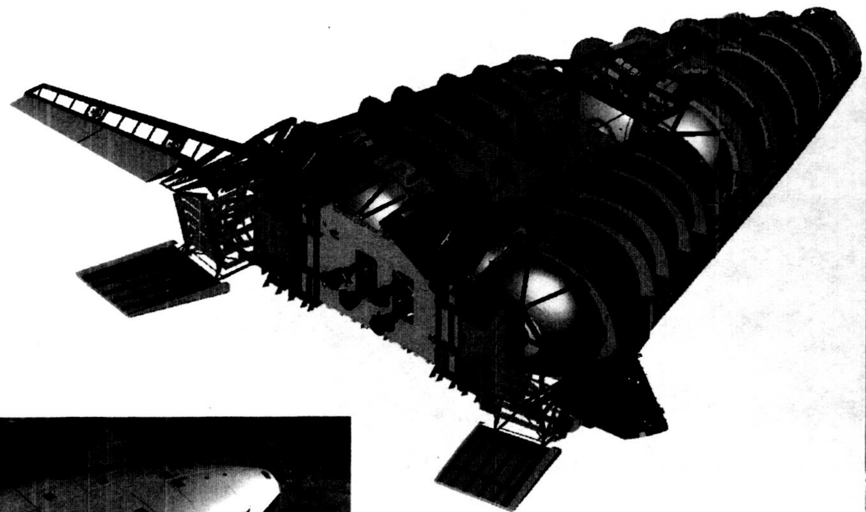
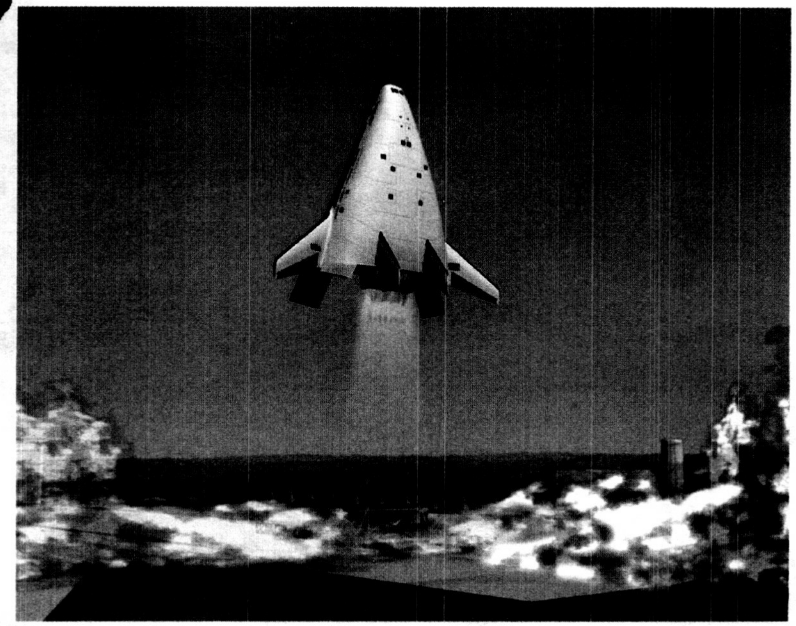
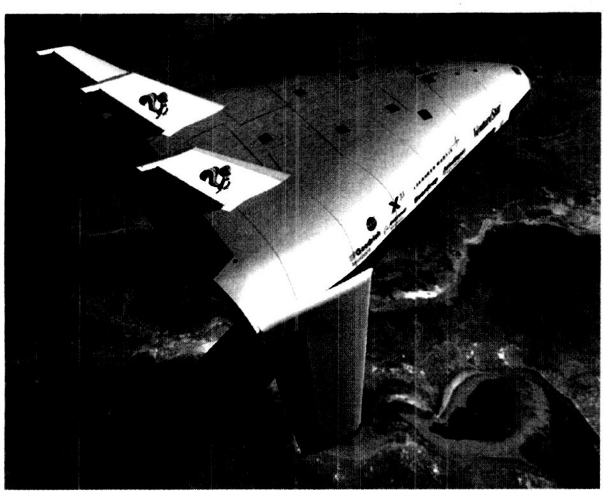
X-33 LH_2 Tank Failure Investigation Findings







Presented by
Mindy Niedermeyer
MSFC

Aerospace Materials, Processes, and Environmental Technology Conference

September 18 - 20, 2000

X-33 LH_2 Tank Failure Investigation Findings

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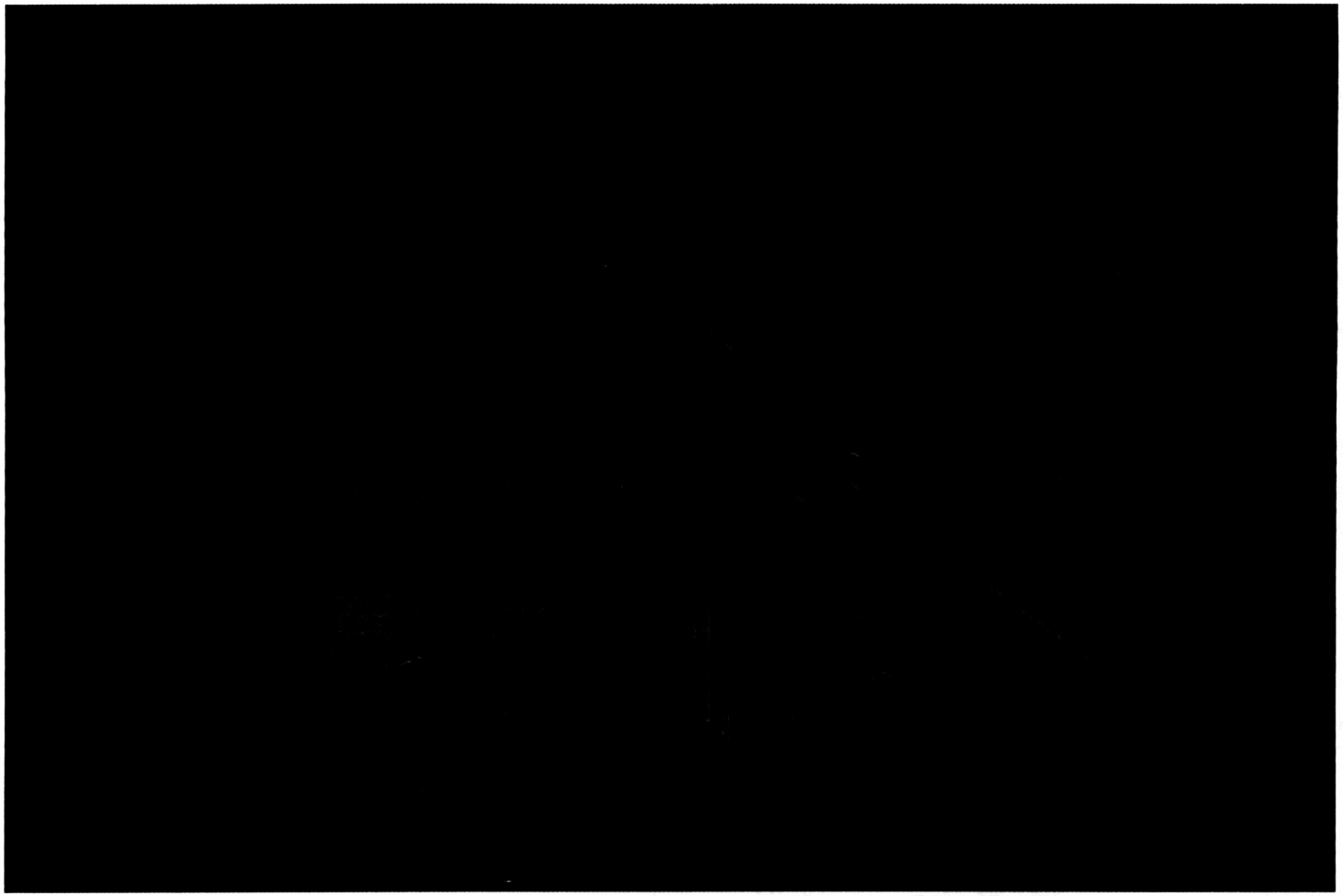
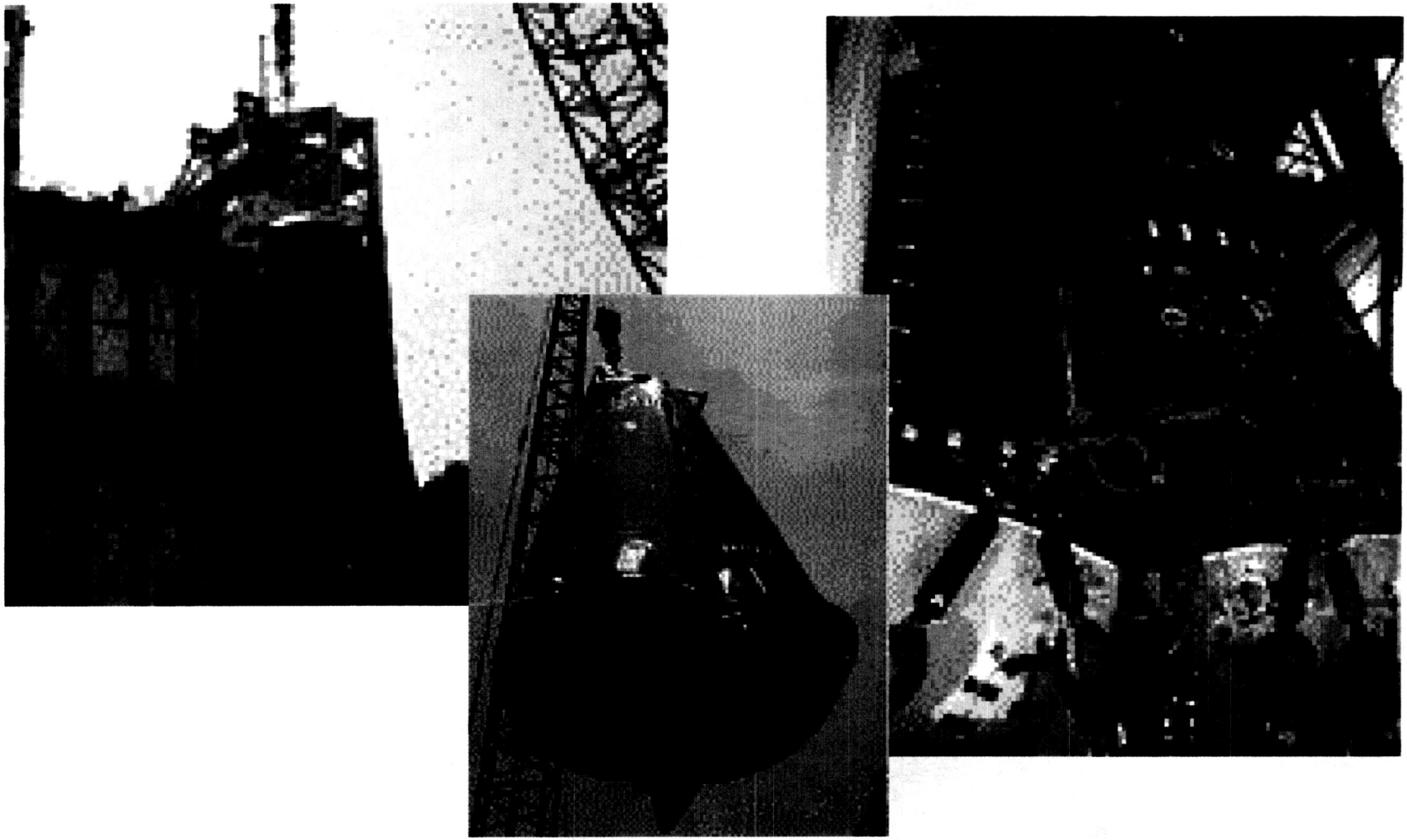


X-33 LH_2 Tank Failure Investigation Findings

Introduction

- **Tank History and Test Objectives**
- **Failure Description**
- **Investigation**
- **Conclusions**

X-33 LH_2 Tank Failure Investigation Findings

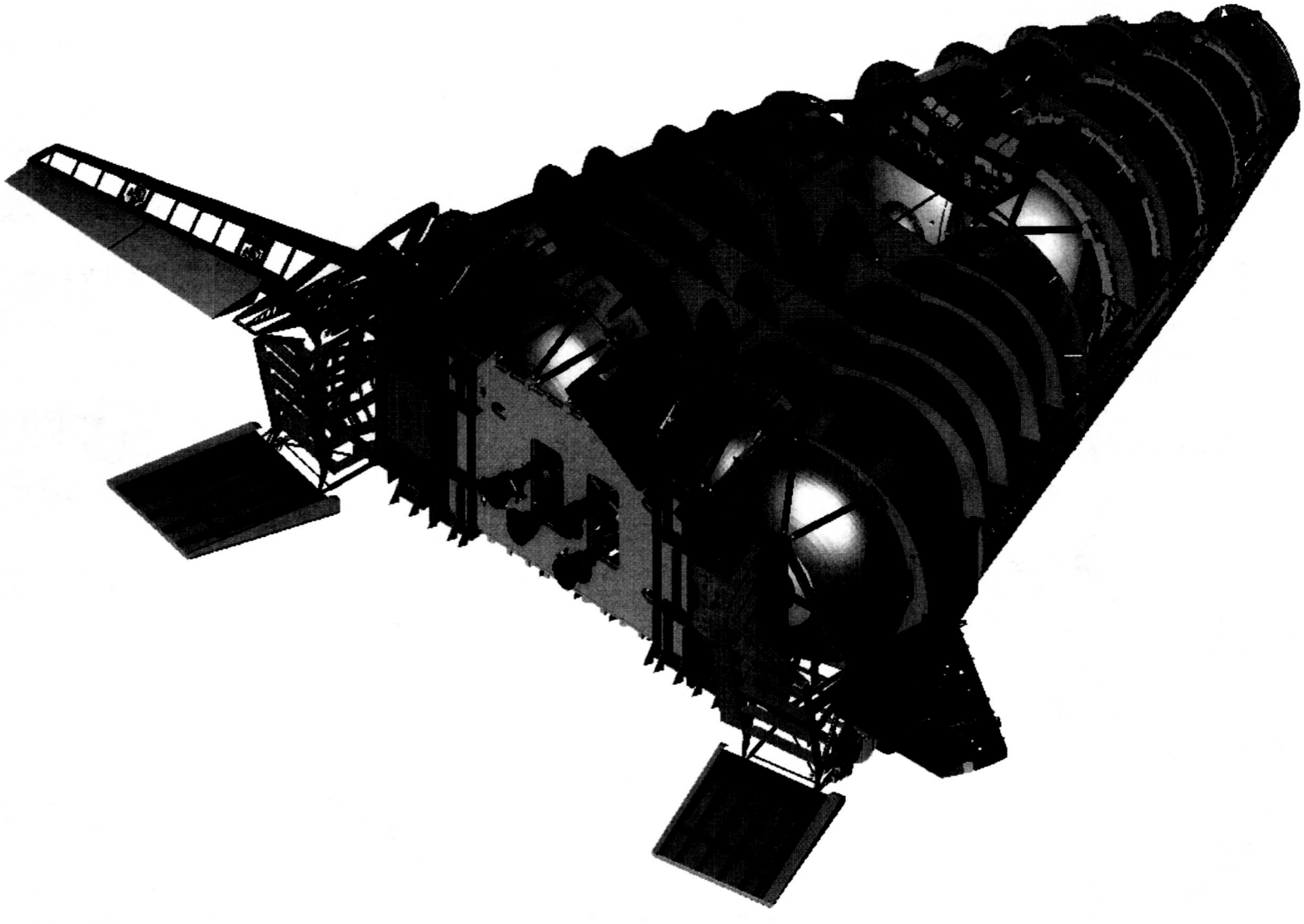


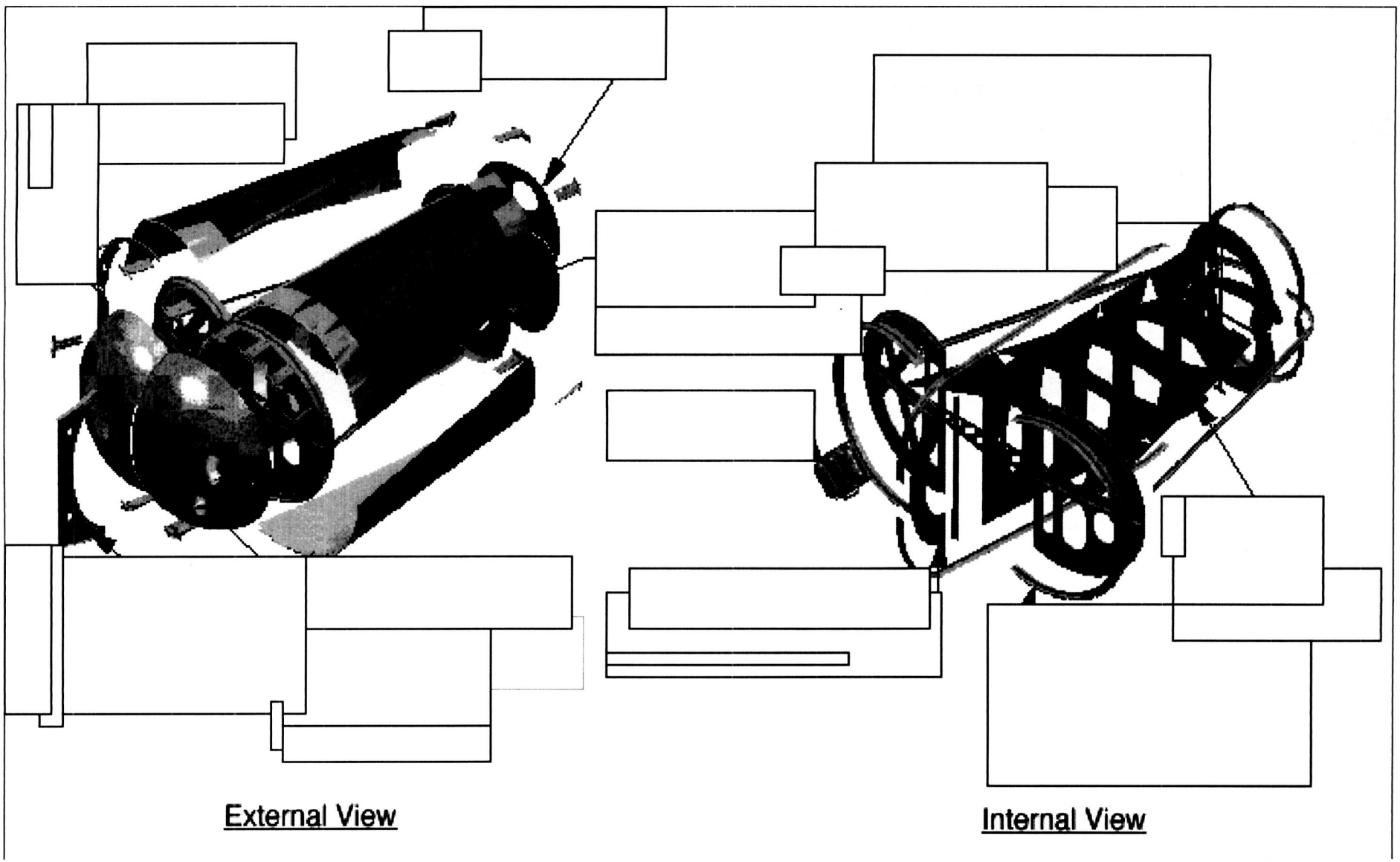
X-33 LH_2 Tank Failure Investigation Findings

X-33 LH_2 Tank Failure Investigation Findings

Tank Description

- **Structural component of the aft body**
- **Quad-lobe design**
- **Sandwich - honeycomb graphite epoxy construction**

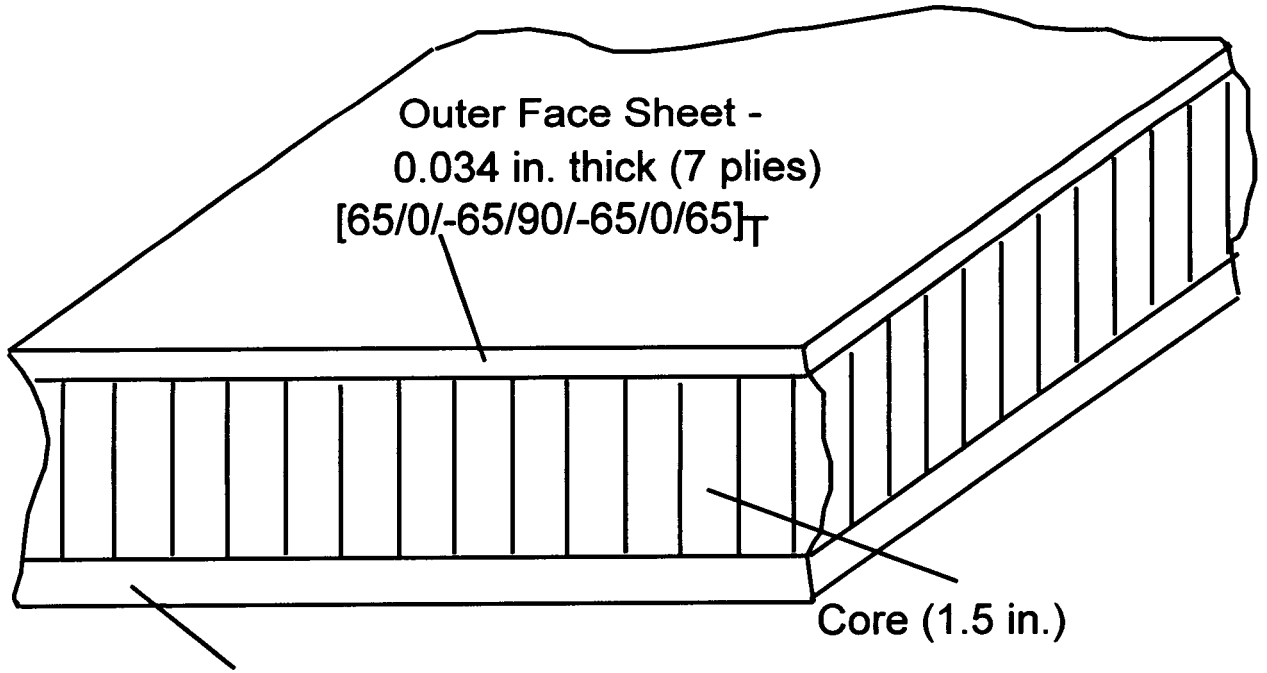




External View

Internal View

X-33 LH_2 Tank Failure Investigation Findings



Geometry of sandwich structure

Test Objectives

- **Verify structural integrity at 105% expected flight load limit varying the following parameters**
  - **Cryogenic temperature**
  - **Internal pressure**
  - **Mechanical loading**

X-33 LH_2 Tank Failure Investigation Findings

- **September 21, 1999 test aborted due to hydrogen leaks**
  - **100% cryogen fill (LH2)**
  - **20 psig internal pressure**

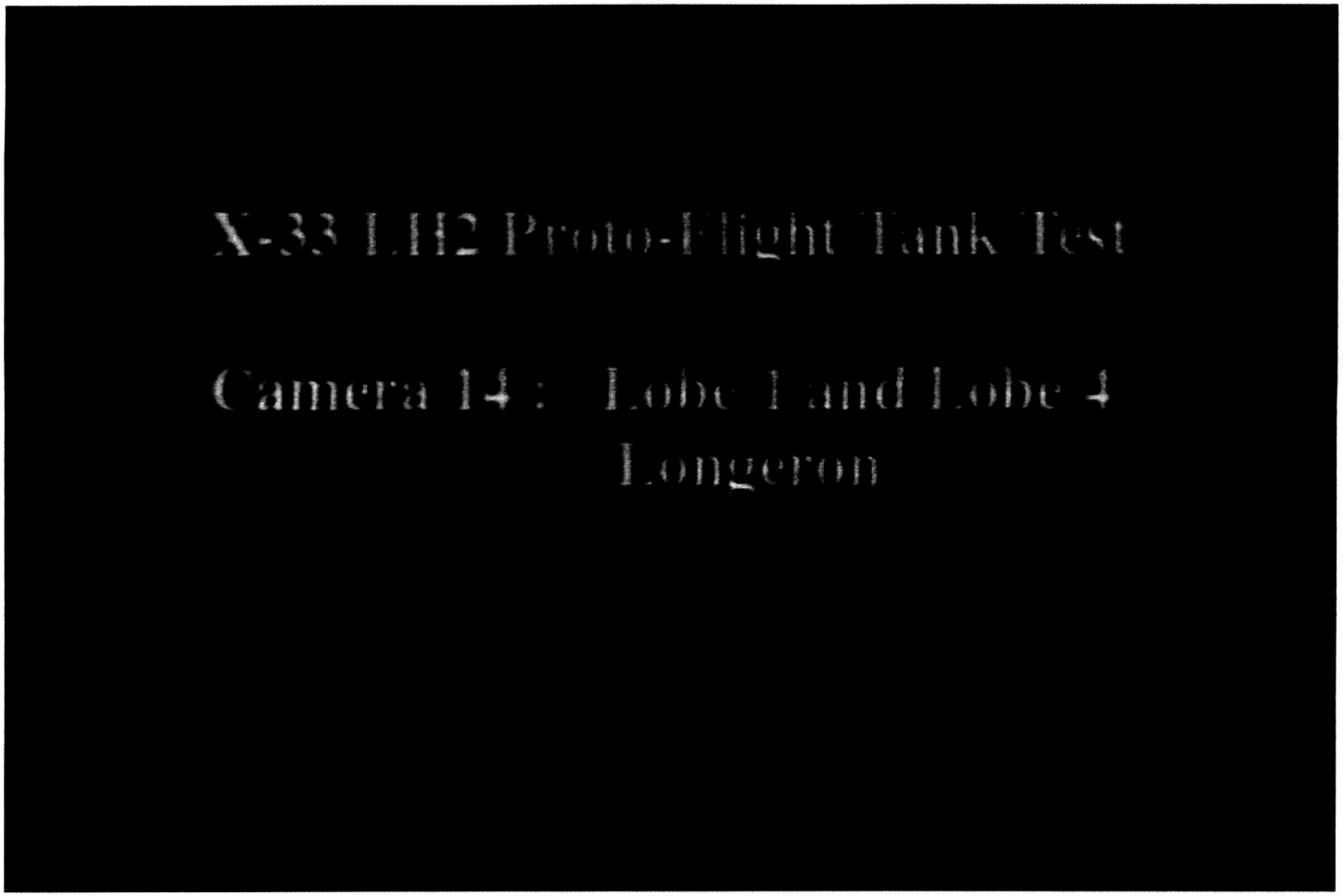
- **November 3, 1999 test completed**
  - **100% cryogen fill (LH2) at 42 psig internal pressure**
  - **Load case 5 applied at 5 psig internal pressure**
  - **Tank drained of cryogen**

X-33 LH_2 Tank Failure Investigation Findings

Timeline

- **Tank filled,12:30 PM**
- **Tank pressurized to 42 psig, 2:00 PM**
- **Tank vented to 2 psig, 3:00 PM**
- **Loads applied, pressure increased to 5 psig, 4:40 PM**
- **Tank drained, 6:00 PM**
- **Lobe 1 failure, 6:24 PM**

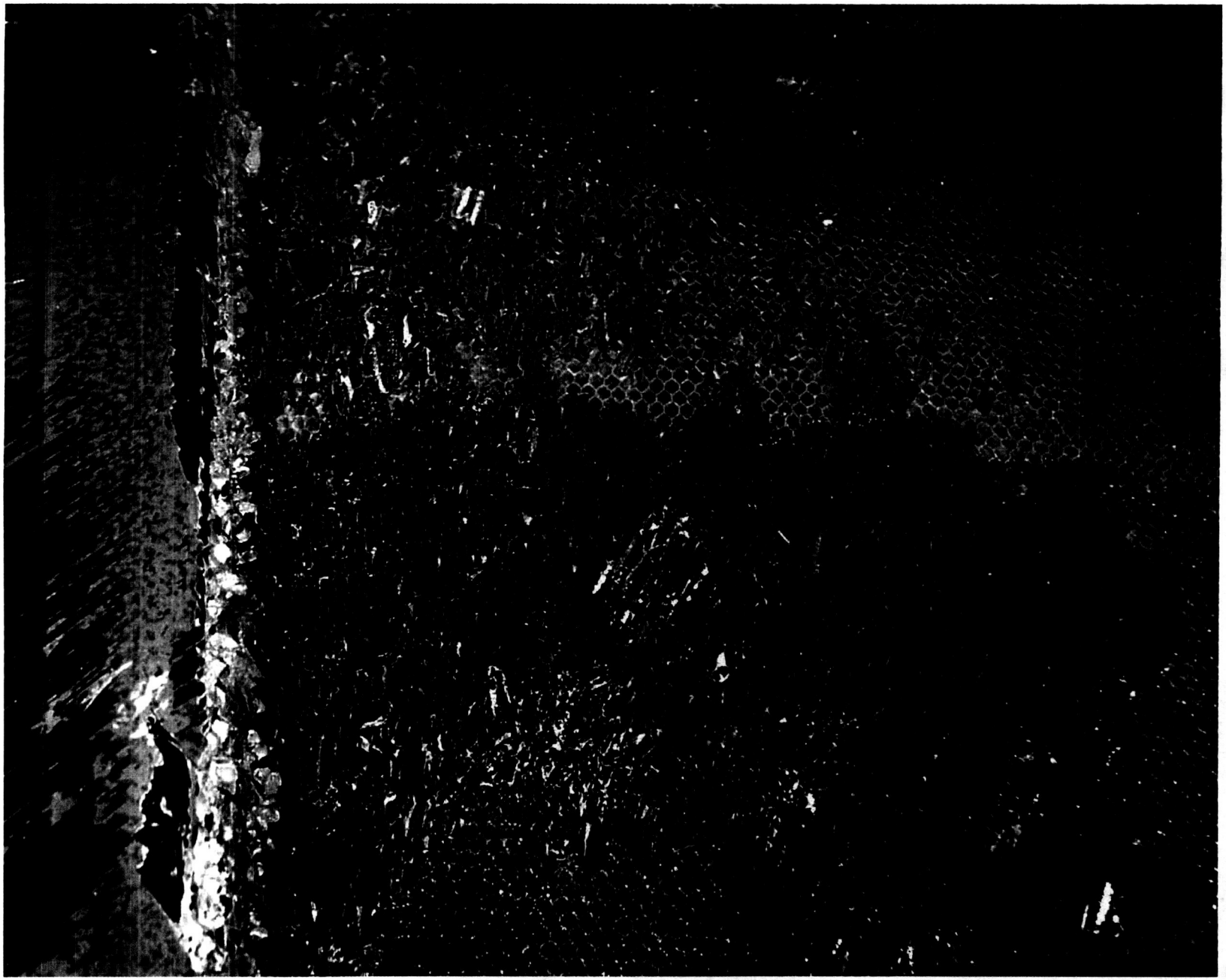
X-33 LH_2 Tank Failure Investigation Findings

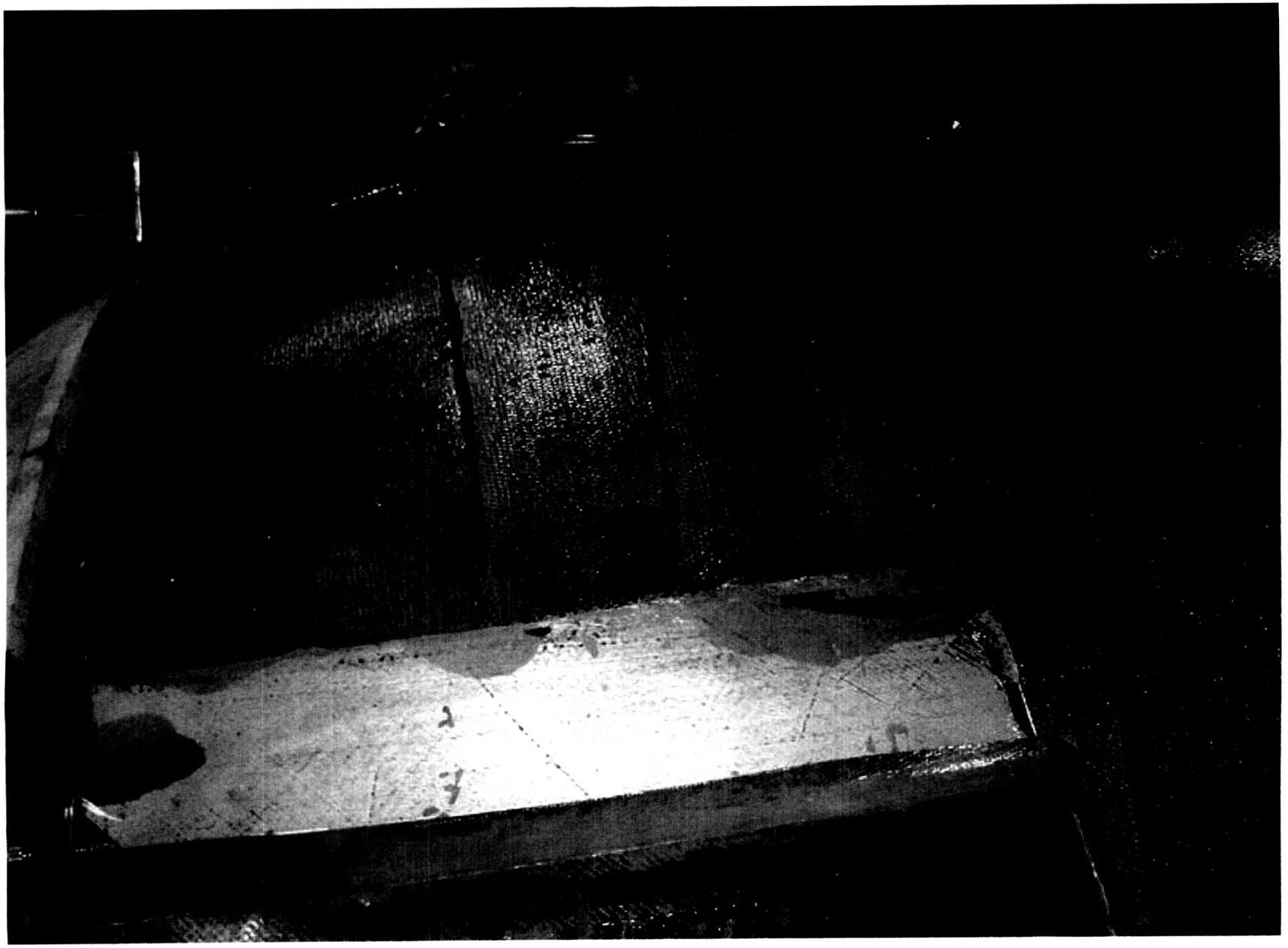


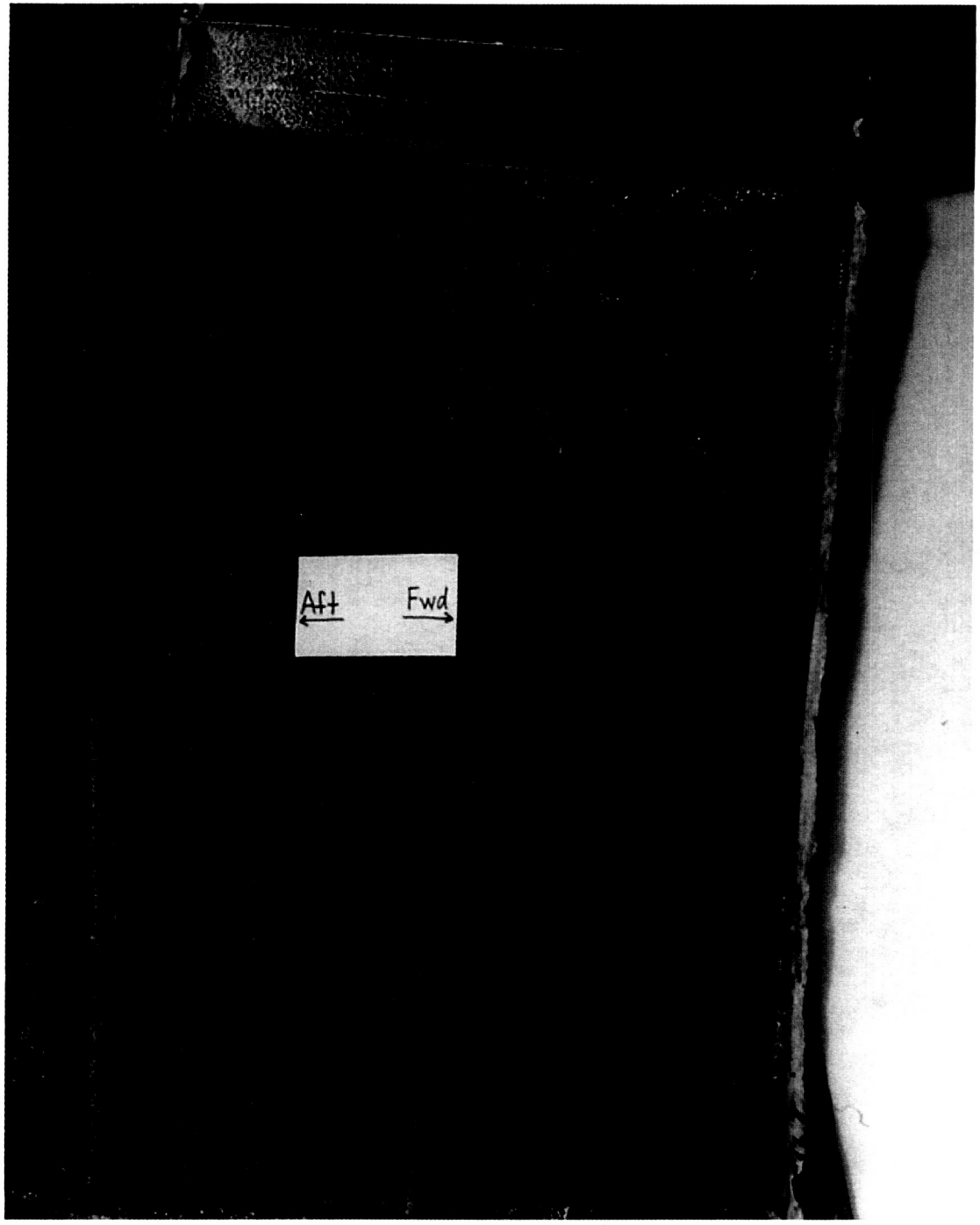
X-33 LH_2 Tank Failure Investigation Findings

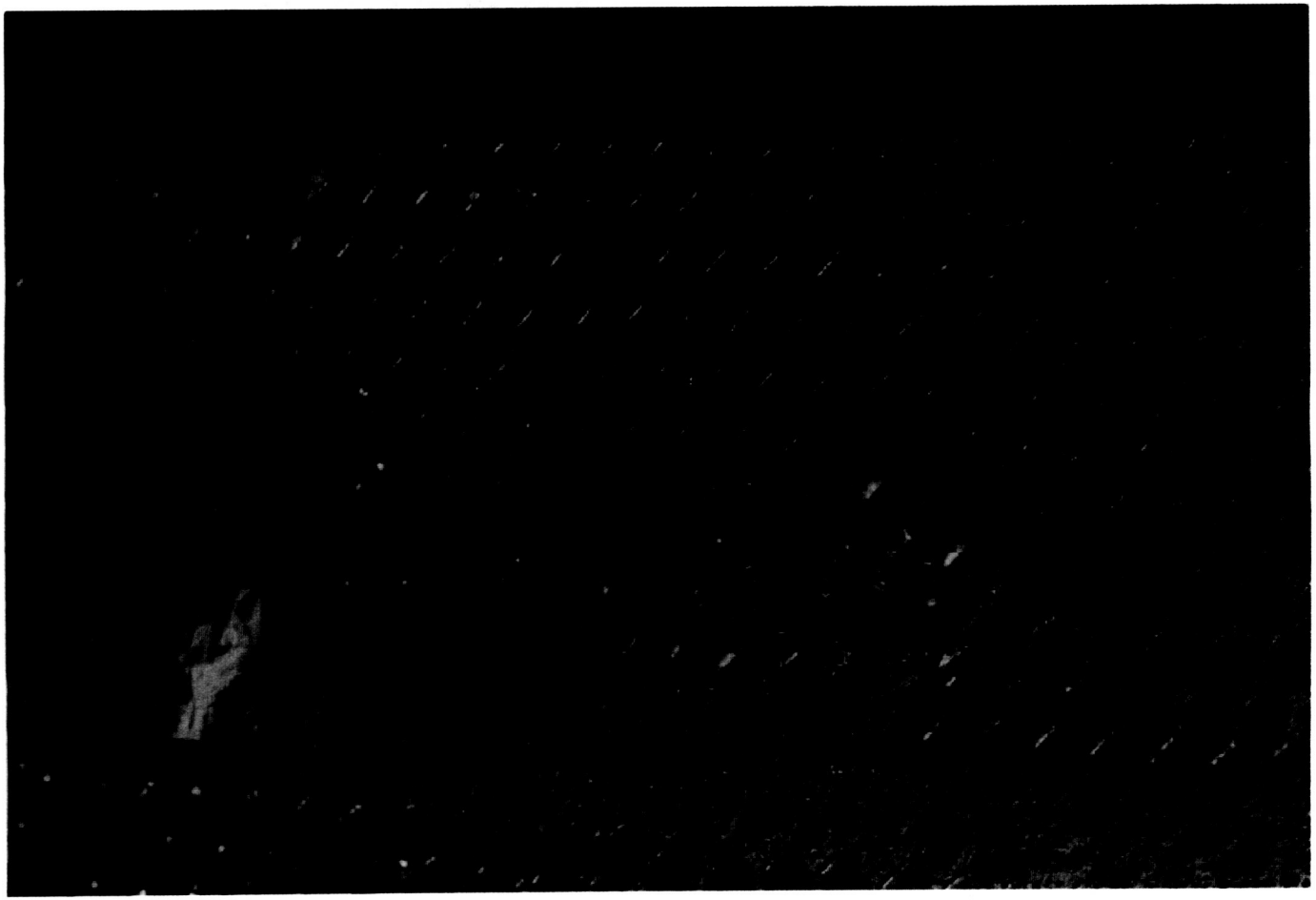
Initial Findings

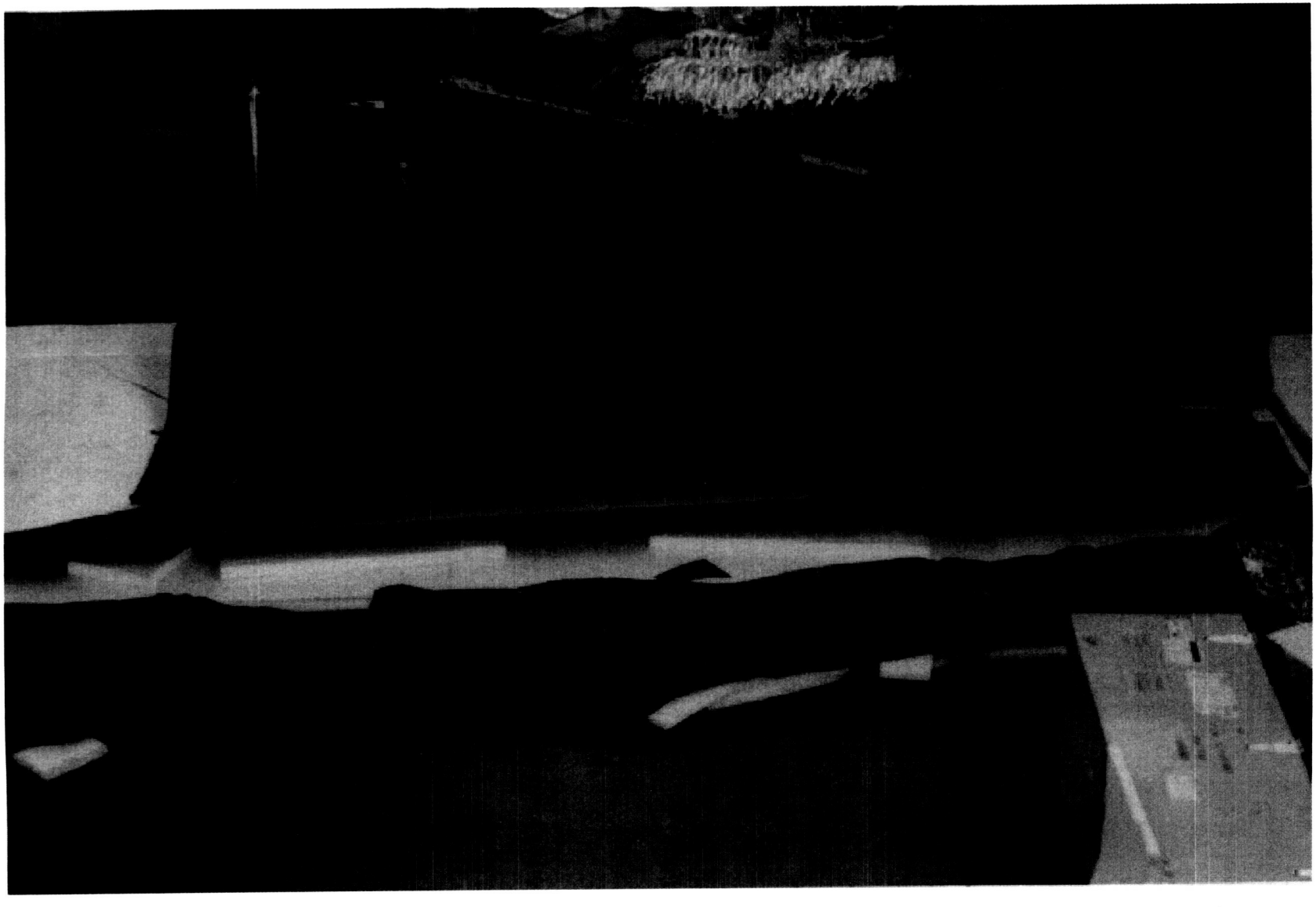
- **Peel Failure**
  - **Outer skin and core peeled away from inner skin**
- **Core Failure**
  - **Core is 'mangled'**
- **Hydraulic fluid on test article**
- **Foreign Object Debris (FOD)**
- **Poor bondlines**
- **Pressure in core above ambient 13 hours after failure**






Aft
Fwd





X-33 LH_2 Tank Failure Investigation Findings

Subsequent Findings

- Core pressures behaved unexpectedly
- Microcracking

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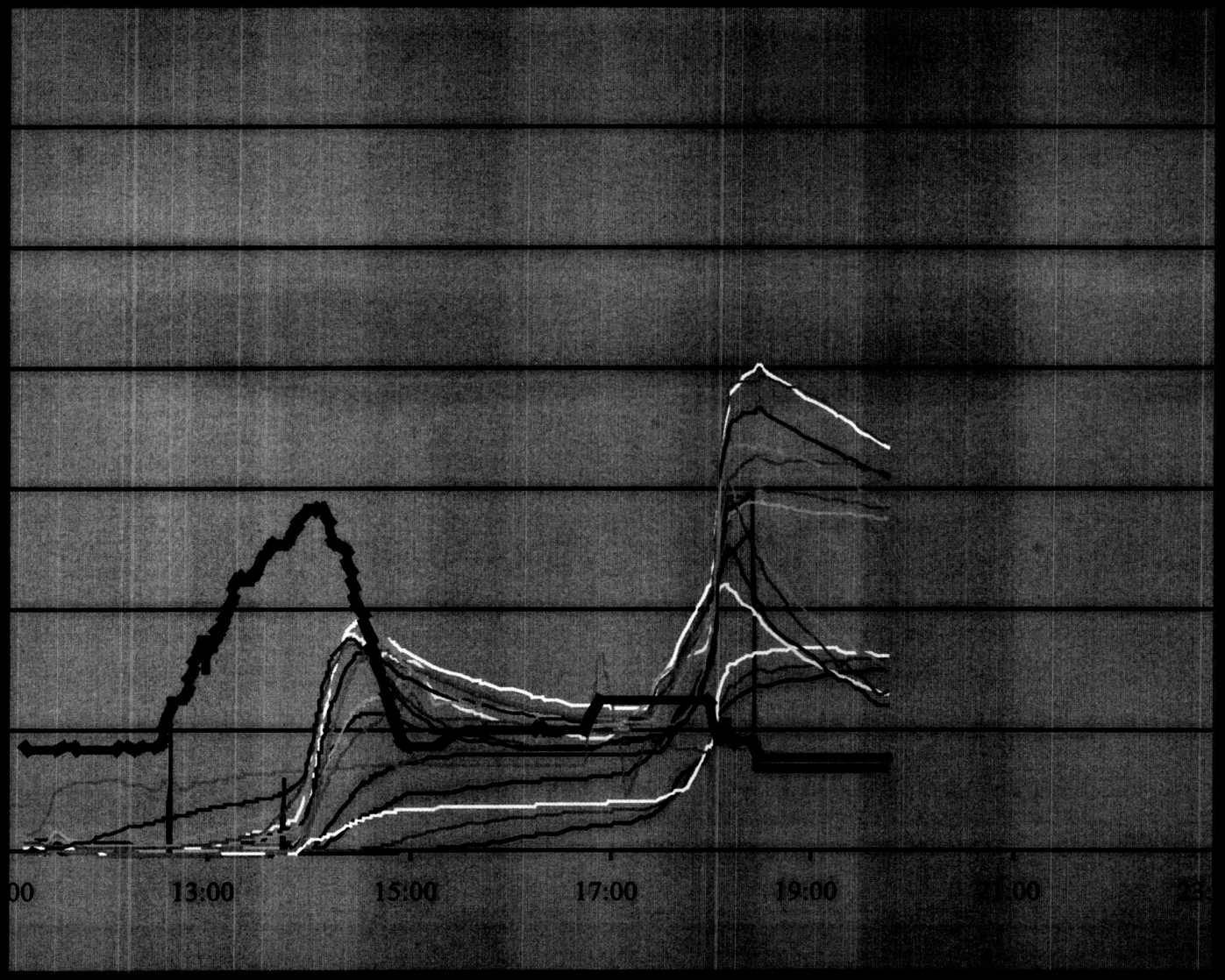

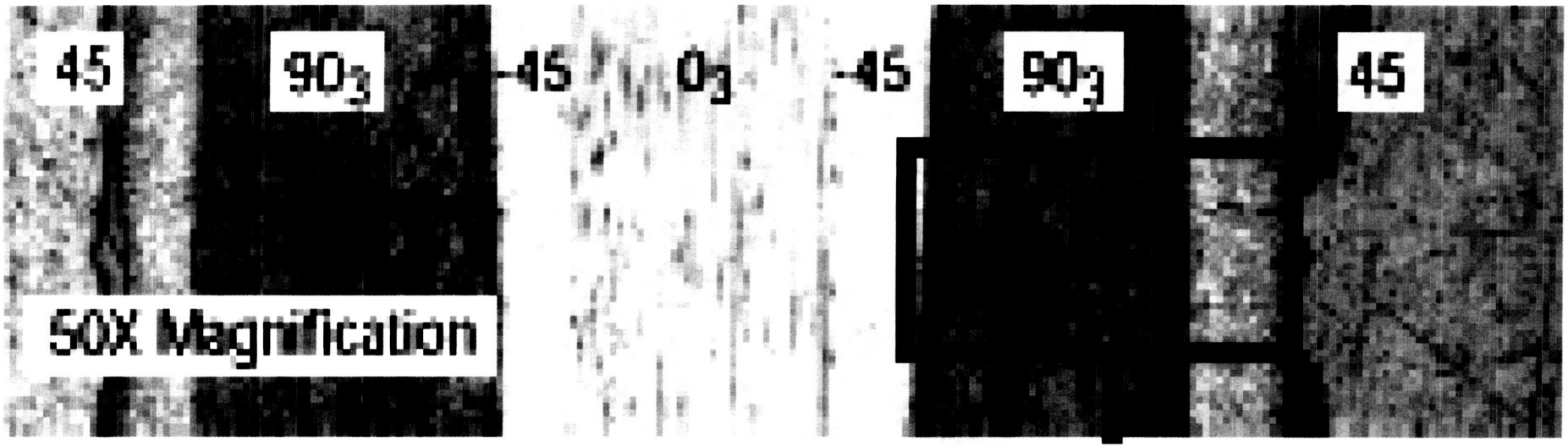
45
90$_3$
-45
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-45
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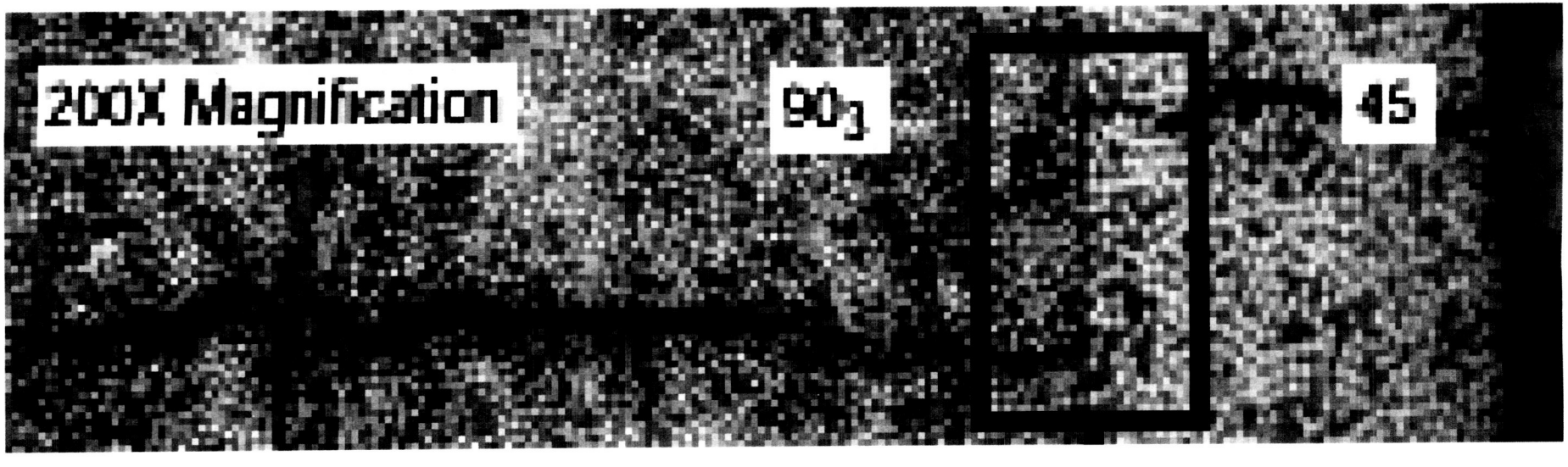
45
50X Magnification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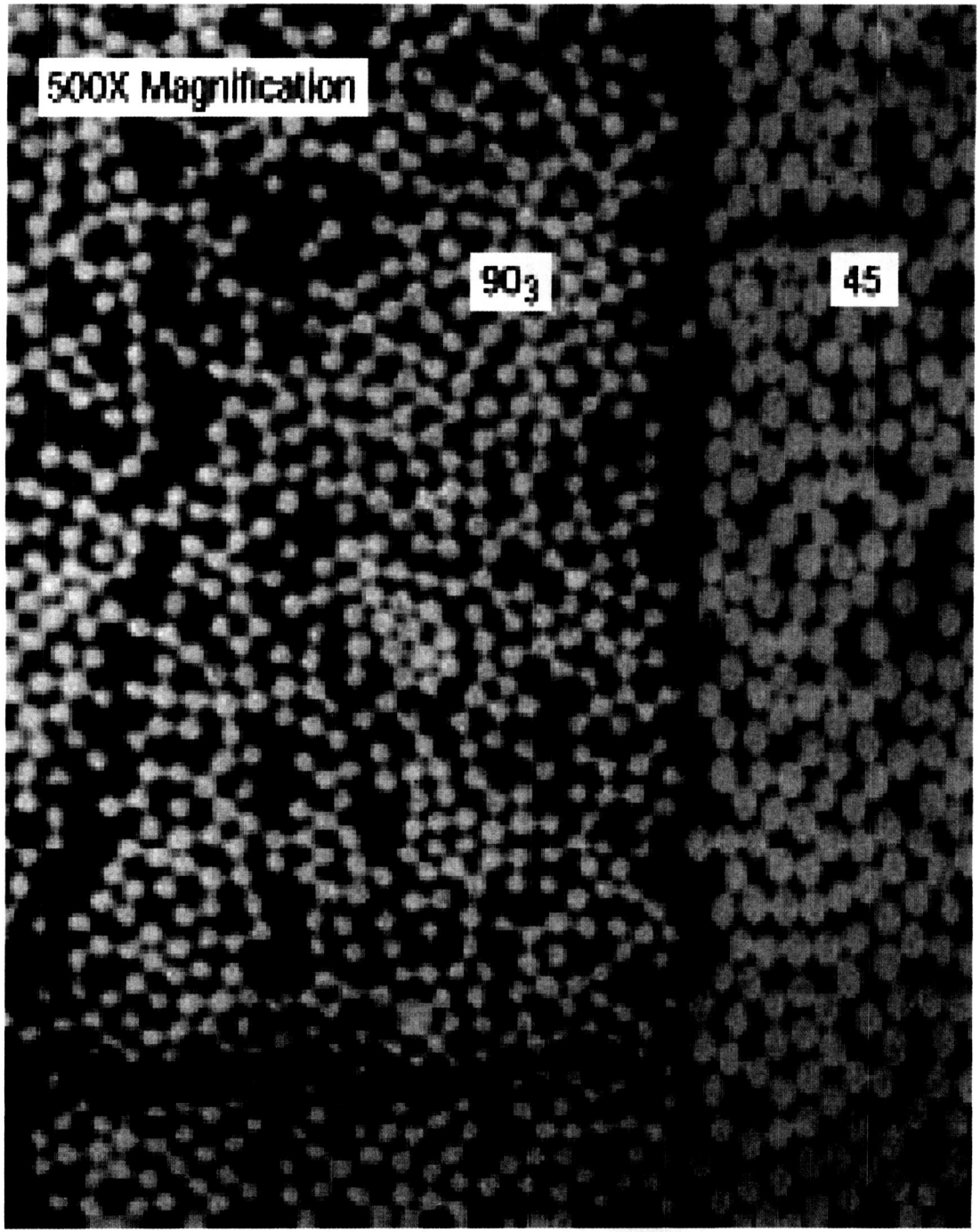
500X Magnification
90_3
45

X-33 LH_2 Tank Failure Investigation Findings

Conclusions

- The inner skin microcracked and hydrogen infiltrated
- The cracks grew larger under pressure
- When pressure was removed cracks closed slightly
- When tank was drained and warmed, cracks closed and blocked leak path
- FOD and debond areas provided an opportunity for a leak path
- There is still hydrogen in the other 3 lobes today