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Report 989

ABSTRACTED

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LYCOMING
DIVISION - THE AVIATION CORPORATION
WILLIAMSPORT, PENNA.

**INITIAL OPERATION OF A SINGLE REED VALVE
COMBUSTION CHAMBER**

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FORM 874 17M-12-42

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LYCOMING
DIVISION--THE AVIATION CORPORATION

REPORT NO. 989

Date of Test:

January 28, 1946 to February 9, 1946

ABSTRACTED

Date of Report:

March 7, 1946

(INITIAL OPERATION OF A SINGLE REED VALVE
COMBUSTION CHAMBER)

Reported by:

S. P. Mitchell
S. P. Mitchell

Approved by:

B. J. Ryder
B. J. Ryder
Chief Experimental Engineer

A. T. Briggs
A. T. Briggs
Project Engineer

C. H. Wiegman
C. H. Wiegman
Chief Engineer

Distribution:

Mr. C. H. Wiegman
Mr. A. T. Briggs
Engineering Records
Experimental File
Aeropulse Laboratory
Navy Dept. Bureau of Aeronautics (5)

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REPORT NO. 989

INITIAL OPERATION OF A SINGLE REED VALVE
COMBUSTION CHAMBER

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INITIAL OPERATION OF A SINGLE REED VALVE
COMBUSTION CHAMBEROBJECT:

1. The object of this report is to present the data and observations obtained during the initial operation of a single reed valve on a model combustion chamber for the period thru February 9, 1946.

SUMMARY:

2. In order to obtain air flow data on the reed valve proposed for the second combustion chamber to be built under Item III of Contract NOa(s)-4718, a single Reed valve was constructed and flow tested. See Reports No. 928 and 936.

3. Subsequently this reed valve assembly was welded into a piece of pipe provided with spark plugs and a fuel injection nozzle to form a crude combustion chamber.

4. The data given herein cover the results of the preliminary runs with this crude model. Three reed valves were tested under various operating conditions, the maximum time of operation on any one reed was 9 hours and 29.5 minutes. The preliminary results of the tests of this model with the single reed valve were very encouraging and such to indicate that it would be a very useful tool in the development program of a combustion chamber of this type.

CONCLUSIONS:

5. It is concluded that:

- a) A combustion chamber employing a fixed size open nozzle exhaust, an automatic inlet valve and constant spark ignition can be made to fire in cyclic order by injecting fuel at regular intervals.
- b) The reed valve shows promise as an automatic inlet valve for intermittently firing combustion chambers.

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- c) The single reed valve unit is a very useful tool to expedite the development program of a combustion chamber using this type of valve.
- d) The scavenging of the combustion chamber depends upon the location of the exhaust opening as well as the size.

RECOMMENDATIONS:

- 6. It is recommended that:
 - a) A more durable small combustion chamber with water cooling and a better nozzle entrance be constructed for use in endurance testing of single reed valve assemblies.
 - b) A single reed valve combustion chamber should be used for the investigation of temperature drift in dynamic pick-ups.

DESCRIPTION:

7. The single reed valve combustion chamber model was assembled as shown on drawing No. 70614 or as illustrated on page 10 of this report. The valve assembly consisted of the valve seat plate on the inlet side, the valve cover or stop plate on the exit side and the valve reed, Lycoming No. 70723 between the two plates.

8. Photo No. E-4038 on page 19 shows the reed on the seat with the cover plate at the side.

9. Photo No. E-4039 on page 20 shows the reed between the seat plate and cover plate.

10. In photo No. E-4042 on page 21 the reed valve assembly is shown attached to the combustion chamber.

11. The single reed valve unit was mounted on a test bench and connected to an air supply tank and to a Bosch fuel injection pump as shown on photo No. E-4041 on page 22.

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12. The fuel pump, drive unit, mount and all equipment other than the single reed valve chamber assembly are equipment designed and assembled for other tests and are consequently larger units than would have been required for only the single valve test.

13. The fuel pump is made of two units, Bosch numbers EJN7648-62 Serial EG4035-17 and EJN7648-7 Serial EG4035-16.

14. The injector nozzle is a Bendix part number 135026 Lycoming serial No. 21.

15. The Bosch fuel pump with the surge tank is shown with the drive and electric tachometer in photograph No. E-4040 on page 23.

16. The original .281 jet hole is shown in the plate on photo No. E-4041 on page 22.

17. Photo No. E-4042 on page 21 shows the fuel injector surrounded by a coil to spray cooling water against the injector end of the chamber. The line for cooling the main chamber is shown above the unit.

18. A General Electric Company Catalog 5102 neon light transformer serial 2004784 supplied a continuous arc through two spark plugs with .050 gap.

METHOD OF TEST:

19. The initial test was conducted on January 28, 1946 with a reed of Brown & Sharpe gage stock as received to find conditions under which the unit would operate. The fuel used during all tests was 73 octane aviation gasoline.

20. The first reed was replaced by a reed of the same material heat treated to Rockwell C 40-45 and testing continued on January 29, 1946.

21. A surge tank was installed in a line connecting the inlet chambers of the Bosch pumps to minimize the fuel surge.

22. Thermocouples were located as shown on page 10.

23. An electric tachometer was connected to the fuel pump drive to determine the I.P.M. (fuel injections per minute).

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24. The fuel system was connected through a 14 to 220 lb./hr. rotameter and through the Pittsburgh type displacement meter.

25. The air tank was connected to pressure gages to record the ram air pressure.

26. On February 7, a uniflow ball check valve was installed between the combustion chamber and a 0 - 600 PSI indicating gage to record peak cylinder pressures.

27. With the preliminary instrumentation installed, the plan was to operate in one-half hour intervals starting at 300 IPM and continue with increased IPM until difficulty was encountered.

28. In attempts to increase the limiting number of injections per minute, tests were conducted with dual and single ignition, with water spray on the fuel injector end and on the cylinder, and with different nozzle opening combinations.

29. Short interval operation was also attempted with auto-ignition.

RECORD OF TESTS:

30. In the summary of test variables shown on page 9, the runs are identified by date and time. The reed valves are identified by number. The letter "R" given after the nozzle diameter signifies a smooth approach.

31. The recorded data are given on page 12 through page 18.

32. The first test on January 28, 1946 showed that the unit would operate at around 200 cycles per minute but that the life of the soft valve was of the order of five minutes before mal-firing occurred due to distortion of the valve.

33. One hour of operation on January 29, 1946 with the hardened valve indicated continued investigation with preliminary instrumentation was desirable.

34. With the hardened valve (#2) the unit would operate at 300 IPM (injections per minute) but mal-firing occurred after short operation at 400 IPM. It was noted that the injector plate temperatures started increasing rapidly with mal-firing occurring within 8 minutes when the IPM was increased from 300 to 400.

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35. The second attempt to operate at 400 IPM confirmed the above.
36. Number 2 valve was examined and found to be in good condition.
37. The valve was installed with the convex side toward the inlet or valve seat side.
38. When the top injector end spark plug wire was removed so the unit was operating on the single ignition spark from the jet end plug, the exhaust flame shortened. By increasing the fuel flow the length of the flame was increased and made equivalent to the dual ignition flame. Stabilized operation was possible up to 350 IPM. With this single plug location flash readings indicated that 500 IPM was the maximum value for short interval cyclic operation.
39. The top injector end plug wire was reconnected and the jet end plug disconnected. The temperatures of the chamber were higher at 300 IPM than were observed for the 350 IPM operation with the other plug. However, flash operation indicated that smooth cyclic operation with the injector end plug alone was possible up to 800 IPM.
40. A water spray was added to cool the fuel injector nozzle end of the chamber, extending stabilized operation on dual ignition from 300 to 600 IPM.
41. The maximum cyclic frequency with stabilized operation as in the preceding paragraph was further increased to 1000 IPM by machining a smooth approach in the .281 diameter nozzle.
42. A series of flash readings were taken to determine the maximum chamber peak pressures at the various IPM with the optimum throttle setting and with the ram air pressure limited by the output of the 64D9 Ingersoll Rand compressor. The results are plotted on Curve No. 6619 on page 11.
43. Number 2 reed was damaged in attempting to increase the bow or tension in the reed and number 3 reed was installed.

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44. The jet flange gasket blew out as tests were to be started with a .315 dia. nozzle. The flame first shortened and then increased to the longest flame encountered during the period covered by this report as the fuel supply was increased. Peak combustion pressures were correspondingly increased.

45. When normal operation was resumed with the .315 diameter nozzle, the maximum frequency was extended from 1000 to 1200 IPM.

46. At 600 IPM the peak combustion pressures were considerably above values recorded for stabilized operation at the same cyclic frequency with other jet openings. After 17 minutes of operation at 600 IPM the cyclic speed was increased to 805 IPM. During this interval, the peak combustion pressure was 200-210 psi with ram air pressures of 50-55 psi. After 4.5 minutes of operation at 805 IPM, the valve failed. The net nozzle area was then increased by drilling three equally spaced .187 inch diameter holes in the nozzle plate close to the outer diameter of the chamber.

47. Photo No. E-4036 on page 24 shows the valve reed in place as seen when the ram air approach was removed.

48. Photo No. E-4037 on page 25 shows the exit side of the reed and valve seat plate.

49. Photos No. E-4034 and 4035 on pages 26 and 27 show the valve reed as removed from the housing.

DISCUSSION:

50. From the first test with the soft reed valve it was apparent that the reed valve had possibilities but that a soft valve was not satisfactory.

51. A heat treated valve was operated for one hour. The condition of the valve was found to be quite satisfactory with no indications of deterioration.

52. After preliminary instrumentation was installed the valve was tried with the convex side and the concave side toward the seat. Although conclusive tests were not conducted it is believed that the convex side should be toward the inlet

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or valve seat. The best initial bow or tension was not determined.

53. The preliminary work with the spark plug locations clearly indicates that the position of the spark relative to the chamber or fuel spray is important. Further work on spark plug locations was deferred for later consideration due to the major differences in the combustion chambers of the single reed valve and the full scale multi reed single cylinder design.

54. From the general performance of the unit, it was believed that the major factor which limited the IPM and caused mal-firing during the first few tests was the temperature of the fuel injector nozzle and the gasoline. It was interesting to note that in some cases mal-firing could be overcome by increasing the fuel flow to extremely rich values and then returning to a normal operating fuel flow. Probably the injector was fuel cooled from this procedure. This was not a permanent fix as temperatures would again increase to the point where mal-firing was present. The high fuel temperature of the fuel injector probably caused vapor locks and nozzle dribbling at irregular intervals resulting in mal-firing of the engine. The limiting temperature of the injector end of the cylinder seemed to be of the order of 850°. This value probably would change with the rate of fuel flow. The fuel temperature limitation was apparently overcome by the use of the water spray on the fuel injector nozzle end of the chamber.

55. The water line was added to spray water on the top of the chamber to avoid difficulty with portions of the equipment not of primary interest during the tests.

56. After the high temperatures around the fuel injector nozzle were reduced by water cooling further increases in the cyclic operating frequency were made by enlarging the effective size of the exhaust jet. The experience with a blown exhaust jet flange gasket and the four hole combination exhaust jet demonstrated that increased performance was dependent upon the location of the exhaust opening as well as the size. With the relatively large ratio between the

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cross sectional area of the combustion chamber and the single nozzle area there were apparently large volumes of unscavenged gas.

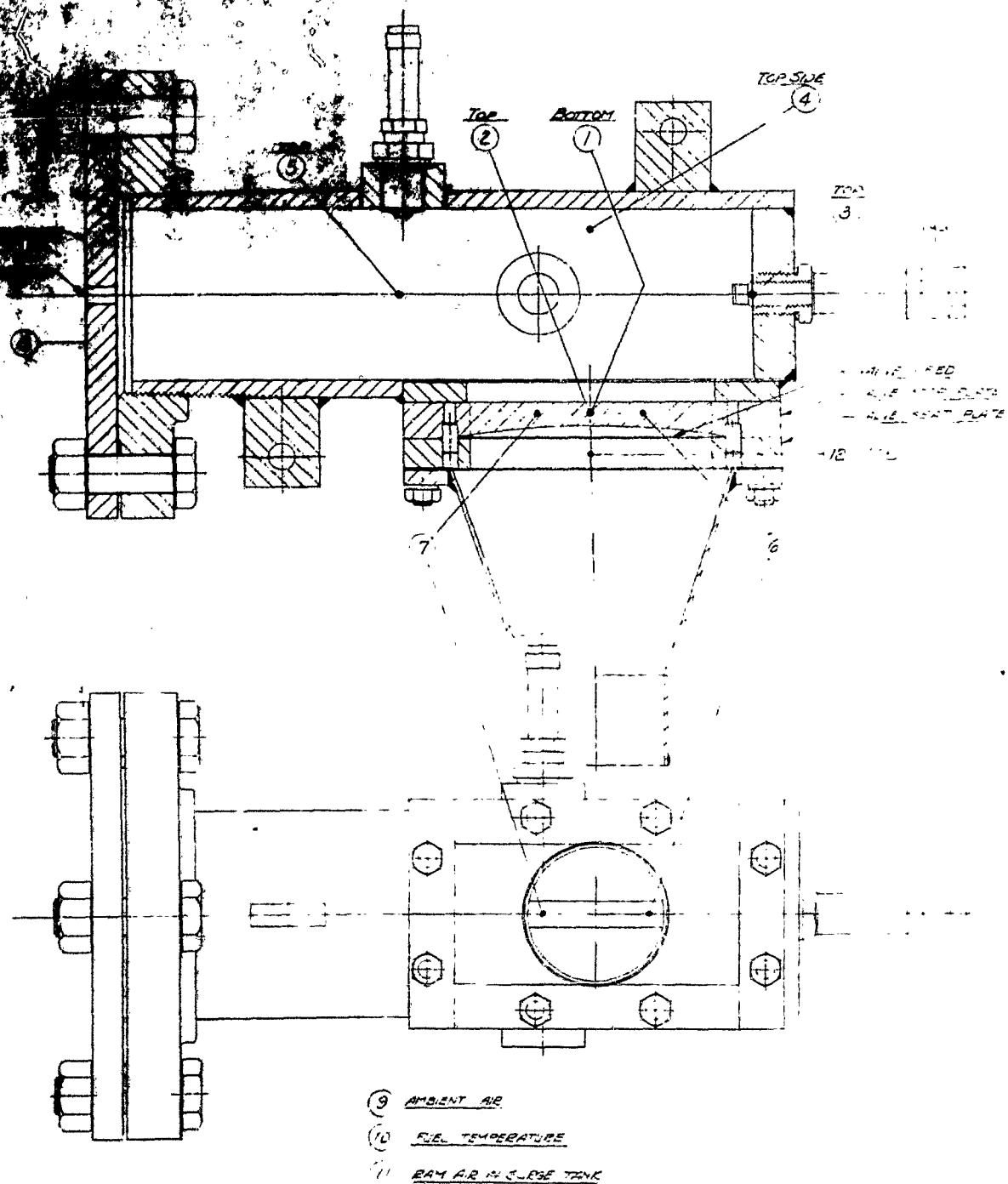
57. A cylindrical combustion chamber of similar volume but of smaller diameter and with a gradual reduction in cross sectional area to the jet area should improve the scavenging with a single nozzle.

58. The failure of the valve occurred at a point where the seat had been eroded by a leak between the reed and the seat. As the leak between the reed and seat increased, the localized heating of the valve probably caused the failure of the reed. This condition can be improved by a change in the design or material of the seat.

ELIOTT CO., PITTSBURGH

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THERMOCOUPLE LOCATIONS



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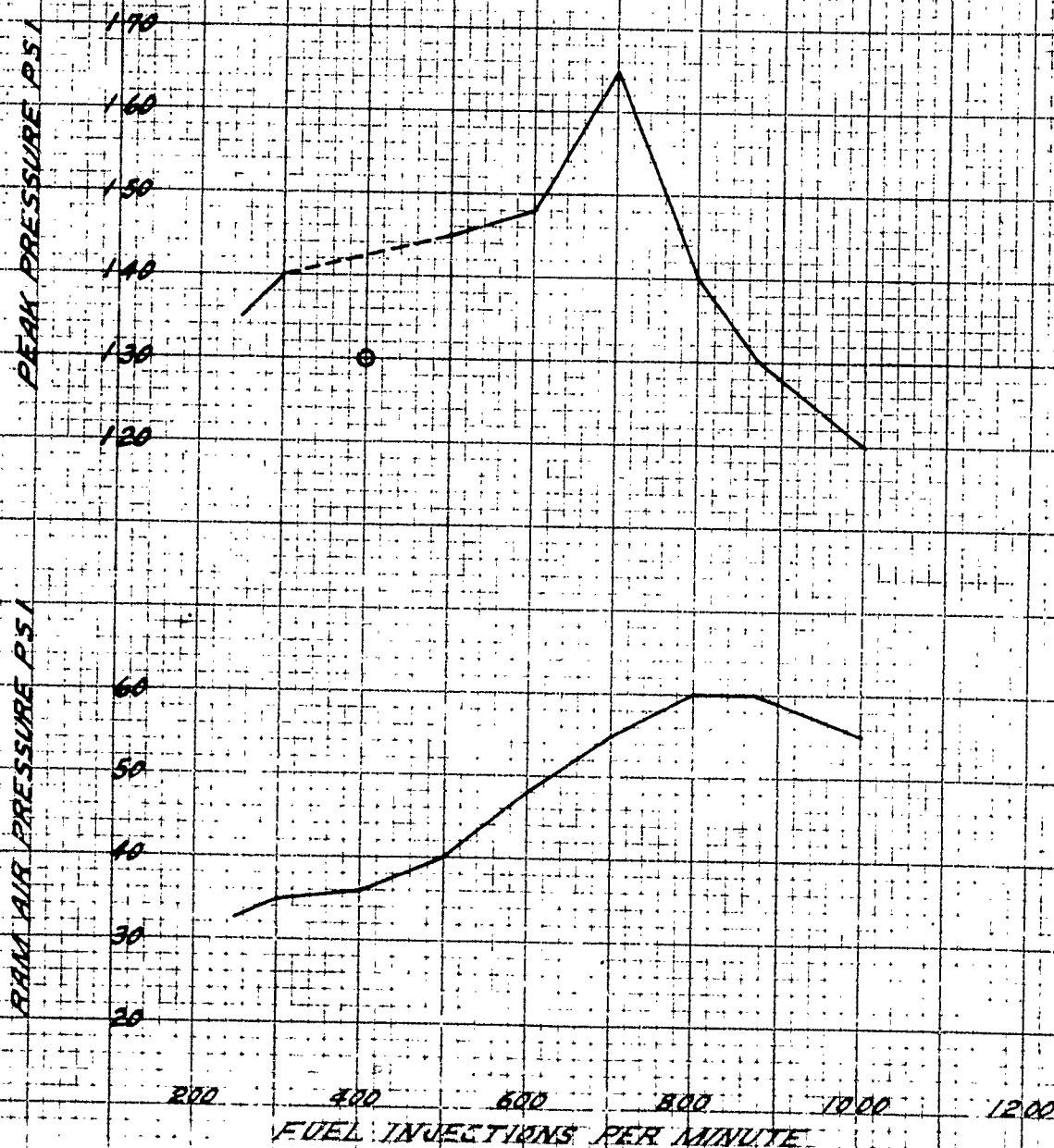
REPORT NO. 989
CURVE NO. 6619

PEAK COMBUSTION PRESSURE VS. FUEL INJECTIONS PER MINUTE

OPTIMUM FUEL FLOW
RAM AIR PRESSURE AS GIVEN
281 DIA SMOOTH APPROACH NOZZLE
WATER COOLING
DUAL IGNITION

"PRECISE"
TRADE MARK

NO 60516 10 x 10 to 1 INCH



FUEL - 73 OCTANE AVIATION GASOLINE

ENGINE LOG

Compression Ratio

CONDO

[illegible]

Recorded by:

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Division - The Aviation Corporation

Division - The Aviation Corporation

ENGINE LOG

FUEL - 73 OCTANE AVIATION GASOLINE

[illegible]

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Compression Ratio

ENGINE LOG

FUEL - 73 OCTANE AVIATION GASOLINE

RUN NUMBER		2-5-46	9:50	10:05	10:10	10:13	10:23	10:30	10:32	10:40	10:41	10:45	10:46	10:47	10:52	10:57	11:07	11:21	11:22	11:30	11:30	11:39	11:45
1	DATE																						
2	TIME																						
3	R.P.M. x 4		1200	1200	1200	1400	1400	1400	1600	1600	1600	1600	1600	1800	1800	1800	2000	2000	2200	2200	2400	2400	2400
4	I.A.M.		300	300	300	350	350	350	400	400	400	400	400	450	450	450	500	500	550	550	600	600	600
5	RAM AIR PRESS. P.S.I.		30	30.5	30.8	32.6	33.8	34.5	35.5	36.5	38	38	38	38.5	40	40	41	41.5	43	45	44	45	44.5
6	COOLANT TEMP. °F		-	480	535	760	840	930	1100	1220	1150	1200	-	1330	1400	1320	1390	1490	1500	1600	1590	1300	1400
7	ROTARY TEMP. °F																						
8	FUEL QUANTITY GAL.																						
9	FUEL TIME MIN. SEC.																						
10	WATER TEMP. °F																						
11	WATER PRESS. P.S.I.																						
12	CYLINDER TEMP. INLET °F				70		150					160			130					120		80	
13	WATER STOP VALVE END °F				180		330					450			630					720		830	
14	WATER STOP VALVE END °F				300		550					680			840					910		980	
15	WATER STOP VALVE END °F																						
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43	WATER STOP VALVE END °F																						
44	WATER STOP VALVE END °F																						
45	WATER STOP VALVE END °F																						

Note 19 - A water spray was added to cool the inlet air end.

Note 20 - Unit was firing on auto ignition for five minutes.

Engine Type

No.

No. **CONFIDENTIAL**

RUN NUMBER		TIME												TEMP.												PRESS.												FUEL												AIR												OIL												WATER												GAS												OTHER																																																																																																																																																																																																																																																																																							
DATE		2-7-46				2-8-46				2-9-46				2-10-46				2-11-46				2-12-46				2-13-46				2-14-46				2-15-46				2-16-46				2-17-46				2-18-46				2-19-46				2-20-46				2-21-46				2-22-46				2-23-46				2-24-46				2-25-46				2-26-46				2-27-46				2-28-46				2-29-46				2-30-46				2-31-46				2-32-46				2-33-46				2-34-46				2-35-46				2-36-46				2-37-46				2-38-46				2-39-46				2-40-46				2-41-46				2-42-46				2-43-46				2-44-46				2-45-46				2-46-46				2-47-46				2-48-46				2-49-46				2-50-46				2-51-46				2-52-46				2-53-46				2-54-46				2-55-46				2-56-46				2-57-46				2-58-46				2-59-46				2-60-46				2-61-46				2-62-46				2-63-46				2-64-46				2-65-46				2-66-46				2-67-46				2-68-46				2-69-46				2-70-46				2-71-46				2-72-46				2-73-46				2-74-46				2-75-46				2-76-46				2-77-46				2-78-46				2-79-46				2-80-46				2-81-46				2-82-46				2-83-46				2-84-46				2-85-46				2-86-46				2-87-46				2-88-46				2-89-46				2-90-46				2-91-46				2-92-46				2-93-46				2-94-46				2-95-46				2-96-46				2-97-46				2-98-46				2-99-46				2-100-46			
1	DATE	2-7-46	2-8-46	2-9-46	2-10-46	2-11-46	2-12-46	2-13-46	2-14-46	2-15-46	2-16-46	2-17-46	2-18-46	2-19-46	2-20-46	2-21-46	2-22-46	2-23-46	2-24-46	2-25-46	2-26-46	2-27-46	2-28-46	2-29-46	2-30-46	2-31-46	2-32-46	2-33-46	2-34-46	2-35-46	2-36-46	2-37-46	2-38-46	2-39-46	2-40-46	2-41-46	2-42-46	2-43-46	2-44-46	2-45-46	2-46-46	2-47-46	2-48-46	2-49-46	2-50-46	2-51-46	2-52-46	2-53-46	2-54-46	2-55-46	2-56-46	2-57-46	2-58-46	2-59-46	2-60-46	2-61-46	2-62-46	2-63-46	2-64-46	2-65-46	2-66-46	2-67-46	2-68-46	2-69-46	2-70-46	2-71-46	2-72-46	2-73-46	2-74-46	2-75-46	2-76-46	2-77-46	2-78-46	2-79-46	2-80-46	2-81-46	2-82-46	2-83-46	2-84-46	2-85-46	2-86-46	2-87-46	2-88-46	2-89-46	2-90-46	2-91-46	2-92-46	2-93-46	2-94-46	2-95-46	2-96-46	2-97-46	2-98-46	2-99-46	2-100-46																																																																																																																																																																																																																																																																																										
2	TIME	3:33	3:35	3:37	3:40	3:42	3:44	3:46	3:48	3:50	3:52	3:54	3:56	3:58	4:00	4:02	4:04	4:06	4:08	4:10	4:12	4:14	4:16	4:18	4:20	4:22	4:24	4:26	4:28	4:30	4:32	4:34	4:36	4:38	4:40	4:42	4:44	4:46	4:48	4:50	4:52	4:54	4:56	4:58	5:00	5:02	5:04	5:06	5:08	5:10	5:12	5:14	5:16	5:18	5:20	5:22	5:24	5:26	5:28	5:30	5:32	5:34	5:36	5:38	5:40	5:42	5:44	5:46	5:48	5:50	5:52	5:54	5:56	5:58	6:00	6:02	6:04	6:06	6:08	6:10	6:12	6:14	6:16	6:18	6:20	6:22	6:24	6:26	6:28	6:30	6:32	6:34	6:36	6:38	6:40	6:42	6:44	6:46	6:48	6:50	6:52	6:54	6:56	6:58	7:00	7:02	7:04	7:06	7:08	7:10	7:12	7:14	7:16	7:18	7:20	7:22	7:24	7:26	7:28																																																																																																																																																																																																																																																																		

MoMa 29 - The read valve was found to require about 1/6 of the force previously required to remove the box. An attempt to increase the box diameter the read or number three valve was installed in the unit.

Note 30 - The jet plate hole was increased from .280 to .3125 diameter.

Note 31 - Engine blew out jet plate gasket in about one minute. The jet flame started to shorten but was restored by increasing fuel flow from 18 to 43 lb.-hr. The ram air pressure dropped from 61 to 43 PSI. The peak combustion pressure increased from 120 to over 200 PSI. This confirms the need to further increase the jet area.

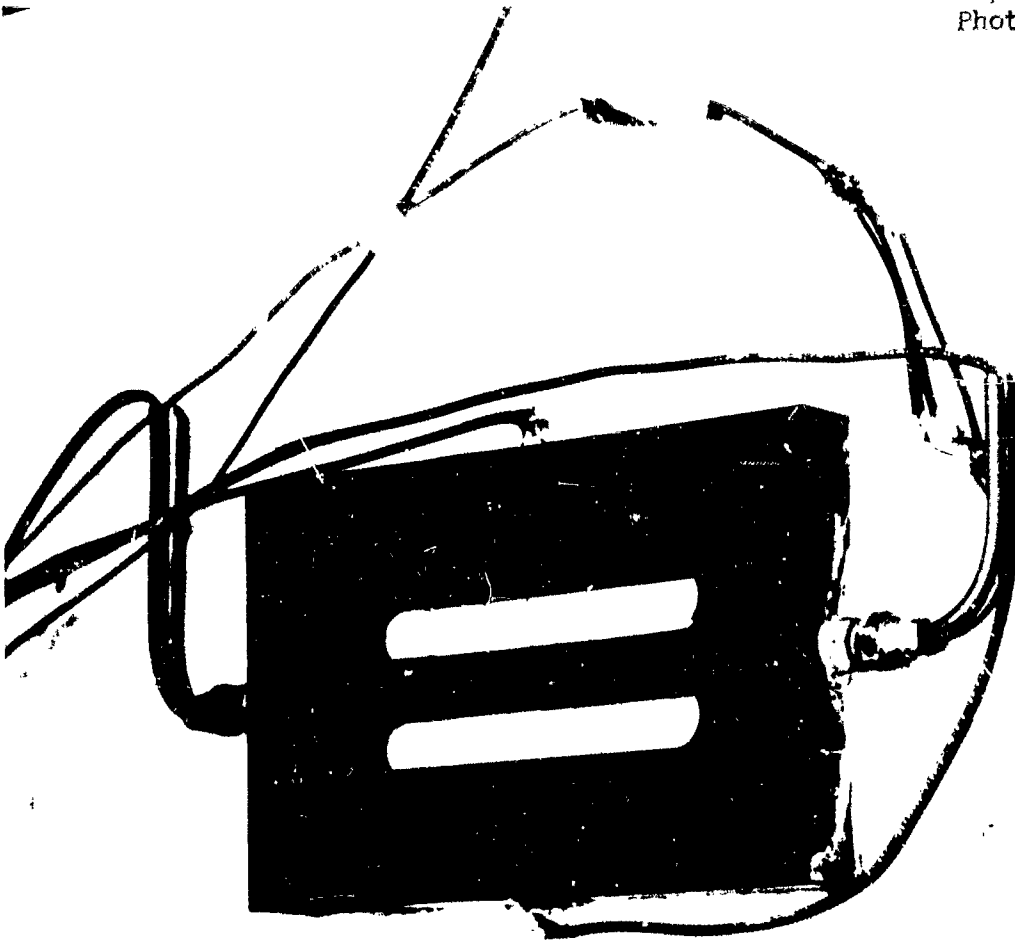
Note 32 - The jet plate gasket was replaced.

Note 33 - The ignition was shut off for one minute to allow engine to auto fire. No changes in pressures or temperatures were noted.

Note 34 - The engines are very critical on fuel adjustment. Timing was irregular.

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Photo No. E-4038



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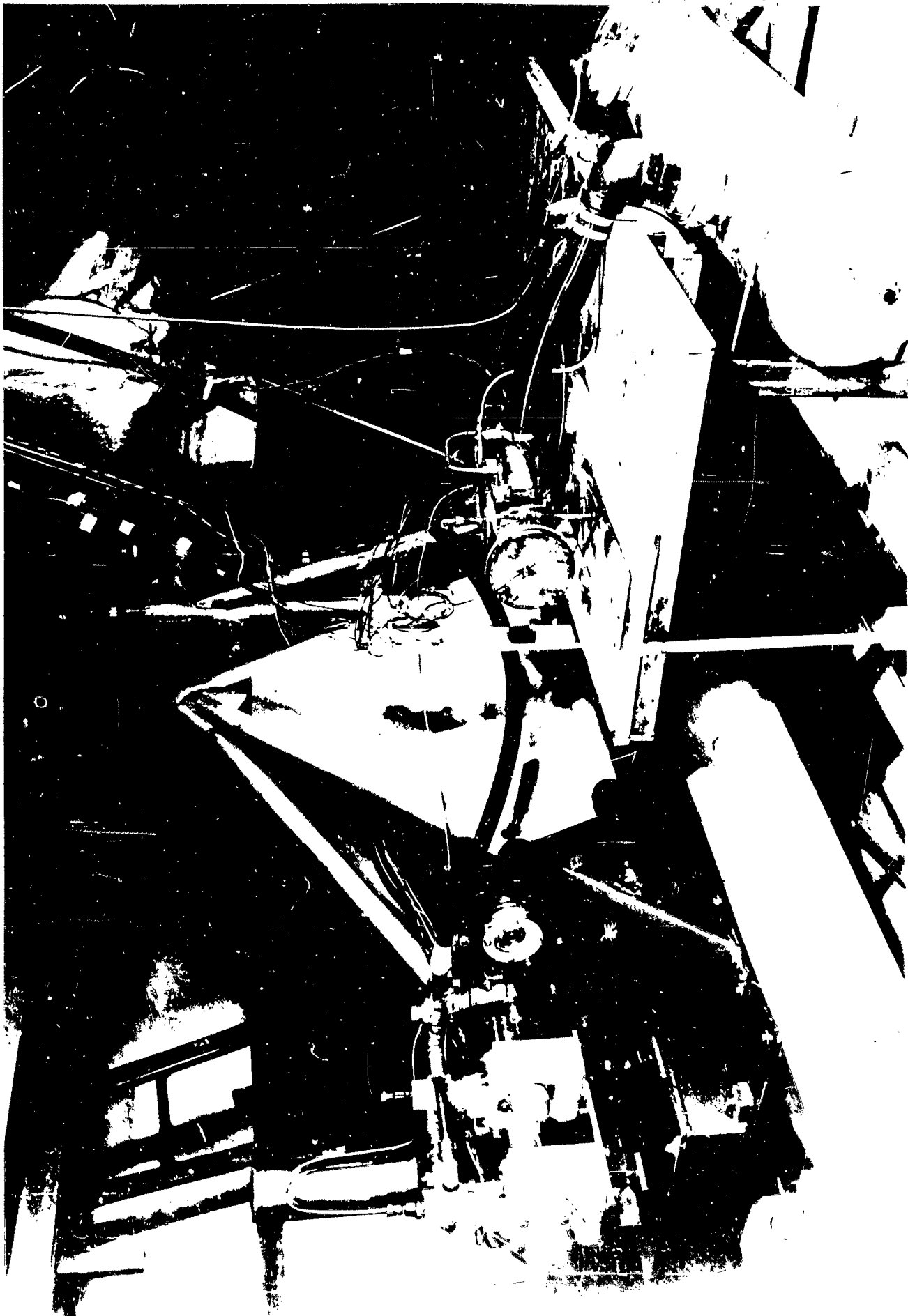
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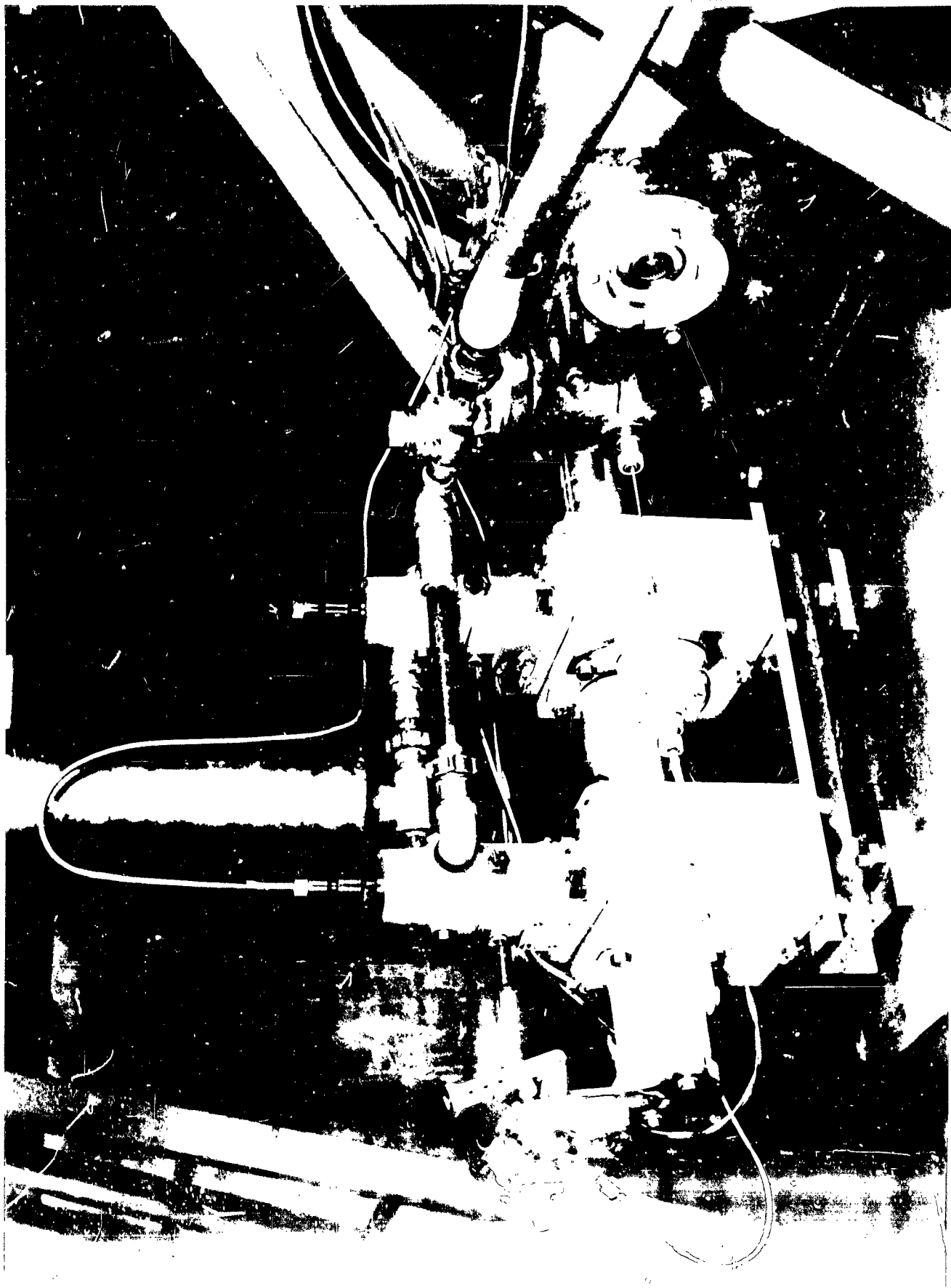
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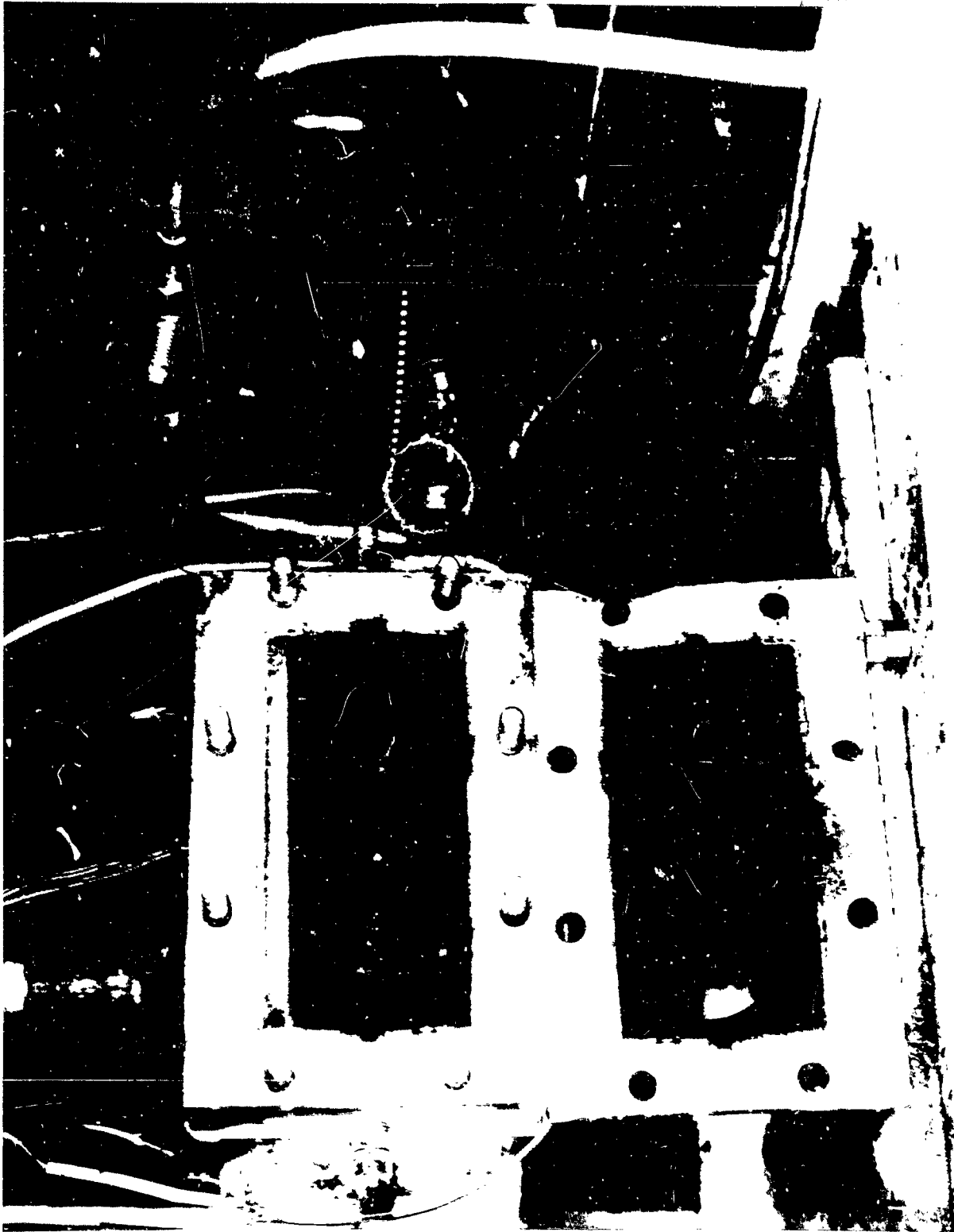
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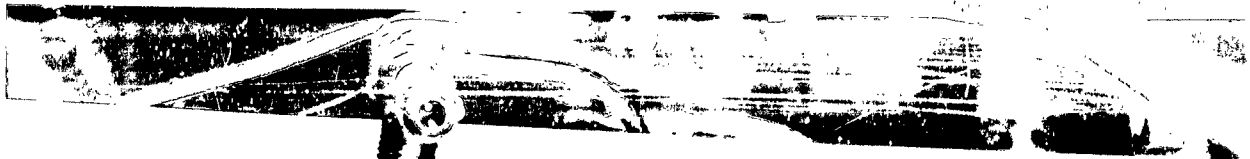
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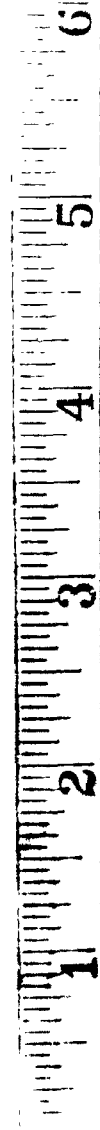


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