOULD EXIST IF THE FROZEN HYDROGEN HAD FORMED BEFORE UMBILICAL SEPARATION. A 3-FOOT STRIP OF THE KAPTON BAGGIE MATERIAL WAS STILL ATTACHED TO THE ORBITER.

On-Orbit View of External Tank separation from the ET/ORB
35mm still LO2 umbilical camera

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

Comments: TPS CHARRING HAS OCCURRED ON THE ET AFT DOME, ACREAGE JUST FORWARD OF THE 2058 RING, CROSSBEAM, DIAGONAL STRUT, PART OF THE LH2 TANK CABLE TRAY BEHIND THE THRUST STRUT, AND THE TOPCOAT-COVERED PORTION OF THE RH THRUST STRUT, ALL OF WHICH IS EXPECTED. THE LH2 TANK ACREAGE WAS IN GOOD CONDITION WITH NORMAL 'POPCORNING' AND NO VISIBLE DIVOTS. THE ET/SRB UPPER STRUT FAIRING SUSTAINED MINOR DIVOTS ON THE AFT FACE. FIVE MINOR DIVOTS OCCURRED ON THE RIGHT THRUST STRUT FLANGE. THE RED-COLORED RTV BARRIER SEAL WAS STILL ATTACHED TO THE EO-3 FITTING.

THE VALVES ON THE ET/ORB LO2 UMBILICAL CLOSED PROPERLY AND NO ICE ADHERED TO THE 17-INCH FLAPPER VALVE. UMBILICAL PURGE BARRIER AND RTV APPLICATION WAS IN GOOD CONDITION WITH NO EVIDENCE OF ANY LEAK PATHS. THE LO2 UMBILICAL CABLE TRAY EXHIBITED SMALL DIVOTS AND 'POPCORNING' ON BOTH AFT FACING SURFACES, AN EXPECTED OCCURRENCE. THE TPS ALONG THE ENTIRE TOP OF THE LO2 UMBILICAL WAS DISPLACED WITH A LOOSE CHUNK (18"Wx8"Lx2"D) IN THE CENTER AND MISSING PIECES AT THE 11 AND 2 O'CLOCK POSITIONS.

THE LO2 FEEDLINE EXHIBITED NO ANOMALIES. ICE WAS STILL PRESENT IN THE AFT BELLOWS, BUT NO ICE WAS VISIBLE IN THE FORWARD BELLOWS. MOST OF THE LH2 TANK PRESSURIZATION LINE ICE/FROST RAMPS AND SUPPORTS SHOWED ONLY SLIGHT EROSION OR MINOR PIECES OF TPS MISSING, THOUGH THE RAMP THIRD DOWN FROM THE LH2 TANK-TO-INTERTANK FLANGE HAD ONE DIVOT.

A LARGE DIVOT (23"Lx15"Wx1" MAX DEPTH) OCCURRED IN THE INTERTANK ACREAGE TPS JUST ABOVE THE RH BIPOD RAMP AND TO THE LEFT OF THE LO2 FEEDLINE. THIS DIVOT WAS LOCATED IN THE VENTED SOFI AREA. THE SHALLOW DEPTH INDICATES A COHESIVE FAILURE INTERNAL TO THE CPR NET SPRAY MATERIAL. THE FAILURE OCCURRED PRIOR TO L+90 SECONDS AND EXHIBITS A CONTINUATION OF A CHAR LINE FROM ASCENT HEATING. THIS IS A FIRST FOR SUCH A LARGE SHALLOW DIVOT AND MAY BE INDICATIVE OF DAMAGED SOFI DURING ET PROCESSING.

THE BIPODS HAD NOT ROTATED OR FOLDED AWAY FROM THE ORBITER DURING ET SEPARATION. THE JACK PAD PDL CLOSEOUTS WERE INTACT. AS EXPECTED, THE FORWARD FACING SURFACES OF THE BIPODS, AND A TRIANGULAR AREA JUST AFT OF THE BIPODS, WERE CHARRED FROM ASCENT HEATING. SIMILARLY, THE BOLT CATCHER ON THE RH (EB-2) FORWARD ATTACH POINT WAS CHARRED BUT INTACT. THERE WERE NO ANOMALIES ON THE INTERTANK SPLICES EXCEPT FOR ONE 4"x8" DIVOT ON THE INTERTANK-TO-LH2 TANK FLANGE TO THE RIGHT OF THE PAL RAMP. THE

FORWARD FACING SLOPE OF THE LH2 TANK PAL RAMP EXHIBITED SOME EROSION AND CHARRING. THIS FORWARD FACING SLOPE HAD BEEN REPLACED WITH NEW TPS PRIOR TO LAUNCH AND ACCOUNTS FOR THE LIGHTER COLOR.

THERE WERE NO ACREAGE DIVOTS VISIBLE ON THE LO2 TANK OGIVE AND BARREL SECTION. LO2 PRESSURIZATION LINE SUPPORTS/RAMPS WERE IN GOOD CONDITION. THE LO2 TANK PAL RAMP WAS INTACT, THOUGH SOME CHARRING HAD OCCURRED ON THE LEADING EDGE. LIGHTER COLORED SOFI, WHICH COULD BE EXPOSED WHEN A DIVOT OCCURS, IS A 10" X 6" SANDED AREA OF ACREAGE AT THE LEADING EDGE OF THE RAMP. EXAMINATION OF THE BSM SCAR REVEALED SOME EROSION, BUT THE SPRAY PATTERN IS STILL DEFINED WITH NO MISSING TPS TO SUBSTRATE.

ON-ORBIT View of External Tank after separation from the Orbiter. Photos were taken by flight crew using a hand held camera
70mm still

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

Comments: NO LARGE ACREAGE DIVOTS ARE VISIBLE ON THE LO2 TANK, LH2 TANK, AFT DOME, OR INTERTANK EXCEPT FOR THE ONE LOCATION JUST ABOVE THE RIGHT BIPOD RAMP. CHARRING OF THE TPS FROM ASCENT HEATING OCCURRED AT THE FORWARD SRB ATTACH POINTS, BIPODS, AND AFT ET/SRB STRUT ATTACH POINTS. BURN SCARS FROM THE FORWARD SRB BSM'S EXTENDED FROM THE LO2 TANK OGIVE HALFWAY DOWN THE INTERTANK. THE BIPODS WERE STILL EXTENDED INSTEAD OF FOLDING BACK AGAINST THE ET DURING ORBITER SEPARATION.

6.3 LANDING FILM AND DATA REVIEW

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

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

Comments: LH MAIN LANDING GEAR DOOR IS EXTENDED 0.25 TO 0.50 SECONDS BEFORE RIGHT SIDE. GEAR EXTENSION LAGS SIMILARLY. ALL FOUR ELEVONS OSCILLATE PRIOR TO TOUCHDOWN. TOTAL STROKE OF NOSE LANDING GEAR STRUT WAS 21.82 INCHES (MAXIMUM STROKE IS 22 +/- 1 INCH) AND NLG STRUT APPEARED TO HAVE SIGNIFICANT FORWARD/AFT FLEX OF 1-2 INCHES AT TOUCHDOWN.

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

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

Comments: LH MLG DOOR IS EXTENDED BEFORE RIGHT SIDE. SIMILARLY, LH MAIN LANDING GEAR IS EXTENDED PRIOR TO RH MLG. ALL FOUR ELEVONS OSCILLATE PRIOR TO TOUCHDOWN. NOSE LANDING GEAR APPEARS TO COME CLOSE TO FULL STROKE.

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

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

Comments: LH MLG DOOR EXTENDS PRIOR TO RIGHT SIDE. SIMILARLY, LH MAIN LANDING GEAR IS EXTENDED PRIOR TO RH MLG. ALL FOUR ELEVONS OSCILLATE PRIOR TO TOUCHDOWN. NOSE LANDING GEAR APPEARS TO TOUCH DOWN HARD - CLOSE TO FULL STROKE.

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

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

Comments: SAME MLG DOOR AND WHEEL EXTENSION TIMING DIFFERENTIAL. ALL FOUR ELEVONS OSCILLATE PRIOR TO TOUCHDOWN.

E-1008 Orbiter landing at Ames-Dryden Flight Research
35mm Facility

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

Comments: LH MLG DOOR IS EXTENDED BEFORE RIGHT SIDE. SIMILARLY, LH MAIN LANDING GEAR IS EXTENDED PRIOR TO RH MLG. ALL FOUR ELEVONS OSCILLATE PRIOR TO TOUCHDOWN. MISSING CORNER TILE FROM RH MLG DOOR IS VISIBLE AS VEHICLE PASSES CAMERA POSITION. NOSE LANDING GEAR APPEARS TO TOUCH DOWN HARD - STRUT IS CLOSE TO FULL STROKE.

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

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

Comments: ALL FOUR ELEVONS OSCILLATE PRIOR TO TOUCHDOWN. BODY FLAP COMES WITHIN TWO FEET OF THE GROUND. NOSE LANDING GEAR STROKE APPEARS TO BE EXCESSIVE.

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

Focus : OK
F. O. V.: OK, THOUGH TRACKING IS POOR INITIALLY
Exposure: OK

Comments: ALL FOUR ELEVONS OSCILLATE PRIOR TO MAIN LANDING GEAR TOUCHDOWN AND CONTINUE UNTIL NOSE GEAR TOUCHES DOWN.

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

Focus : OK
F. O. V.: OK, THOUGH TRACKING IS POOR INITIALLY
Exposure: OK

Comments: ALL FOUR ELEVONS OSCILLATE PRIOR TO MAIN LANDING GEAR TOUCHDOWN AND CONTINUE UNTIL NOSE GEAR TOUCHES DOWN.

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

Focus : OK
F. O. V.: OK, THOUGH TRACKING IS POOR INITIALLY
Exposure: OK

Comments: ALL FOUR ELEVONS OSCILLATE PRIOR TO MAIN LANDING GEAR TOUCHDOWN AND CONTINUE UNTIL NOSE GEAR TOUCHES DOWN.

7.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and sources at CCAFS Hangar AF on 11 August 1989 from 0900 to 1130 hours.

7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no MSA-2 TPS but exhibited two debonds, which measured 1 and 2 inches in diameter. Prior to MSA-2 spray operations, the sealant caps had been removed from the PR1422 sealant thereby creating a better adhesion surface. Blistering and peeling of the Hypalon paint had occurred in several areas near the forward end of the frustum (Figure 8). The four BSM aero heatshield covers were intact and locked in the open position.

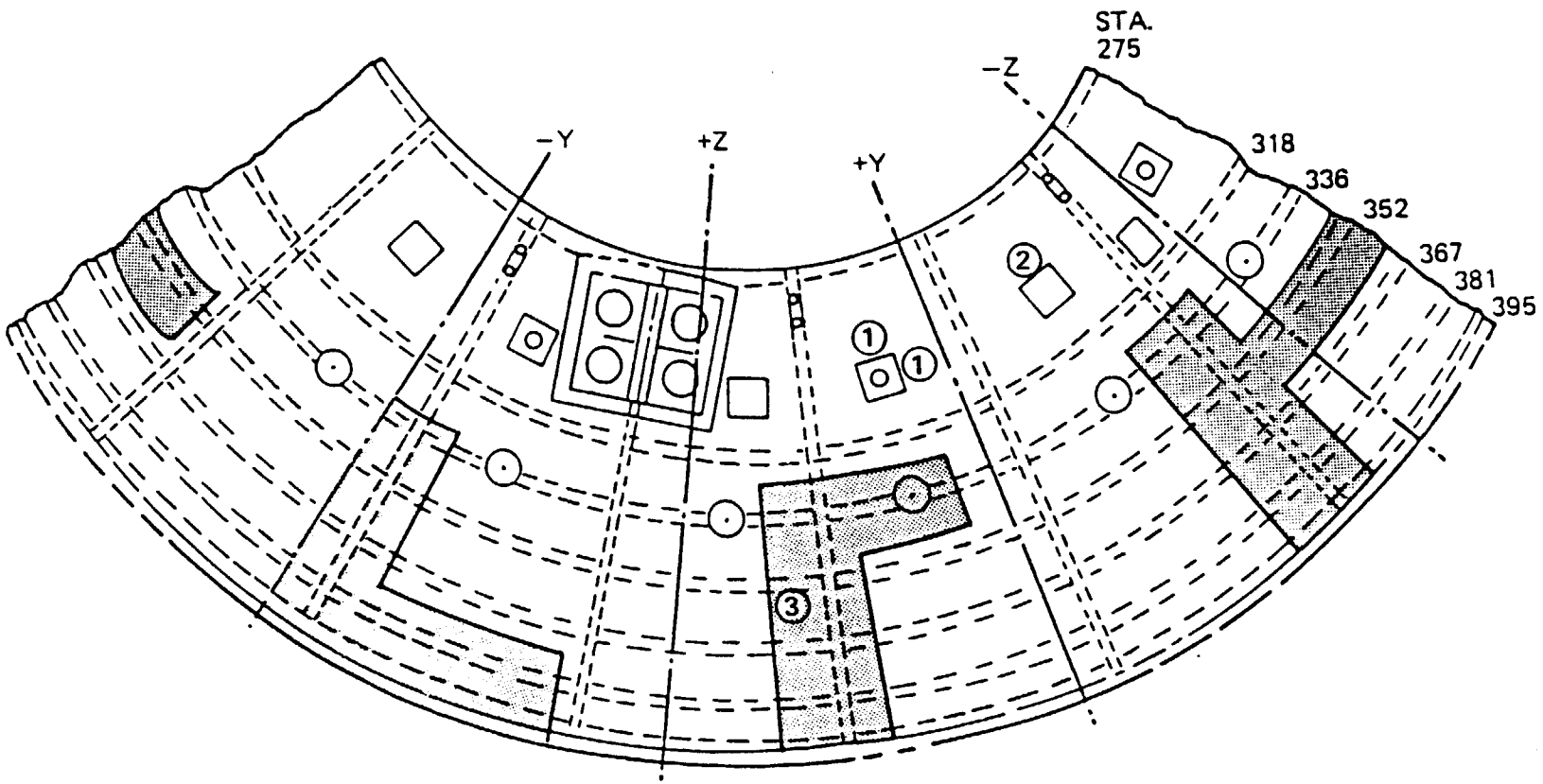
The RH Forward Skirt exhibited no missing TPS or debonds. The Hypalon paint forward of the thrust fitting was blistered. Phenolic plates on the RSS antennae and K5NA closeouts were intact (Figure 9). Separation of the forward attach fitting was nominal and the RSS cables separated cleanly. Only one gallon of water was present in the retrieved forward skirt.

A 2.5-inch crack on the aft field joint K5NA was removed for analysis. All other field joint closeouts were undamaged. Known void areas on the field joint closeouts and repairs remained intact. Trailing edge damage to the GEI cork runs was attributed to debris hits from nozzle extension severance. Prior to flight, GEI ID epoxy-covered tags and been removed and replaced with identification numbers stenciled on the cases.

All three stiffener rings sustained water impact damage. The web and web-to-flange interface on the forward ring was cracked and bolts sheared at 100-110 degrees. K5NA was cracked on the other two rings. A sliver from the aft stiffener ring was found embedded in a GEI cable. Separation of the aft ET/SRB struts was nominal except for squawk 28-006 on a loose sliver of metal. K5NA closeouts on the IEA covers were intact though some TPS was missing from the ET attach ring.

The phenolic kick ring delaminated in some locations. K5NA was missing from all four aft BSM nozzles (Figure 10). K5NA was also missing from several phenolic aft kick ring bolt heads (squawk 28-031). The area under the missing K5NA was sooted, which indicates heating after material loss. The TPS over the aft skirt acreage was generally in good condition. The TVC system was virtually undamaged. Instafoam was missing from the aft ring around the holddown post shoes, HPU exhaust horns, and joint heater umbilical. A 3-inch diameter piece of material was missing from both holddown post #3 and #4 shims.

FIGURE 8. RIGHT SRB FRUSTUM



MISSING TPS

NONE

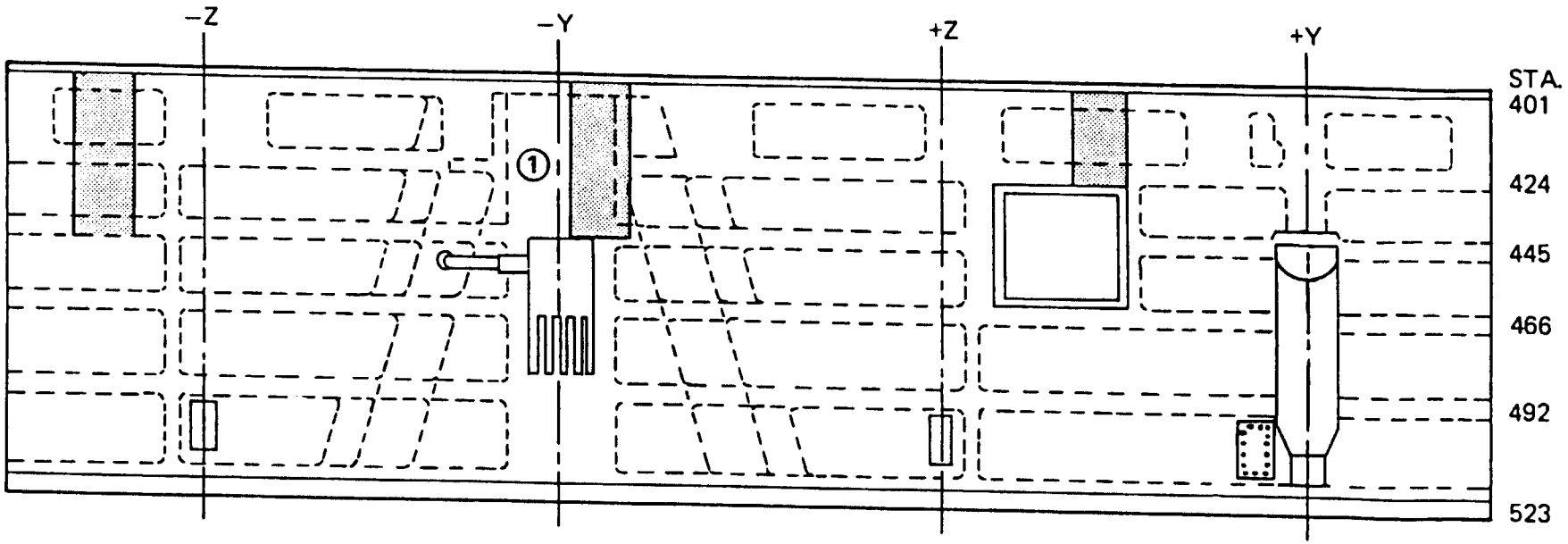
DEBONDS

② 2" DIA

③ 1" DIA

① HYPALON PAINT BLISTERING/PEELING SEVERAL AREAS.

FIGURE 9. RIGHT SRB FWD SKIRT



TPS MISSING

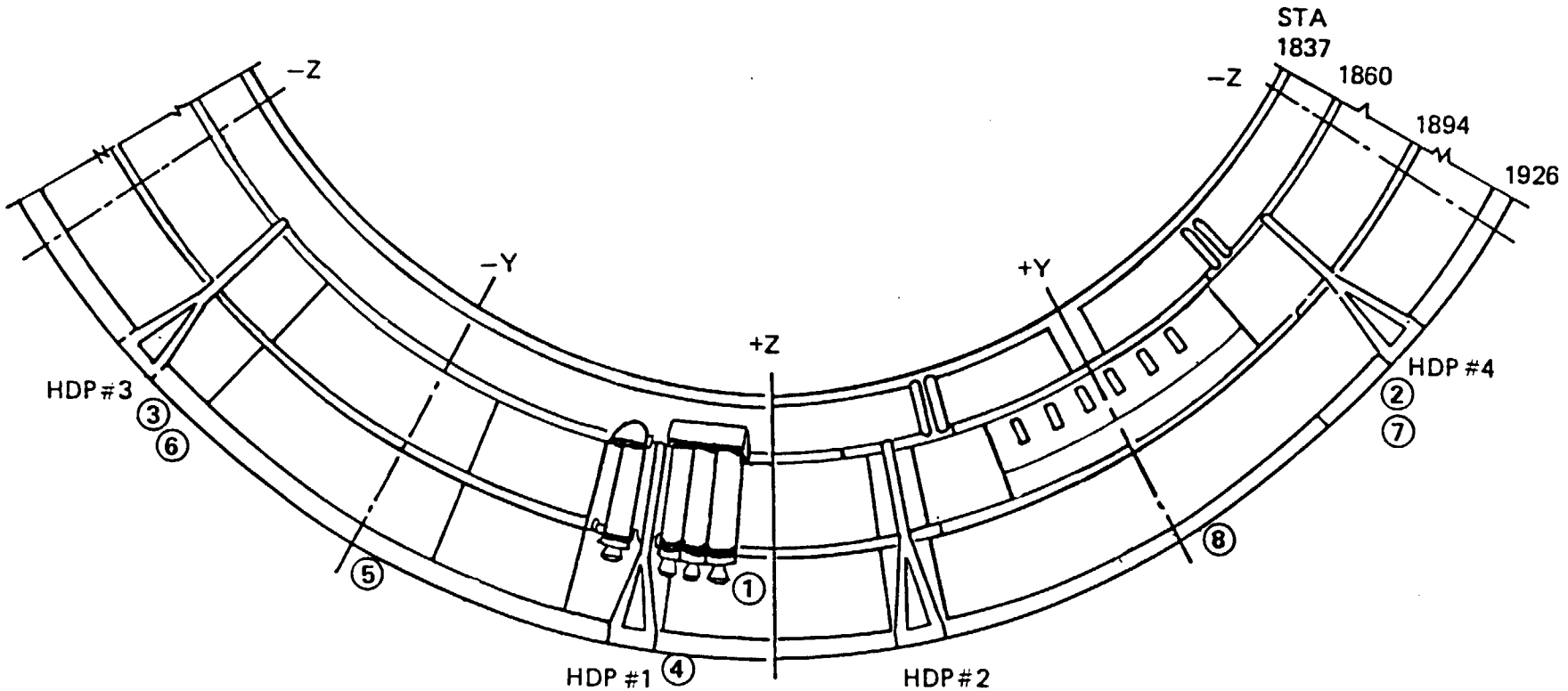
NONE

DEBONDS

NONE

① HYPALON PAINT BLISTERING

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



① KSNA MISSING AROUND FOUR BSM NOZZLES
② SHIM MATERIAL MISSING 3" DIA
③ SHIM MATERIAL MISSING 3" DIA
④ INSTAFOAM MISSING ON INBOARD SIDE OF POST
⑤ INSTAFOAM MISSING AROUND T–0 UMBILICAL
⑥ INSTAFOAM MISSING INBOARD SIDE OF POST
⑦ INSTAFOAM MISSING INBOARD SIDE OF POST
⑧ INSTAFOAM MISSING AROUND APU PIPE

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum exhibited no debonds or missing MSA-2 TPS. There were no significant areas of blistered Hypalon paint (Figure 11). Three of the four BSM aero heatshield covers were present and locked in the open position. However, the cover in the lower right corner of the BSM cluster was missing at the time of recovery operations. The cover, hinge, and a section of the stainless steel attachment ring directly connected to the hinge was completely broken off. On the remaining portion of the attachment ring, the upper break appeared to have three fracture planes, of which the first two were sooted and the last showed a minute, clean point. The lower break was sooted, smooth, and exhibited a sharp, pointed 'finger' of metal.

The failure occurred at the upper fracture plane first with subsequent torsional/tension loading on the lower fracture plane. The nozzle had three sets of distinct indentations (MAB Report 206-89, Section 9.0) indicating three cover/hinge impacts with each successive set of indentations rotating aft and occurring further outboard of the nozzle. These data indicate the cover oscillated through three cycles most likely in the time frame between BSM firing and parachute deployment. The one, clear, upper fracture point is inconclusive and does not support the hypothesis that the final cover/hinge separation/failure occurred at or after water impact. While the cause of the failure is still under investigation, the continued bending observed in many of the attach ring assemblies would suggest a redesign may be required.

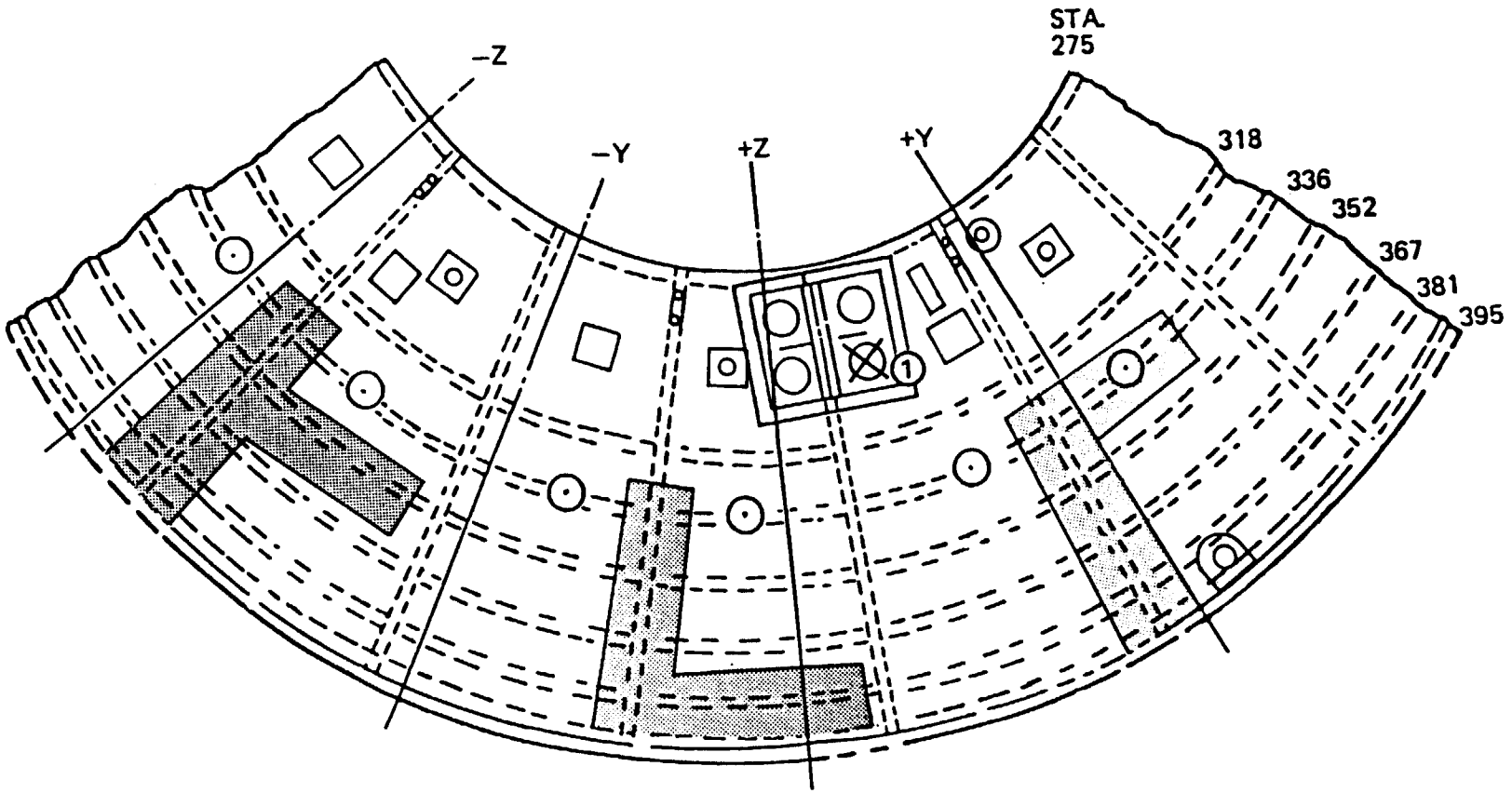
The LH Forward Skirt exhibited no missing TPS or debonds (Figure 12). Although both RSS antenna phenolic plates were present, a subsurface delamination, approximately 2-1/2 inches long by 1 inch wide, was detected on the -Z antenna. Hypalon paint was blistered and peeling on both sides and forward of the thrust fitting. The blister craters measured 1/4 to 3/4 inches in diameter. Hypalon paint was scraped, or abraded, in an area just aft of the thrust fitting. Separation of the forward attach fitting was nominal and the RSS cables separated cleanly. Only 3 ounces of water was removed from the forward skirt after retrieval.

All field joint closeouts were undamaged and known void areas in the field joint closeouts were still intact. Trailing edge damage to the GEI cork runs were attributed to debris hits from the nozzle extension severance. All GEI ID epoxy-covered tags had been removed prior to flight and replaced with identification numbers stenciled on the cases.

All three stiffener rings were undamaged after water impact. The IEA case was cracked on the forward and aft inboard corner. Both IEA end covers exhibited structural damage. Some TPS was missing from the ET attach ring. Separation of the aft ET/SRB struts was nominal.

The phenolic kick ring exhibited torn and delaminated material. K5NA was missing from all four aft BSM nozzles (Figure 13). The TPS acreage areas on the aft skirt were in generally good condition. The TVC system was virtually undamaged. Instafoam was missing from the aft ring around the holddown post shoes, the HPU exhaust horns, and the joint heater umbilical. A 3-inch diameter piece of material was missing from the holddown post #7 shim prior to water impact. The holddown post #8 shim was also missing a 3x2 inch piece of material prior to splashdown.

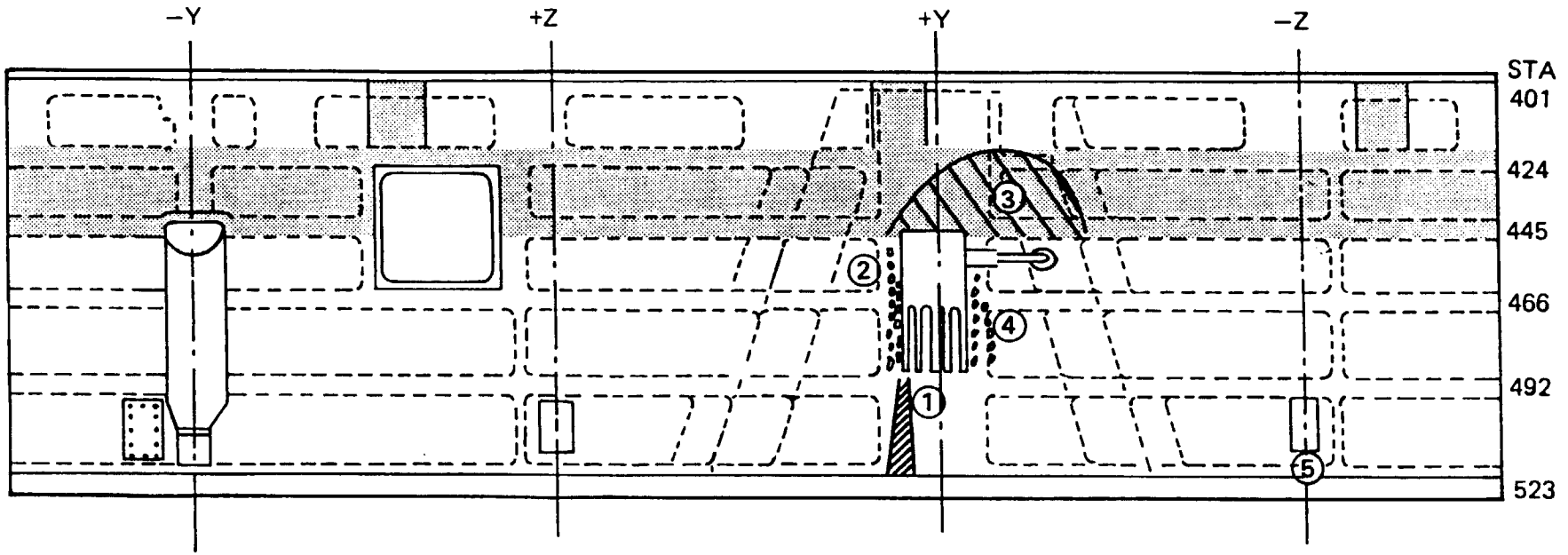
FIGURE 11. LEFT SRB FRUSTUM



MISSING TPS	DEBONDS	
NONE	NONE	① LOWER RH BSM COVER MISSING UPON RETRIEVAL

EGG/V-326E

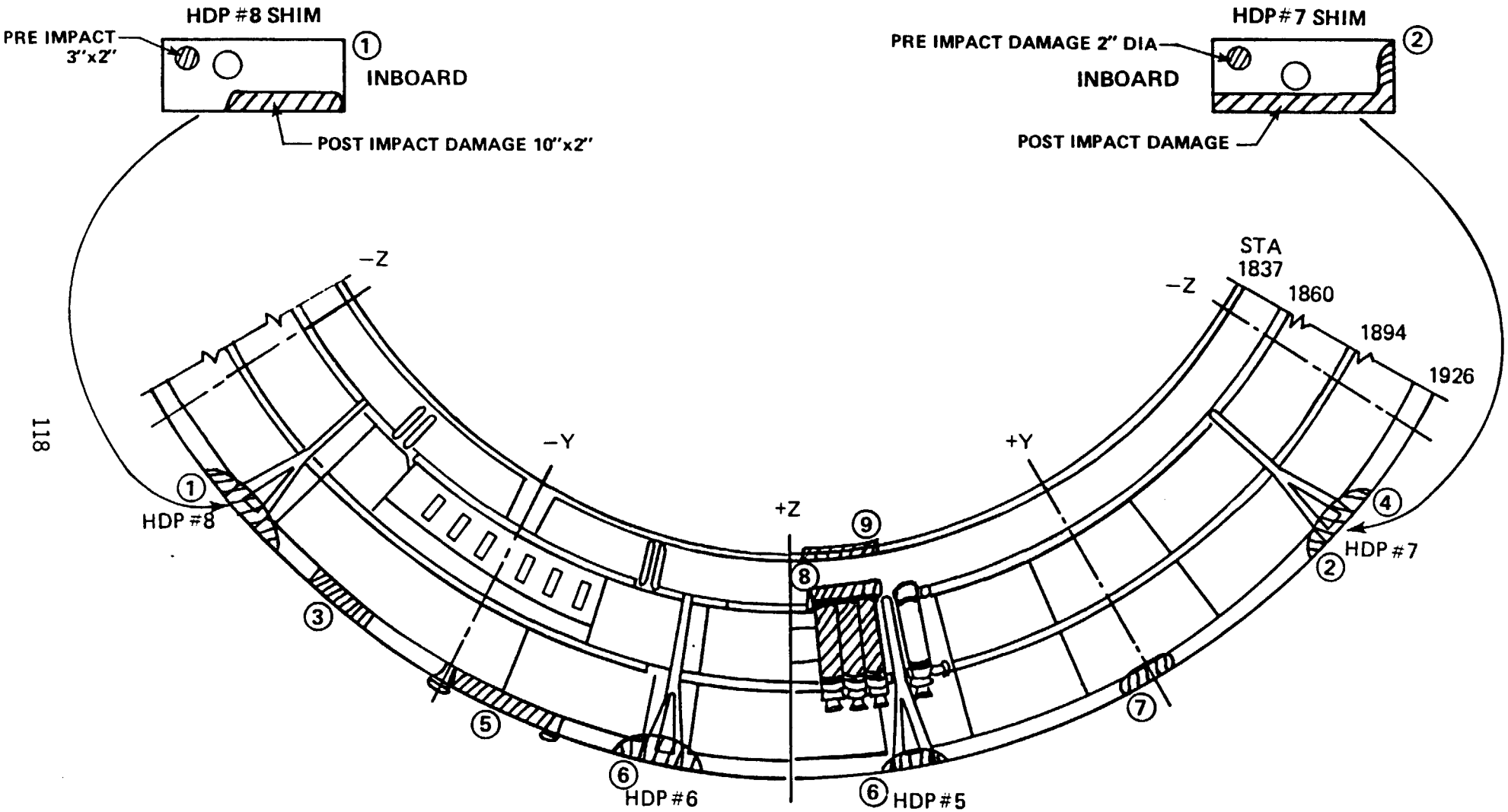
FIGURE 12. **LEFT SRB FWD SKIRT**



TPS MISSING	DEBONDS
NONE	NONE

1. ABRASION OF HYPALON PAINT NO EXPOSED CORK
2. 20 HYPALON PAINT BLISTERS ¼" DIA – ¾" DIA
3. HIGH CONCENTRATION OF HYPALON PAINT BLISTERS SIZE NO LARGER THAN ¾" DIA
4. 30 HYPALON PAINT BLISTERS ¼" DIA – ¾" DIA
5. SUBSURFACE DELIMINATION OF PHENOLIC COVER ON AFT FACE OF ANTENNAE. IS APPROX. 2½" LONG x 1" WIDE.

FIGURE 13. LEFT SRB AFT SKIRT EXTERIOR TPS



1. MISSING PORTION OF SHIM (SEE SKETCH)
2. MISSING PORTION OF SHIM (SEE SKETCH)
3. MISSING INSTAFOAM FROM RSS CABLE AREA
4. MISSING INSTAFOAM
5. INSTAFOAM MISSING BETWEEN APU EXHAUST HORNS
6. MISSING INSTAFOAM AND CHARRING
7. INSTAFOAM MISSING AROUND BACK OF T-0 UMB
8. ABLATOR MISSING FROM BSM's
9. ABLATION OF PHENOLIC

NASA

DIRECTOR OF ENGINEERING DEVELOPMENT

DIRECTOR, MECHANICAL ENGINEERING

MATERIALS SCIENCE LABORATORY

MALFUNCTION ANALYSIS BRANCH

DM-MSL-3, ROOM 2217, O&C BUILDING

KENNEDY SPACE CENTER, FLORIDA 32899

AUGUST 28, 1989

MAB 206-89

SUBJECT: CORK/INSULATION FROM STS-28 LEFT HAND (L/H) AND RIGHT HAND (R/H) SRB FRUSTRUM AND MOLD IMPRESSIONS OF THE STS-28 L/H SRB FRUSTRUM BSM NOZZEL'S.

REQUESTED ANALYSIS: MEASURE DEPTH OF SCRATCH/IMPACTS ON MOLD IMPRESSIONS AND CORK INSULATION THICKNESS OF SAMPLES SUBMITTED.

CORK INSULATION RESULTS: (6 measurements per sample)

SAMPLE	MAX. THICKNESS	MIN. THICKNESS	AVERAGE THICKNESS
A R/H	0.271"	0.246"	0.255"
A L/H	0.315"	0.275"	0.290"
B R/H	0.285"	0.273"	0.276"
B L/H	0.285"	0.245"	0.269"
C R/H	0.296"	0.270"	0.281"
C L/H	0.335"	0.312"	0.320"

MOLD IMPRESSION RESULTS:

SAMPLE NUMBER	MAXIMUM DEPTH SCRATCH #1	MAXIMUM DEPTH SCRATCH #2
A 1	0.0029"	0.0040"
A	0.0055"	0.0033"
B 1	0.0039"	N/A
B	0.0049"	N/A

MOLD IMPRESSION RESULTS OF THE BSM DOOR FASTENER DEPTH OF THE HEXAGON INDENTATION:

DEPTH	HEXAGON DIMENSION
0.098"	0.500"

H.A. Petersen,NASA,DM-MSL-3

7.3 RECOVERED SRB DISASSEMBLY FINDINGS

All blast covers from the holddown posts were removed. The plungers appeared to operate correctly and the reconstruction showed 99-100 percent retention on the frangible nuts and 94-99 percent (by weight) retention of the ordnance pieces.

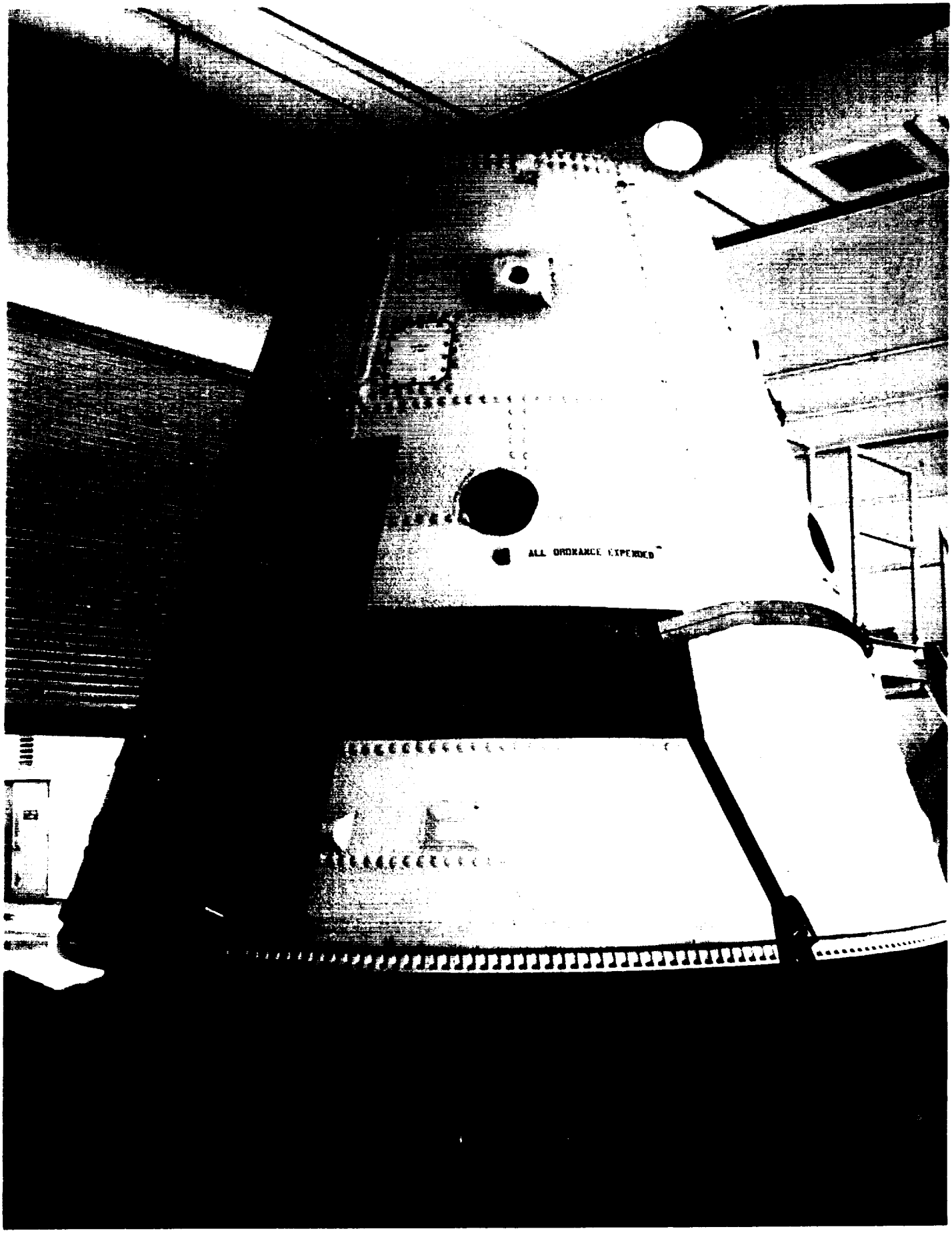
Both igniters had one each blowhole in the putty, an expected condition according to MTI. However, squawk 28-026 was written against a depression on the RH SRB inner gask-o-seal. Nozzle performance was nominal and erosion was smooth.

The O-rings in the field joints were undamaged and there was no evidence that any heat/pressure had gone past the J-seals. Fretting was extensive around the entire circumference of the right center field joint, moderate at 90 degrees on the right forward joint, and light on the remaining joints.

Corrosion was extensive on the right aft field joint under the hat band. Several pin holes were heavily corroded. This condition was attributed to poor primer application. All other joints were in good condition.

Bolts were loose and could be turned by hand on both the LH and RH ETA rings. Further analysis is being conducted by KSC, MSFC, and USBI.

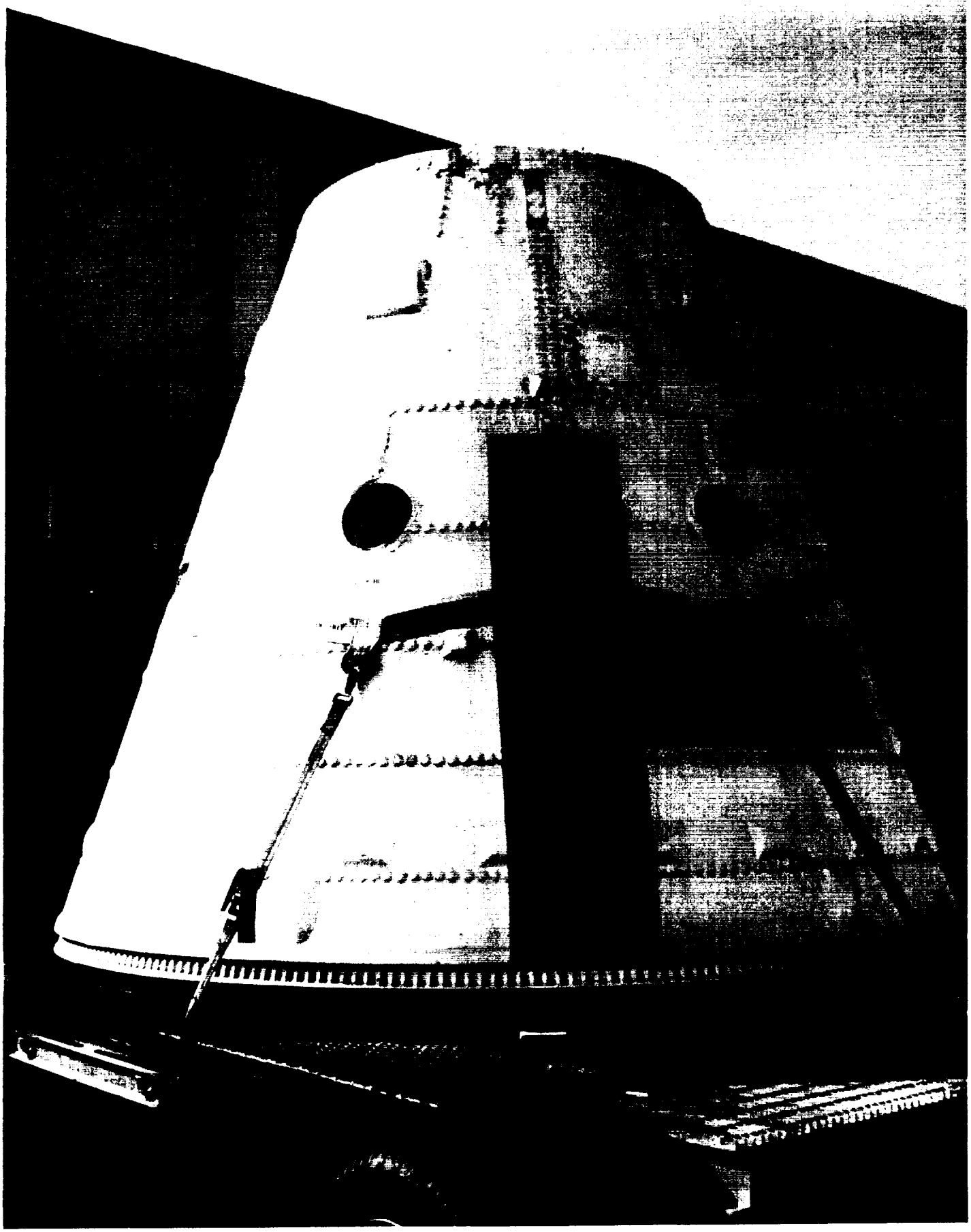
Observed SRB Post Launch Anomalies are listed in Section 10.2.



POST FLIGHT CONDITION OF RH SRB FRUSTUM TPS

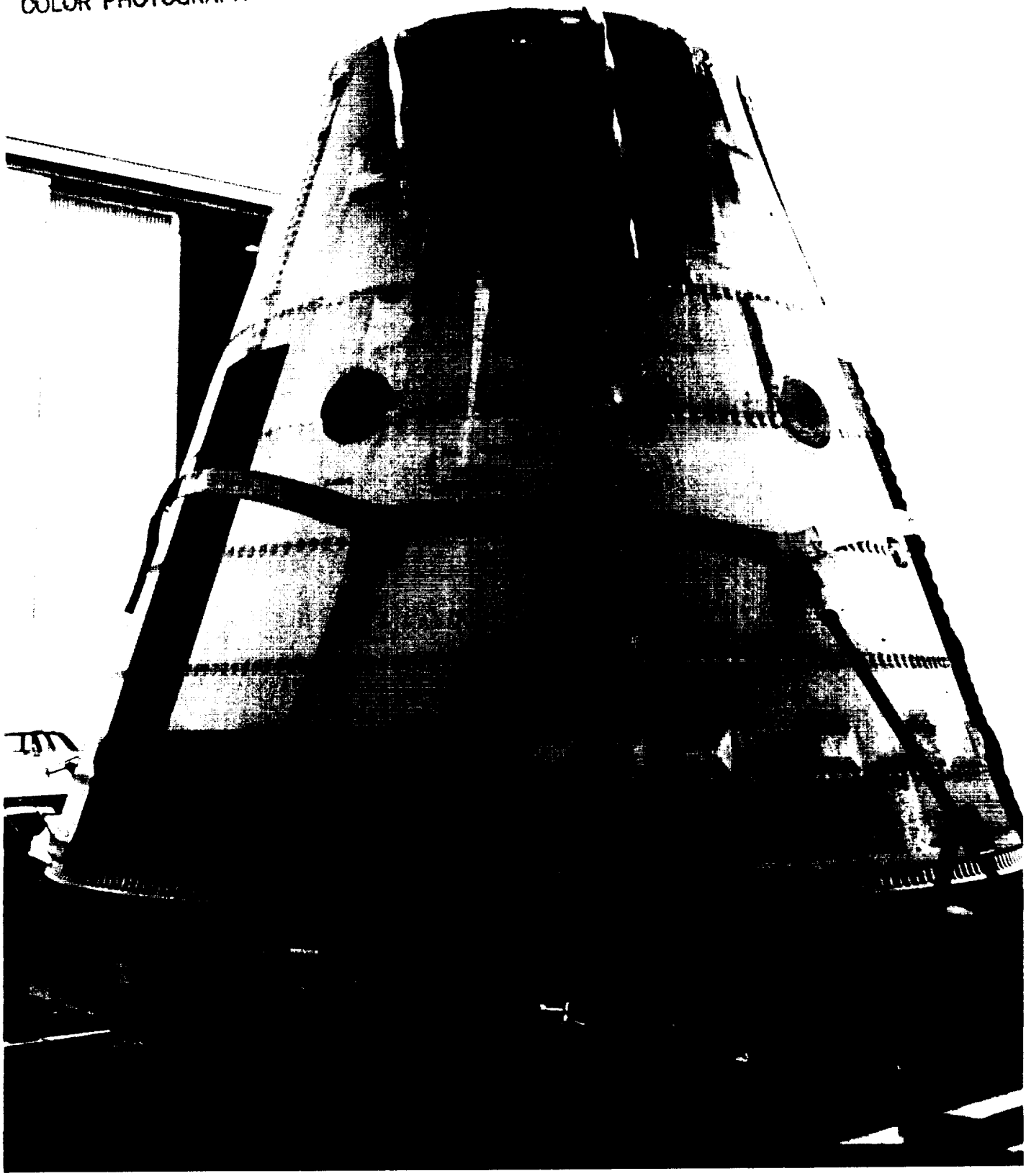
ORIGINAL PAGE
COLOR PHOTOGRAPH

BLISTERING/PEELING OF HYPALON PAINT ON RH SRB FRUSTUM



POST FLIGHT CONDITION OF LH SRB FRUSTUM TPS

ORIGINAL PAGE
COLOR PHOTOGRAPH



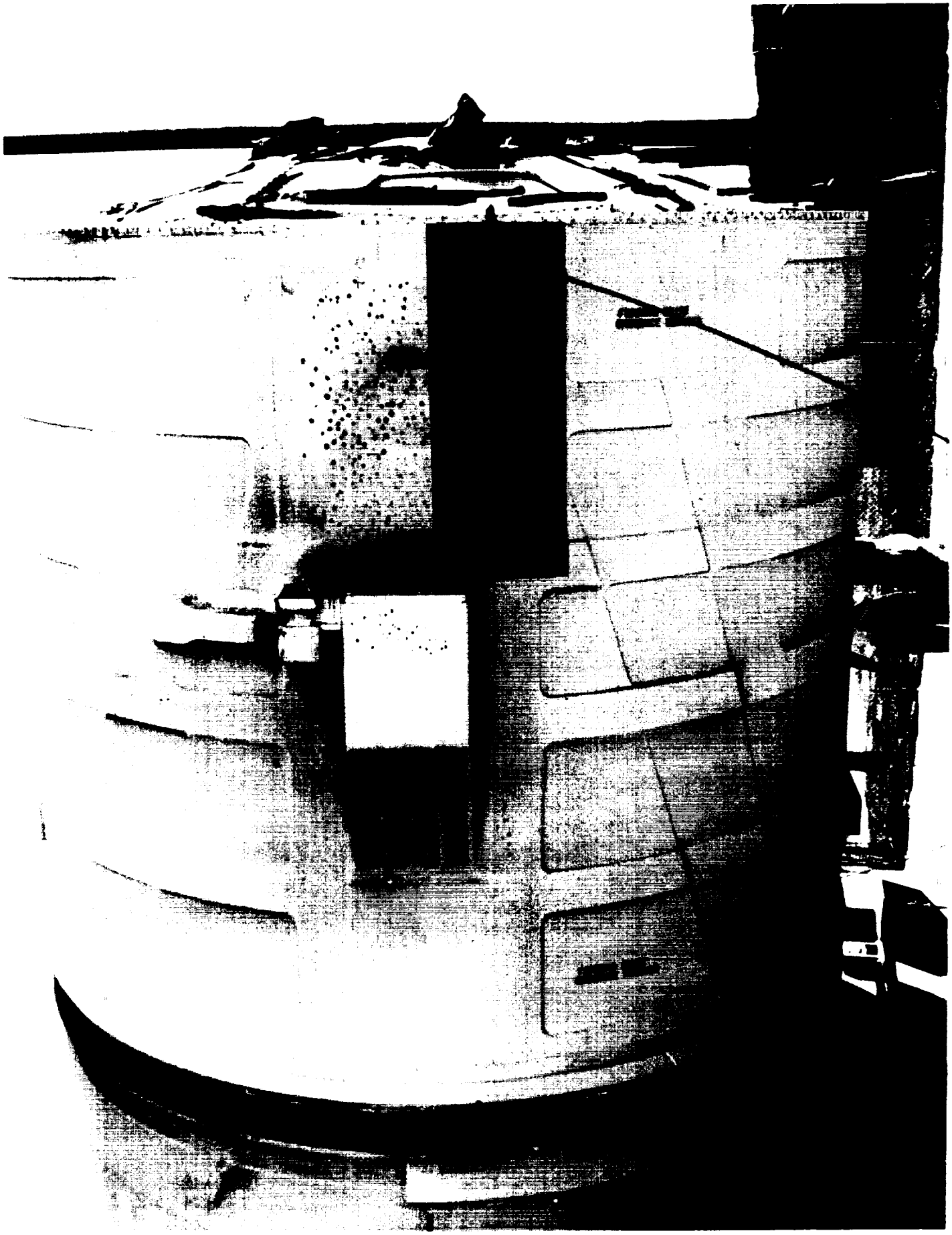
LH FRUSTUM BSM NOZZLES AFTER REMOVAL OF COVERS

LOWER RIGHT BSM COVER ON THE LH FRUSTUM WAS DISCOVERED MISSING
DURING RECOVERY OPERATIONS

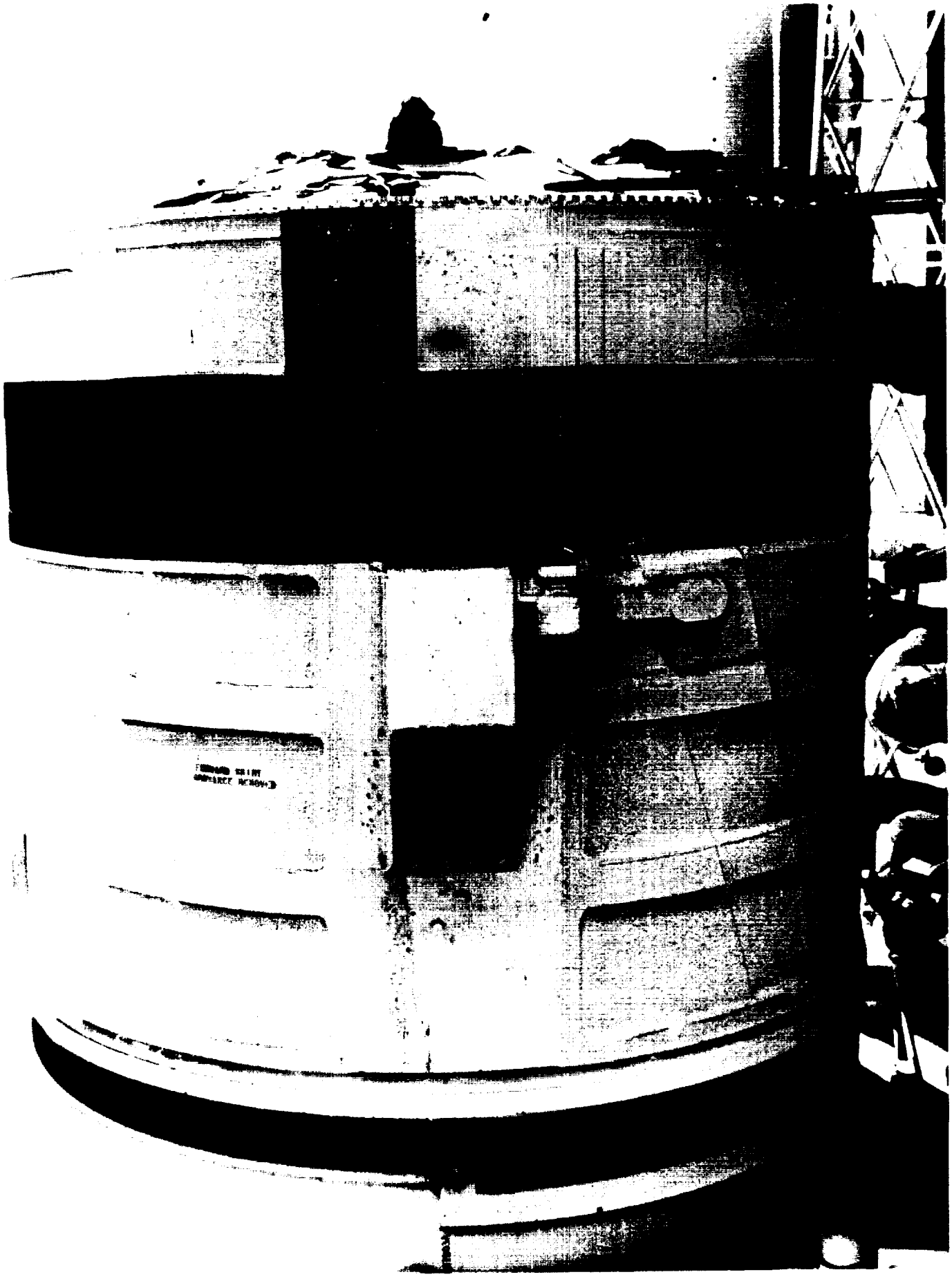
AS-RECOVERED BSM COVER ATTACH RING SHOWING MISSING SECTION
NOTE FRACTURE PLANES SHOW SIGNS OF SOOTING

TORSIONAL/TENSION LOADING EFFECTS ON ATTACH RING

INDENTATIONS ON NOZZLE RESULTED FROM THREE BSM AERO HEAT SHIELD COVER OSCILLATIONS/IMPACTS

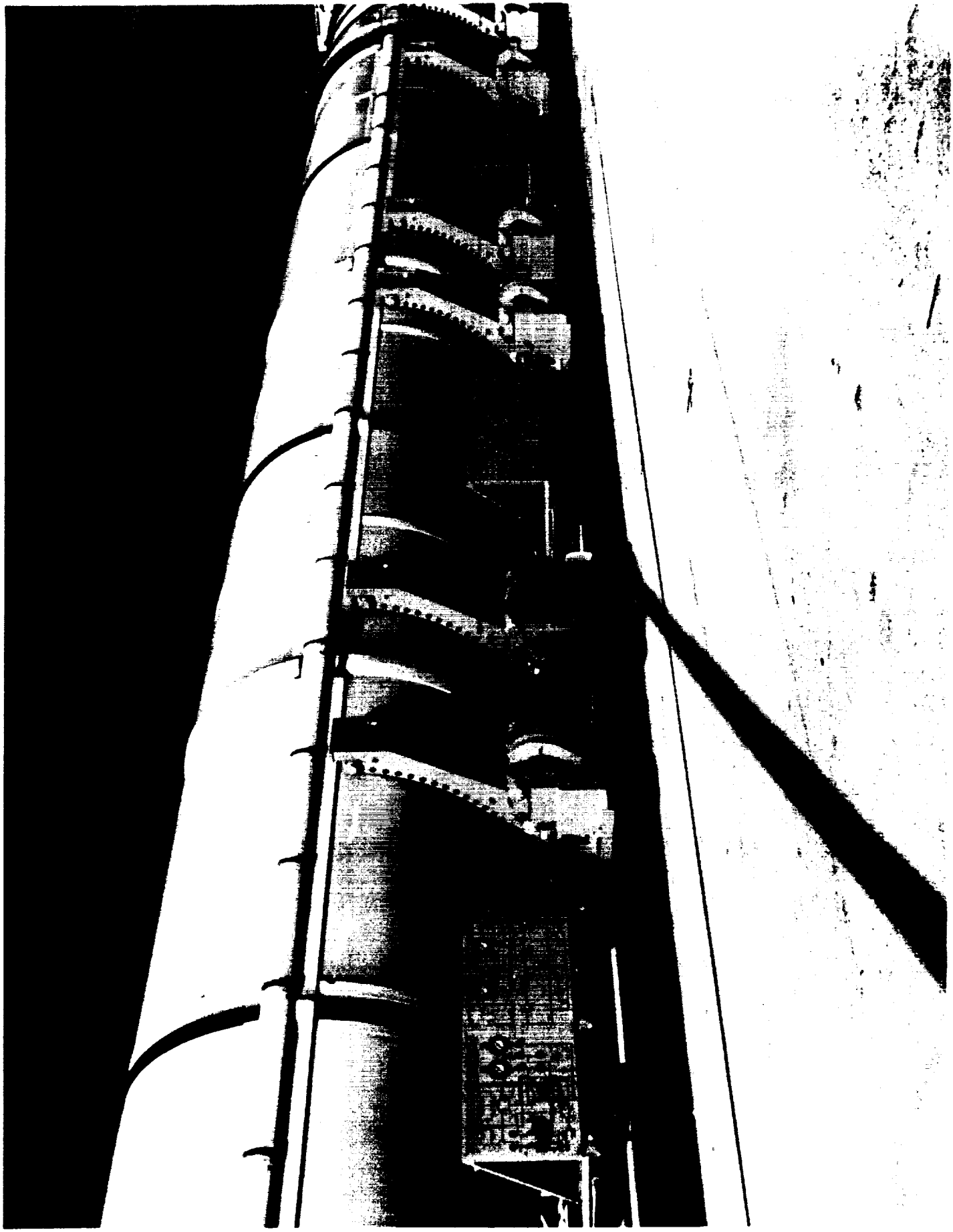


BLISTERING AND 'CRATERING' OF HYPALON PAINT/MSA ON
RH SRB FORWARD SKIRT

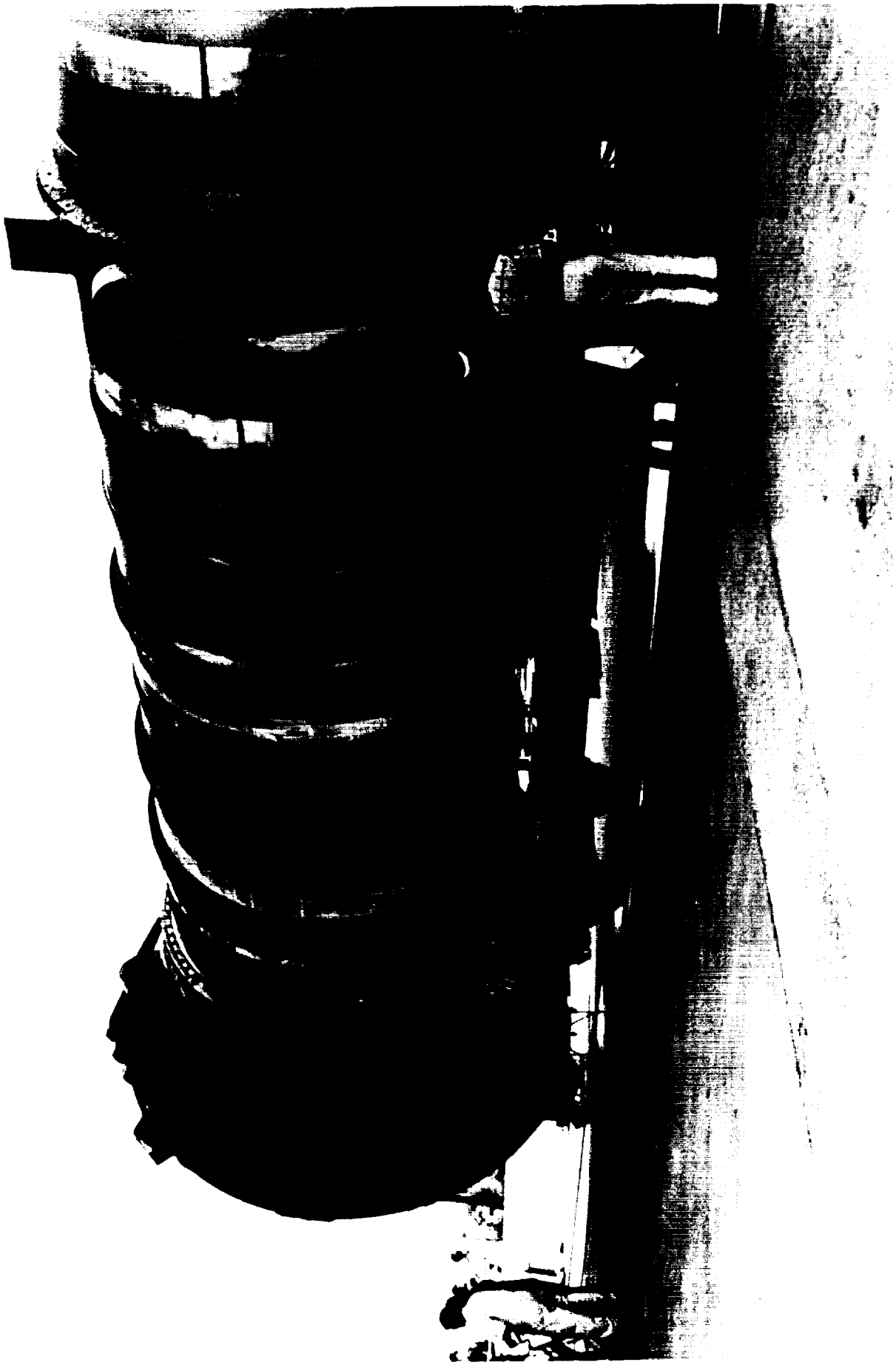


BLISTERING OF HYPALON PAINT AND SCRAPE MARK AFT OF THRUST POST ON LH SRB FORWARD SKIRT

ORIGINAL PAGE
COLOR PHOTOGRAPH

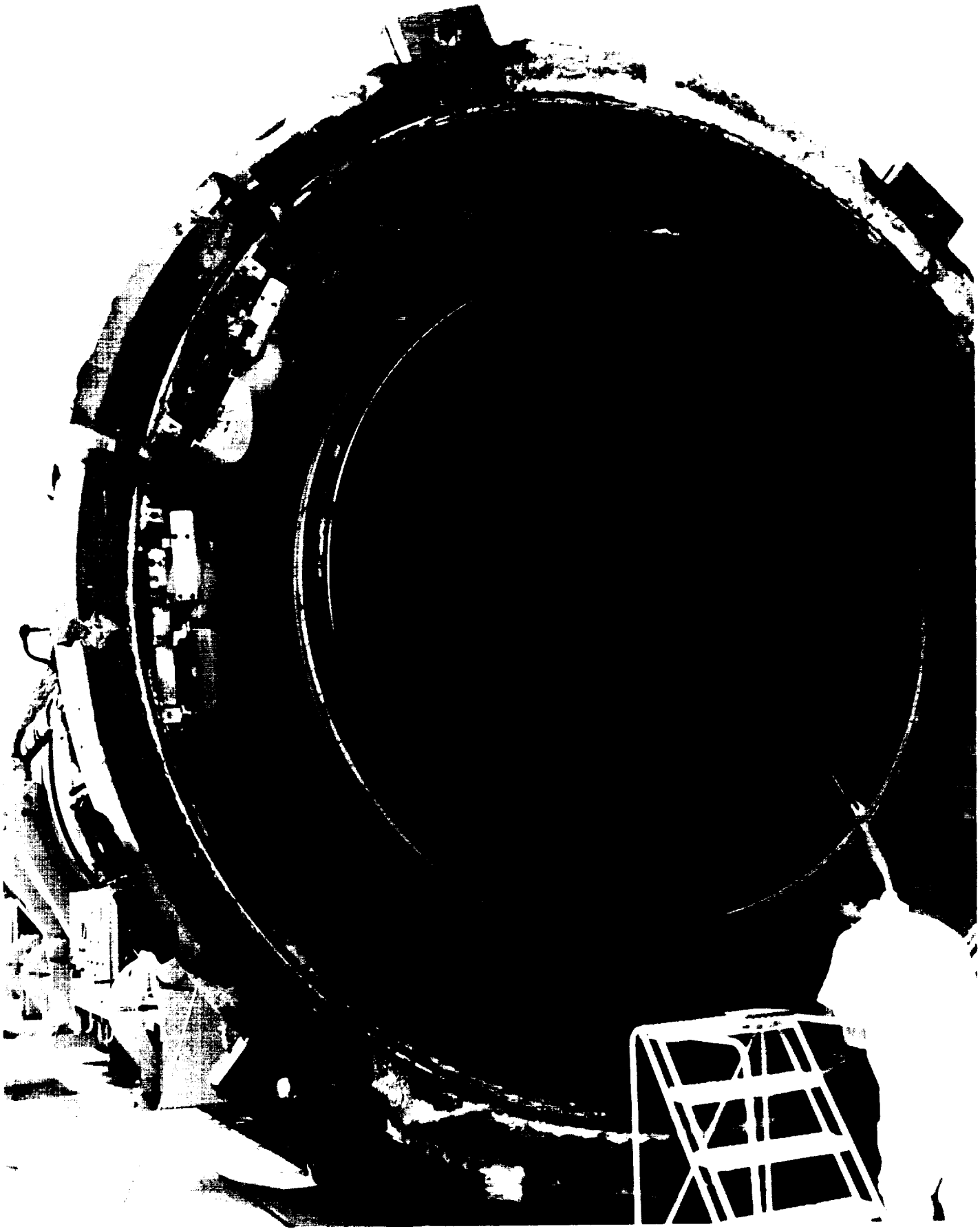


POST FLIGHT CONDITION OF SRB SEGMENT CASES



TYPICAL POST FLIGHT CONDITION AND DISCOLORATION OF AFT BOOSTER

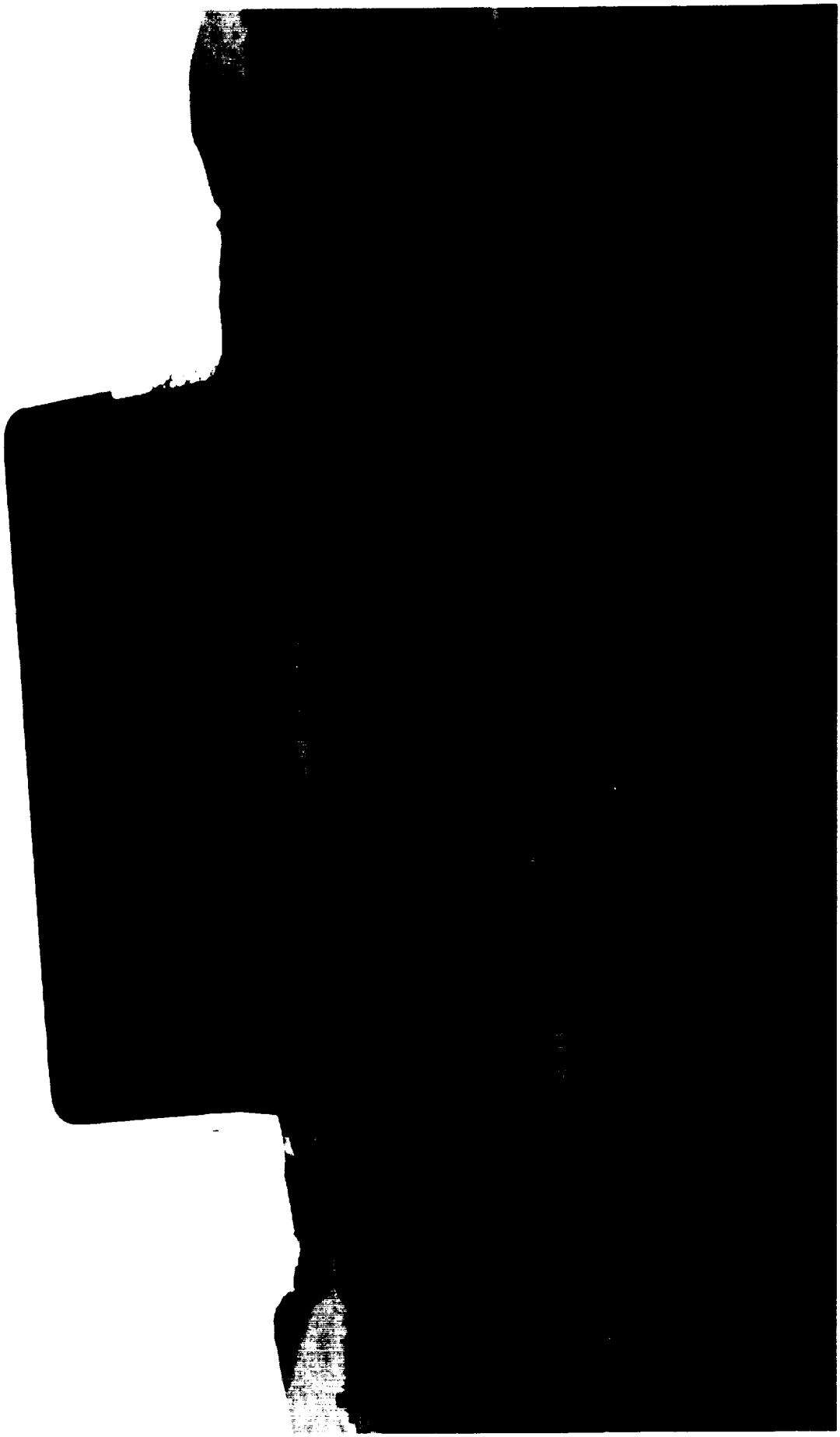
WATER IMPACT DAMAGE TO RH SRB FORWARD STIFFENER RING



MISSING FOAM FROM AFT RING

ORIGINAL PAGE
COLOR PHOTOGRAPH

PIECE OF SHIM MATERIAL MISSING PRIOR TO WATER IMPACT. AFT RING FOAM IS ALSO MISSING.



PIECES OF SHIM/SIDEWALL MATERIAL MISSING PRIOR TO SPLASHDOWN

K5NA IS MISSING FROM AFT BSM NOZZLES

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A detailed post landing inspection of OV-102 was conducted August 13-14, 1989 at Ames-Dryden (EAFB) on Runway 17L and in the Mate/Demate Device (MDD) to identify debris impacts, damage caused, and if possible, debris sources. The Orbiter TPS sustained a total of 76 hits, of which 20 had a major dimension of one inch or greater. This total does not include approximately 100 to 150 hits on the base heatshield. This total also does not include degradation to upper surface white tiles which was not the result of debris impacts.

The Orbiter lower surface had a total of 60 hits, of which 13 had a major dimension of 1-inch or greater. Based on these numbers, comparison to statistics from 22 previous missions of similar configuration (excluding missions STS-24, 25, 26, 26R, and 27R which had damage from known debris sources), the total number of hits on the lower surface is less than average. Based on the severity of damage as indicated by surface area and depth, this flight is considered to be better than average.

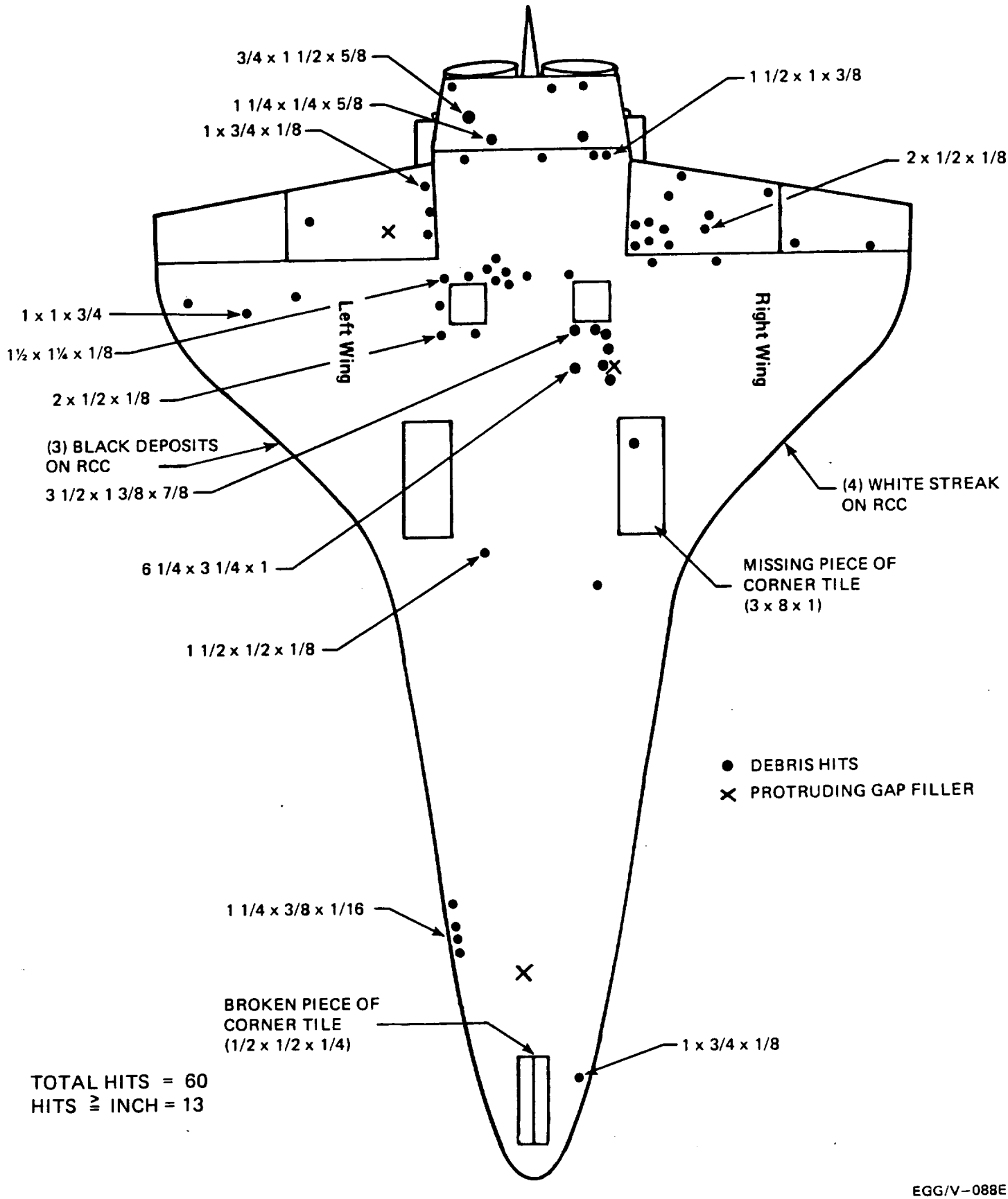
The primary (17L) and secondary (23) runways were inspected and debris collected the day prior to landing. Alternate runway 15 was also inspected and runway 22 was swept prior to landing.

The post landing walkdown of Runway 17L was performed at approximately L+15 minutes. Several pieces of the outboard forward corner tile from the RH main landing gear door were found near the end of the runway near a point where the landing gear door was opened. The missing corner was approximately 8"x3"x1". Ten pieces of Ames gap filler material were also found in this area. A small piece of foil insulation material from the SSME nozzle was found approximately 200 yards from the wheel stop position. Rollout distance of the Orbiter was 6015 feet.

The majority of the lower surface damage was concentrated aft of the main landing gear doors in an amount approximately equal on each side of the centerline. The most significant damage site measured 6-1/4"x3-1/4"x1" and was located forward of the ET/ORB LO2 umbilical. Just aft of this site, a 3-1/2"x1-3/8"x7/8" damage site occurred. Both sites were glazed from reentry heating and were probably caused by the 23x15x1 inch piece of ET intertank SOFI debris. Figures 14-17 illustrate the TPS debris damage assessment for STS-28R. Figures 18 and 19 show detail of the larger damage sites on the lower surface. Samples from selected sites were taken for laboratory analysis in an attempt to identify the sources of TPS damage. Three protruding gap fillers were visible on the lower surface. A piece of gap filler sleeving approximately 6 inches long was loose between the right wing elevons. No detectable damage to adjacent tiles resulted from these gap fillers.

STS-28R

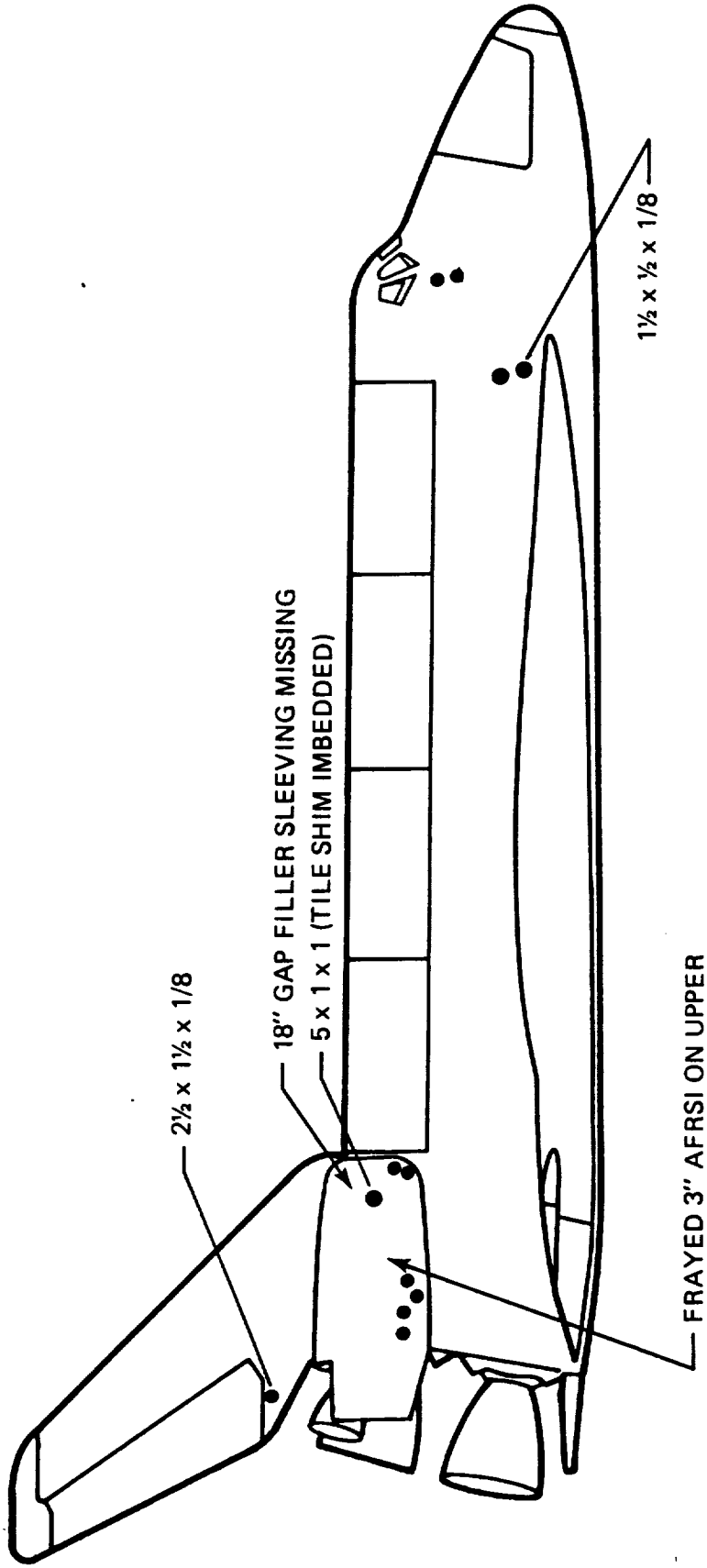
FIGURE 14. **DEBRIS DAMAGE LOCATIONS**



EGG/V-088E

STS-28R

FIGURE 15. DEBRIS DAMAGE LOCATIONS



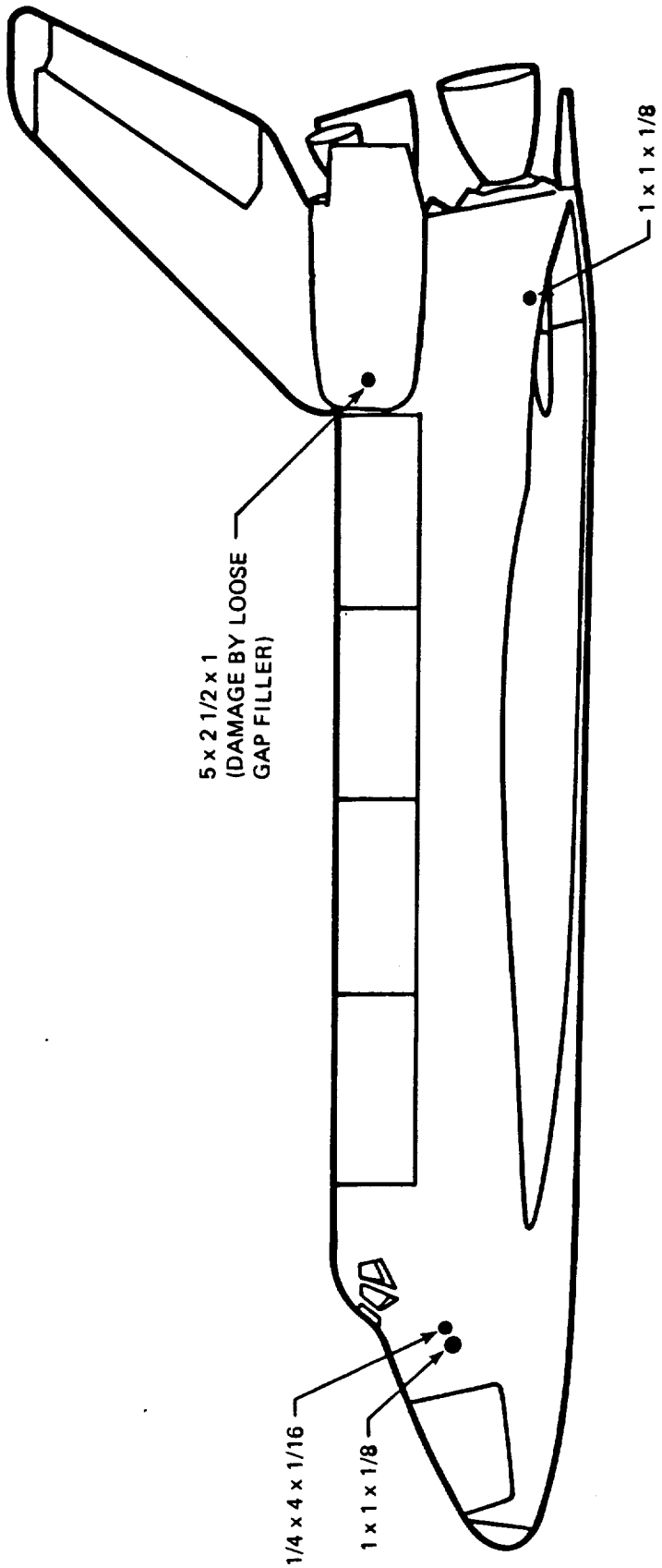
NOTE: TOTAL OF 7 PROTRUDING GAP FILLER SLEEVES ON RIGHT OMS POD

TOTAL HITS = 12
HITS ≥ 1 INCH = 3

EGG/V-088A

STS-28R

FIGURE 16. **DEBRIS DAMAGE LOCATIONS**

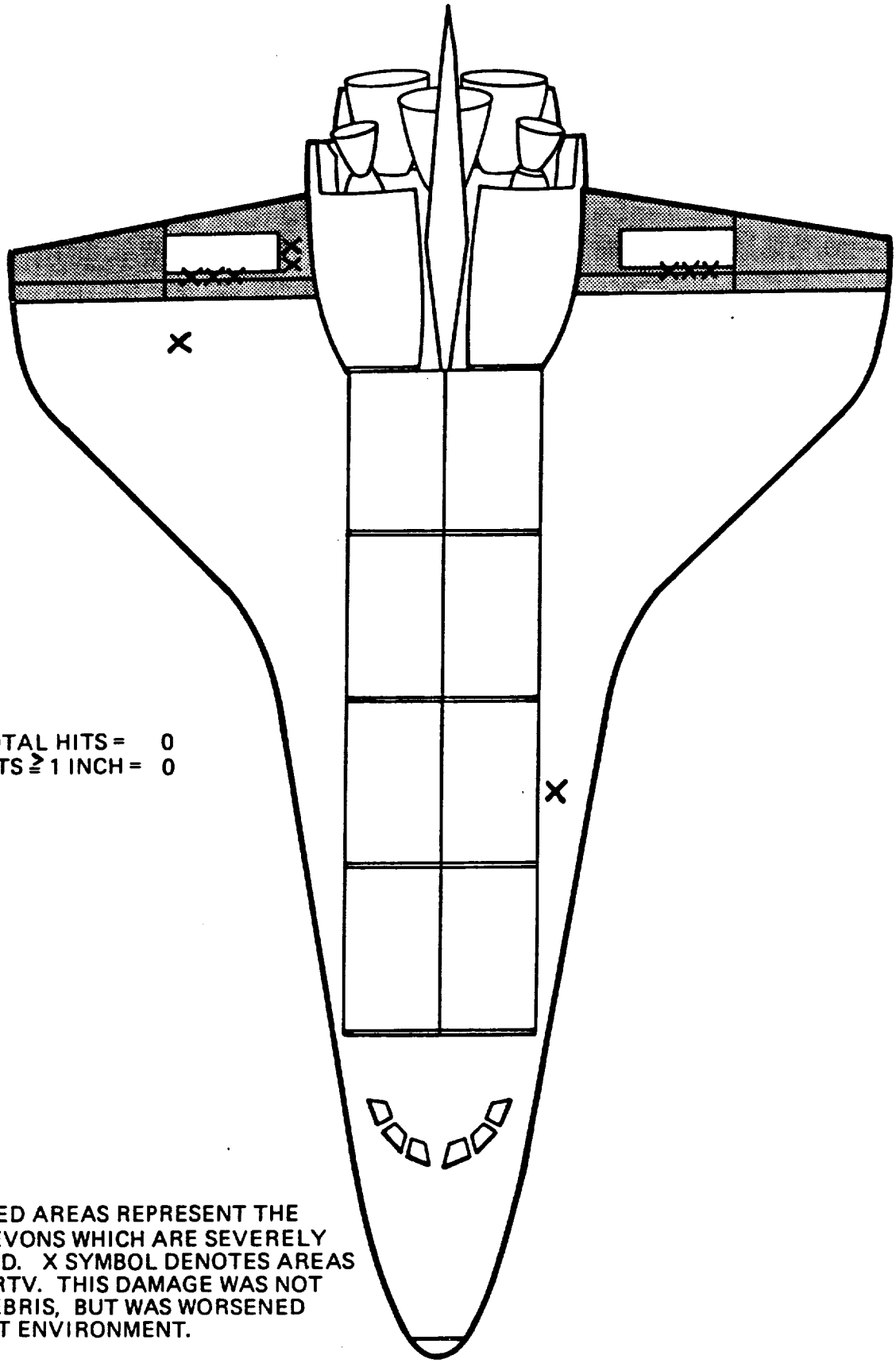


TOTAL HITS = 4
HITS ≥ 1 INCH = 4

EGG/V-088

STS-28R

FIGURE 17. **DEBRIS DAMAGE LOCATIONS**

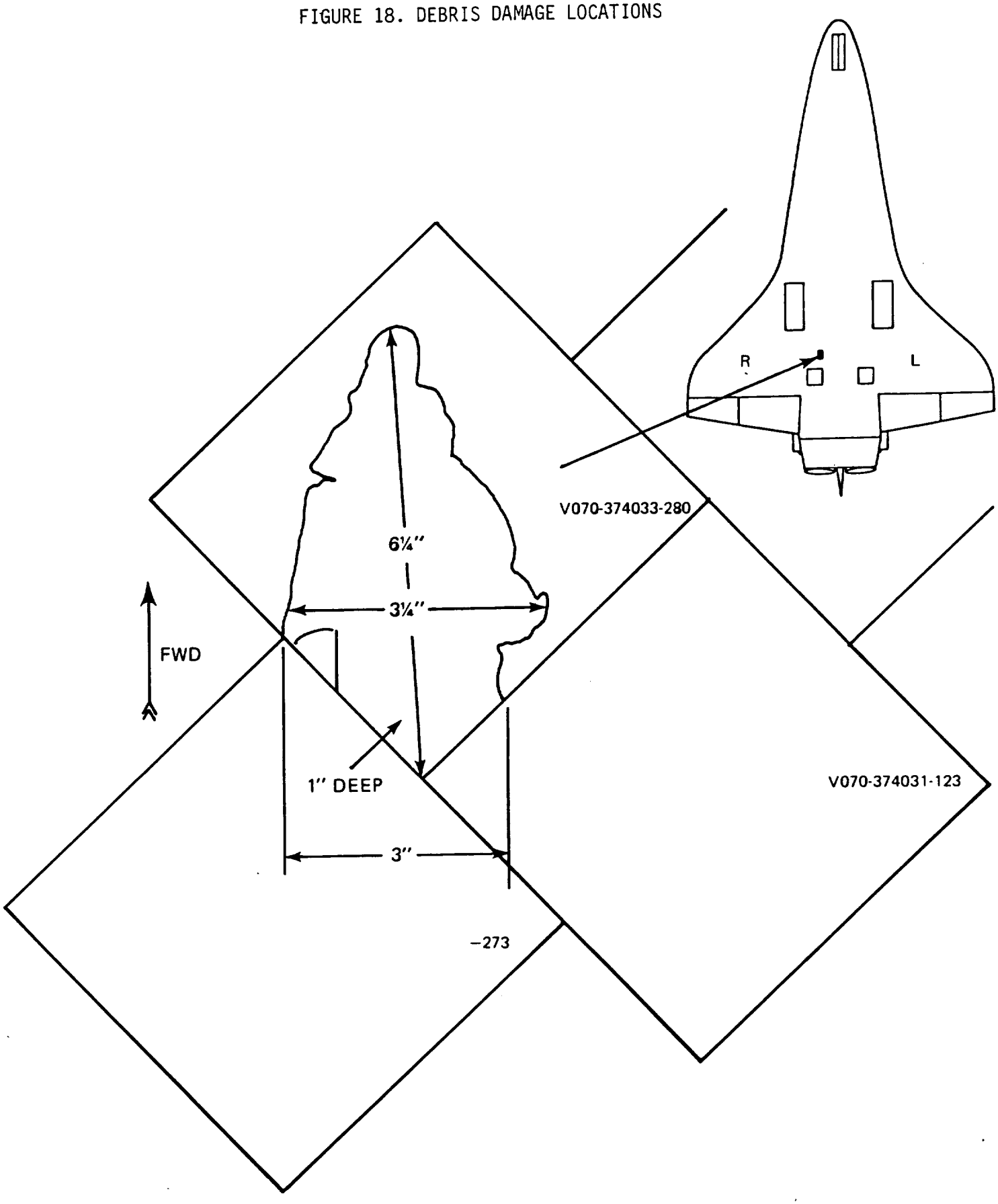


TOTAL HITS = 0
HITS ≥ 1 INCH = 0

NOTE: SHADED AREAS REPRESENT THE AREAS ON ELEVONS WHICH ARE SEVERELY DETERIORATED. X SYMBOL DENOTES AREAS OF EXPOSED RTV. THIS DAMAGE WAS NOT CAUSED BY DEBRIS, BUT WAS WORSENED BY THE FLIGHT ENVIRONMENT.

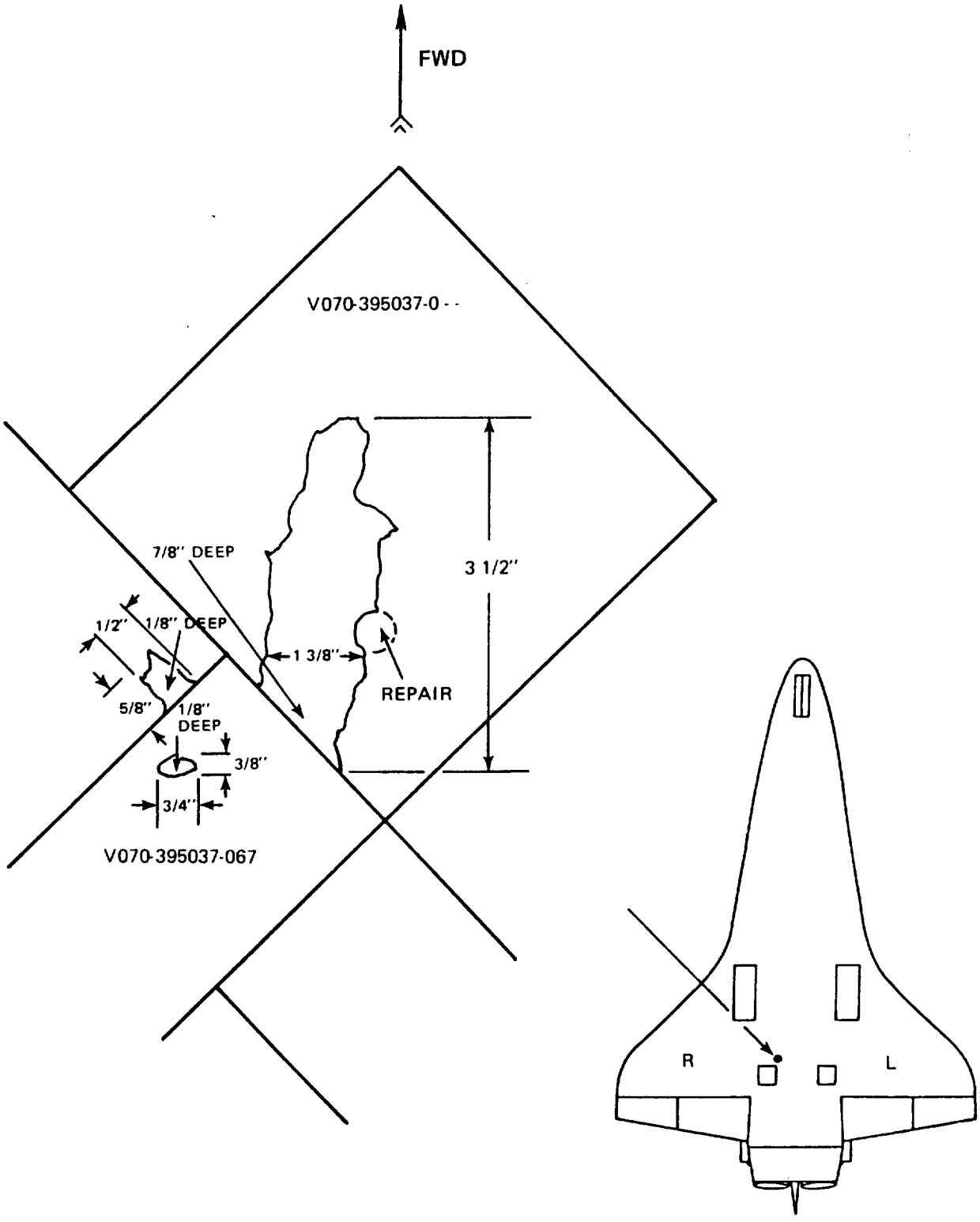
EGG/V-088C

FIGURE 18. DEBRIS DAMAGE LOCATIONS



STS-28R

FIGURE 19. **DEBRIS DAMAGE LOCATIONS**



White tiles on the upper orbiter surfaces showed considerable continued degradation. The most significant damage was on the wing upper surface forward and aft of the elevon hinge line. This particular damage was not caused by debris impacts. Prior to launch, considerable degradation of the white tiles was noted. The flight acoustic and dynamic environments resulted in the loss of significant additional tile material which was observed falling from the vehicle during review of several launch films. Eight locations on the inboard elevons and two on the wings had material missing to the substrate. The coating over the entire surface area on some tiles was also missing.

Gap filler sleeving material was loose on the forward areas of both OMS pods. There were approximately 14 protruding gap fillers on the LH OMS pod and 7 on the RH OMS pod. One 5 inch length of gap filler on the LH pod caused considerable damage (5"x2-1/2"x1") to an adjacent white tile. An 18-inch long section of gap filler sleeving was missing from the RH OMS pod. The RH OMS pod also sustained a damage site measuring 5"x1"x1" on a white tile. The damage site contained a thin, orange/red, 1-inch wide piece of foreign material embedded in it. The material was removed for laboratory analysis and determined to be GSE tile shim material (feeler gage).

Damage to the base heat shield tiles was considerably less than average. The main engine white beta bags sustained minor damage on all three SSME's. The nozzle foil insulation on SSME #1 and #3 were damaged on the ninth and eighth ring, respectively.

The RH wing leading edge RCC exhibited four white streaks, the largest of which measured 12 inches long by 4 inches wide. The LH wing leading edge RCC exhibited three black streaks with residual particles. Samples of both types of streaks were taken for laboratory analysis and were determined to be vehicle TPS bonding material and landing site products, such as sand (Report MCB-0774-89, Section 9.0).

Orbiter window #3 was heavily hazed; window #4 was less hazed. Window #5 exhibited a 6 inch long by 1 inch wide deposit. Laboratory analysis was performed on samples taken from all windows and was most likely adhesive from the forward RCS paper covers (Report MCB-0774-89, Section 9.0). Figures 20 and 21 show the locations for all samples taken from the Orbiter for analysis.

Orbiter wheels, tires, and brakes were in excellent condition. There was no evidence of tire tread wear.

Due to equipment difficulties, the Shuttle Thermal Imager system was not operational for this landing.

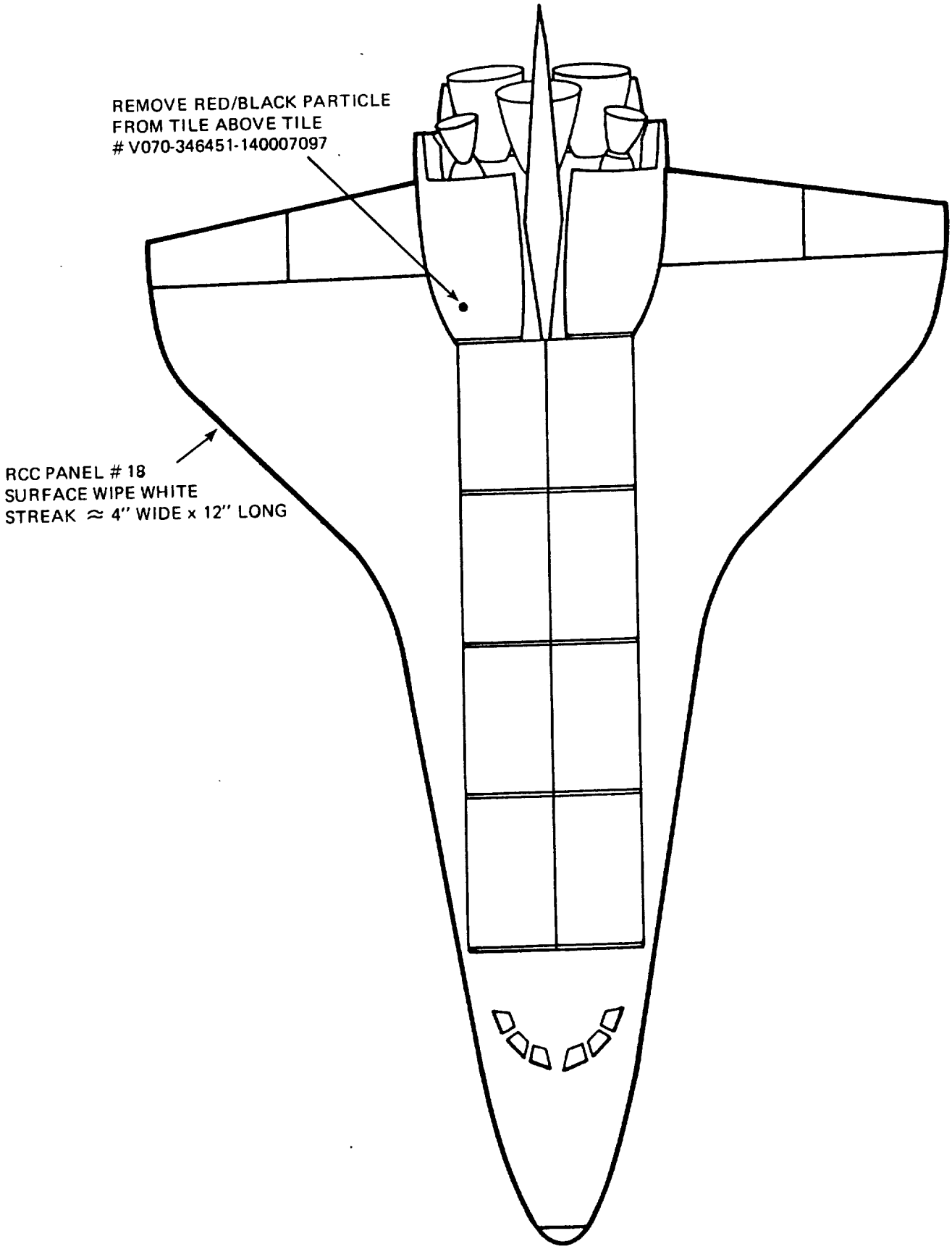
In summary, the total number of lower surface Orbiter TPS debris hits was less than average when compared to previous flights, as shown in the comparison chart (Figure 22). The dis-

tribution of hits on the Orbiter does not point to a single source of ascent debris, but indicates a shedding of ice and TPS debris from random sources. The potential identification of sources of debris for mission STS-28R will be based on the laboratory analysis of TPS damage sites, inspection of the recovered SRB components, and analysis of air/ground photography.

Observed Orbiter Post Launch Anomalies are listed in Section 10.3.

STS-28R

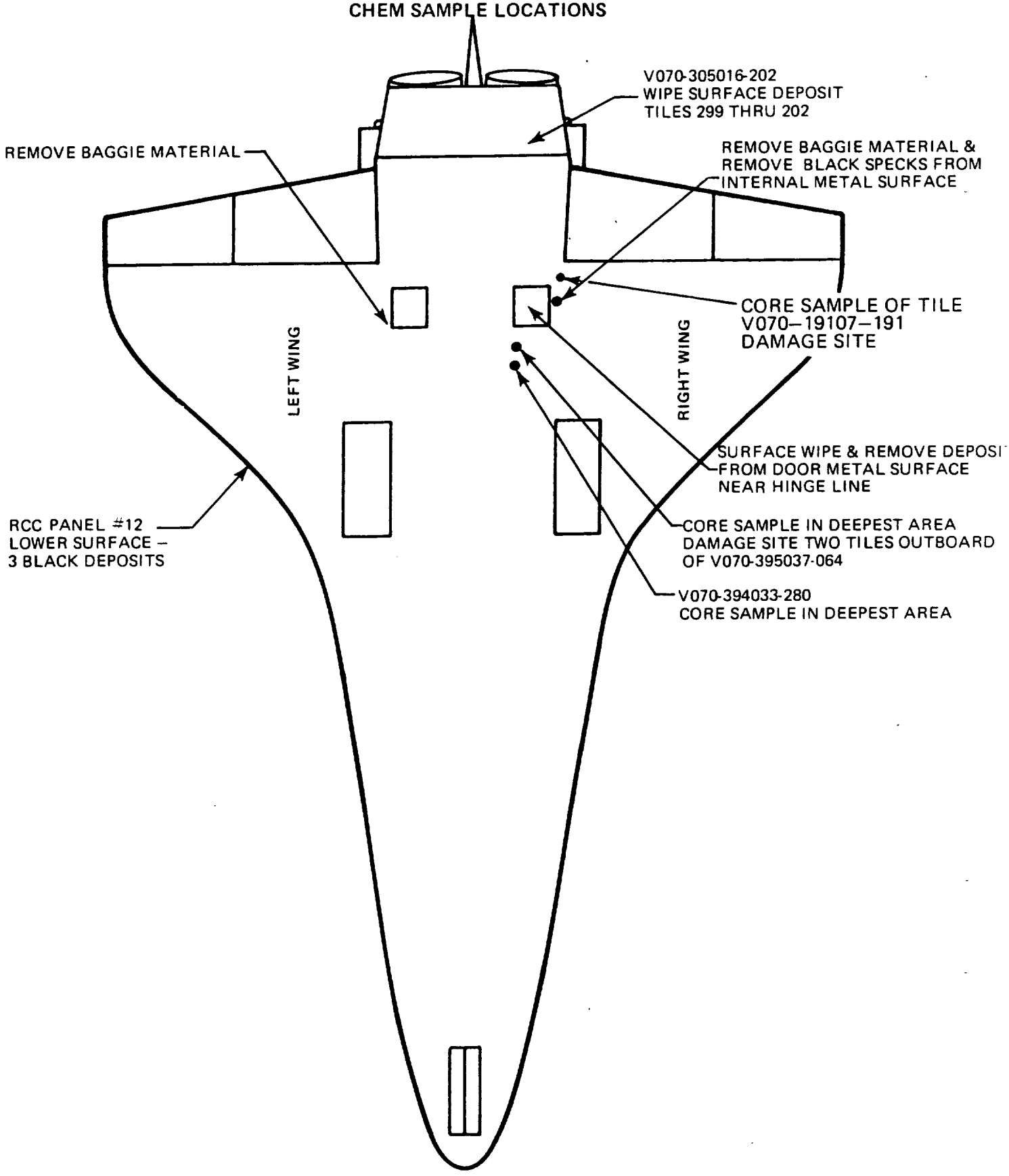
FIGURE 20. **DEBRIS SAMPLE LOCATIONS**



EGG/V-088C

STS-28R

FIGURE 21. DEBRIS DAMAGE LOCATIONS



EGG/V 0888

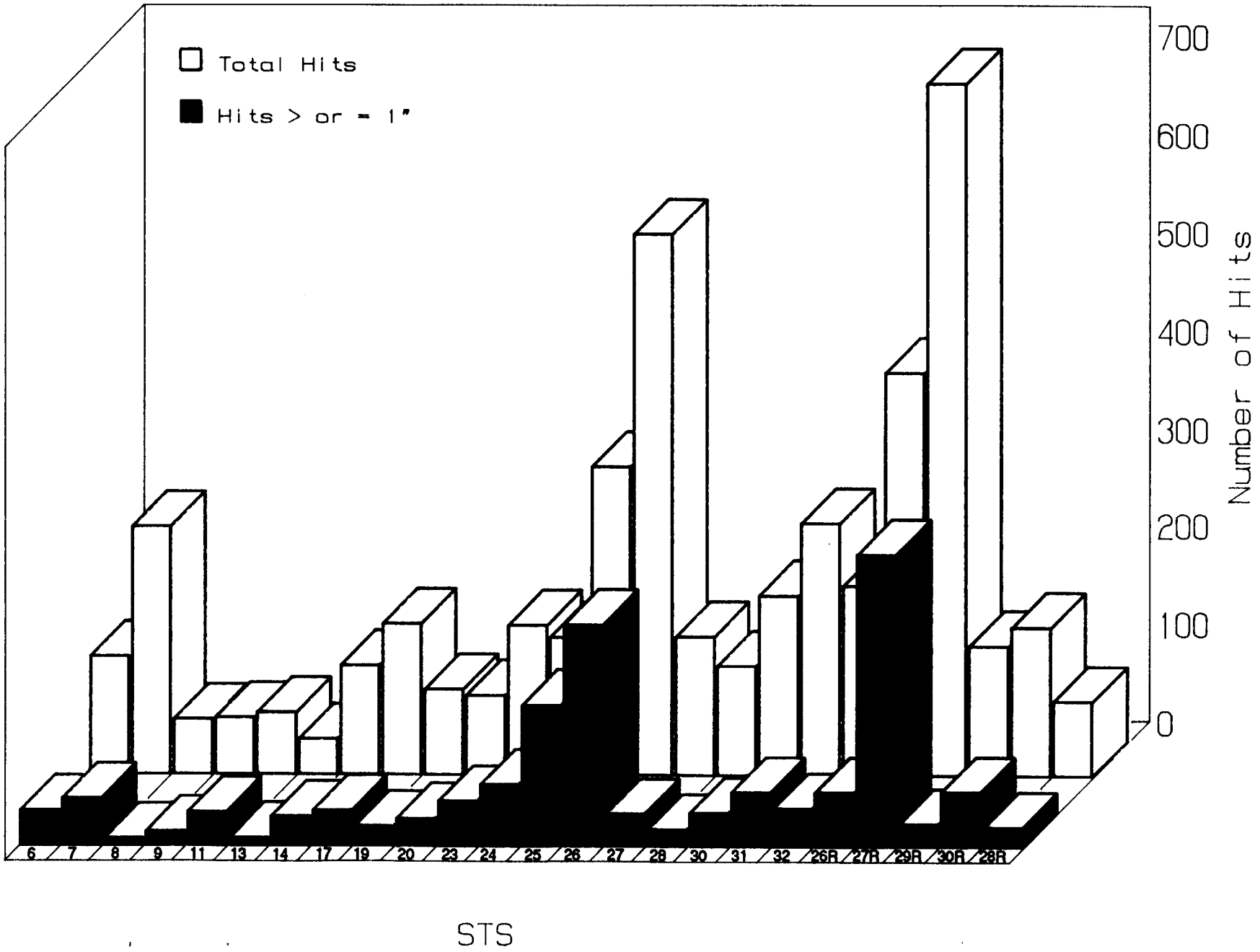
FIGURE 22. STS-28R DEBRIS DAMAGE ASSESSMENT SUMMARY

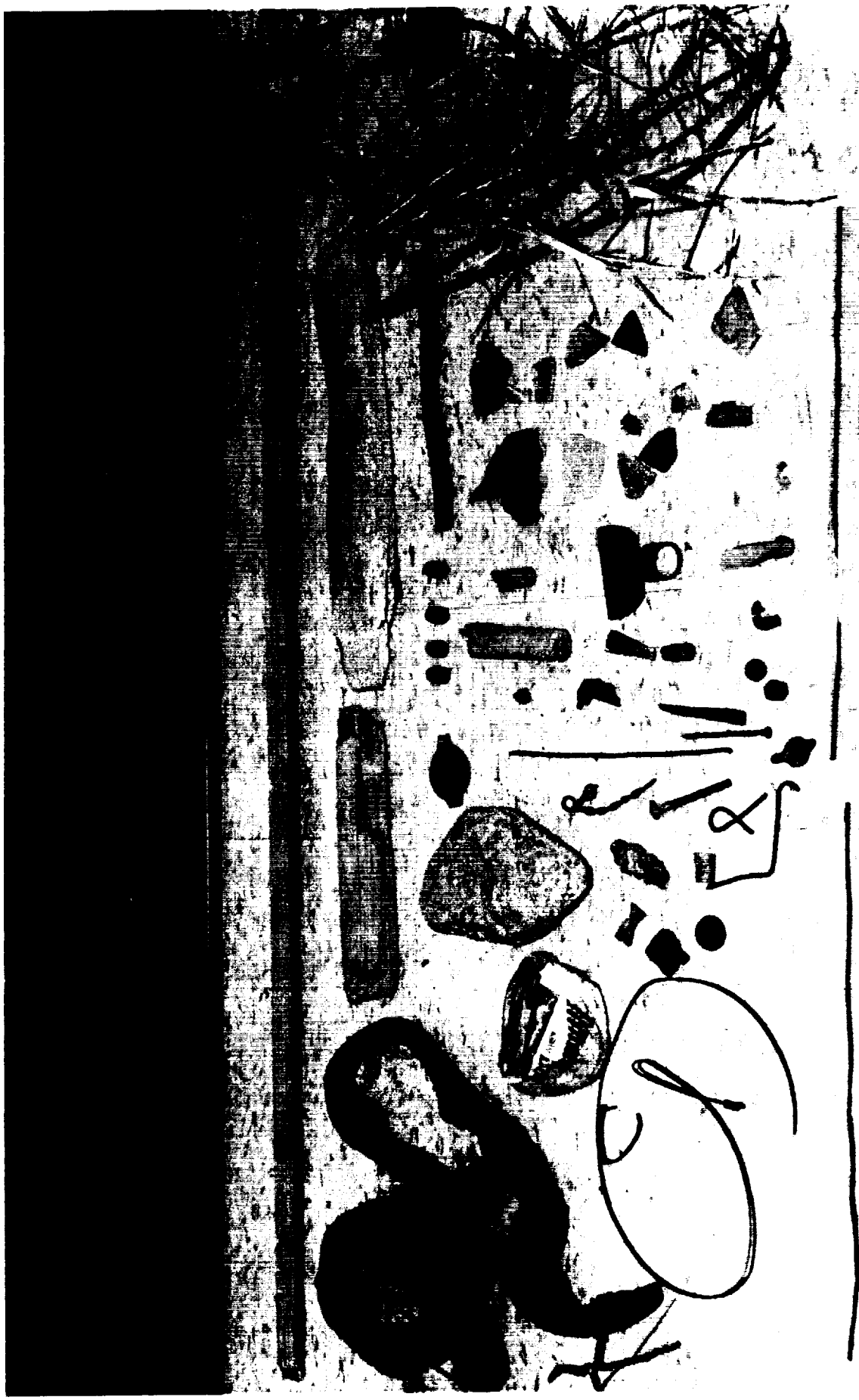
	Hits > or = 1"	Total Hits
Lower Surface	13	60
Upper Surface	0	0
Right Side	2	5
Left Side	3	3
Right OMS Pod	1	7
Left OMS Pod	1	1
TOTALS	20	76

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

COMPARISON TABLE





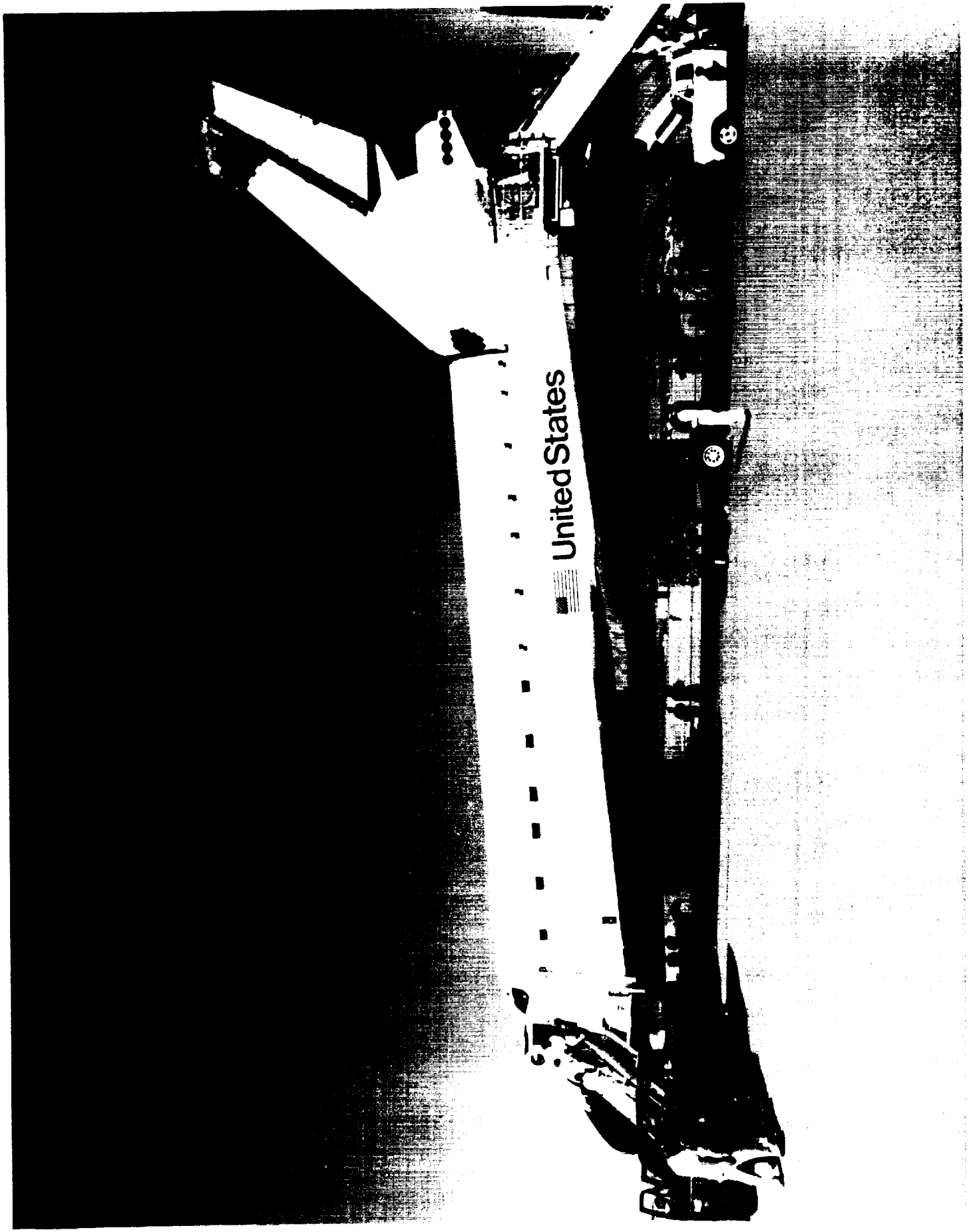
DEBRIS COLLECTED DURING PRE-LANDING RUNWAY INSPECTION

PIECES OF RH MLG DOOR CORNER TILE RECOVERED NEAR POINT OF DOOR OPENING

NOSE LANDING GEAR TIRE IMPRESSION AT POINT OF TOUCHDOWN

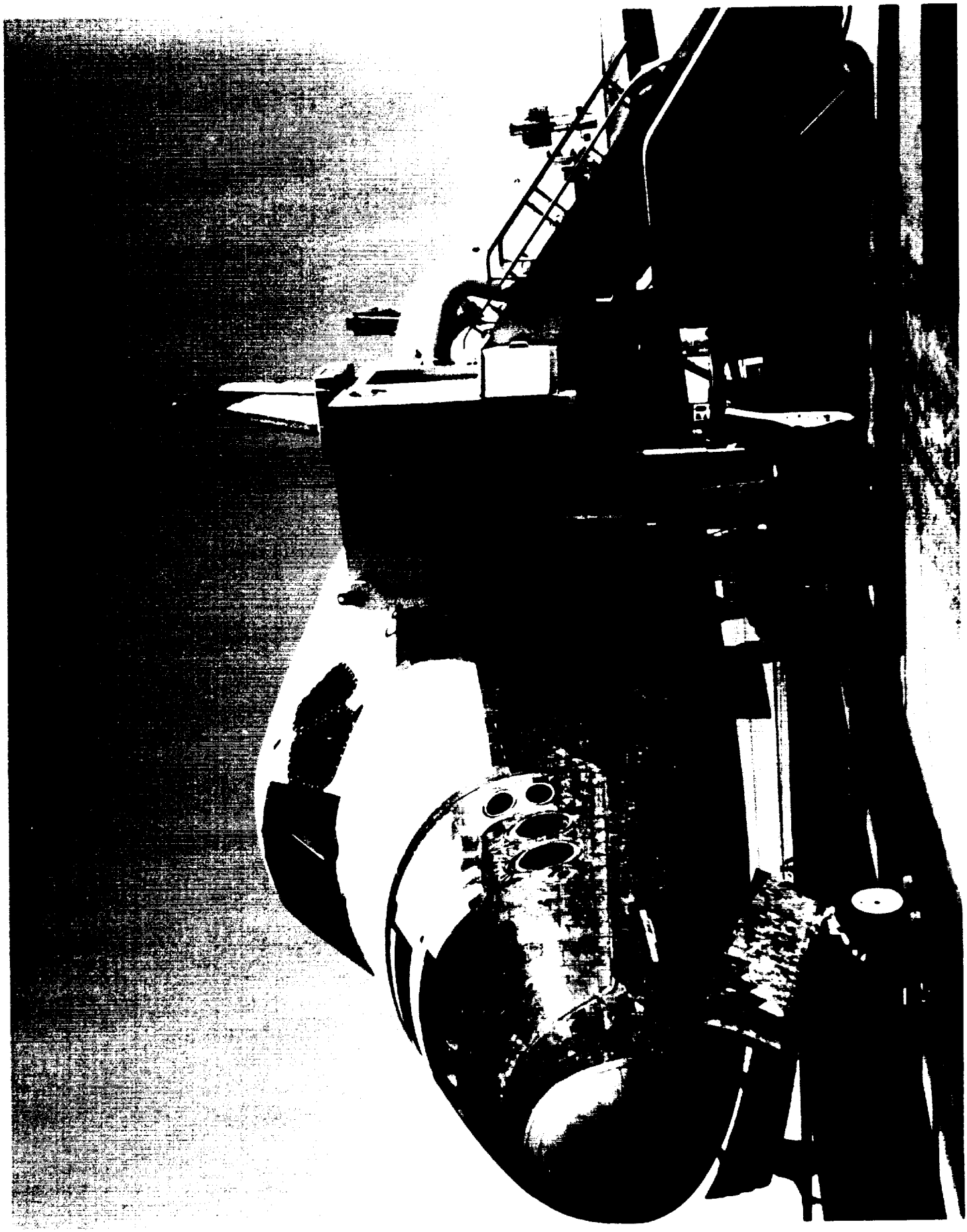
ORIGINAL PAGE
COLOR PHOTOGRAPH

ORBITER TILE PIECES AND AMES GAP FILLERS RECOVERED DURING
POST LANDING RUNWAY INSPECTION



OVERALL VIEW OF ORBITER AFTER LANDING

ORIGINAL PAGE
COLOR PHOTOGRAPH

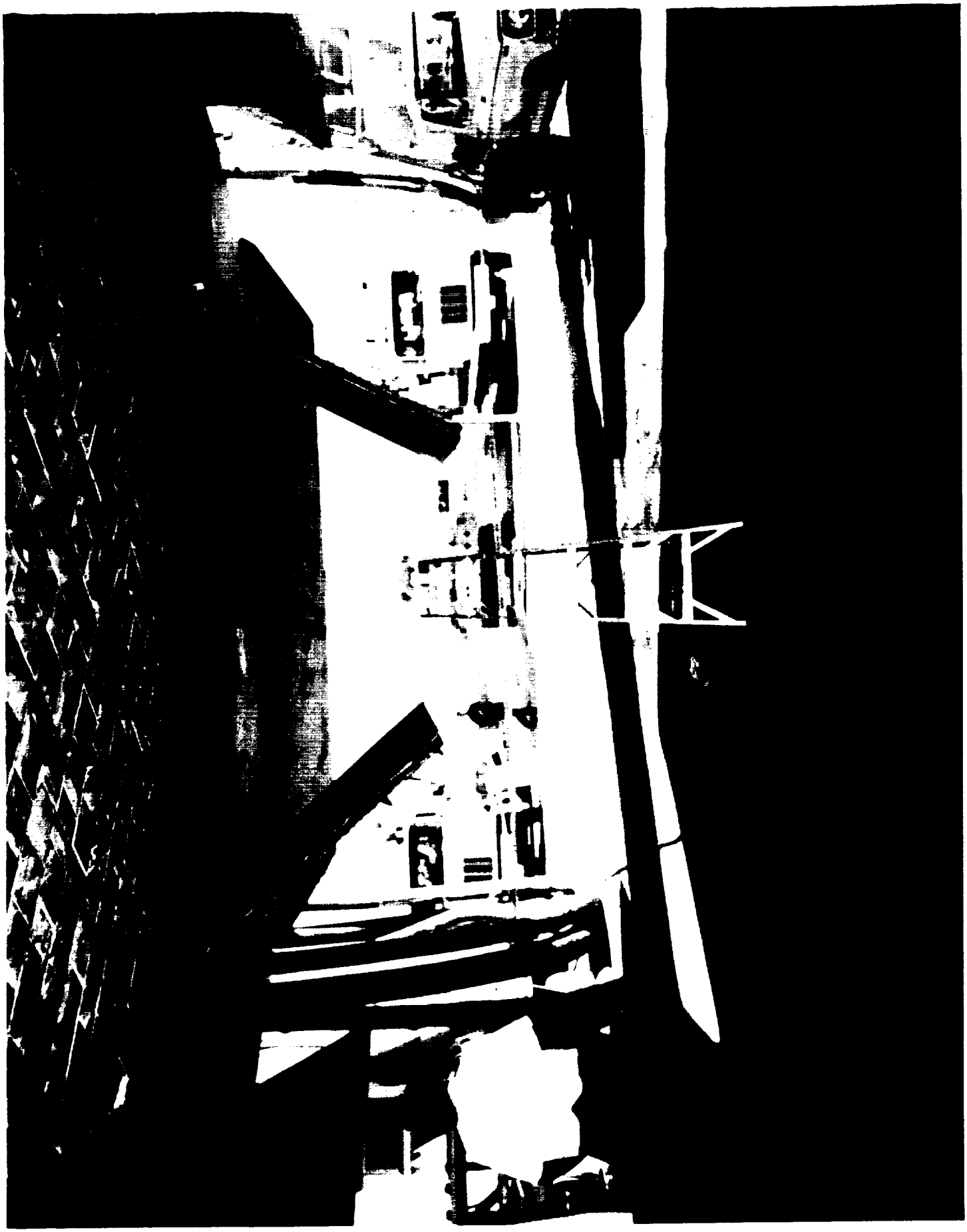


OVERALL VIEW OF ORBITER NOSE TILES AFTER LANDING

ORIGINAL PAGE
COLOR PHOTOGRAPH

DAMAGED CORNER TILE ON RH MLG DOOR. THIS DAMAGE OCCURS WHEN THE MLG DOOR IS OPENED AND LANDING GEAR EXTENDED

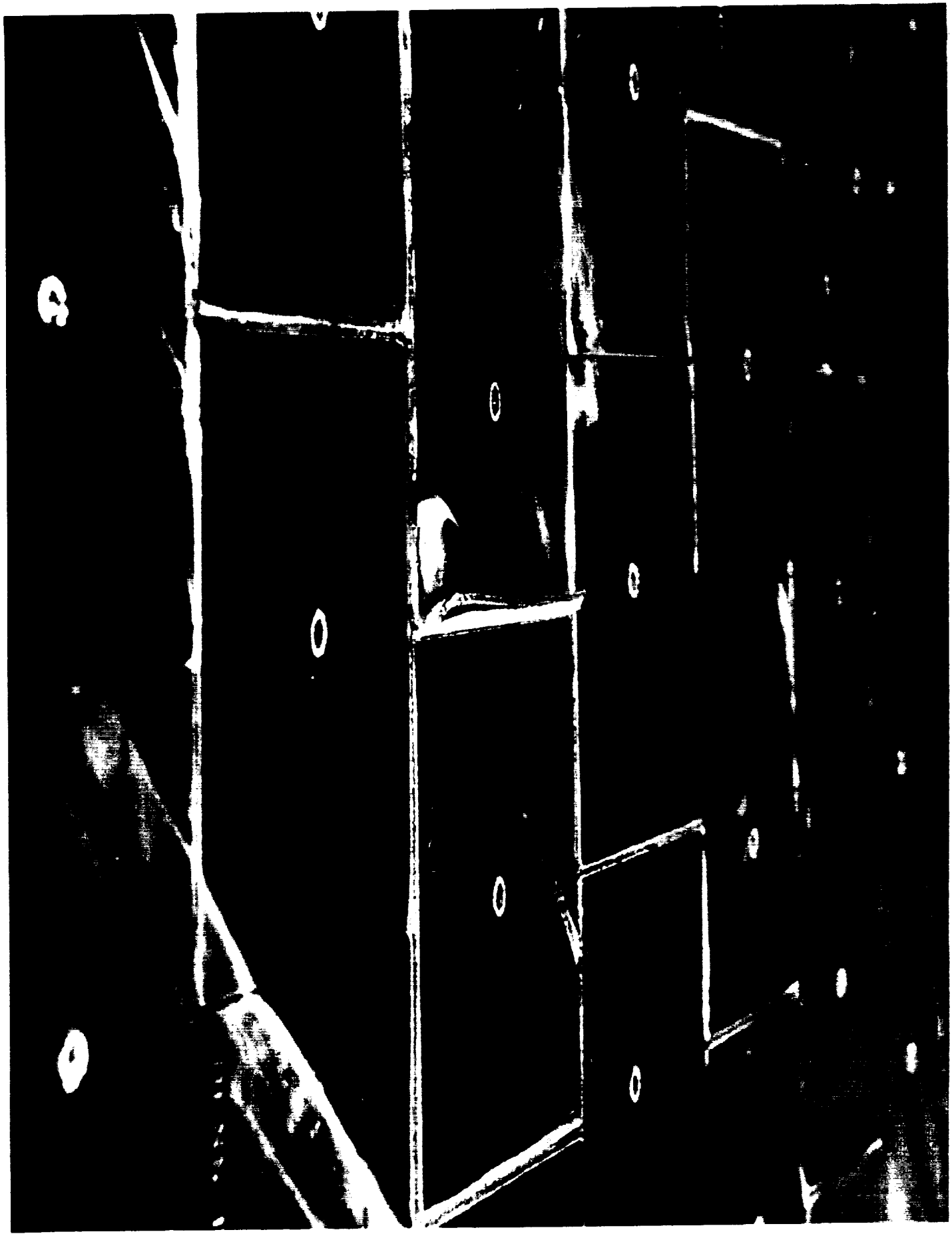
ORIGINAL PAGE
COLOR PHOTOGRAPH



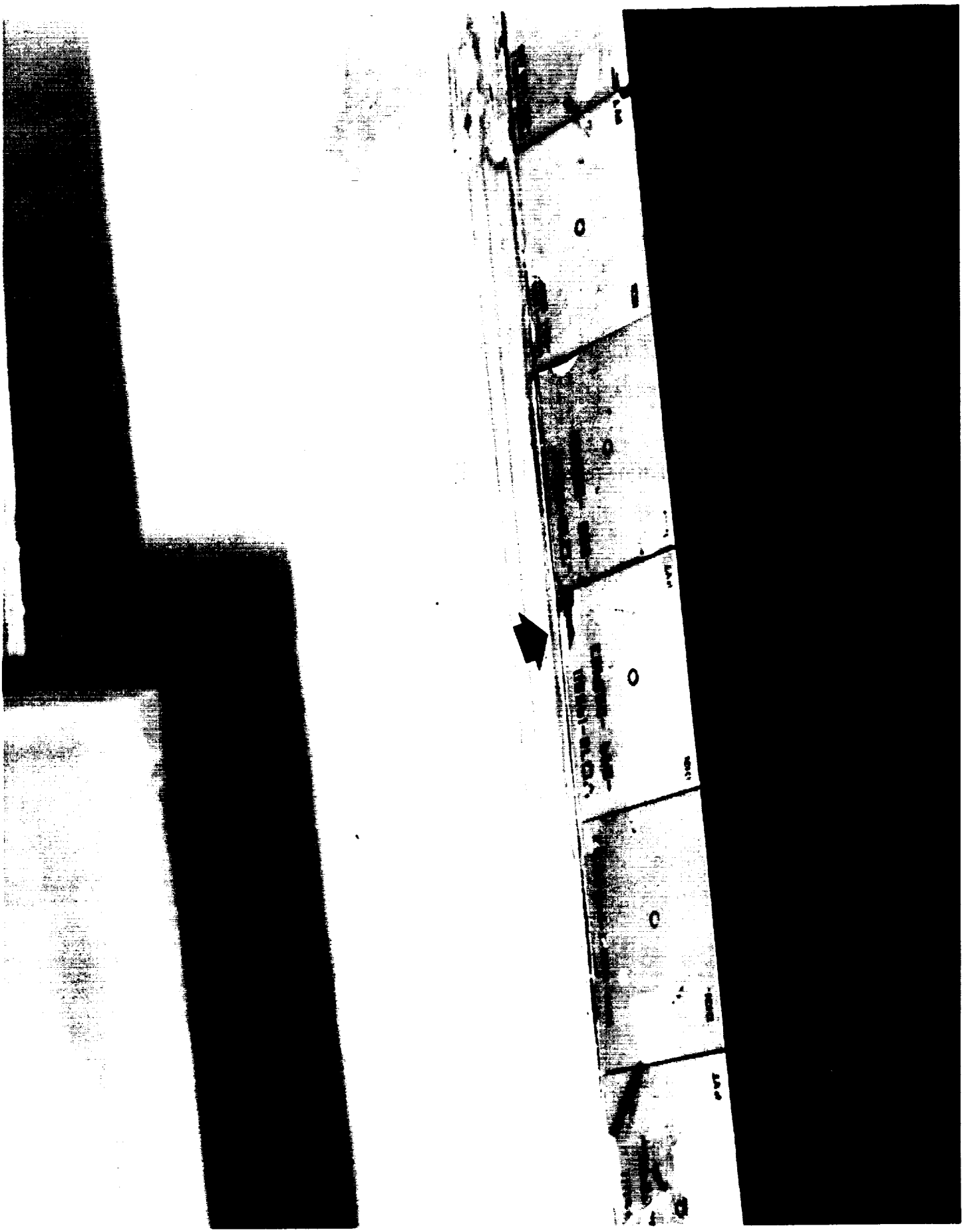
VIEW OF TILES AROUND ET/ORB UMBILICALS AND ON BODY FLAP.
DEBRIS IMPACT OCCURRED FORWARD OF LO2 ET/ORB UMBILICAL.

6"x3" DEBRIS IMPACT FORWARD OF LO2 ET/ORB UMBILICAL

TILE DAMAGE SITE FORWARD OF ET/ORB LO2 UMBILICAL



PROTRUDING TILE GAP FILLER



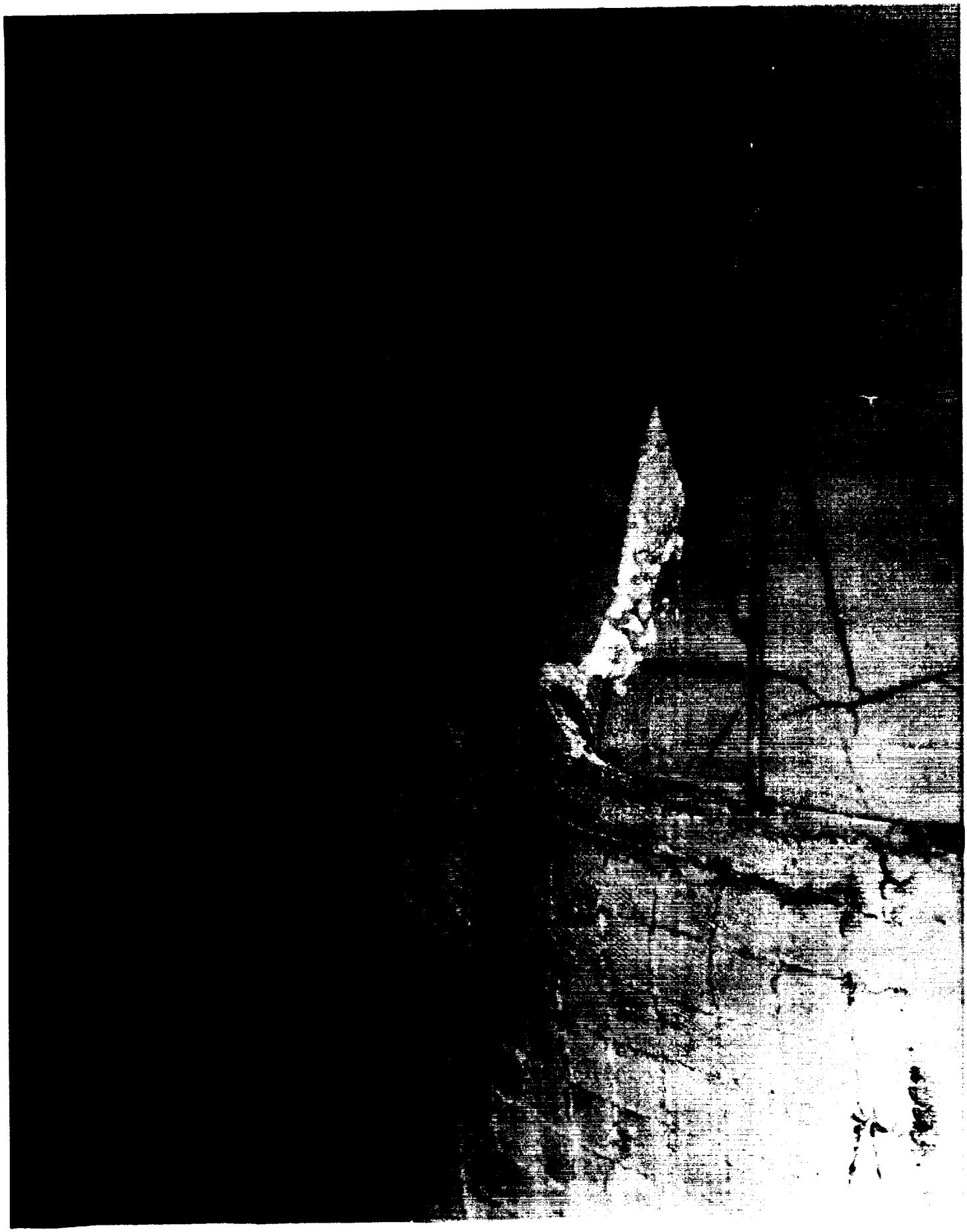
RED RTV REPAIRS ON WHITE, UPPER-SURFACE ELEVON TILES
NOTE AREAS OF MISSING TILE SURFACE MATERIAL

LAUNCH FILMS SHOW TILE MATERIAL SHAKEN FROM WHITE TILES ON THE UPPER SURFACE OF THE RH ELEVONS DURING SSME IGNITION

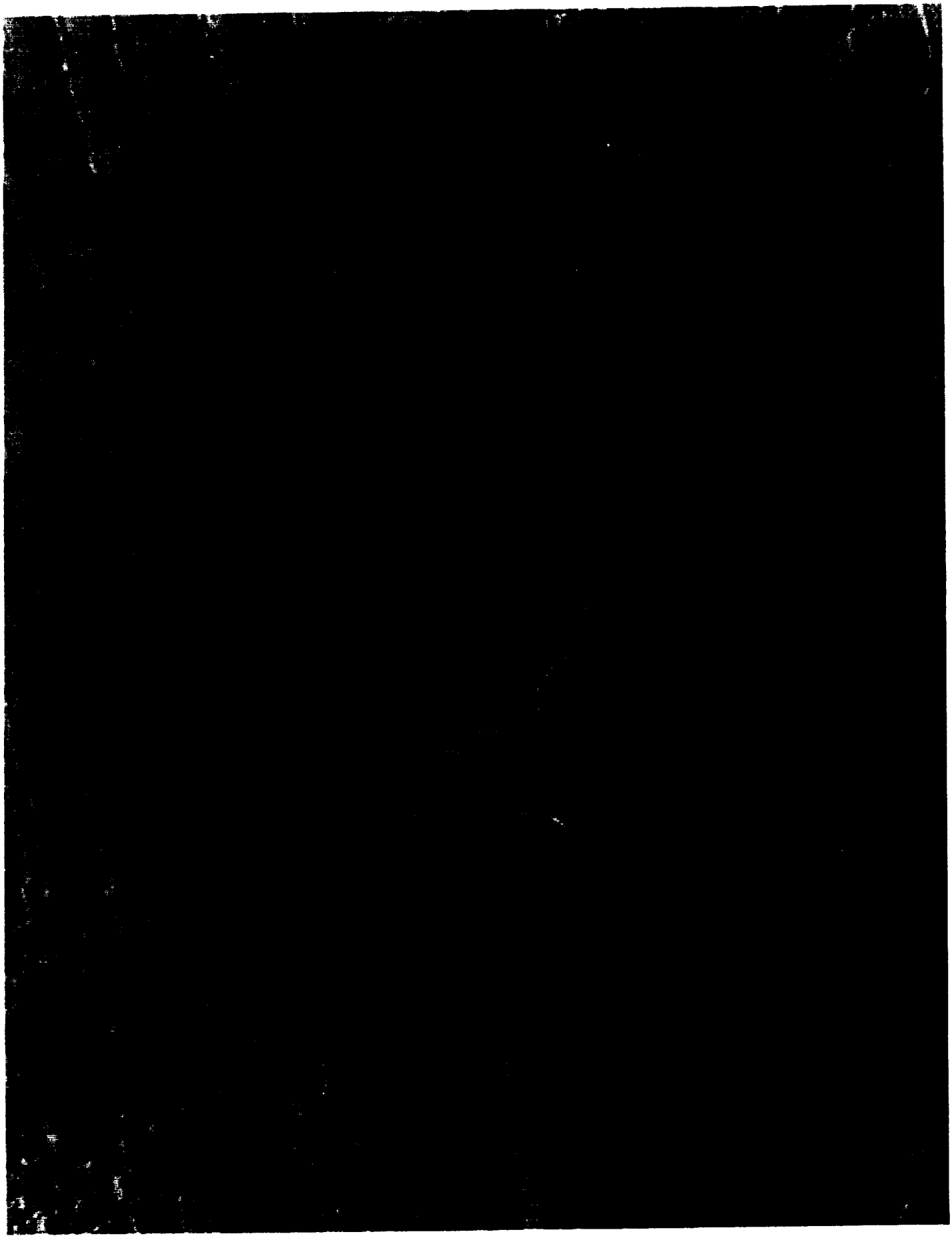
LOOSE/PROTRUDING GAP FILLER MOVEMENT IN AIRSTREAM CAUSES TILE DAMAGE

ORIGINAL PAGE
COLOR PHOTOGRAPH

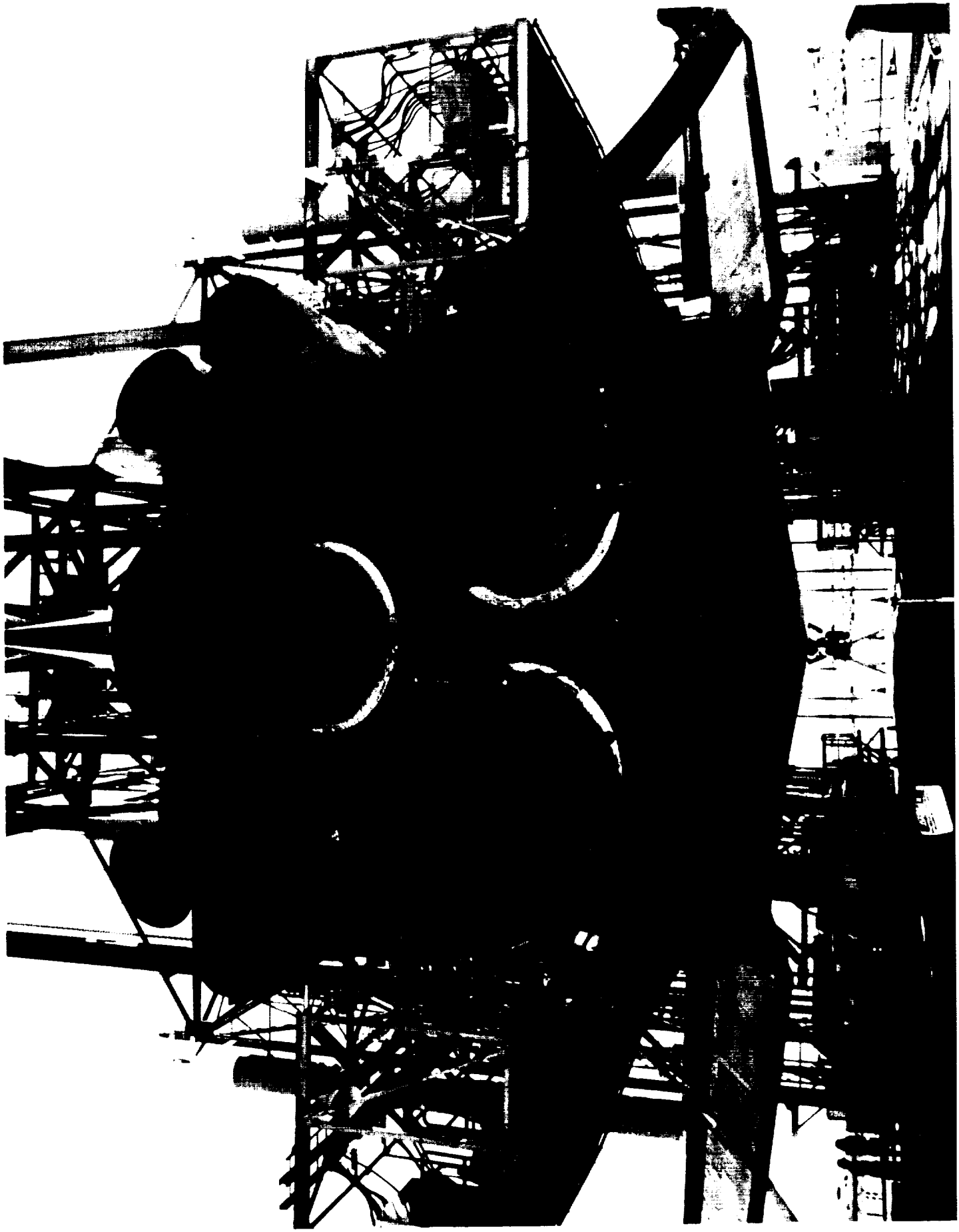
18-INCH SECTION OF MISSING TILE GAP FILLER NEXT TO
6-INCH PIECE OF PROTRUDING GAP FILLER



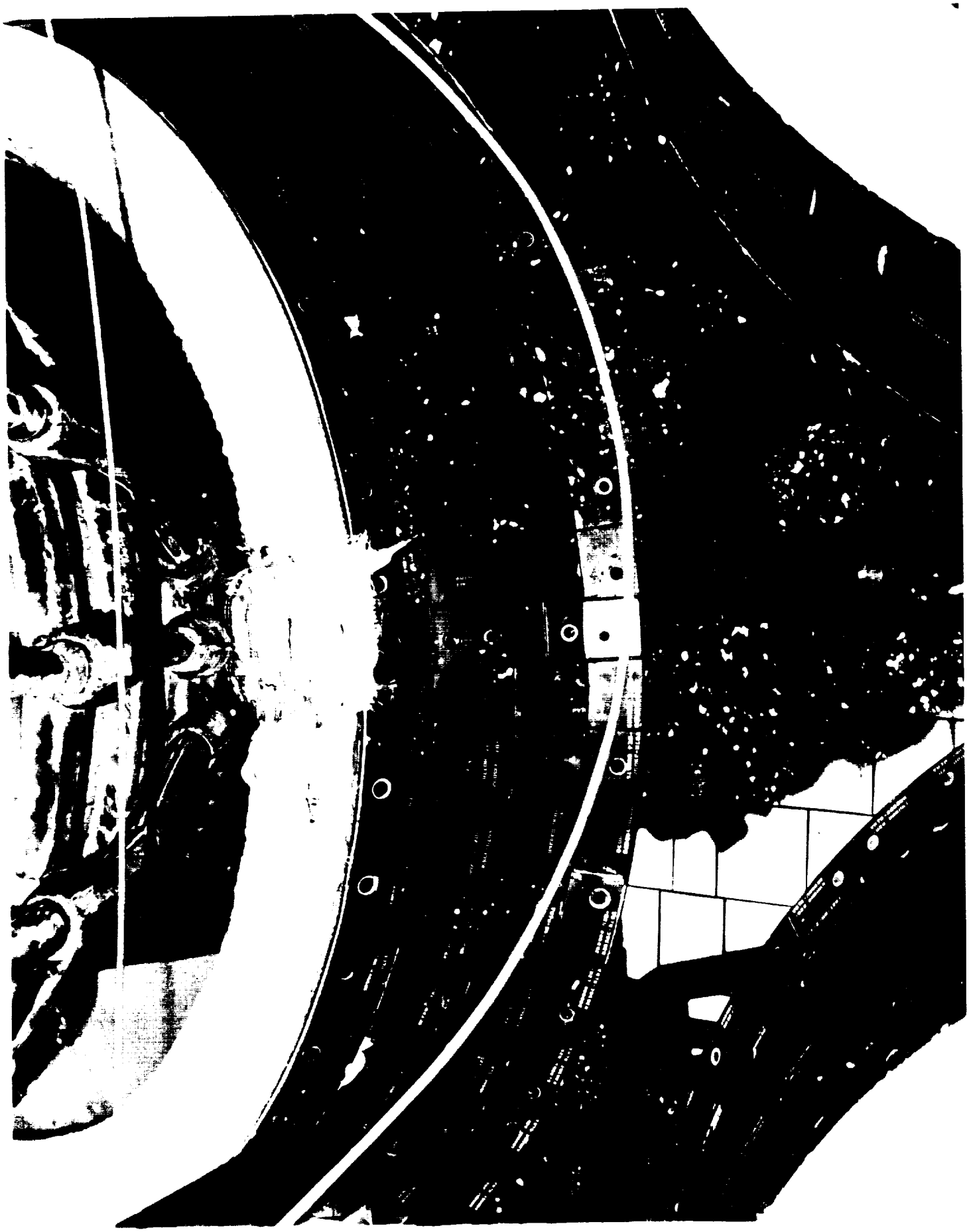
GSE TILE SHIM (FEELER GAGE) EMBEDDED IN OMS POD TILE



FRAYED AFRSI BLANKET ON RH OMS POD

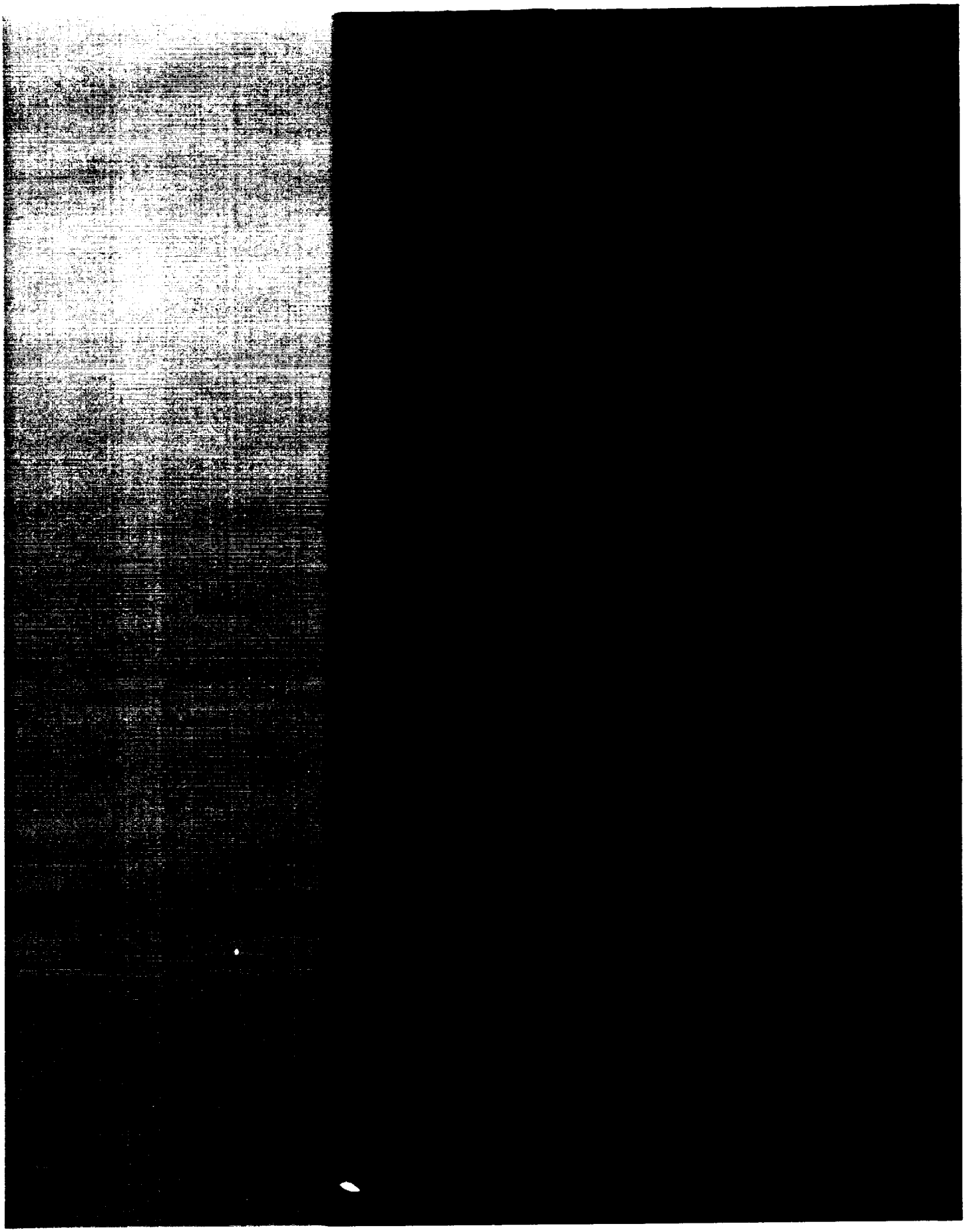


OVERALL VIEW OF MAIN ENGINES AND BASE HEAT SHIELD

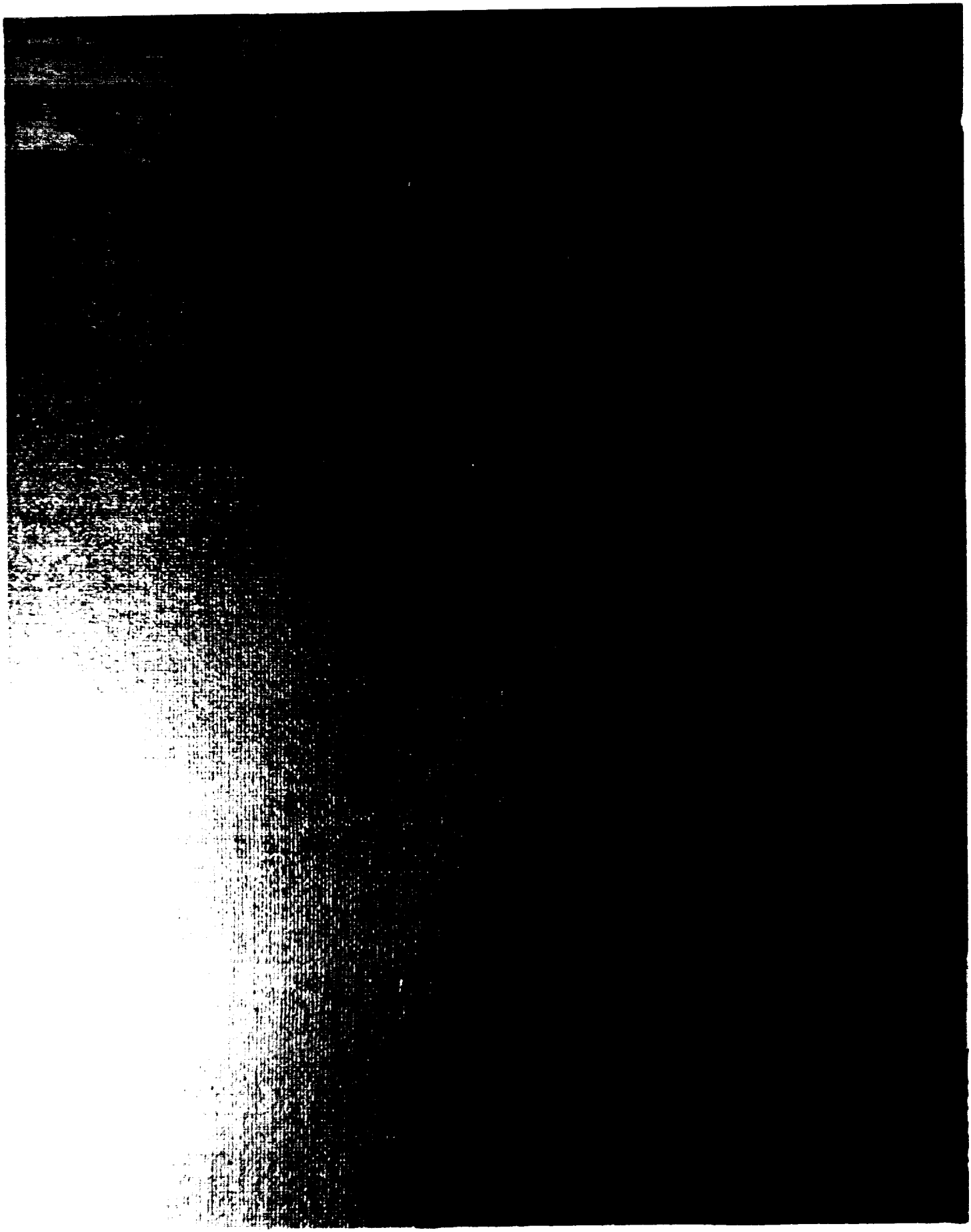


FRAYED THERMAL BARRIER ON SSME #1. NOTE MIX OF PREVIOUSLY REPAIRED TILES AND NEW DAMAGE

DAMAGED SSME FOIL INSULATION ORIGINAL PAGE COLOR PHOTOGRAPH



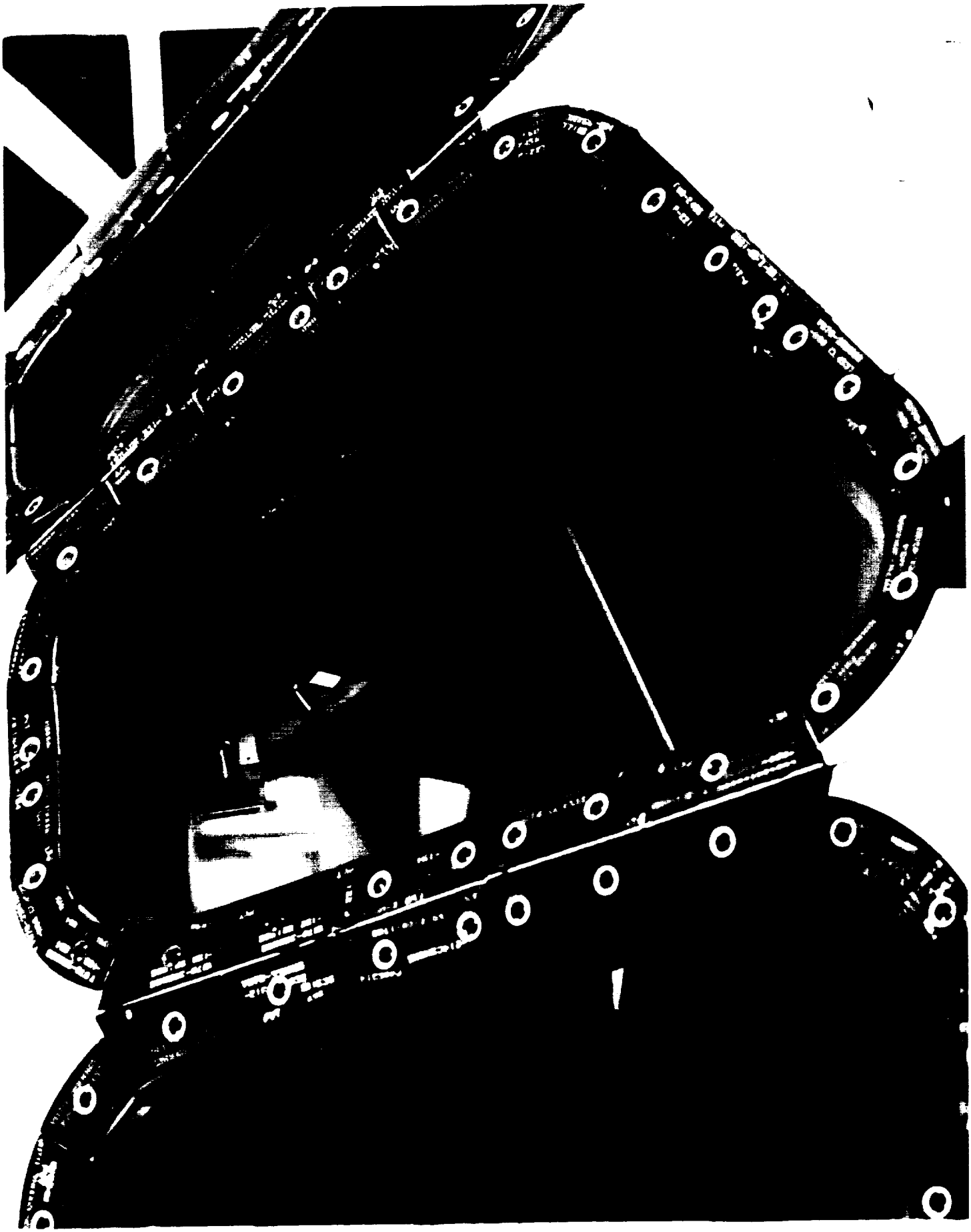
WHITE STREAK ON RCC PANEL



FOREIGN SUBSTANCE ADHERING TO RCC PANEL

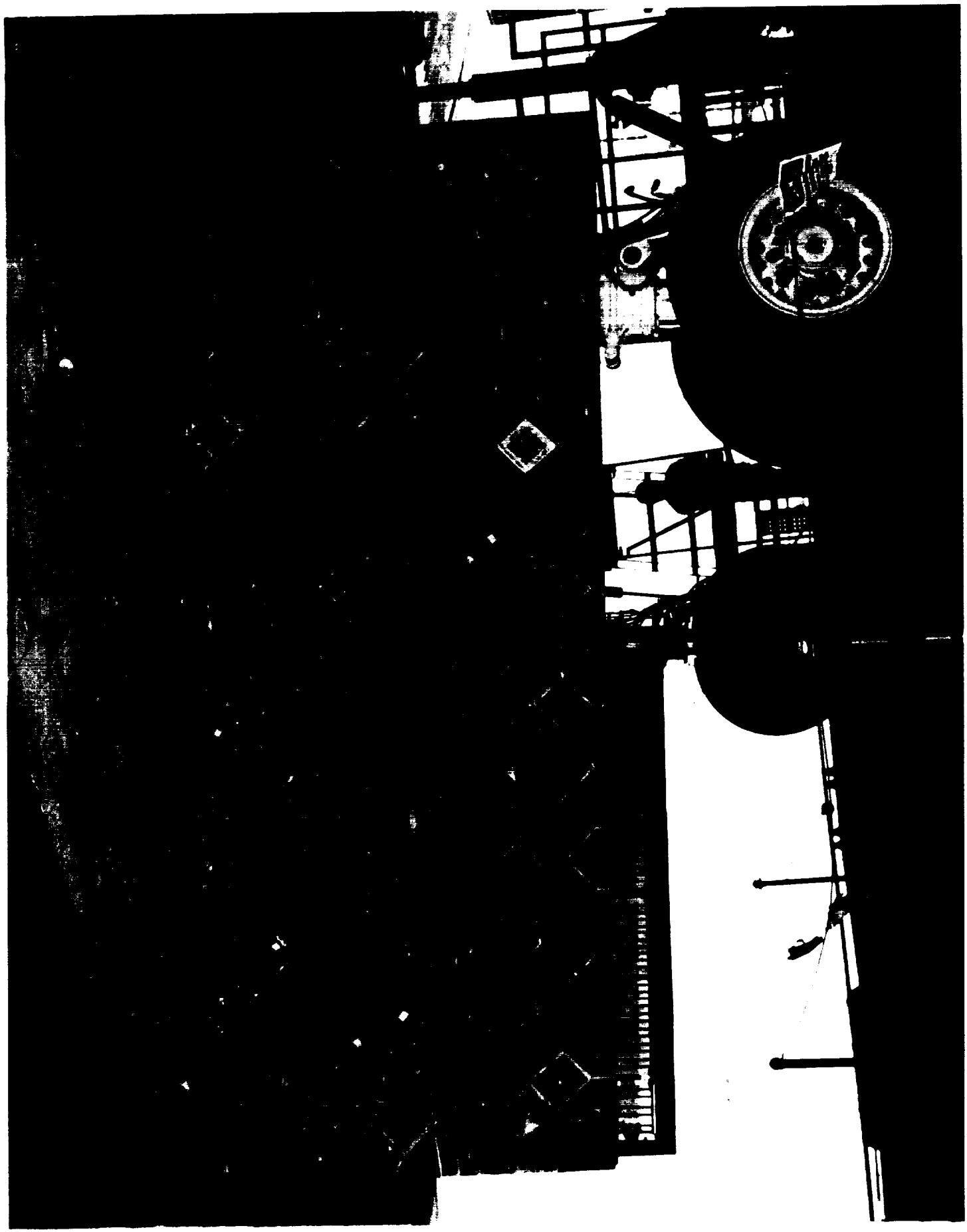
NOTE HAZED WINDOW #3 COMPARED TO CLEAR WINDOW #2

ORIGINAL PAGE
COLOR PHOTOGRAPH

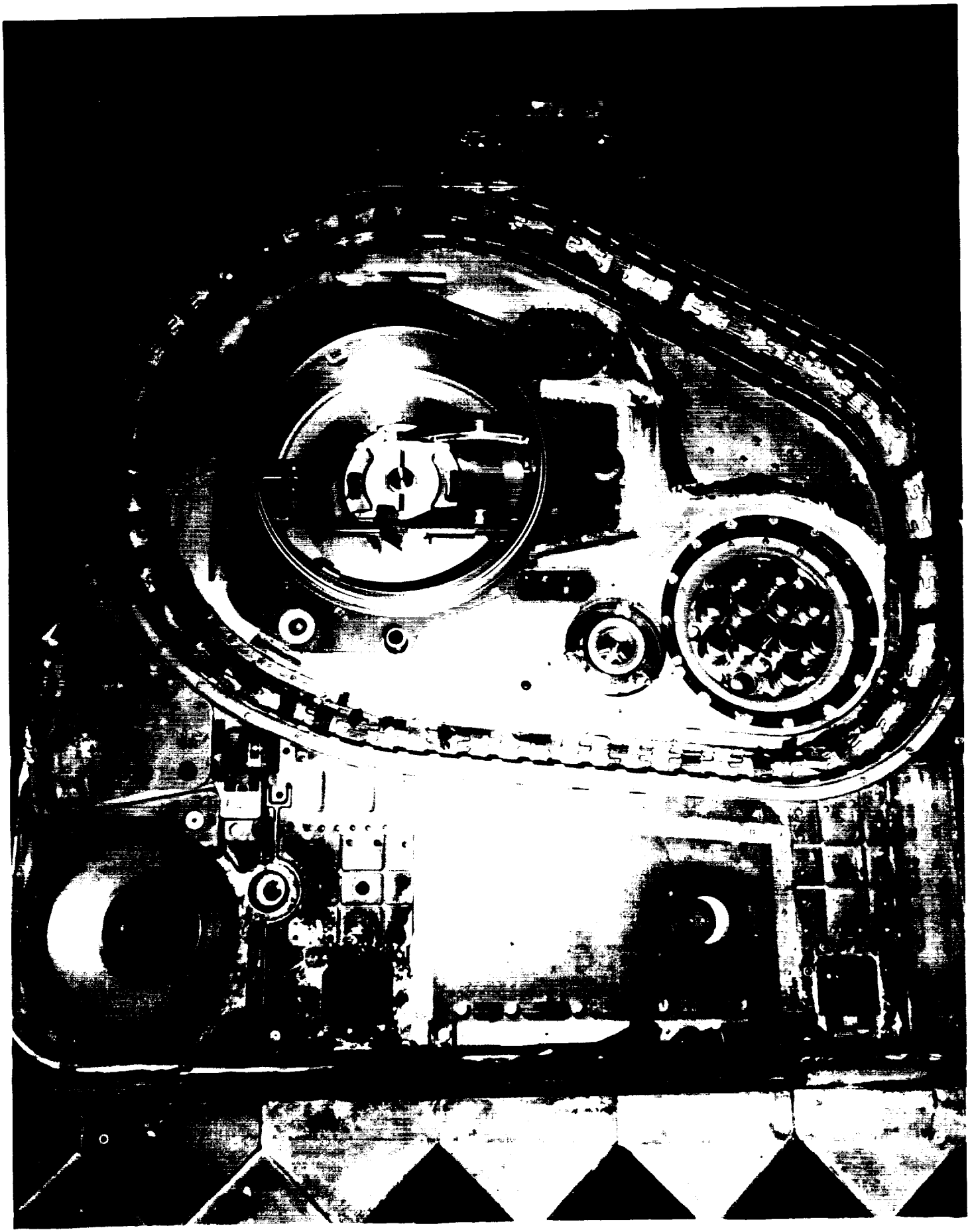


WHITE STREAK ON WINDOW #5

ORIGINAL PAGE
COLOR PHOTOGRAPH

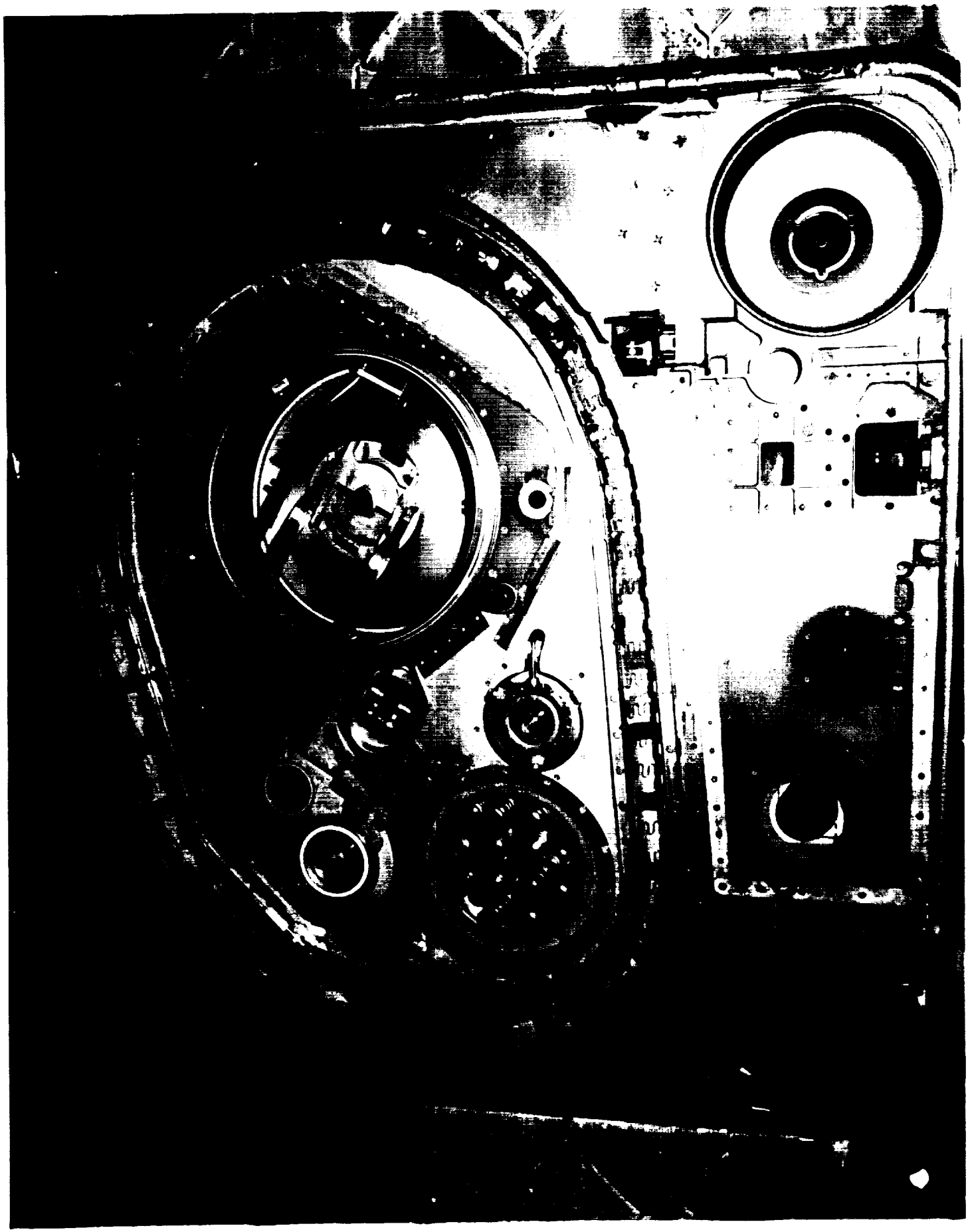


OVERALL VIEW OF MAIN LANDING GEAR TIRES AND LH MLG DOOR



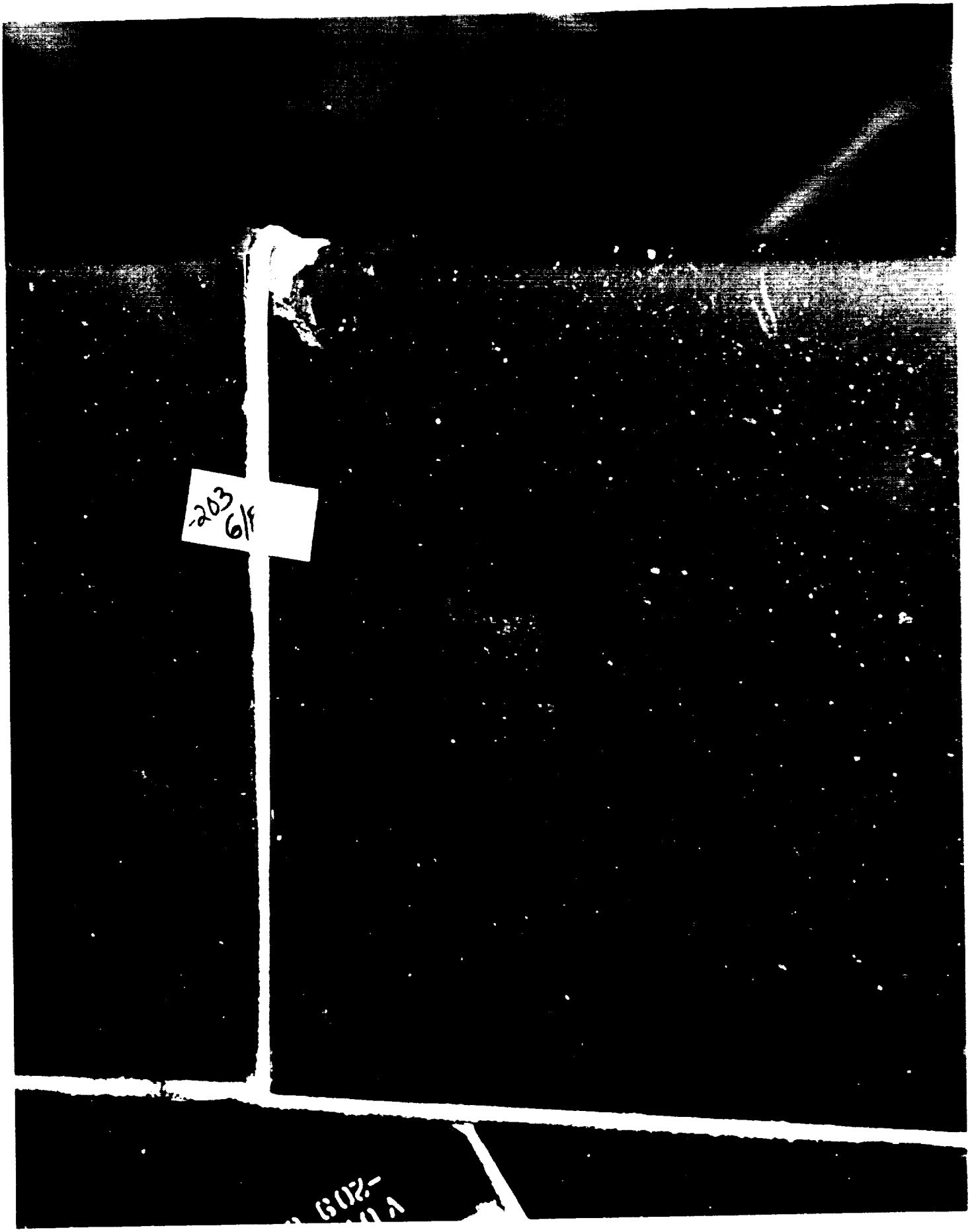
ET/ORB LO2 UMBILICAL

ORIGINAL PAGE
COLOR PHOTOGRAPH



ET/ORB LH2 UMBILICAL. NOTE PIECES OF FOAM ADHERING TO THE CARRIER PLATE NEAR THE RECIRCULATION LINE VALVE

FOREIGN MATERIAL ON ET/ORB LO2 UMBILICAL DOOR



SRB RESIDUE ON BODY FLAP LH EDGE LOWER SURFACE

9.0 DEBRIS SAMPLE LAB REPORTS

POST-LAUNCH PAD DEBRIS

Samples of RTV-like coating debris were recovered after the launch of STS-28R from the LC-39 pad B area. These samples were submitted to the KSC Microchemical Analysis Branch (MAB) for material identification testing. Results of the testing revealed the presence of four materials:

1) Siliceous (silicon) filled epoxy resins
2) Polyester resins with siliceous (silicon) fillers
3) Hydrocarbon as in a tar
4) Styrenated polyester

All of the samples were grey in color and many had rust particles adhering to the samples.

The chemical analysis of these samples did reveal the presence of silicon filled epoxy resins, that had been identified by similar analysis for STS-30R. As stated in previous (STS-30R) report, the exact source is not known; but the area is a ferrous alloy that requires thermal protection provided by the silicon-filled resin. The hydrocarbon and styrenated polyester material source is yet unknown and is under investigation.

ORBITER DEBRIS

A total of 14 samples were obtained from the STS-28R Orbiter during post-landing debris assessment operations at Ames-Dryden Flight Research Facility, California. The 14 submitted samples (reference Figure 20-21 for locations) consisted of 1 Orbiter window wipe (W-5), 3 tile samples, 3 wing RCC panel wipes, 2 wipes from Orbiter body flap, 4 samples from ET umbilical area, and 1 tile sample from RH OMS pod. 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 Microchemical Analysis Branch reports. Debris samples and analysis are provided by Orbiter location in the following summaries. An overall summary for the mission is provided as a conclusion.

ORBITER WINDOW WIPE (W-5)

Results of the W-5 window chemical analyses revealed the material contained silicone, as does the adhesive that holds butcher paper covers to the FRCS thruster nozzles. Insufficient sample material was available to positively identify the material as the FRCS cover adhesive.

Debris analysis, based on observations of previous mission cockpit (window) cameras, concludes the material on the window is probably FRCS cover adhesive. Launch films show the FRCS covers coming off the vehicle and passing through the Orbiter window area.

ORBITER TILE (LOWER SURFACE)

Results of the tile debris analysis showed the materials to be of tile thermal protection system origin. The elemental analysis indicates silicon and iron, the major constituents of heated tile/RTV system.

Debris analysis of the tile damage area samples show tile slumping, which indicates the damage sites experienced heating effects. The absence of non-tile material indicates the damage-causing debris was not retained at the damage site or the debris itself was tile materials.

ORBITER WING RCC PANELS

Chemical analysis results of the RCC panel samples revealed the presence of the following materials:

1. mineral and metallic silicates
2. silica (quartz) and silicone
3. organics
4. fibers (synthetic, cotton)
5. starch, grease
6. paint
7. brass chip

Debris analysis provides the following correlations:

1. Mineral, mineral compounds, and metallic silicates source is most likely landing site products.
2. Silica (quartz) is one of the purest forms of the earth mineral and tile material base. Silicone is a primary bonding material of the thermal protection system.
3. Mineral compounds probably originated at the landing site, organics could be linked to animal or insects remains and deposits.
4. Fibers (synthetics, cotton) probably originated from dust for the synthetic category and from the wipe rag for the cotton category.
5. The starch source could be the rubber gloves used in sample gathering since starch is utilized as a treatment of rubber gloves to reduce sticking. The grease could originate from processing activities.
6. Paint particles may also originate from processing activities on the flight elements, facility, or ground support equipment.
7. The brass chip may also be attributed to processing of the flight elements, facility, or ground support equipment.

ORBITER BODY FLAP

Chemical analysis results of Orbiter body flap samples indicate the presence of the following materials:

1. silicates
2. silica fibers, particles
3. red RTV
4. clay, sand
5. zinc, aluminum
6. steel corrosion particles
7. organic particles

Debris analysis provides the following correlations:

1. Silicate materials are most likely tile material in origin or natural products at the landing site. Aluminum silicate from the leading edge heat tiles, and mica as a natural silicate, are two examples.
2. Silica fibers/particles could also be tile TPS material or landing site products. Tiles are an excellent source of silica fibers. Silica particles, as in 'charred' Si, Cr, are probably of Orbiter origin. Silica particles, as in silicon dioxide (quartz), most likely originated at the landing site.
3. Red RTV is a primary bonding material for tiles and probably originated from the Orbiter.
4. Clay and sand are typical landing site products.
5. Zinc and aluminum materials are common to processing activities and could originate from the flight elements, facility, or ground support equipment. These residues are not associated with a damage site, which indicate the debris particle sizes were not significant.
6. Steel corrosion particles are probably SRB separation products, but the residue size does not represent a debris concern.
7. Organic particles may be animal or insect remains and deposits.

ET/ORB UMBILICALS

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

1. organics, foam
2. sand, silicates, calcium
3. aluminum oxide
4. Koropon paint
5. red RTV
6. Kapton film

Debris analysis of these materials provides the following correlations:

1. The organics and organic foam particles are most likely from closeout material residuals. The number of different materials shows that the umbilical cavities are good areas for the entrapment of debris particles.
2. Sand and calcium probably originated from the landing site. Silicates are heated tile-residuals or naturally occurring landing site products.
3. SRB residuals contain aluminum oxide.
4. Koropon paint is used as an Orbiter coating.
5. Red RTV is a bonding material for Orbiter tile systems.
6. Kapton film is used as a vapor barrier and for purge containment on the ET/ORB umbilicals.

ORBITER TILE (UPPER SURFACE - OMS POD)

Chemical analysis of the GSE tile shim (feeler gage) fragments from the RH OMS pod tile damage site revealed PVC (polyvinylchloride) with calcium carbonate filler. Black residue visible on the orange fragments has an elemental composition of an RTV adhesive. A larger piece of the shim was identified as a three-layer laminate.

Debris analysis correlates the GSE tile shim (feeler gage) to Orbiter tile TPS processing operations. The shims are used during tile bonding operations to maintain design gaps between adjacent tiles.

CONCLUSIONS

The Orbiter window (W-5) sampling, coupled with debris analysis (including film review), have established the silicone deposits as forward Orbiter Reaction Control System (FRCS) thruster nozzle paper cover adhesive.

The Orbiter tile (lower surface) samples continue to indicate heating effects at the damage sites. This data correlates tile damage prior to re-entry heating -- most probably the ascent mission phase. The only material recovered from the damage sites were tile thermal protection system elements, so the damaging agent was either not held within the tile or was tile material itself.

The Orbiter wing RCC panel samples contain a variety of elemental/material compounds. The earth mineral and thermal protection system compound sources are easily discernible, as are those of trace organic compounds. The fibers and starch are indicative of dust/sampling materials. The grease, paint and brass particles are probably of ground-processing origin and not significant to the debris analysis.

Orbiter body flap sample analysis provided more evidence of earth-mineral and tile thermal protection system element debris deposits. The trace metallic element particles (zinc, aluminum) are most likely of vehicle processing-type origin; the steel corrosion products are typical of landing site products. The organic particles, though of various elemental composure, are not unique to previous analyses.

The ET/Orbiter umbilical samples contained a variety of closeout residue, earth-mineral, and tile TPS materials. The variety of materials indicate the umbilical area's capability to entrap debris residuals. Debris analysis does not promote a concern with this residual variety.

Analysis of the OMS pod tile damage site "feeler gage" shim fragments demonstrates the program debris concern. Specifically, the analysis identified the material as non-flight hardware. Chemical comparison testing is currently being done to verify the shim material as a GSE tool used for establishing the tile-to-tile gap. Debris analysis and visual observations indicate this shim material is the same as that removed from the OMS pod tile damage site. The "black material" on the recovered sample chemically compares to a burned RTV adhesive.

On the basis of Orbiter debris sample analyses, this mission did not produce unusual debris concerns. There was no apparent evidence of orbital debris impacts. The only Shuttle flight element problem was that of the tile GSE shim. There were no unexplained debris sample analyses.

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
AUGUST 16, 1989

SUBJECT: Analysis of Debris From LC-39B--Post STS 28R Launch

LABORATORY REQUEST NO: MCB-0734-89

RELATED DOCUMENTATION: None

1.0 FOREWORD:

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

1.2 REQUESTER'S SAMPLE DESCRIPTION:

Recovered debris (RTV--like coating)

1.3 REQUESTED:

Identify material.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 The debris specimens were examined and analyzed using infrared spectrometric techniques.

2.2 All of the specimens were grey in color and many had rust on the underside as though they may have been applied over a rusty surface.

2.3 Of the specimens examined:

Five were siliceous filled epoxy resins.

Two were polyester resins, probably allyl phthalate materials with siliceous fillers.

One was a hydrocarbon like a tar or similar material

One was a styrenated polyester material

CHEMIST: W. R. Carman
W. R. Carman

APPROVED: for Lee D. Underhill
J. F. Jones

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
September 5, 1989

SUBJECT: Debris Samples from STS-28R after Flight

LABORATORY REQUEST NO: MCB-0774-89

RELATED DOCUMENTATION: Intercenter Debris Team Requirements

1.0 FOREWORD:

1.1 REQUESTER: S.A. Higginbotham/NASA/TV-MSD-22/7-0806

1.2 REQUESTER'S SAMPLE DESCRIPTION:

Ten samples, see description of each under analysis. Samples from OV-102 (Columbia) mission STS-28R landing at DFRF/EAFB.

1.3 REQUESTED:

Identify composition of samples and compare to known STS materials.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 The particulates found in each specimen were examined by scanning electron microscope (SEM) and analyzed by X-ray energy dispersive spectroscopy (EDS). EDS analysis provides a qualitative and semi-quantitative analysis of all elements in the periodic table above carbon (6). The method is sensitive to most elements if they are present above 0.4% by weight. Light elements (below #9 in the periodic table) have less sensitivity, and require higher relative weight percentages for detection. Alcohol and MEK wipe samples were air dried for 24 hours before examining them for particles. The following results were obtained:

2.2 Sample #1: Alcohol wipe from Orbiter R/H RCC Panel #17.:

After drying, the coarse cotton rag was examined under low magnification microscope for particles, no obvious stains or particles were observed; the rag was then shaken over a clear plastic sheet and particles that fell from the rag were brushed onto a carbon mount. Most particles were fibers from the cotton rag so these were removed by a sharp needle and the remaining particulates were placed in the SEM for EDS analysis. The following materials were observed: The most predominant materials were silicates. These were about

equally divided between iron, potassium, calcium aluminum silicates (clay or sand); flakes of high iron, potassium silicate (mica-like flakes); and high silica only (quartz). Other particles included high calcium only (calcium carbonate and/or calcium oxides); and various mixtures of the above materials. Several different types of fibers (synthetics), cotton (most likely from the rag), red, green, and black (possible) paint traces, and organics with widely varying inorganic trace constituents (such as sulfur, chlorine, potassium and calcium) were observed.

2.3 Sample #2: Alcohol wipe from Orbiter L/H RCC Panel #12:

The primary material in this sample was a mixed white/black crumbly material. EDS analysis of the clear white material showed it to contain silica only so it may be a silicone. EDS of the black showed high silica plus carbon. It appears to be a charred silicone. Another white granular material present in noticeable amounts was a material that was determined by infrared analysis to be a carbohydrate with some fat type ester. Polarized light microscopy identified it to be starch which is often used in rubber gloves to avoid sticking. Other particles present in lesser amounts were the calcium aluminum silicates (described above), a yellow possible paint chip, and a small brass chip.

2.4 Sample #3: Alcohol wipe from Orbiter R/H RCC Panel #18:

Most particulates were white. They consisted primarily of organic starch. Other white particles were silicates, some with high chloride and calcium and others with calcium and aluminum. A flake was identified as likely mica, and several tan potassium aluminum silicates appear to be sand or clay (possibly from Edwards Air Force Base soil). A small amount of calcium filled grease was noted.

2.5 Sample #4: Alcohol wipe from R/H lower surface of Orbiter body flap:

A wide variety of particulates were found in this sample, but silicates were the most predominant. These included several mica flakes (high Fe, K, Al, Si); several aluminum silicate fibers (likely from the leading edge heat tiles); silica fibers (from other tiles); red RTV (high Fe, Si); orange high Cl + Si (shim) particles; white clear glassy particles with high silica (sand, glass); green on black flakes which were high in Si and Cr; and tan Fe, Ca, Al, Si particles (clay or sand). Other particles of lesser amounts

included a zinc plate, a small aluminum chip, black iron chloride, black silica char, rust, and organics with a variety of inorganic elements (Cl, P, Al, Si, Ca, Ti and Fe).

2.6 Sample #5: MEK wipe from R/H lower surface of Orbiter body flap:

This contained several large glassy, high silica particles which were probably quartz (silicon dioxide). The same material was also observed in thin flakes. Other particles included several red RTV particles; several green on black high Si, Cr particles; several Si, Al fibers; black (Si, O) tile material, steel corrosion particles (Fe, Cl); mica; and a white gummy organic with high Cl.

2.7 Sample #6: Alcohol wipe from Orbiter LH2 ET umbilical area:

The most obvious particles in this grease soaked sample were black spongy organics that contained high silicon, moderate magnesium and traces of calcium, titanium, sulfur, and iron. It may be a rubber, but matching samples of known materials would be needed to exactly identify this material. Other particulates identified included sand grains, red RTV, white calcium with aluminum oxide spheres (evidence of SRB residue), brown silicates, organic foam, green Koropon paint, and a few other organics. The grease appears to contain a high calcium filler. An overview analysis of material washed from the rag with alcohol showed high silicon, calcium and iron with minor-to-trace amounts of aluminum, phosphorous, sulfur, chlorine, potassium titanium chromium, nickel, zinc, oxygen and carbon.

2.8 Sample #7: Alcohol wipe from IML of R/H Orbiter ET Door:

This sample contained nearly all greasy organics. Samples were analyzed by infrared spectroscopy to be acrylic polymer with slight variations due to pigmentation. Four types of materials were noted: a red gummy organic with high silicon, calcium and chlorine; a yellow organic foam; a grey greasy organic, and a black/white mixed organic with high chlorine

2.9 Sample #8: Material removed from L/H Orbiter ET door: The white material was analyzed by infrared to be a phenyl methyl silicone rubbery material with calcium carbonate filler (similar to RTV). The foam material was a polyether urethane with residual unreacted isocyanate.

2.10 Sample #9: Aclar "baggie" material removed from Orbiter R/H (LO2) umbilical (composition of material deposits on Aclar): The film appears to be a high in silicon and chloride with an adhesive that contains high calcium. When it is charred, the organic film shows high silicon, and the adhesive shows high calcium. All the black particles on the film were either charred film or adhesive. Infrared analysis was made on this film and it was determined to be Kapton (polyimide) film <u>not Aclar</u>. The adhesive on the back of some pieces is an acrylate resin - probably polyethylacrylate, commonly used in adhesives.

2.11 Sample #10: Orbiter tile shim fragments found embedded in R/H OMS Pod tile damage site (black residue visible on shim fragments and any reentry heating effects to shim fragments):

The shim material was identified by infrared analysis as a PVC formulation with calcium carbonate filler. The one piece was a 3 layer laminate. The black material was high in manganese, iron and silicon (with a trace of copper). It is mostly along one edge and appears mostly like an adhesive.

CHEMIST: Stan Young
Stan Young

APPROVED: J. E. Jones
J. E. Jones

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
SEPTEMBER 6, 1989

SUBJECT: Orbiter Tiles

LABORATORY REQUEST NO: MCB-0788-89

RELATED DOCUMENTATION: Intercenter Debris Team Requirements

1.0 FOREWORD:

1.1 REQUESTER: S. A. Higginbotham/TV-MSD-22/7-0806

1.2 REQUESTER'S SAMPLE DESCRIPTION:

The tiles were from OV-102 (Columbia), mission STS-28R landing at DFRF/EAFB, and were identified as follows:

Sample #1: Fragments of orbiter tile VO-394032-095
Sample #2: Fragments of orbiter tile V070-394033-280
Sample #3: Orbiter tile V070-191017-191

1.3 REQUESTED:

Determine if debris residuals remain and if so, determine their composition and compare to known STS materials.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

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

2.2 Results:

2.2.1 Figure 1 is low OM photomacrograph of debris from sample #1 to show the areas of analysis, the fused appearance of surface and depressed areas of black tiles. Figure 2 is high magnification OM photomicrograph of the area A in Figure 1 to show the fused appearance of silica tile and cracks developed on the black tile surface.

2.2.2 Figures 3 is low magnification OM photomacrograph of tile fragments from sample #2 to show the areas of analysis and the depressed surface. Figure 4 is high magnification OM photomicrograph of area C in Figure 3 to show the white clear fused silica.

2.2.3 Figure 5 is low magnification OM photomacrograph of sample #3 to show the depressed surface. Figure 6 is high magnification OM photomicrograph of area G in Figure 5 to show the red colored RTV and light grey colored areas.

2.2.4 Table 1 lists elemental analysis of each area from each sample numbers (see Figures 1, 3, and 5 for locations of each area).

Table 1

AREA	Elemental Analysis by EDS*	
	Major	Minor
Sample #1		
Area A		
a. White Glassy Mtls	Si	
b. Grey Glassy Mtls	Si	
c. Grey Porous Mtls	Si	
d. White Fibrous Mtls	Si	
Area B		
a. Red Mtls (T)	Si, Fe	
b. White Sugary Mtls	Si	
c. Blk Coating Mtls	Si	
Sample #2		
Area C		
a. White Clear Mtls	Si	
b. Red Mtls (T)	Si, Fe	
Area D		
a. Red Mtls (T)	Si, Fe	
b. White Mtls	Si	
Area E		
a. Red Mtls (T)	Si, Fe	
b. White Mtls	Si	
Area F		
a. Red Mtls (T)	Si, Fe	
b. White Mtls	Si	
Sample #3		
Area G		
a. Red Mtls (L)	Si, Fe	
b. Grey Mtls (L)	Si	

T: Trace
L: Large Amount
*O, C, H, and B are not detectable by using this technique.

3.0 CONCLUSIONS:

3.1 The sample numbers 1, 2, and 3 are very similar in composition and are composed of black and white silica tile with small to trace amounts of white clear glassy materials, grey glassy or porous materials, and red materials on the surface of black tiles.

3.2 The white clear glassy materials and grey glassy or porous materials were composed entirely of silica. The OM data suggested that some of white clear glassy materials were composed of poorly crystallized cryptocrystalline materials. The poorly crystallized cryptocrystalline silica could be formed from high temperature.

3.3 Some fragments of black tile show fused or melted or resolidified appearance.

3.4 The red materials were identified to be room temperature vulcanizing (RTV) rubber.

3.5 All of the above materials probably originated with the TPS system.

3.6 The samples were attached with this report.

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

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

FIGURE 1. LOW MAGNIFICATION OPTICAL PHOTOMACROGRAPH OF SAMPLE #1 TO SHOW THE AREAS OF ANALYSIS AND THE DEPRESSED AREAS (A, B). 1X

ORIGINAL PAGE
COLOR PHOTOGRAPH

FIGURE 2. HIGH MAGNIFICATION OPTICAL PHOTOMICROGRAPH OF AREA A IN FIGURE 1 TO SHOW THE FUSED APPEARANCE OF SILICA TILE. 10X

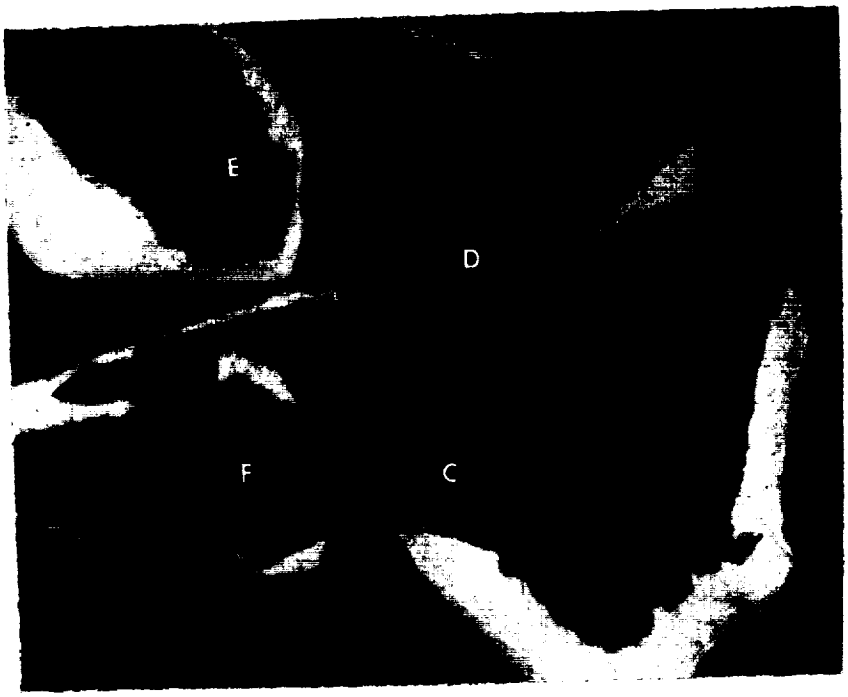


FIGURE 3. LOW MAGNIFICATION OPTICAL PHOTOMACROGRAPH OF SAMPLE #2 TO SHOW THE AREAS OF ANALYSIS. 1X

ORIGINAL PAGE
COLOR PHOTOGRAPH

FIGURE 4. HIGH MAGNIFICATION OPTICAL PHOTOMICROGRAPH OF AREA C IN FIGURE 3 TO SHOW THE WHITE CLEAR COLORED SILICA (BLACK ARROW). 10X #2

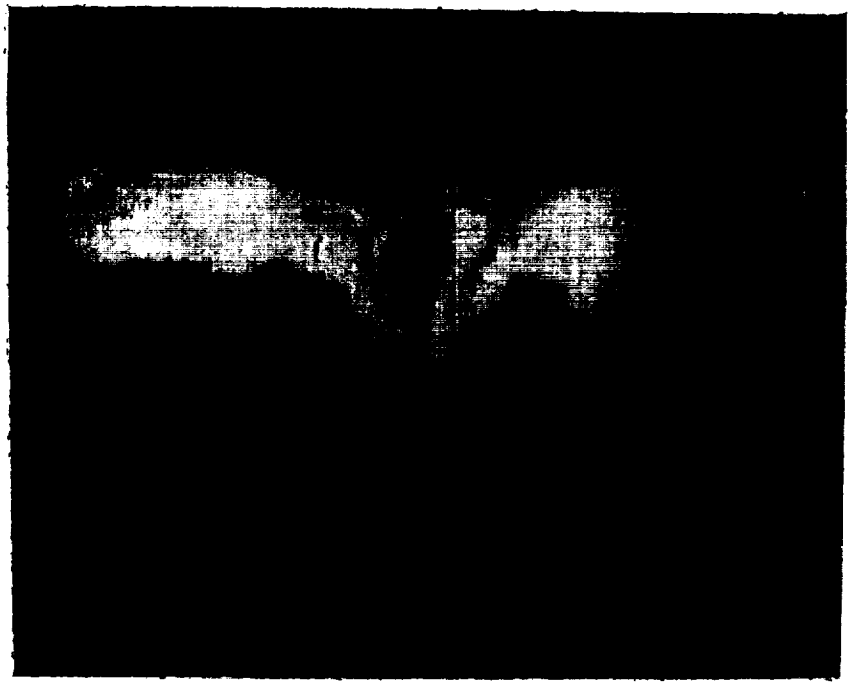


FIGURE 5. LOW MAGNIFICATION OPTICAL PHOTOMACROGRAPH OF SAMPLE #3 TO SHOW THE DEPRESSED AREAS. 1X, SIDE VIEW OF TILE BLOCK.

ORIGINAL PAGE
COLOR PHOTOGRAPH

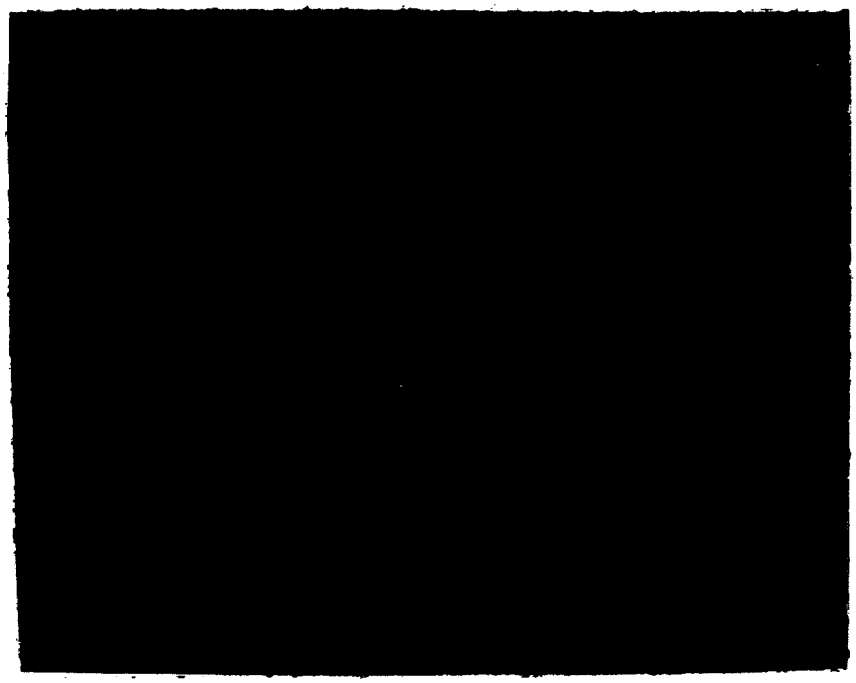


FIGURE 6. HIGH MAGNIFICATION OPTICAL PHOTOMICROGRAPH OF AREA G IN FIGURE 5. 10X

10.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 45 Post Launch Anomalies were observed for STS-28R.

10.1 EXTERNAL TANK

Pieces of ice from both LH2 and LO2 ET/ORB umbilicals were shaken loose during SSME ignition and fell past the Orbiter body flap, but no tile damage was visible.

Views of the ET during ascent showed the LH2 umbilical cable tray was missing a significant area (4"Wx10"Lx1"deep) of TPS, but had not eroded down to the SLA. A 6"x4" piece of TPS broke off the LH2 umbilical feedline attach structure at separation.

After separation, the bipods were still extended instead of folding forward against the ET. Five minor divots were visible on the right thrust strut flange. The TPS along the entire top of the LO2 umbilical was displaced with a loose chunk (18"Wx8"Lx 2"deep) in the center and missing pieces at the 11 and 2 o'clock positions. The ice/frost ramp third down from the LH2 tank-to-intertank flange (XT-1270) had one divot. A large divot, measuring 23"Lx15"Wx1"deep, occurred in the intertank acreage TPS just above the RH bipod ramp and to the left of the LO2 feedline. This divot was located in the vented SOFI area. The shallow depth indicates a cohesive failure internal to the CPR net spray material.

10.2 SOLID ROCKET BOOSTERS

Cork thickness was measured and found to be excessive at the forward EB attach points.

Firing of the separation ordnance at T-0 caused the HDP #1 and #5 debris containers/plunger housings to rock slightly (two oscillations).

Liftoff of the vehicle caused holddown post shim putty (HDP #1) and holddown post shoe sidewall epoxy material (HDP #7) to pull loose

HDP #2 sidewall epoxy material debonded from the shoe.

A rubber boot/retainer from the HDP #5 debris plunger fell from the aft skirt stud hole as the vehicle ascended.

Numerous, small pieces of aft skirt instafoam and holddown post K5NA closeout material fell as the vehicle cleared the holddown posts.

Instafoam particles from the SRB aft rings continued to fall throughout ascent.

A particle appeared from or behind the LH SRB plume moving at a high angle to the plume and fell away from the vehicle. The particle size estimate is 24x10x6 inches and was probably foam from the LH SRB aft ring.

The lower right BSM aero heatshield cover was missing from the LH SRB frustum BSM cluster. Image enhancement and analysis of the cover attach ring could not determine exactly when the cover separated.

After SRB recovery, a subsurface delamination, approximately 2-1/2 inches long by 1 inch wide was detected on the LH SRB -Z RSS antenna.

Hypalon paint blistering and cratering occurred on both forward skirts and the RH frustum.

The MSA-2 was debonded in two places on the RH frustum.

A 2.5 inch crack occurred in the RH SRB aft field joint K5NA.

The LH SRB IEA case was cracked on the forward and aft inboard corners. Both IEA end covers exhibited structural damage. Some TPS was missing from the ET attach ring.

K5NA was missing from several bolt heads on both aft phenolic kick rings.

K5NA was missing from all aft BSM nozzles.

Both aft rings were missing foam around the holddown post shoes, HPU exhaust horns, and joint heater umbilicals.

Holddown post #3, 4, 7 and 8 epon shims were missing material prior to water impact.

10.3 ORBITER

A tile gap filler from the right side leading edge of the vertical stabilizer fell during SSME startup.

Acoustical vibration from SSME ignition caused white tile material on the upper surface of the elevons to chip and fall past the LO2 TSM. In addition, an orange tile shim fell from the same general area.

One blue and 4 orange tile shims were shaken loose from the base heat shield/aft fuselage area near the LH2 T-0 umbilical by SSME ignition.

Three Q-felt plugs and a portion of another fell from the base heat shield during SSME ignition and early ascent.

Vehicle appears to overshoot heading during roll maneuver. A correction was made followed almost immediately by a secondary correction.

During ascent, the body flap appeared to move in amplitudes that were greater than expected. Maximum deflection occurs between GMT 12:37:49.21 - 12:37:52.83 (Max Q 12:37:49.76). Measurements from the film indicate the frequency was 7.7-8.7 Hz and the amplitude averaged 5.5 +/-2 inches.

The LH main landing gear door extended 0.25 to 0.50 seconds before the right side. Extension of the landing gear/wheels lagged similarly.

All four elevons oscillated prior to, during, and just after main landing gear touchdown. Elevon movement matched control stick input and was pilot-induced.

Due to the high sink rate, the nose gear strut came within 3/4-inch of full hydraulic stroke. Flexure data ???

Several pieces of the outboard forward corner tile fell onto the runway when the RH main landing gear door was opened.

Ten pieces of Ames gap filler material and a small piece of SSME nozzle foil insulation were found on the runway after landing.

Three gap fillers protruded from lower surface black tiles. Gap filler sleeving material was loose on the forward areas of both OMS pods. There were 14 protruding gap fillers on the LH OMS pod and 7 on the RH pod. One 5-inch length of gap filler on the LH OMS pod caused considerable damage to an adjacent white tile. An 18-inch long section of gap filler sleeving was missing from the RH OMS pod.

White tiles on the upper orbiter surfaces showed considerable degradation. The most significant damage occurred on the wing upper surface forward and aft of the elevon hinge line.

The Orbiter TPS sustained a total of 76 hits, of which 20 had a major dimension of 1-inch or greater.

The main engine white beta bags sustained minor damage on all 3 SSME's. The nozzle foil insulation on SSME #1 and #3 was damaged on the 9th and 8th ring, respectively.

Orbiter window #3 was heavily hazed; window #4 was less hazed. Window #5 exhibited a 6 inch long by 1 inch wide deposit.

10.4 FACILITY

Many film items showed the FSS water deluge was not activated prior to SSME ignition through tower clear.

Although the GH2 vent line latched and did not rebound, the leg capture occurred "off center". The deceleration cable twisted to the south and the stabilizer rod was caught between the latches. The "S" pulley appeared to have excessive friction. PR PV6-136757 was dispositioned to take alignment measurements and inspect the bushings.

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Charles G. Stevenson
Gregory N. Katnik
Scott A. Higginbotham

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16. Abstract

A Debris/Ice/TPS assessment and photographic analysis was conducted for Space Shuttle Mission STS-28R. Debris inspections of the flight elements and launch pad are performed before and after launch. Ice/Frost conditions on the External Tank are 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 is 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-28R, and their overall effect on the Space Shuttle Program.

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