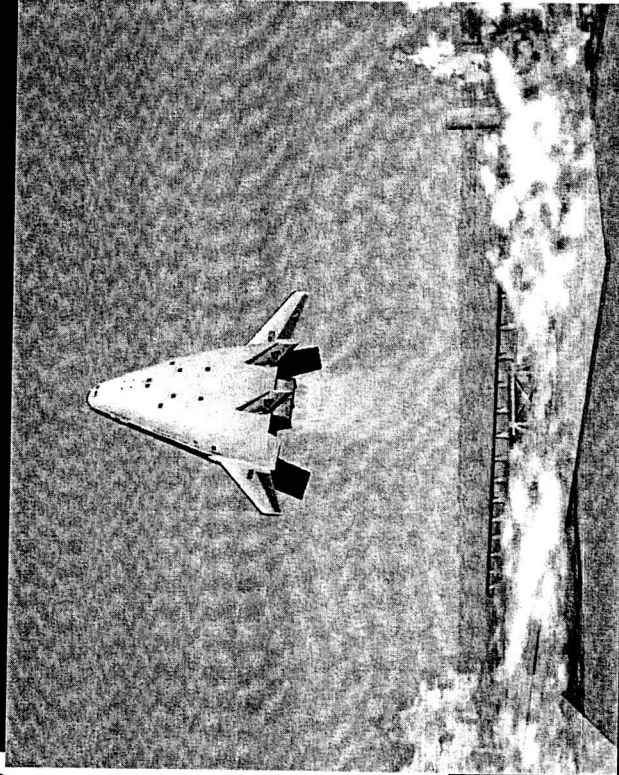
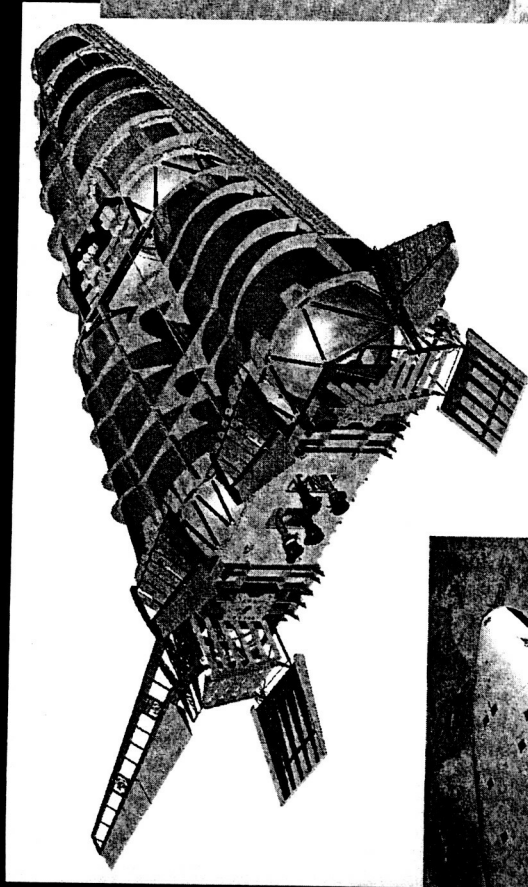


X-33 LH₂ Tank Failure Investigation Findings



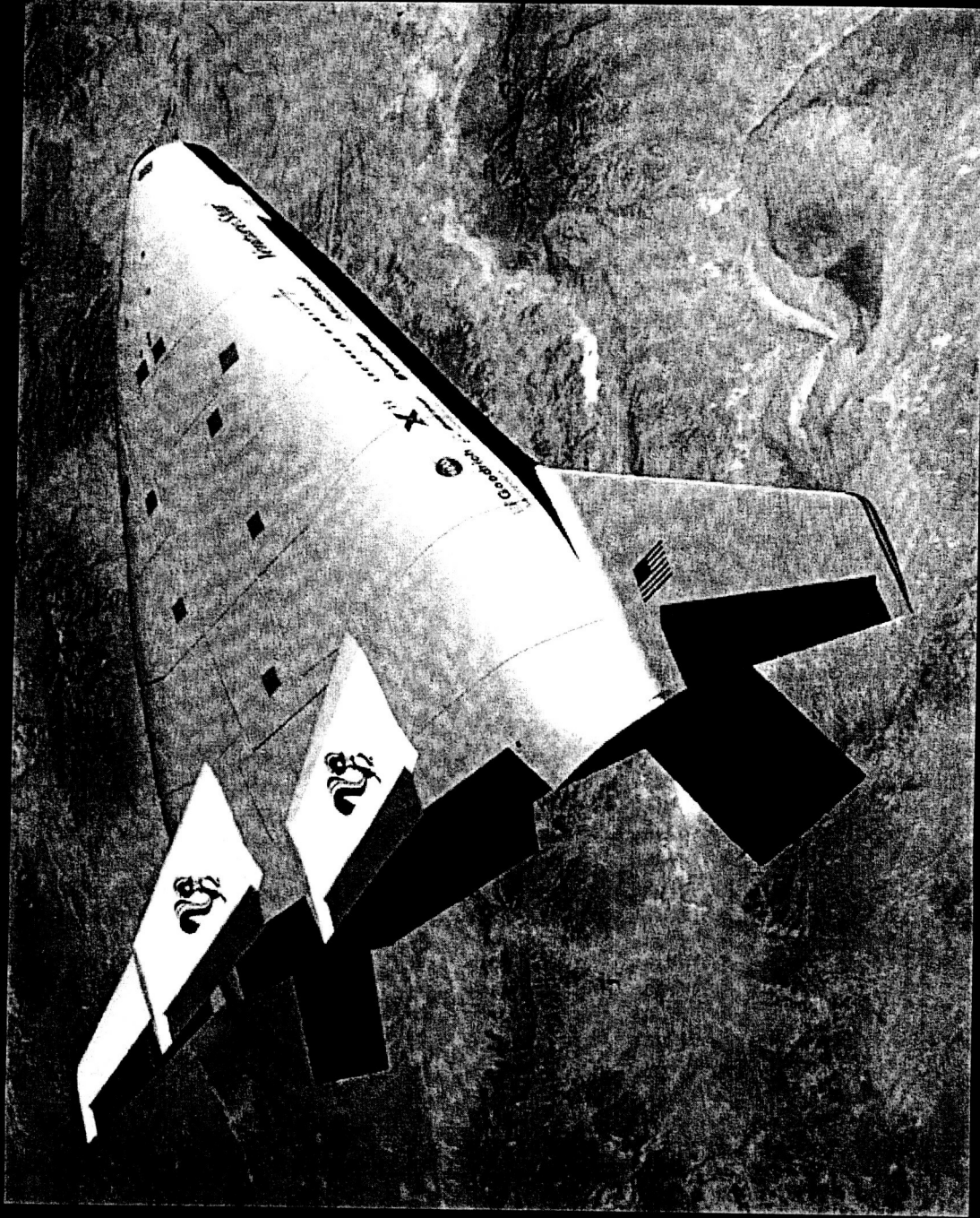
Presented by
Mindy Niedermeyer
MSFC

International Conference on Composites Engineering

July 23, 2003

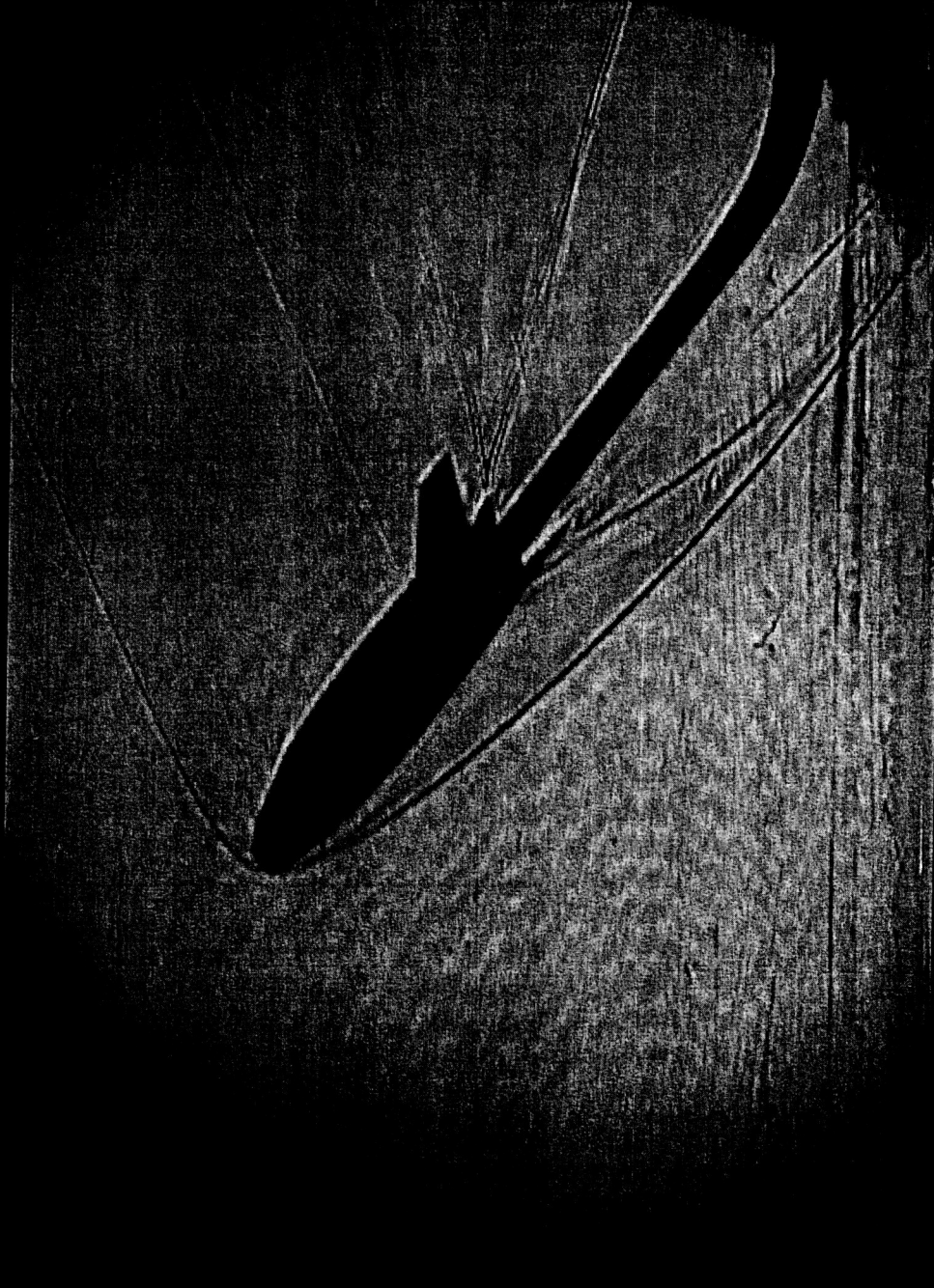
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X-33 LH₂ Tank Failure Investigation Findings



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X-33 LH₂ Tank Failure Investigation Findings



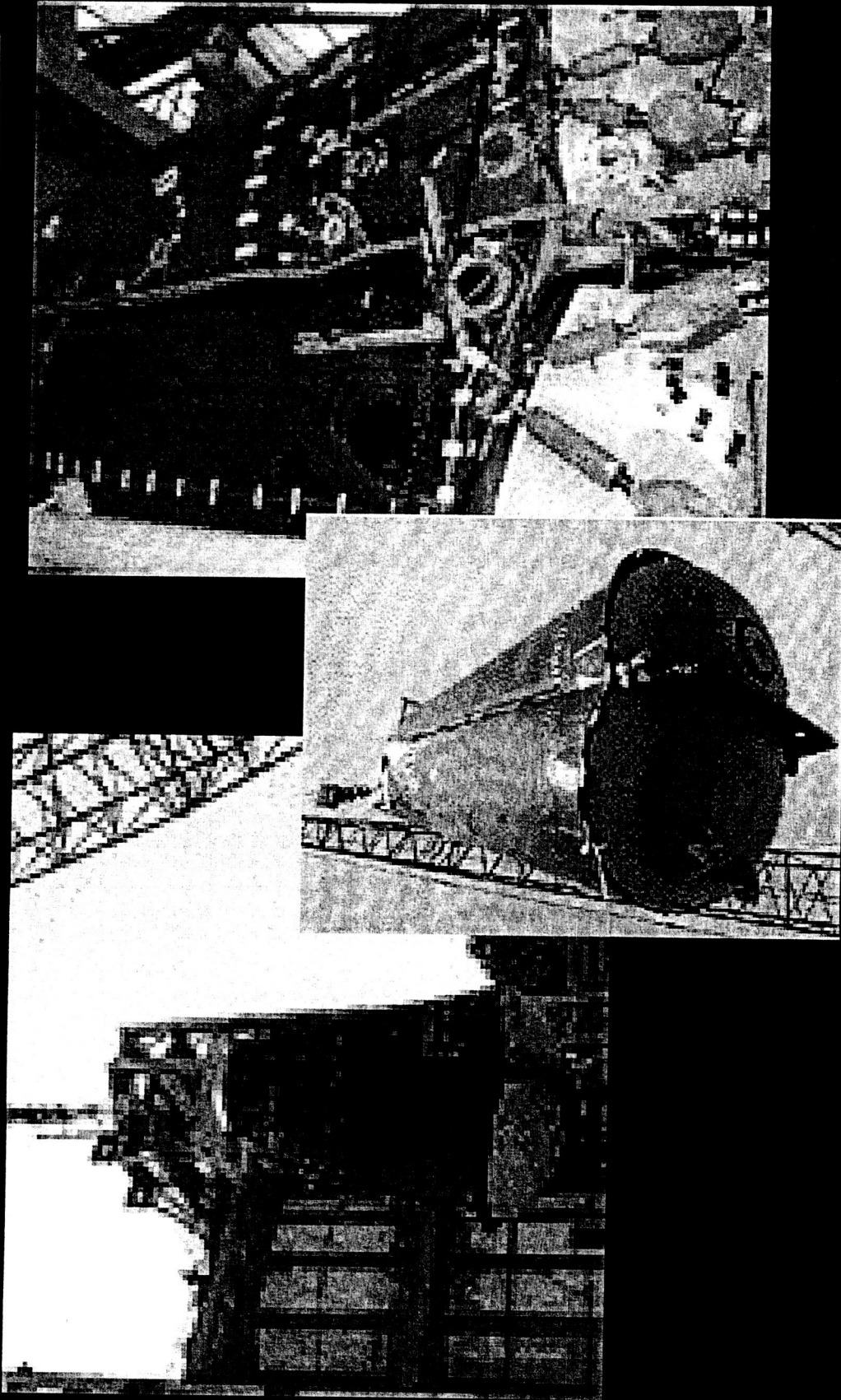
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X-33 LH₂ Tank Failure Investigation Findings

Introduction

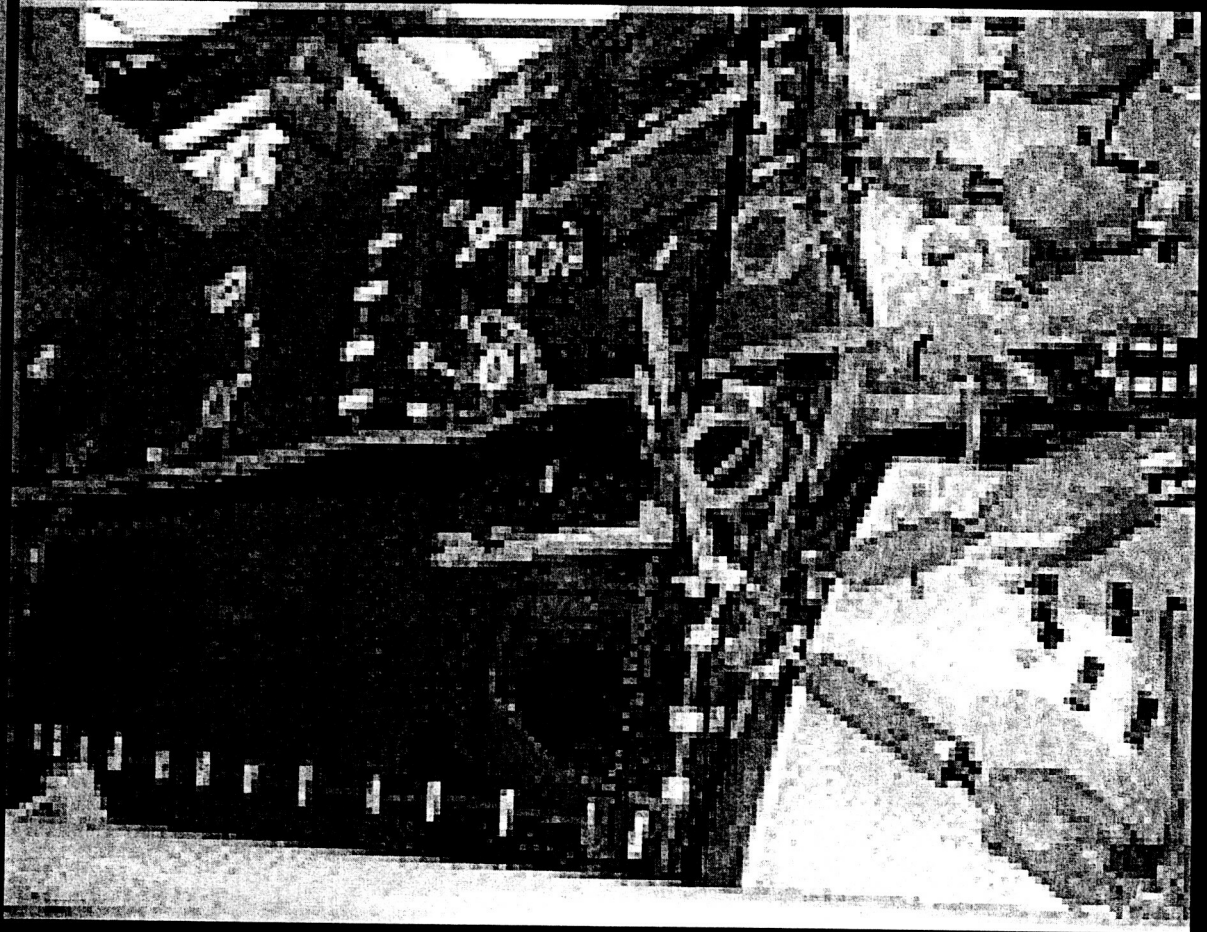
- **Tank History and Test Objectives**
- **Failure Description**
- **Investigation**
- **Conclusions**

X-33 LH₂ Tank Failure Investigation Findings



07/02/2003

X-33 LH₂ Tank Failure Investigation Findings

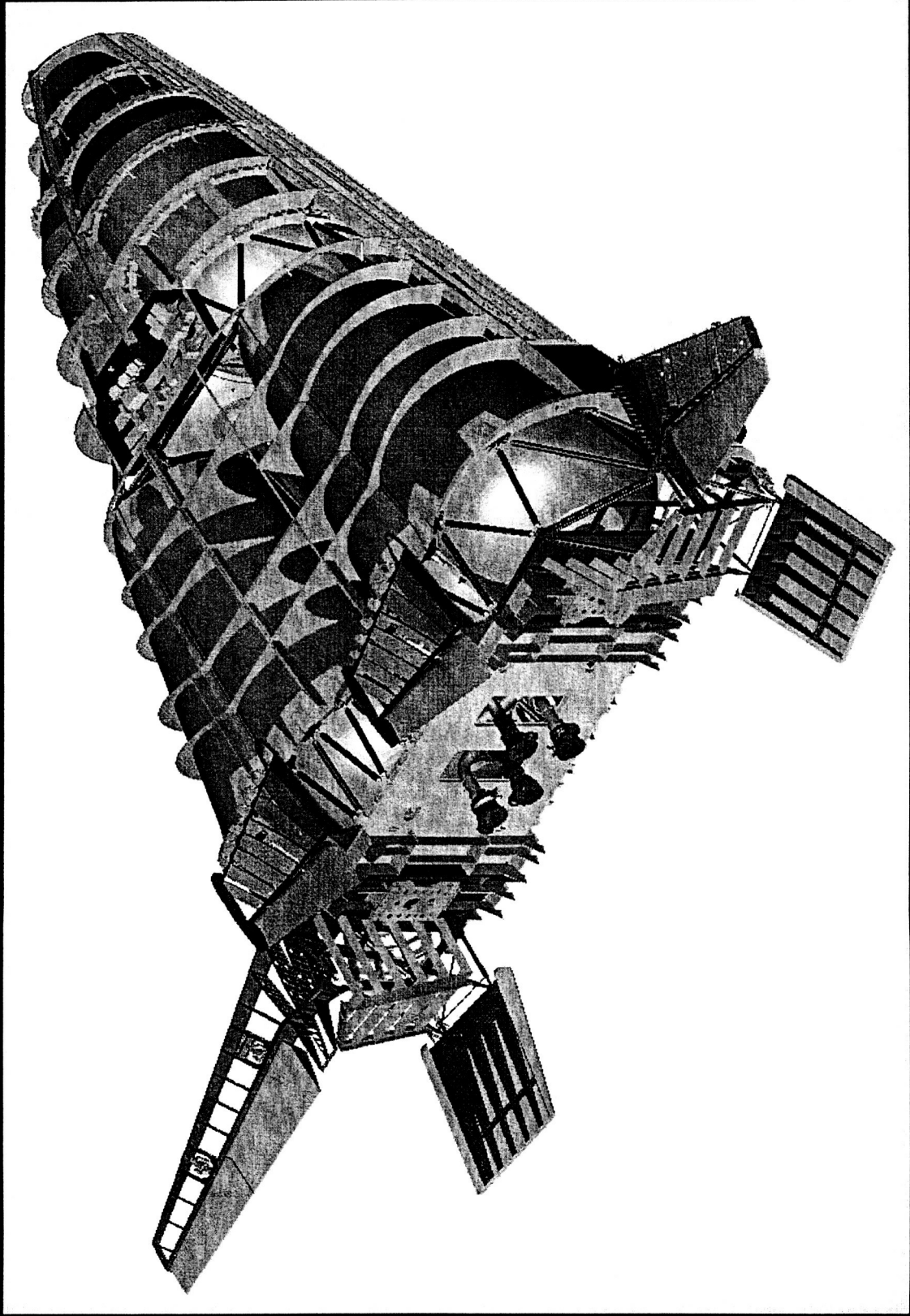


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X-33 LH₂ Tank Failure Investigation Findings

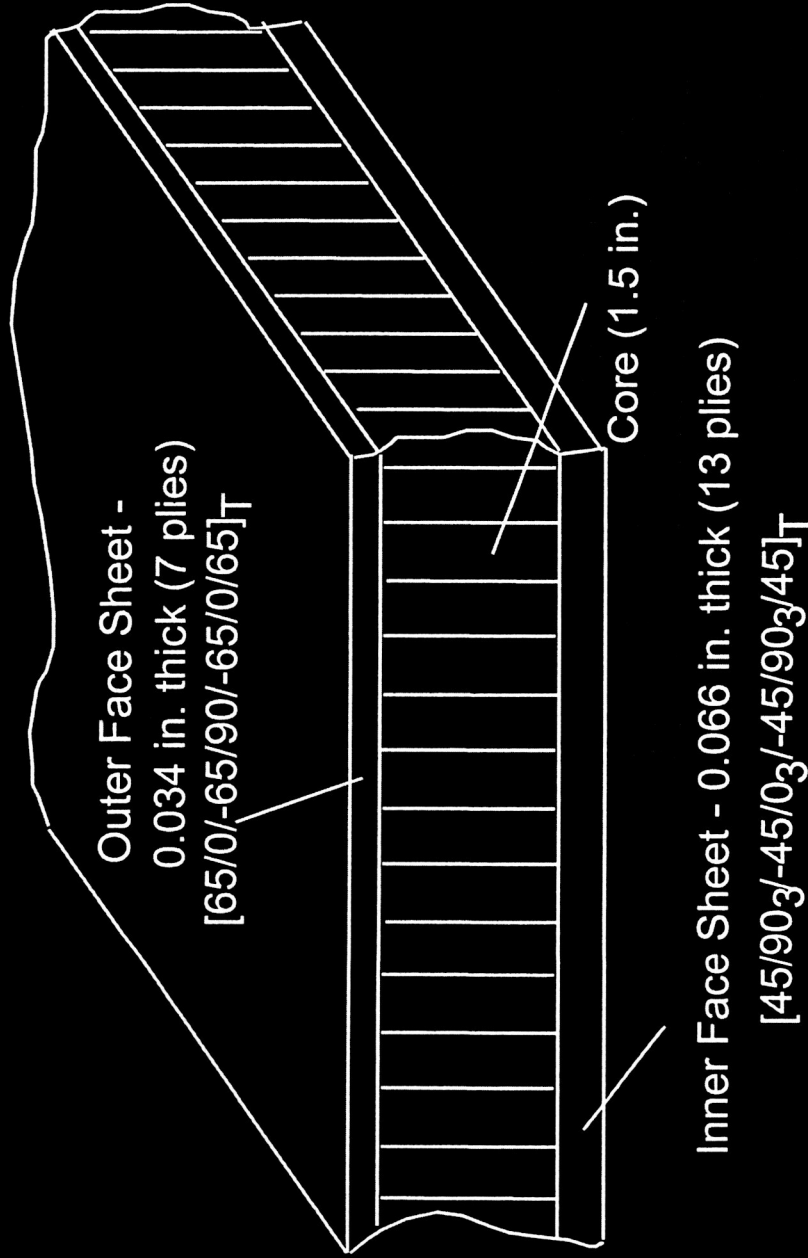
Tank Description

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



07/02/2003

X-33 LH₂ Tank Failure Investigation Findings



Geometry of sandwich structure

X-33 LH₂ Tank Failure Investigation Findings

Test Objectives

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

X-33 LH₂ 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 LH₂ 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 LH₂ Tank Failure Investigation Findings

X-33 LH₂ Proto-Flight Tank Test

**Camera 14 : Lobe 1 and Lobe 4
Longeron**

X-33 LH₂ 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**

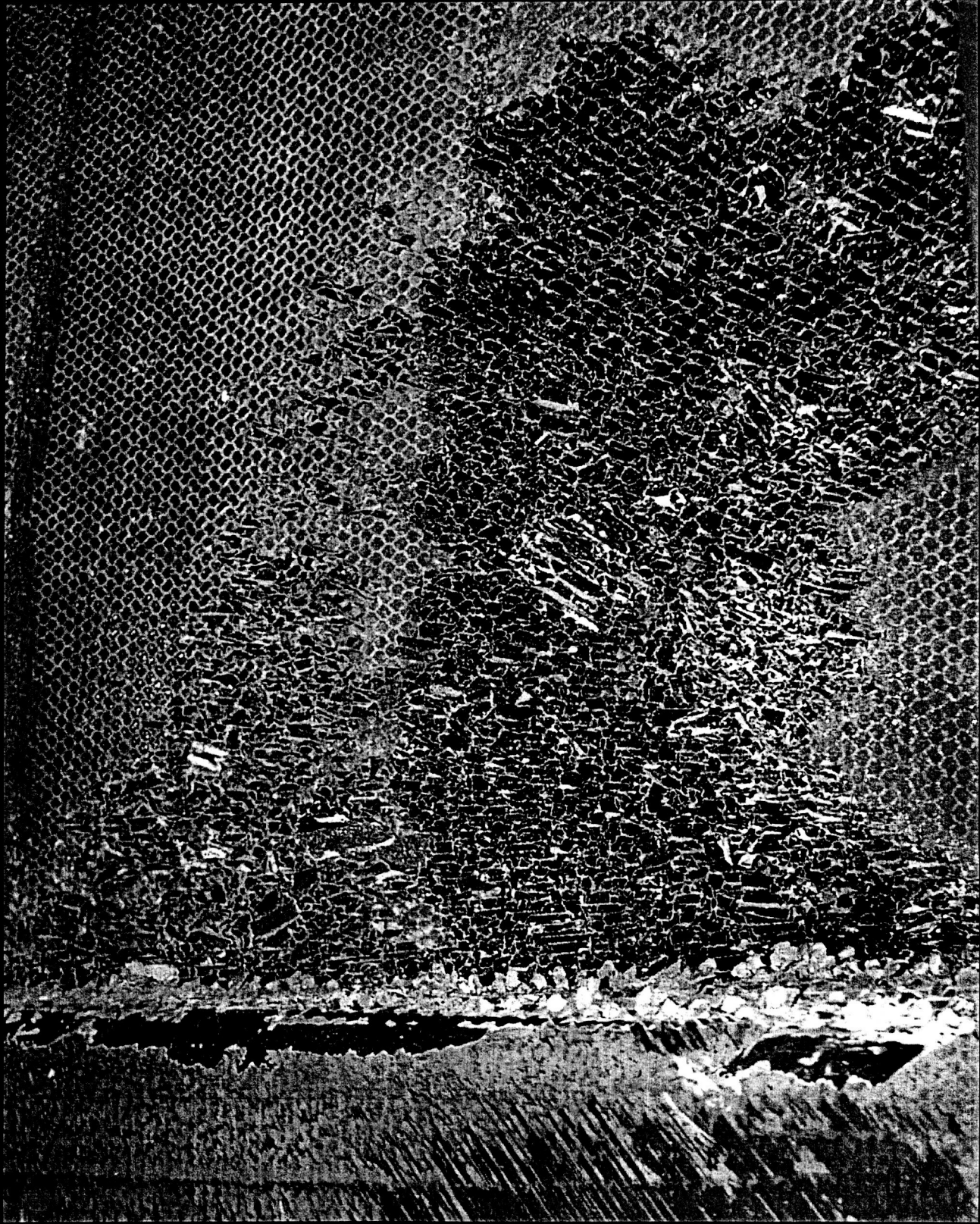


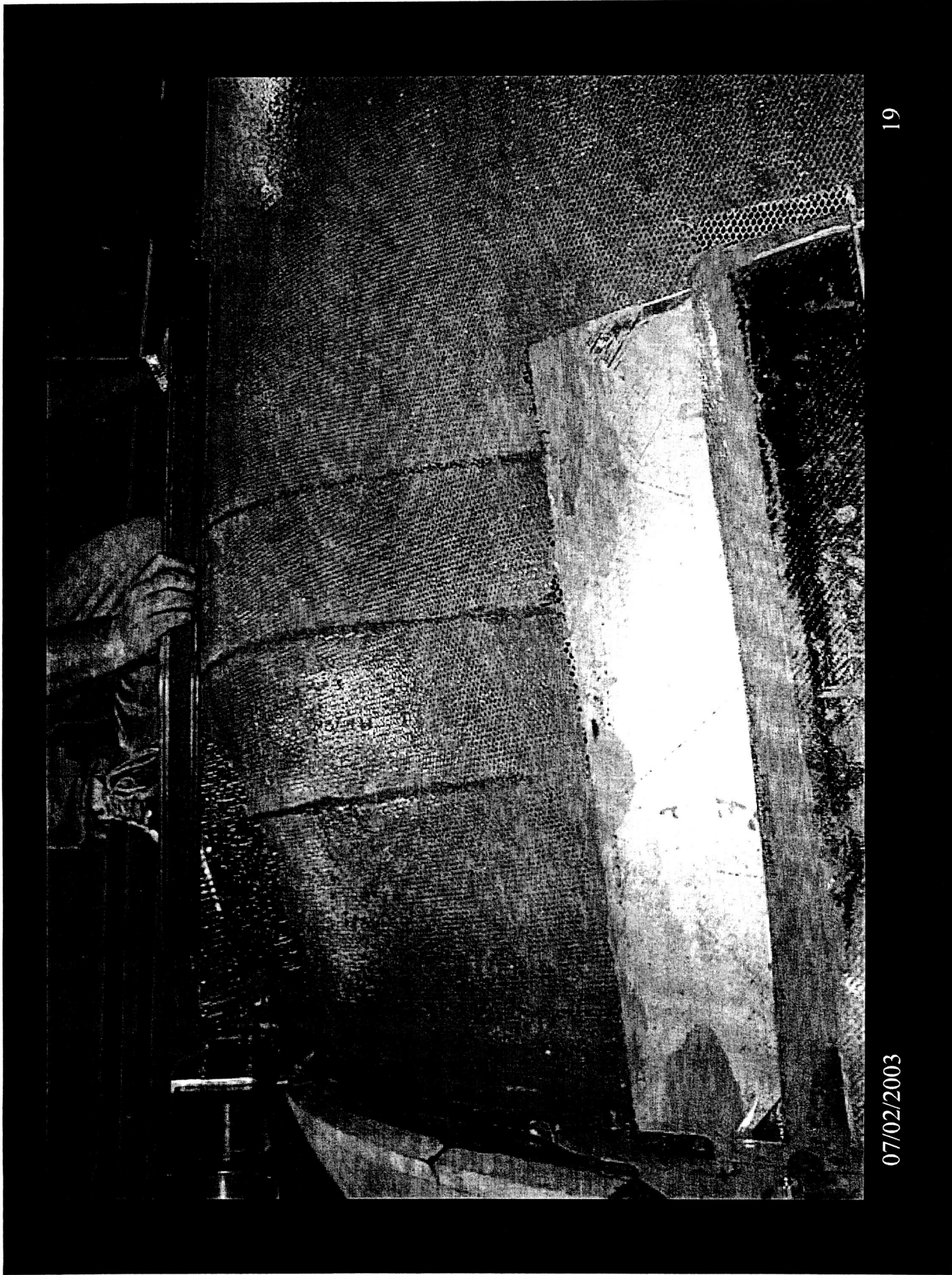
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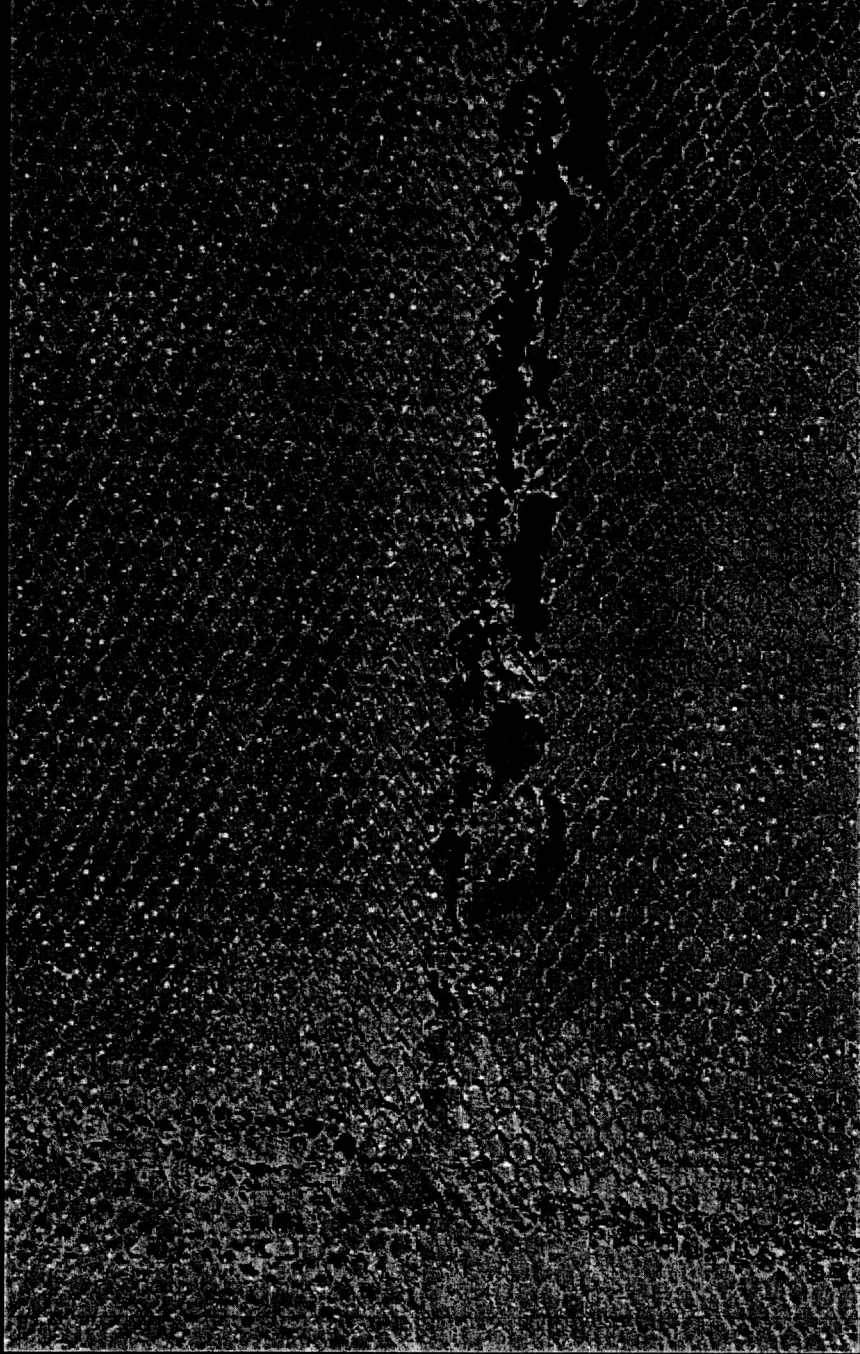


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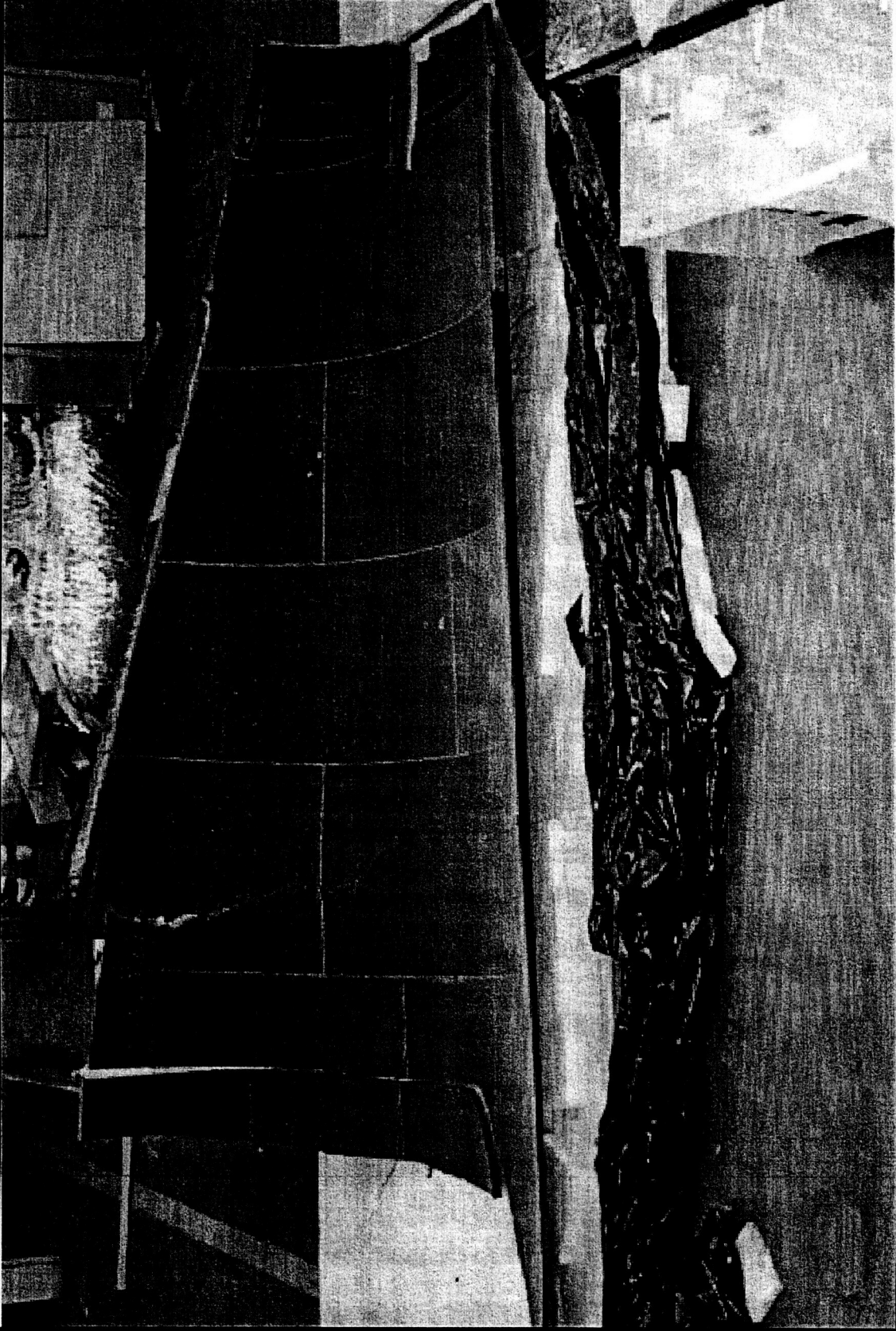




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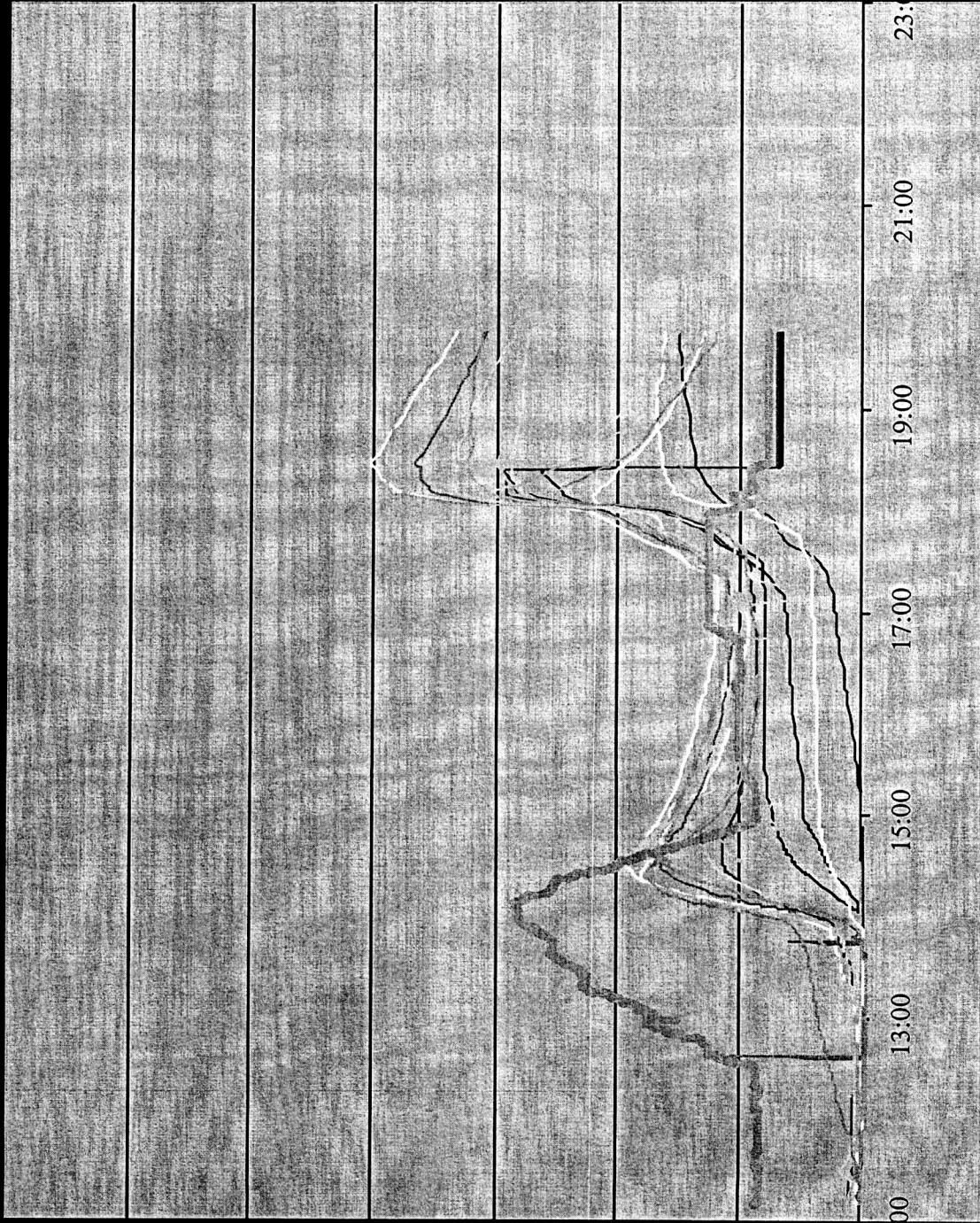
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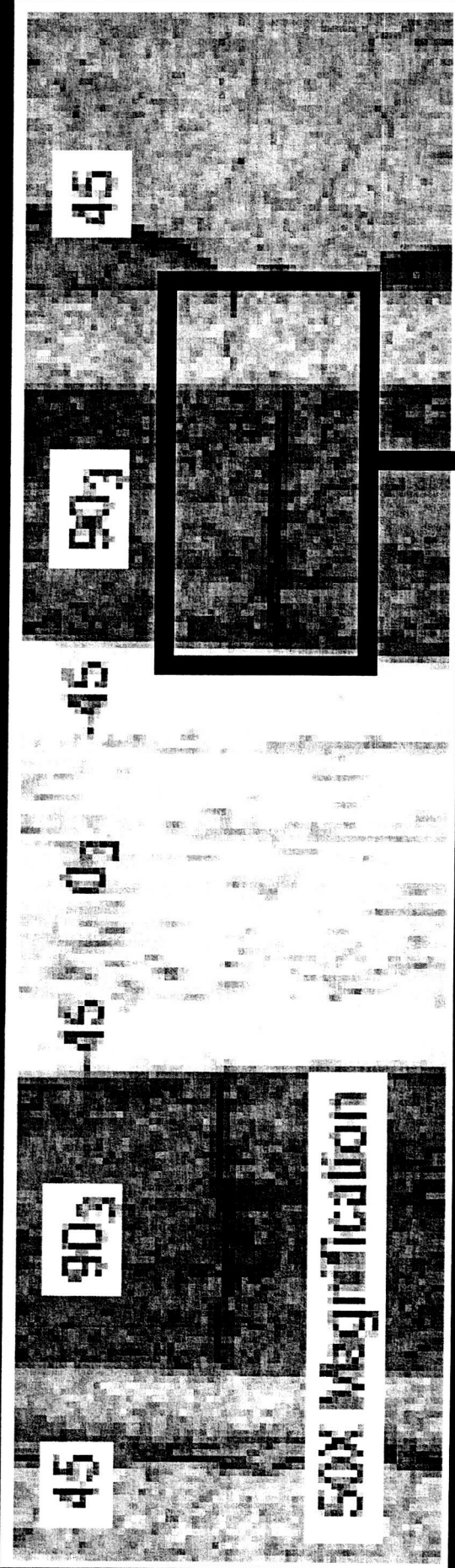
X-33 LH₂ Tank Failure Investigation Findings

Subsequent Findings

- Core pressures behaved unexpectedly
- Microcracking

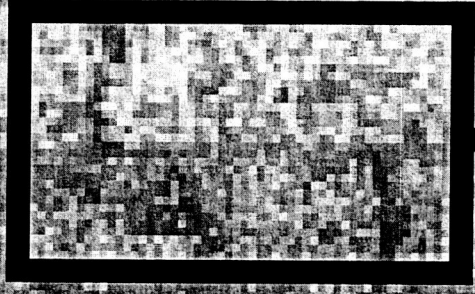
Core Pressure vs Time



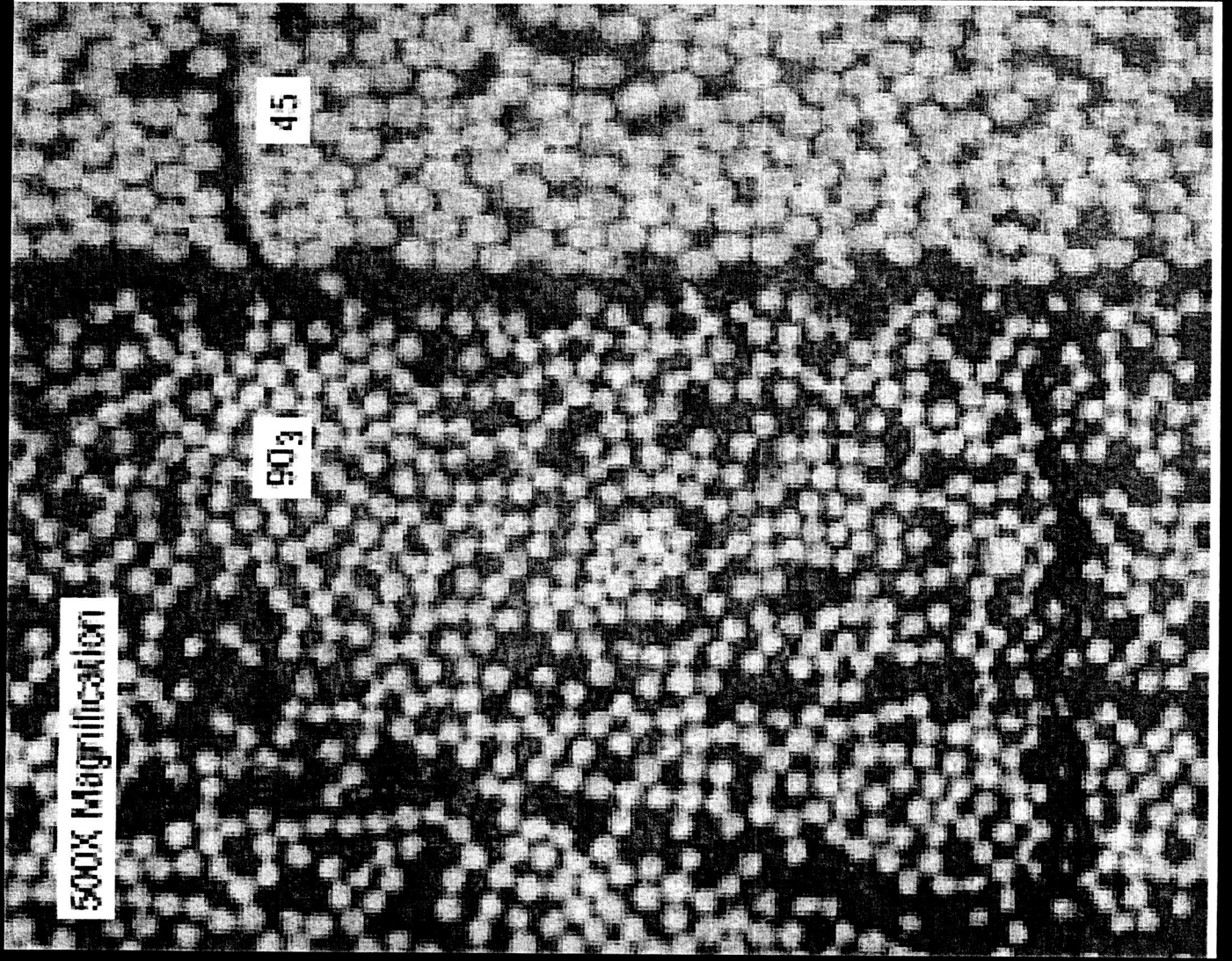


200X Magnification

903



45



07/02/2003

X-33 LH₂ 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