DOCKET No. SA-509

EXHIBIT No. 8-B

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D. C.

PWA-5542

Water Ingestion Testing on Pratt & Whitney Aircraft Group JT8D-7 Engine

Water Ingestion Testing on Pratt & Whitney Aircraft Group JT8D-7 Engine

Date of Report - July 15, 1977
Number of Pages - 16
Dates of Test - April 21, 1977 and June 2, 1977

PRATT & WHITNEY AIRCRAFT GROUP
Commercial Products Division

UNITED TECHNOLOGIES

elo

EAST HARTFORD, CONNECTICUT 06108

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Object

1. To demonstrate the ability of the Pratt & Whitney Aircraft Group JT8D engine to ingest water.

Resume

2. Water ingestion testing was conducted in an indoor test facility using a Pratt & Whitney Aircraft Group JT8D-7 Bill of Material production engine.

3. Fog nozzles mounted in front of the engine inlet were used to simulate rain for the ingestion test.

4. The 4% water ingestion tests were made at idle and takeoff conditions based on dry engine performance.

5. The engine durability was unaffected by the water ingestion tests.

6. Water ingestion testing had no adverse effects on dry steady state engine performance.

7. Motion picture and T.V. cameras aimed at the engine inlet and exhaust recorded the water ingestion testing.

Conclusions

8. The Pratt & Whitney Aircraft Group JT8D engine can ingest water as required by F.A.R. 33 (Effective October 31, 1974) without adversely affecting the engine durability or performance.

Description of Subject

9. A JT8D-7 Bill of Material production engine P-649244 was used for the water ingestion testing.

10. Production engine P-649244 had accumulated ETT 17704, ETC 16454 and was overhauled at Pratt & Whitney Aircraft Group Service Center at Southington, Connecticut prior to the water ingestion testing.

Method of Test

11. Production engine P-649244 was installed in an indoor test facility, X-16 and all testing was conducted at the Main Test Facility in East Hartford, Connecticut. The water ingestion tests at idle and takeoff conditions were conducted on April 21, 1977 and June 2, 1977, respectively. The test facility was equipped with an ADR temperature and pressure system, a strain gage load cell thrust measurement system, rotor speed tachometers, vibration equipment, and all other equipment normally used for sea level performance testing.

12. Installation of P-649244 engine with the associated equipment is shown in Photograph 77-441-9571, Page 11.

13. The inlet screen was removed from the bellmouth for the water ingestion testing. The first stage fan blades and the bellmouth were painted flat white for improved visibility. Demineralized water was used for all engine testing.

14. The water ingestion system consisted of four 1.5 inch diameter 142-48 SML205 fog nozzles mounted approximately six feet in front of the engine inlet. The fog nozzles were arranged in a square pattern approximately two feet apart with each nozzle directed at the center of the annulus of the engine inlet as shown in Photograph 77-441-9605A, Page 12.

15. The water droplet size was determined by photographing droplets sprayed from a single fog nozzle similar to those used for the water ingestion testing. Magnified water droplets at three flow rates are shown in Photograph 17430-1, Page 13. The mean diameter water droplet size for the range of water flow is shown in Table J17522-1, Page 8. The 1.5 inch diameter 142-48 SML205 fog nozzle was set up so that a portion of the spray passed between a special camera and an EG & G spark source located approximately six feet from the nozzle. The nozzle setting was adjusted as closely as possible to the actual water ingestion test conditions and a flowmeter was used to measure the water flow. The special camera was constructed to provide a magnification of 1.89 using a two inch diameter, eight inch focal length achromat lens. The lens was purged with nitrogen to minimize water accumulation on the lens.

16. T.V. and photographic equipment was used to record pictorial evidence of water ingestion at the engine inlet and exhaust. Three T.V. cameras were set up to monitor the engine inlet and the right and left sides of the engine exhaust using a closed circuit video tape system. Two semi-high speed (Mitchel) movie cameras were used to photograph the right and left sides of the engine inlet. The cameras contained color film and were set at a film speed of 90 frames per second. Two high speed framing cameras (Hycam) were installed to photograph the right and left sides of the engine inlet. These cameras used black and white film and were set at 200 frames per second. Two grids of lights mounted in front of both sides of the engine inlet created a light intensity at the inlet of approximately 17,000 foot candles.

17. The water ingestion test procedure for idle and takeoff conditions consisted of the following steps:

a. The engine was started and accelerated to idle power.

b. The engine was accelerated to the desired power settings.

c. A complete reading of engine performance instrumentation was taken.

d. The lights were turned on, the movie cameras and T.V. video tape recorders were started, and the water was turned on.

e. Water flow into the engine inlet was increased in increments of 1% each 30 seconds until a water flow of 4% of engine airflow by weight was reached.

f. The 4% water ingestion was continued for a total of 3 minutes during which a second complete reading of engine performance instrumentation was taken.

g. The water was decreased in increments of 1% each 30 seconds until the water was turned off.

h. After 5 minutes with the water turned off a third complete reading of engine performance instrumentation was taken.

i. The engine was decelerated to idle and shut down.

Results of Test

18. Production engine P-649244 successfully ingested 4% or greater water to air ratio by weight in the engine inlet at both idle and takeoff power settings. Engine operation was stable and stall free, before, during and after water ingestion testing. The engine fuel control governed engine operation in a stable manner.

19. The 4% water ingestion testing of production engine P-649244 at idle conditions is shown in Photographs 77-441-9605C and 77-441-9605B, Pages 14 and 15, respectively. The 4% water ingestion testing of production engine P-649244 at takeoff conditions is shown in Photograph 77-441-4180, Page 16.

20. At the idle power setting water was ingested with various combinations of anti-surge bleeds and anti-icing bleeds opened and closed. At the takeoff power setting water was ingested with anti-icing bleeds opened and closed. This data and the corresponding dry points are presented on Curve 319106, Page 9, for selected engine parameters versus engine pressure ratio.

21. Curve 319107, Page 10, shows the engine steady state required to run operating line for both dry and 4% water ingestion operation. This curve is indicative of the energy required by the engine to run steady state at a given power setting. Ingesting water at the engine inlet causes an increase in the required energy level along the fuel control governor control line. The slope of this line explains the decrease in high rotor speed at constant PLA. Terminating the water flow causes the engine to return to the dry operating line at the original speed and required energy.

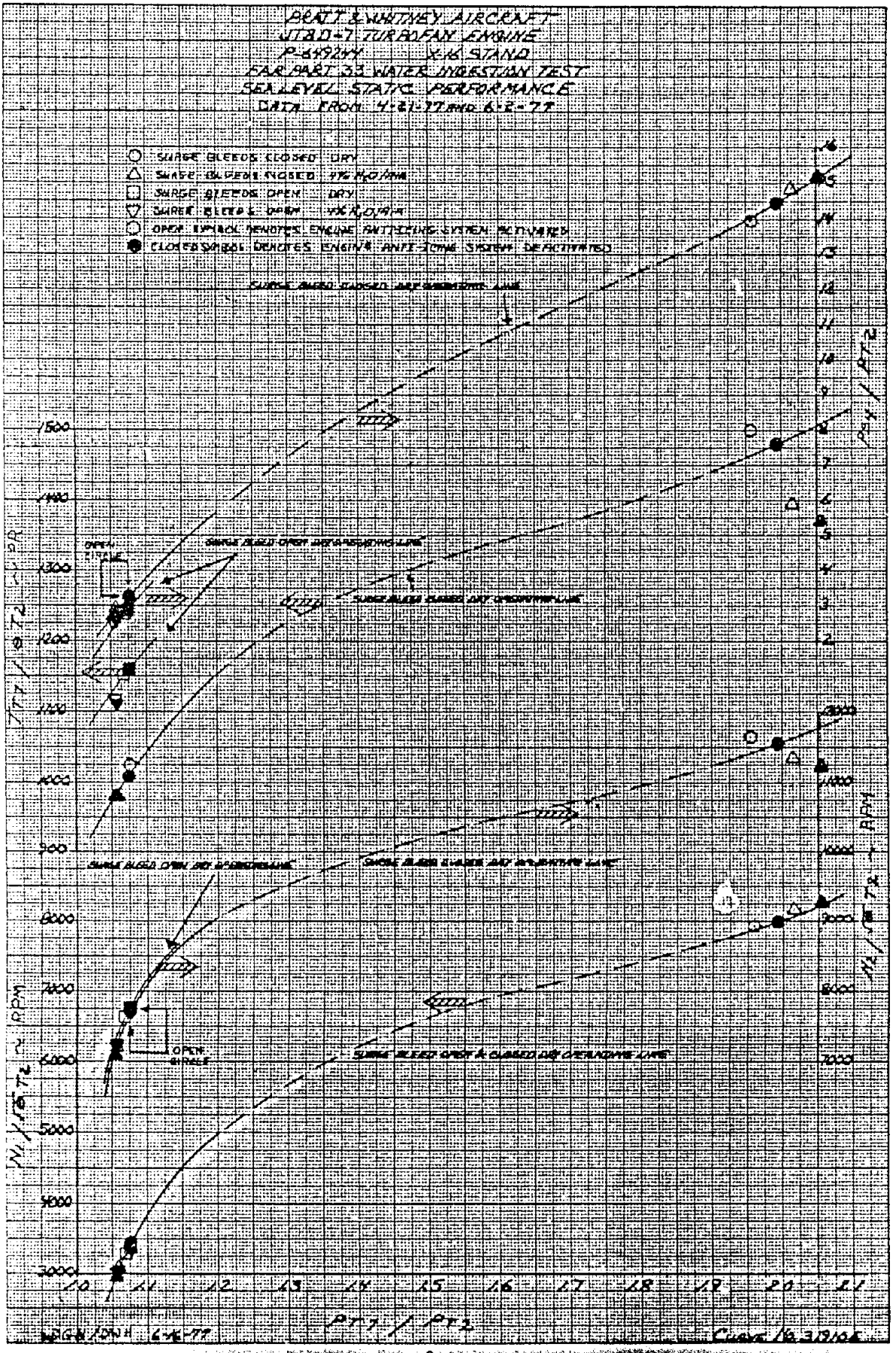
Analysis of Results

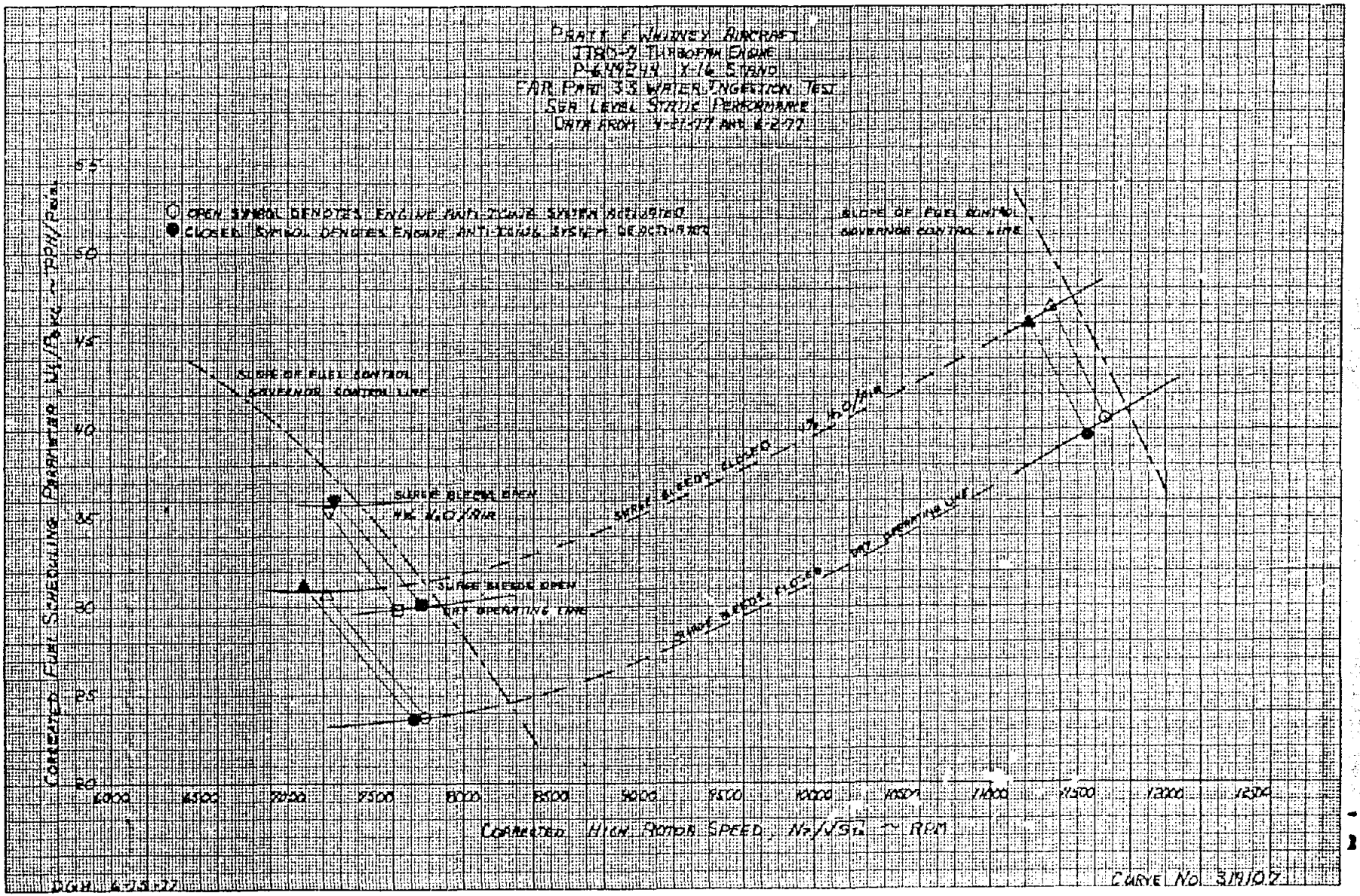
22. The water ingestion testing was conducted to evaluate the ability of the Pratt & Whitney Aircraft Group JT8D engine to ingest water. The fog nozzles mounted in front of the engine closely simulated a rain condition in the engine inlet.

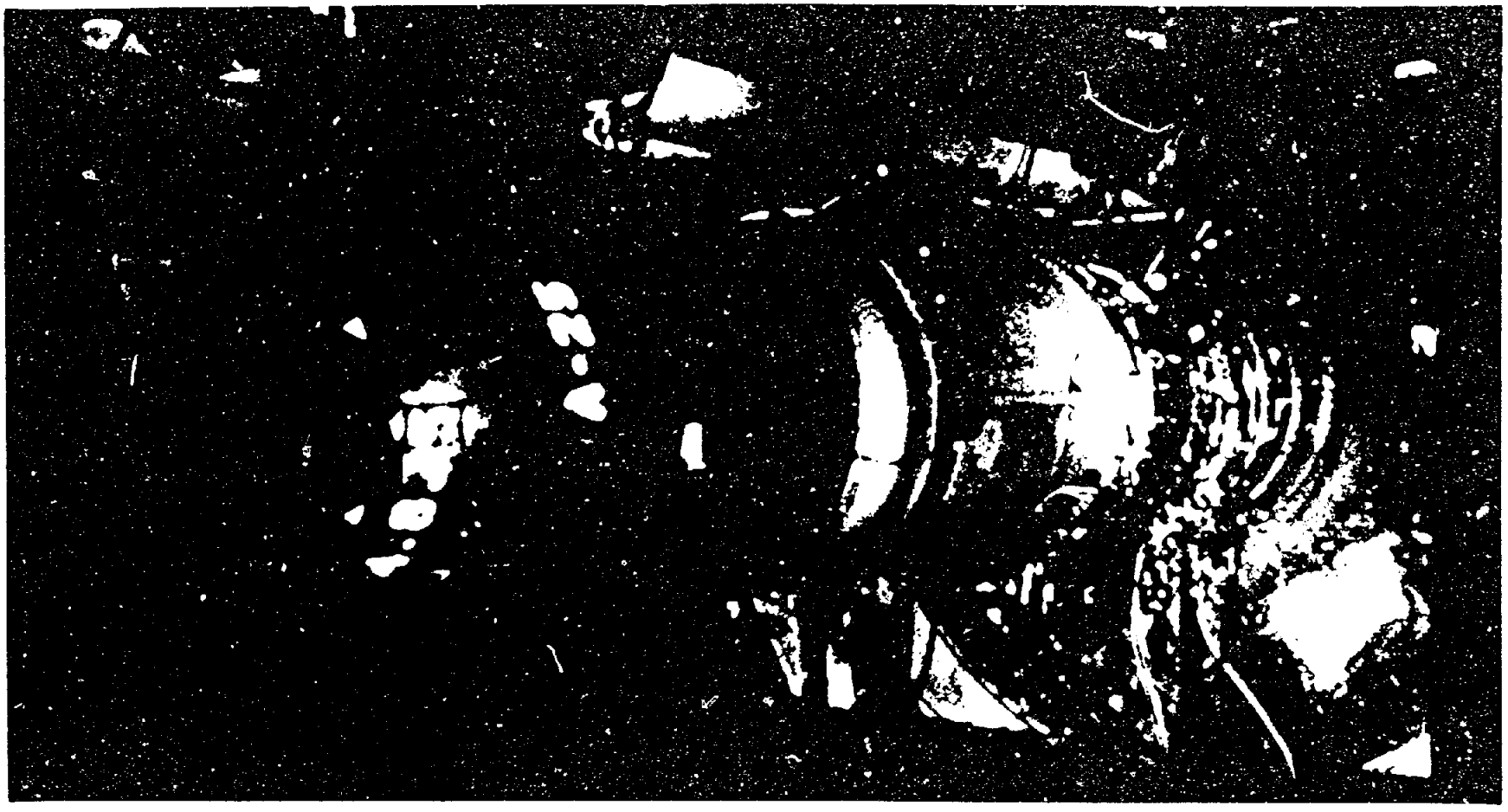
23. There was no effect on engine durability during any of the engine testing. Engine performance was not adversely affected during the water ingestion testing. A reduction in a high rotor speed occurred when water was being ingested. When the water ingestion ceased the engine returned to its original operating speed.

JT8D WATER INGESTION DATA

Flow rate (gal/min.)	Mean droplet diameter (inches)
32	0.061
64	0.015
100	0.010


PRATT & WHITNEY AIRCRAFT
JT8D-7 TURBOFAN ENGINE
P-649244 X-6 STAND
FAR PART 33 WATER INGESTION TEST
SEA LEVEL STATIC PERFORMANCE
DATA FROM 4-21-77 AND 6-2-77
SURGE BLEEDS CLOSED DRY
SURGE BLEEDS CLOSED WET
SURGE BLEEDS OPEN DRY
SURGE BLEEDS OPEN WET
OPEN SYMBOL DENOTES ENGINE ANTI-ICING SYSTEM ACTIVATED
CLOSED SYMBOL DENOTES ENGINE ANTI-ICING SYSTEM DEACTIVATED
SURGE BLEED CLOSED DRY OPERATING LINE
SURGE BLEED OPEN DRY OPERATING LINE
SURGE BLEED CLOSED DRY OPERATING LINE
SURGE BLEED OPEN WET OPERATING LINE
SURGE BLEED CLOSED WET OPERATING LINE
SURGE BLEED OPEN & CLOSED WET OPERATING LINE
OPEN CIRCLE
OPEN CIRCLE
N1 / √θT2 ~ RPM
N1 / √θT2
P4 / PT2
WF / δT2 / PT2
WF / δT2
N1 / √θT2
N1 / √θT2 ~ RPM
P4 / PT2
WF / δT2 / PT2
DRAWN 6-16-77
Curve No. 3191-05

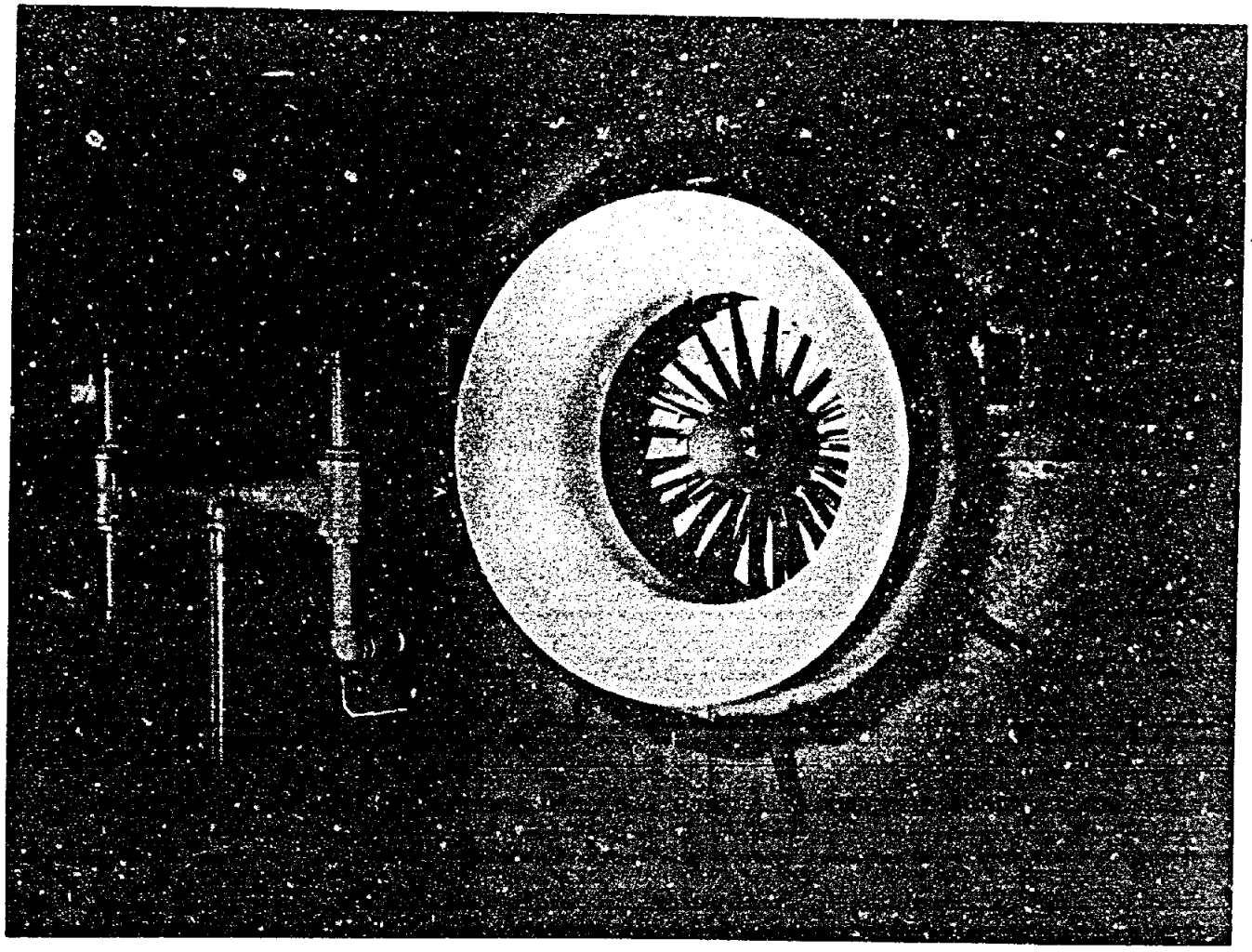

PRATT & WHITNEY AIRCRAFT
JT8D-2 TURBOFAN ENGINE
PW492HR X-16 STAND
FAR PART 33 WATER INGESTION TEST
SEA LEVEL STATIC PERFORMANCE
DATA FROM 4-27-77 AND 6-2-77
OPEN SYMBOL DENOTES ENGINE ANTI-ICING SYSTEM ACTUATED
CLOSED SYMBOL DENOTES ENGINE ANTI-ICING SYSTEM DEACTIVATED
SLOPE OF FUEL CONTROL GOVERNOR CONTROL LINE
SURGE BLEED OPEN
PK 4.0 /AIR
SURGE BLEED OPEN
DAT OPERATING LINE
SURGE BLEEDS CLOSED
PK 4.0 /AIR
SURGE BLEEDS CLOSED
DAT OPERATING LINE
CORRECTED FUEL SCHEDULING PARAMETER, Wf/δ2 ~ PPH/PSIA
CORRECTED HIGH ROTOR SPEED, N2/√θ2 ~ RPM
DGW 6-15-77
CURVE NO. 3191027



VIEW OF JT8D-7 ENGINE P-649244 MOUNTED IN THE INDOOR TEST FACILITY X-16 PRIOR TO WATER INGESTION TESTING.

5-2-77

77-441-9571

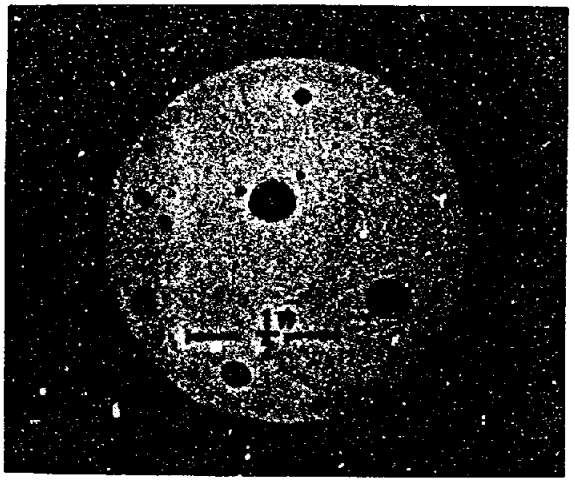


VIEW OF P-649244 ENGINE INLET SHOWING FOG NOZZLES USED TO SIMULATE RAIN DURING THE WATER INGESTION TESTING.

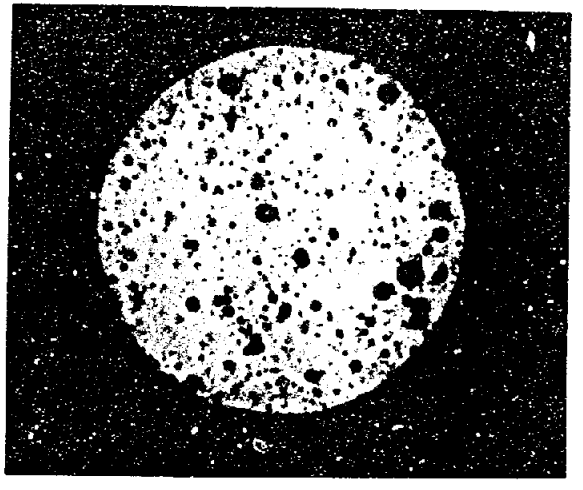
5-2-77

77-441-9605-A

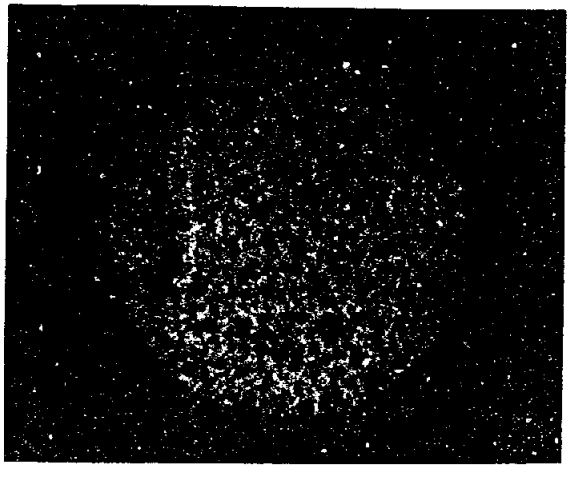
MAGNIFIED WATER DROPLET PHOTOGRAPHS AT JT8D WATER INGESTION TEST CONDITIONS



32 gallons/minute



64 gallons/minute



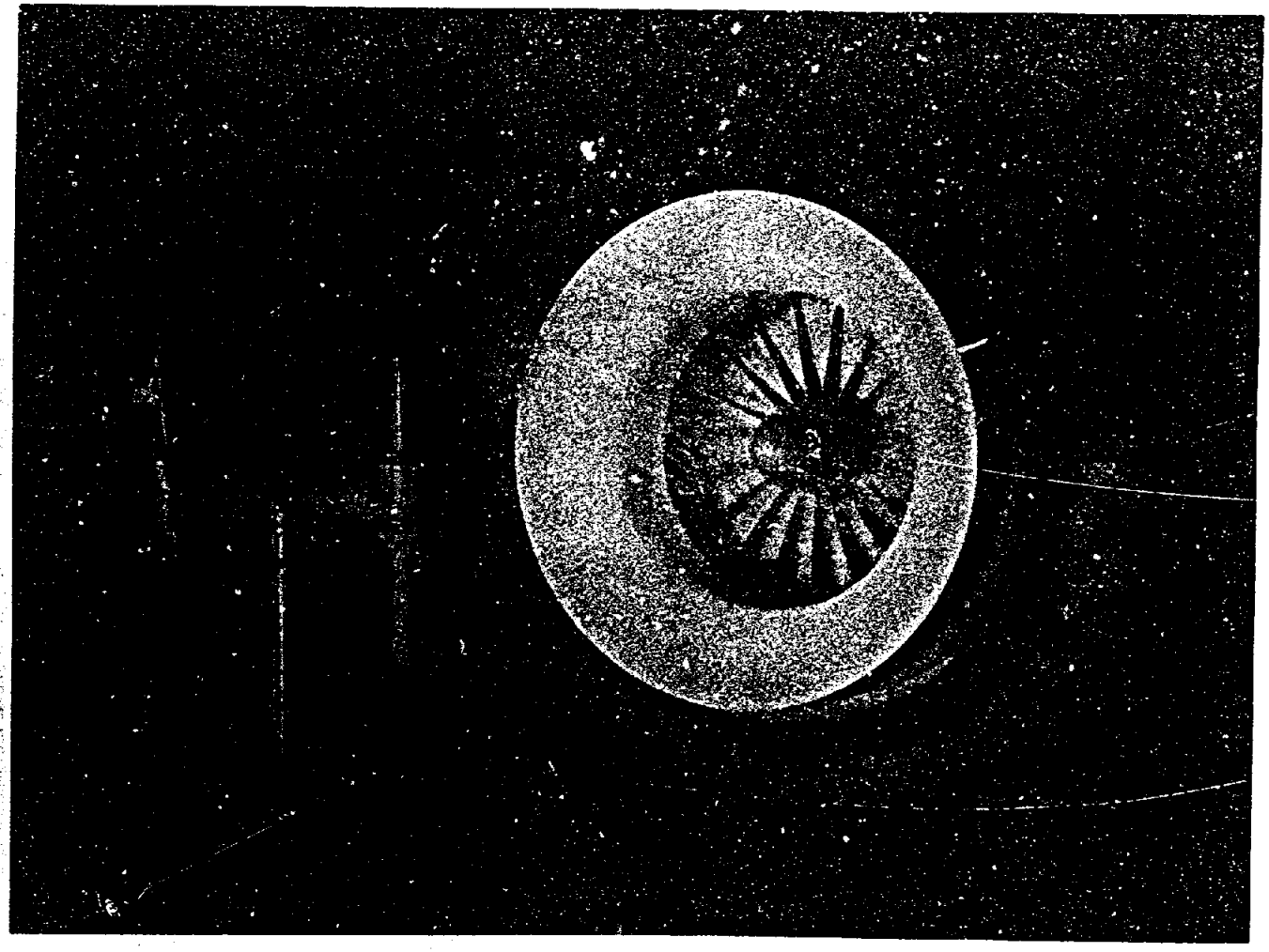
100 gallons/minute

Magnification: $\frac{\text{Image size}}{\text{Object size}} = 1.89$

Flash duration $\approx 1 \times 10^{-6}$ seconds

Film: Polaroid type 52 ASA 400

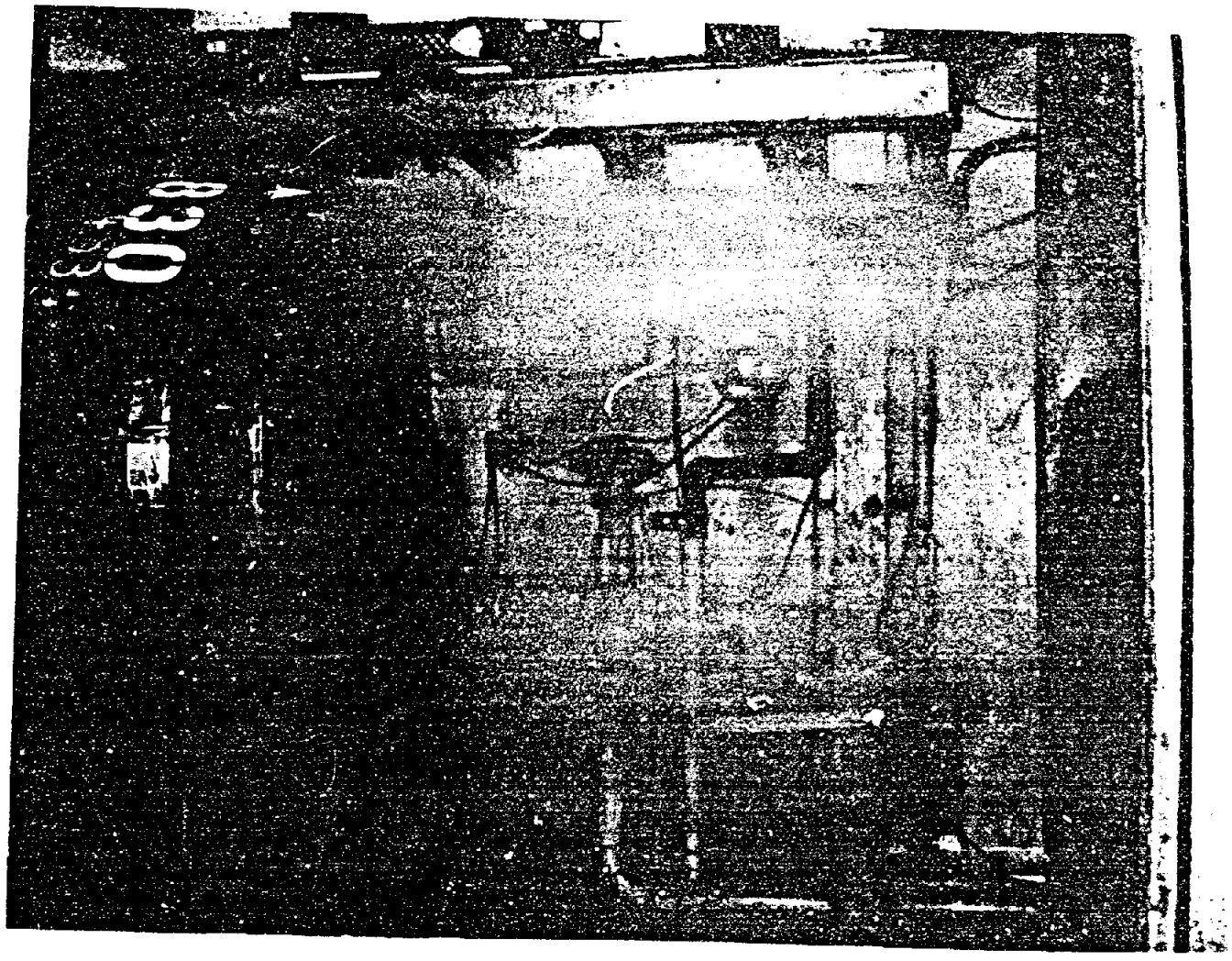
Nozzle: 1½" 142 - 48 SM L205



VIEW OF P-649244 ENGINE INLET SHOWING 4% WATER INGESTION AT IDLE CONDITIONS.

5-4-77

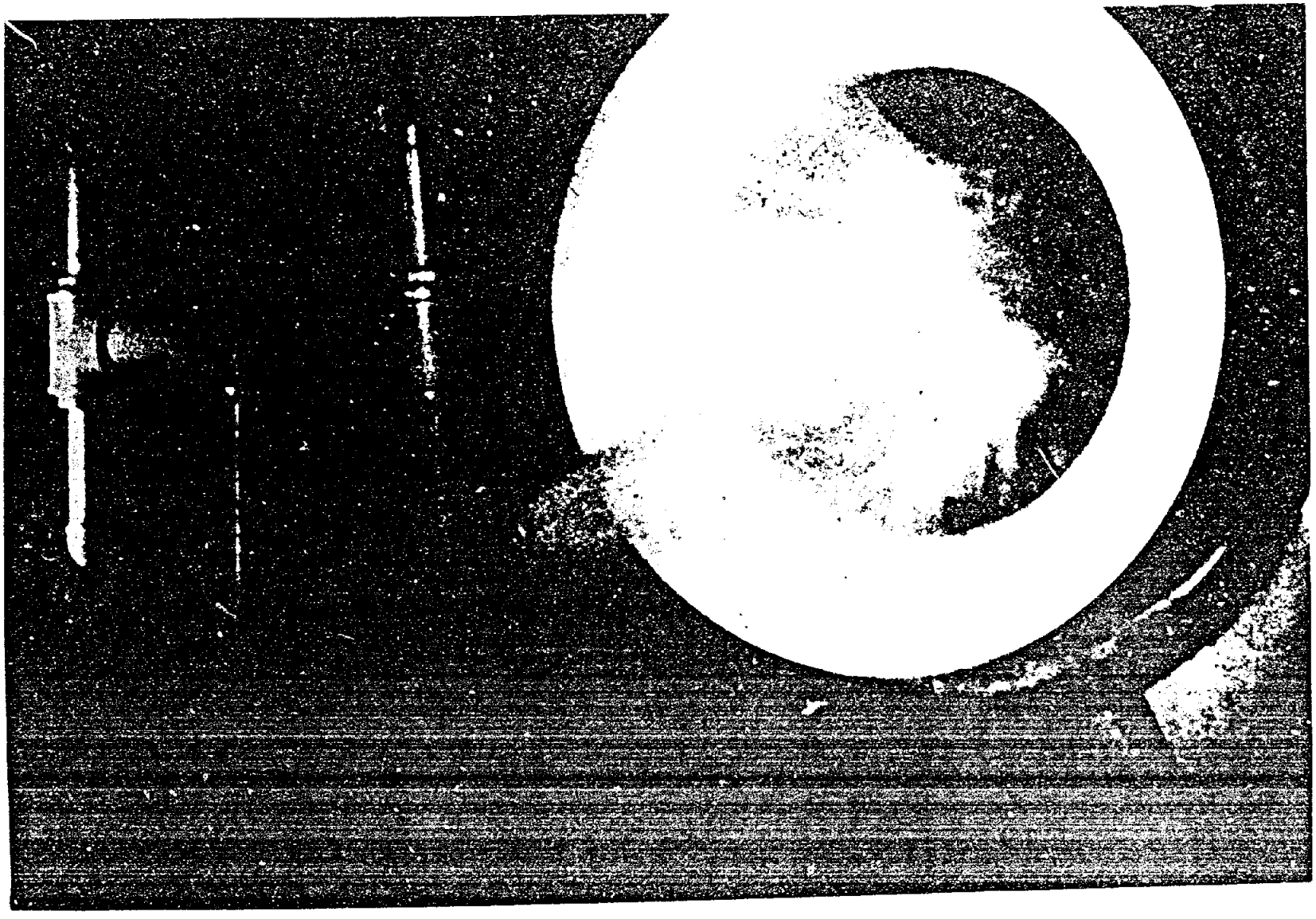
77-441-9605-C



VIEW OF P-649244 ENGINE EXHAUST SHOWING 4% WATER INGESTION AT IDLE CONDITIONS.

5-3-77

77-441-9605-B



VIEW OF P-649244 ENGINE INLET SHOWING 4% WATER INGESTION AT TAKEOFF CONDITIONS.

5-12-77

77-441-4180