LYCOMING
DIVISION - THE AVIATION CORPORATION
WILLIAMSPORT, PENNA.

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

Date of Test:
January 28, 1946 to February 9, 1946

Date of Report:
March 7, 1946

Reported by:
S. P. Mitchell

Approved by:
B. J. Ryder
Chief Experimental Engineer

A. T. Briggs
Project Engineer

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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INITIAL OPERATION OF A SINGLE REED VALVE
COMBUSTION CHAMBER

OBJECT:

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.
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.
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 EQ4035-17 and EJN7648-7 Serial EQ4035-16.

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).
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.
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.
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.
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 IPN 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
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.
**ENGINE LOG**

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<th>RUN NUMBER</th>
<th>DATE</th>
<th>TIME - STARTING</th>
<th>REED</th>
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<th>SIDE JET END</th>
<th>JET - MAIN SIZE</th>
<th>AUX #2</th>
<th>AUX #3</th>
<th>WATER SPRAY - TOP CYL.</th>
<th>J.P.M.</th>
<th>REED BOW TO SEAT</th>
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<td>ON</td>
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</tbody>
</table>

**NOTE**

- A denotes runs where temperatures could not be stabilized before all firing occurred.
- B denotes flash readings where no attempt was made to stabilize.
- C denotes runs made to record peak cylinder pressures.

**Recorded by**
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

PEAK PRESSURE PSI

RAM AIR PRESSURE PSI

FUEL INJECTIONS PER MINUTE

200  400  600  800  1000  1200
### FUEL - 73 OCTANE AVIATION GASOLINE

|------------|------|------|--------|-------|-----------------|------|-----------------|----|------------|------|------------|-----||             |     |                  |     |             |     |             |      |             |       |             |       |             |       |

**Notes:**

1. The valve was used in the test unit and operated for approximately five minutes.
   - The up-steam pressure was set for 25 psi gas. The injection pump was used for approximately 500 injections per minute. The ignition was obtained from the neon light transformer using two spark plugs - 0.500" gap - beam at each high tension lead. The up-steam pressure was taken from the 25 psi gas outlet of the 10 hp 2 stage compressor and regulated by a motor actuating valve. A 30 gal. tank, connected to the valve adapter with 1-1/8" T.D. hose, is used as a surge tank in the air system.

2. A heat treated valve was installed.

3. A surge tank was incorporated in the fuel system. A techronometer and thermocouple were incorporated in the set-up.

4. During this period of operation, the valve bow was such that the convex side of the valve was toward the combustion chamber.

5. The valve was used in the test unit and operated for approximately five minutes. The up-steam pressure was set for 25 psi gas. The injection pump was used for approximately 500 injections per minute. The ignition was obtained from the neon light transformer using two spark plugs - 0.500" gap - beam at each high tension lead. The up-steam pressure was taken from the 25 psi gas outlet of the 10 hp 2 stage compressor and regulated by a motor actuating valve. A 30 gal. tank, connected to the valve adapter with 1-1/8" T.D. hose, is used as a surge tank in the air system.

6. A heat treated valve was installed.

7. The valve was used in the test unit and operated for approximately five minutes. The up-steam pressure was set for 25 psi gas. The injection pump was used for approximately 500 injections per minute. The ignition was obtained from the neon light transformer using two spark plugs - 0.500" gap - beam at each high tension lead. The up-steam pressure was taken from the 25 psi gas outlet of the 10 hp 2 stage compressor and regulated by a motor actuating valve. A 30 gal. tank, connected to the valve adapter with 1-1/8" T.D. hose, is used as a surge tank in the air system.

8. A heat treated valve was installed.

9. The valve was used in the test unit and operated for approximately five minutes. The up-steam pressure was set for 25 psi gas. The injection pump was used for approximately 500 injections per minute. The ignition was obtained from the neon light transformer using two spark plugs - 0.500" gap - beam at each high tension lead. The up-steam pressure was taken from the 25 psi gas outlet of the 10 hp 2 stage compressor and regulated by a motor actuating valve. A 30 gal. tank, connected to the valve adapter with 1-1/8" T.D. hose, is used as a surge tank in the air system.

10. The valve was used in the test unit and operated for approximately five minutes. The up-steam pressure was set for 25 psi gas. The injection pump was used for approximately 500 injections per minute. The ignition was obtained from the neon light transformer using two spark plugs - 0.500" gap - beam at each high tension lead. The up-steam pressure was taken from the 25 psi gas outlet of the 10 hp 2 stage compressor and regulated by a motor actuating valve. A 30 gal. tank, connected to the valve adapter with 1-1/8" T.D. hose, is used as a surge tank in the air system.

11. The valve was used in the test unit and operated for approximately five minutes. The up-steam pressure was set for 25 psi gas. The injection pump was used for approximately 500 injections per minute. The ignition was obtained from the neon light transformer using two spark plugs - 0.500" gap - beam at each high tension lead. The up-steam pressure was taken from the 25 psi gas outlet of the 10 hp 2 stage compressor and regulated by a motor actuating valve. A 30 gal. tank, connected to the valve adapter with 1-1/8" T.D. hose, is used as a surge tank in the air system.
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<th>DATE</th>
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<th>COMB. CH1R TEMP. °F</th>
<th>COMB. CH1R PRESS. LB./IN.</th>
<th>FUEL QMNT. GAL.</th>
<th>FUEL TEMP. °F</th>
<th>BAR TEMP. °F</th>
<th>FKEK COMB. PRESS. P.S.I.</th>
<th>CYLINDER TEMPG IN. END °F</th>
<th>VALVE STOP IN. END °F</th>
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Note 12 - Removing the ignition wire from the injector and spark plug caused the flame to shorten. Operation was with jet and plug only. The flame was returned to previous appearance by increasing the fuel flow.

Note 13 - The air was increased with no change in the fuel setting.

Note 14 - The air was decreased with no change in the fuel setting.

Note 15 - The maximum flash PM was about 500.

Note 16 - Operation was with injection and plug only.

Note 17 - The maximum flash operation was 800 PM.

Note 18 - The temperature at the fuel nozzle was thought to be responsible for the mal-function.
# ENGINE LOG

**FUEL: 73 OCTANE AVIATION GASOLINE**

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<th>POTMETER LBS/HR</th>
<th>FUEL QUANTITY GAL.</th>
<th>FUEL TANK</th>
<th>MAX. VALVE STOP MAX END OF</th>
<th>MAX. VALVE STOP MIN. END OF</th>
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**Note 19** - A water spray was added to cool the intake manifold.

**Note 20** - Unit was running on auto ignition for five minutes.
# ENGINE LOG

**FUEL - 73 OCTANE AVIATION GASOLINE**

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**Compressed Ratio**

1.88

**Note 25** - A ball check was installed in a line between the combustion chamber and a pressure gage to determine peak chamber pressures.

**Note 26** - The unit was stopped to replace the valve plate gasket.

**Note 27** - The flow sector was surging more than a normal amount. The surge chamber on the gasoline pump was removed and repositioned.

**Note 28** - The unit was very critical on fuel adjustment to obtain a good flame and regular firing.
|------------|--------|--------|-----------|--------|-----------|--------|-----------|--------|-----------|--------|-----------|--------|-----------|--------|

**Note 20** - The red valve was found to require about 1/8 of the force previously required to move the box. An attempt to increase the box design did not result in fewer than three valves being installed in the unit.

**Note 30** - The jet plate was increased from 0.20 to 0.22 diameter.

**Note 31** - The jet plate was replaced.

**Note 32** - The jet plate was increased from 0.20 to 0.22 diameter.

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

**Note 34** - The engine was very critical on fuel adjustment. Timing was irregular.
**Fuel - 73 Octane Aviation Gasoline**

**Engine Log**

**Date**: 09-44

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**Note 35**: Three 3/16 diameter jet holes were added. Mal-firing occurred at 1000 RPM so operation was reduced to 600 RPM.

**Note 36**: The engine was stopped when mal-firing occurred due to valve failure.