MAY 31 1944
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RESTRICTED
NA83
VFM-2
PTR 0416
(FT) (561)

TITLE Model FM-2 Airplane - Water Injection Tests of - TED No. PTR 0416 - Report on.

REFERENCES
(a) BuAer spdltr. Aer-E-41-RWS, of 12 February 1944.

(b) BuAer spdltr. Aer-E-432-RMB, of 25 March 1944.

(c) BuAer spdltr. Aer-E-41-RWS, of 18 March 1944.

(d) NAS, Patuxent River, Md. spdltr. NA83 VFM-2 PTR 0416 of 10 May 1944.

(e) BuAer spdltr. Aer-E-431-RMB of 29 February 1944.

(f) NAS, Patuxent River, Md. spdltr. NA83 VFM-2 PTR 0416 of 5 May 1944.

INTRODUCTION

1. The subject tests were conducted in accordance with reference (a) which required water injection performance tests of model FM-2 airplane No. 16169.

PURPOSE

1. The purpose of these tests was to obtain the performance characteristics of model FM-2 airplane No. 16169 using water injection and to evaluate the operation of the power plant at the increased emergency rating.

METHOD OF TEST

1. The performance data were obtained and reduced to standard conditions in accordance with the established Flight Test methods. Engine power was measured by means of a torquemeter.

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DISCUSSION

1. The airplane was loaded as a normal fighter for all tests. This loading may be summarized as follows:

Gross Weight - lbs.	7418
Center of gravity location-% MAC:	
Gear extended	28.3
Gear retracted	28.6
Fuel - gallons	117
Oil - gallons	9
Injection fluid - gallons	10
Armament - .50 caliber machine guns	4
Ammunition - rounds	1600

Photographs forming enclosure 1 show the airplane as flown during the tests.

2. The airplane was equipped with a Wright model R-1820-56 engine with water injection equipment and a Curtiss Electric 3-blade constant speed propeller of 10'-0" diameter, blade design No. 109354-12. Externally the airplane was a typical production model FM-2 airplane. Radio antenna was installed and gun blast openings faired over with tape.

3. The airplane as received was equipped with a movable gate type throttle stop, a picture of which is included in enclosure 1. With the throttle pushed up against the movable stop pin, military power is obtained, the manifold pressure being regulated by the Delco-Remy supercharger regulator. When the throttle is pushed full forward past the stop in low blower, the regulator is reset to give a higher manifold pressure and, also, a limit switch in the water injection circuit is closed. However, no anti-detonant will flow as there is another limit switch in the circuit which is closed only when the supercharger is in high gear. With the throttle full forward past the stop and the supercharger in high gear both limit switches in the water injection circuit are closed and the anti-detonant will flow provided the manifold pressure is 42.5 inches Hg. or greater. The pressure of the anti-detonant when "on" operated to make a further reset of the supercharger

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regulator increasing the regulated manifold pressure approximately 2 inches Hg. over that obtained in low blower without anti-detonant. The operation of the movable gate throttle stop was found to be quite cumbersome, necessitating that the pilot place one finger on the stop and push it aside as the throttle was pushed forward. As requested in reference (b) the stop was removed and throttle operation was found to be much simpler and more convenient. It is believed that the conventional joggle type take-off throttle stop is entirely satisfactory for this installation.

4. The operation of the anti-detonant equipment was further investigated as requested in reference (b), with the gate type throttle stop removed and with the electrical switch system rewired to by-pass the throttle anti-detonant limit switch. The purpose of this arrangement was to give a greater degree of control over the engine power between military and full combat (war emergency) power. With the installation as received there was no intermediate control between the two powers as it was necessary to push the throttle full forward past the stop to close the limit switch and turn on the anti-detonant. With the throttle switch by-passed the operation was as follows: As the throttle was moved forward slowly the anti-detonant started to flow at a manifold pressure of 42.5 inches Hg. As soon as the flow started the manifold pressure increased immediately to 48.0 inches Hg. without further movement of the throttle. Further movement of the throttle forward increased the manifold pressure gradually to its limit of 51.8 inches Hg. On closing the throttle the manifold pressure dropped gradually to a value of 42.5 inches Hg. where it dropped suddenly to 35 inches Hg. as the anti-detonant ceased to flow. Thus complete control of the power was obtained between the range of 42.5 to 51.8 inches Hg. manifold pressure. Although this system gave very good control of the power it is observed that considerable anti-detonant would be wasted when operating between 42.5 and 46.7 inches manifold pressure. It is felt that this arrangement would be satisfactory if the critical manifold pressure for causing the anti-detonant to flow were increased to approximately 47.0 inches Hg. and the critical manifold pressure

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at which the anti-detonant would cease to flow were approximately 44.0 inches Hg., giving a range of from 51.8 to 44.0 inches Hg. manifold pressure within which the anti-detonant would flow. Complete power control would thus be obtained within this range once the limit of 47.0 inches Hg. was exceeded.

5. It is to be noted that with the present regulator settings it is impossible to obtain full throttle operation at sea level in low blower. In order to obtain the data requested by reference (a), the supercharger regulator was by-passed by using a conventional FM-2 throttle linkage and several full throttle runs were made at 2600 and 2700 RPM at 500 and 1000 ft. altitudes.

6. When the anti-detonant started to flow there was found to be a momentary drop in power followed by a rapid surge as full power built up. This effect is similar to that found on the model F4U-1 and F6F-3 airplanes but of a lesser magnitude.

7. During the early part of the tests some difficulty was experienced with the supercharger regulator giving erratic manifold pressure. However, after the first few flights the operation steadied down on the values shown on the performance curves of enclosure 2.

8. Engine cooling was found to be satisfactory. Cowl flaps were kept full closed for all level flight maximum speed runs and full open for high power climbs. The maximum cylinder head temperature observed was 230°C in a war emergency power climb at 20,000 feet altitude, -20°C outside air temperature.

9. All performance was obtained with the mixture control in auto rich. The effect of operating in auto lean was also investigated and it was found that an increase of approximately 12 BHP might be realized by operating in auto lean instead of auto rich in low blower. In tests made near the high blower airplane critical altitude there was no discernable difference in power when operating in auto lean instead of auto rich.

10. Reference (c) requested that tests be made to determine the effect on high blower airplane critical altitude of leaning manually to a specific fuel consumption of .7 lbs/BHP/HR. As reported

in reference (d) it was found that the airplane critical altitude was increased approximately 1800 ft. when operating at the lean mixture, increasing the BHP developed at the auto rich airplane critical altitude from 1215 to 1280.

11. No exhaust stack failures were encountered. However, Solar stacks were installed on several of the cylinders which had given the greatest trouble on previous airplanes. Several stack clamp failures of the type encountered on previous airplanes were the only difficulties experienced with the exhaust system.

RESULTS

1. Charts contained in enclosure 2 are plots of the performance obtained during the tests. The data obtained are summarized as follows:

MAXIMUM SPEED

Military Power:

Blower	Low	Low	High
RPM	2600	2700	2600
BHP	1320	1335	1060
Airplane crit. alt.-ft	3250	3800	15,300
Maximum speed-MPH	311.0	313.5	329.5
Manifold pressure-inches Hg.	46.7	46.7	44.5

Combat (War Emergency) Power:

Blower	Low	Low	High	Low	Low
RPM	2600	2700	2600	2600	2700
BHP	1400	1410	1215	1440	1475
Airplane crit. alt.-ft	1100	1900	10,800	S.L.	S.L.
Maximum speed-MPH	310.5	313.0	328.5	310.	312.5
Manifold pressure-inches Hg.	50.0	50.0	51.8	51.8	53.2

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CLIMB

Military Power:

Blower	Low	Low	High
RPM	2600	2700	2600
BHP	1280	1300	1060
Climb crit. alt.-ft.	1000	1600	12,900
Maximum rate of climb-FPM.	3430	3480	2530
Manifold pressure inches Hg.	46.7	46.7	44.5

Combat (War Emergency) Power:

Blower	Low	Low	High
RPM	2600	2700	2600
BHP	1315	1350	1210
Climb crit. alt.-ft.	S.L.	S.L.	8000
Maximum rate of climb-FPM.	3550	3670	3060
Manifold pressure-inches Hg.	48.2	49.0	51.8

2. Reference (e) requested that measurements be made of the temperature of the anti-detonant within the tank and of the air surrounding the tank. A preliminary report on these temperatures was submitted by reference (f). A summary of the data obtained is as follows:

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Pressure Alt.- ft.	Outside Air Temperature - °C	Temp. of Air Surrounding Tank - °C	Temp. of Fluid Within Tank
5000	- 5	+ 25	+ 20
6000	- 5	+ 25	+ 20
6000	+ 8	+ 33	+ 32
7000	- 5	+ 25	+ 20
7000	+ 7	+ 30	+ 25
8000	- 3	+ 25	+ 20
10,000	- 3	+ 24	+ 18
15,000	- 9	+ 30	+ 20
18,000	-14	+ 27	+ 20
19,000	-17	+ 26	+ 19
23,000	-27	+ 28	+ 23

CONCLUSIONS

1. A valuable gain in performance, particularly rate of climb, may be obtained on the model FM-2 airplane by operating at combat (war emergency) power.

2. As installed, the operating characteristics of the anti-detonant injection system are not considered satisfactory. However, it is believed that all deficiencies may be remedied by incorporating the changes made under Recommendations.

RECOMMENDATIONS

1. It is recommended that the movable gate type throttle stop be removed and replaced by the usual joggle type take-off throttle stop.

2. It is recommended that the throttle limit switch in the anti-detonant operating electrical circuit be removed and the circuit

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rewired to eliminate this switch.

3. It is recommended that the manifold pressure at which the anti-detonant starts to flow be increased from 42.5 to approximately 47.0 inches Hg. and that the manifold pressure at which it ceases to flow be increased from 42.5 to approximately 44.0 inches Hg.

4. It is recommended that the supercharger pressure regulator be modified so that full throttle low blower operation will be possible in level flight at sea level.

5. It is recommended that a derichment feature be added to the carburetor to adjust the mixture automatically to approximately .7 S. F. C. when anti-detonant is being used.

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Comdr., USN

Encl: (HW)
1. Five (5) Photographs
2. Three (3) Sheets of Performance Characteristics

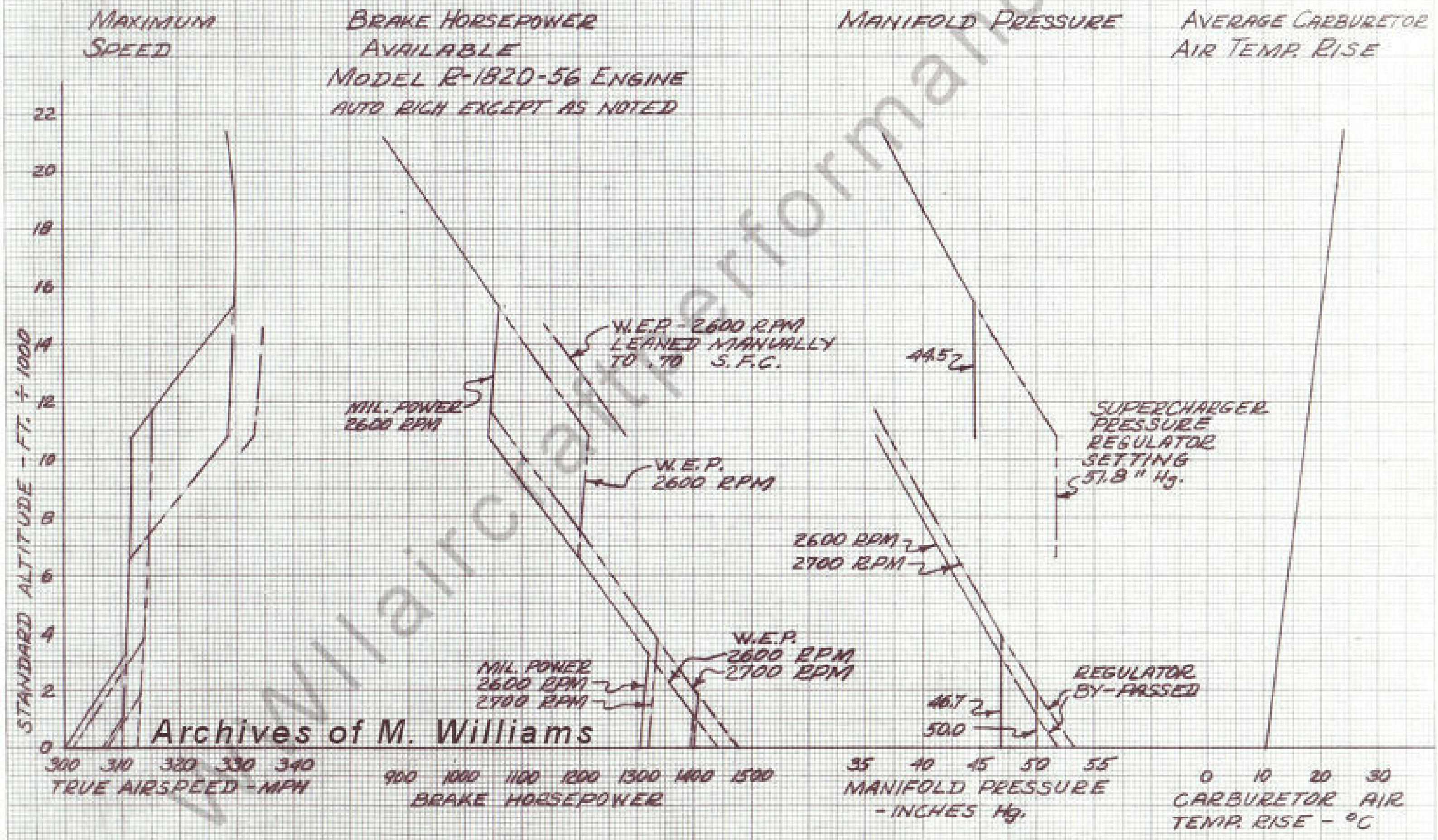
Model FM-2 #16169
3/4 Right Front View

Photo PTR 6630
5-8-44

CONFIDENTIAL
OFFICIAL NAVY PHOTOGRAPH
NOT TO BE USED FOR PUBLICATION

MODEL FM-2 AIRPLANE No. 16169
PERFORMANCE CHARACTERISTICS AT MILITARY
AND WAR EMERGENCY POWERS (COMBAT)
NORMAL FIGHTER GROSS WT. = 7418 LBS.

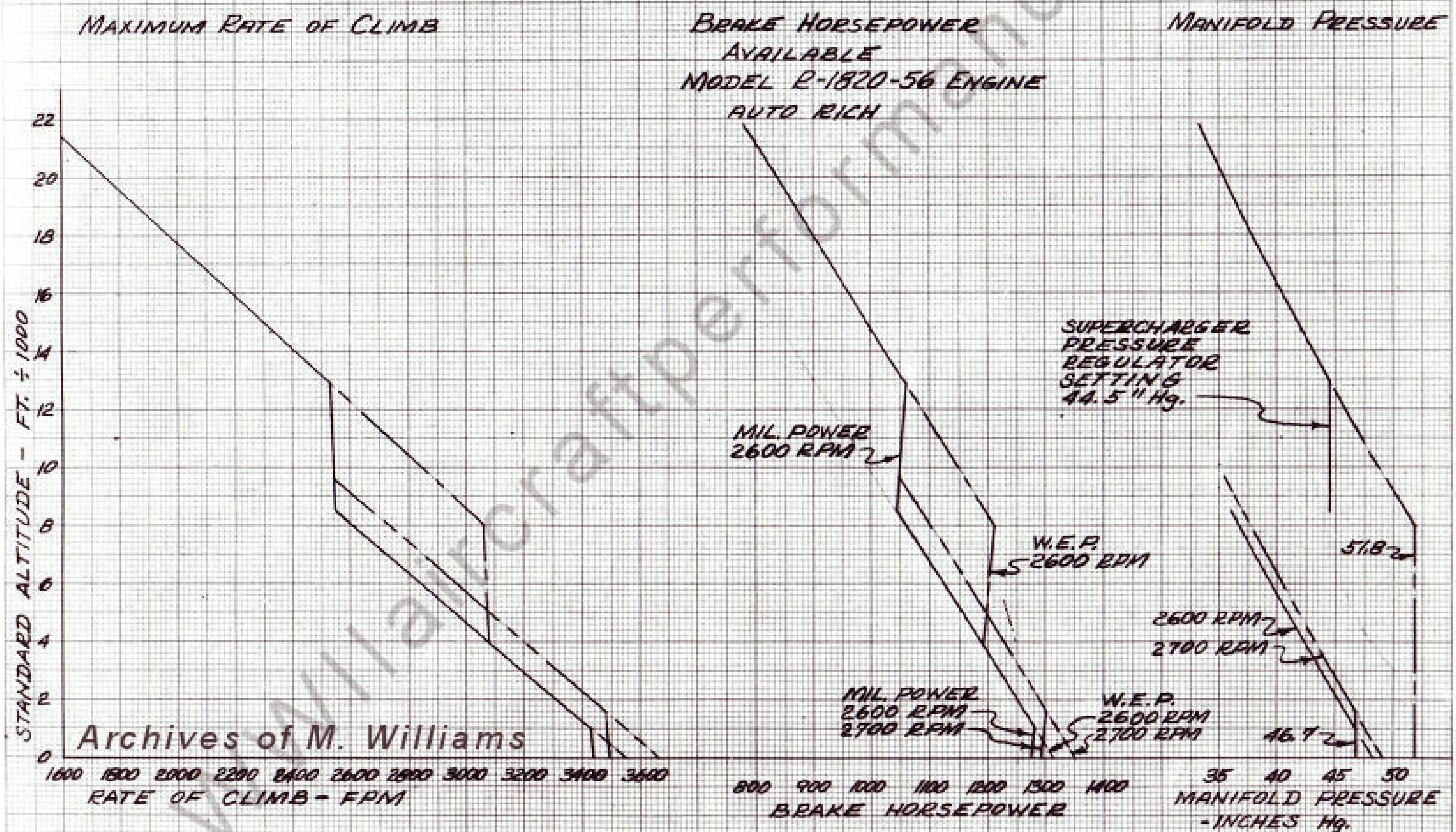
PHOTO FTR 6746
5-9-44
FIG. 1



F.E.E.

MODEL FM-2 AIRPLANE NO. 16169
PERFORMANCE CHARACTERISTICS AT MILITARY
AND WAR EMERGENCY POWERS (COMBAT)
NORMAL FIGHTER GROSS WT. = 7418 LBS.

PHOTO PTR 6747
5-9-44
FIG. 2

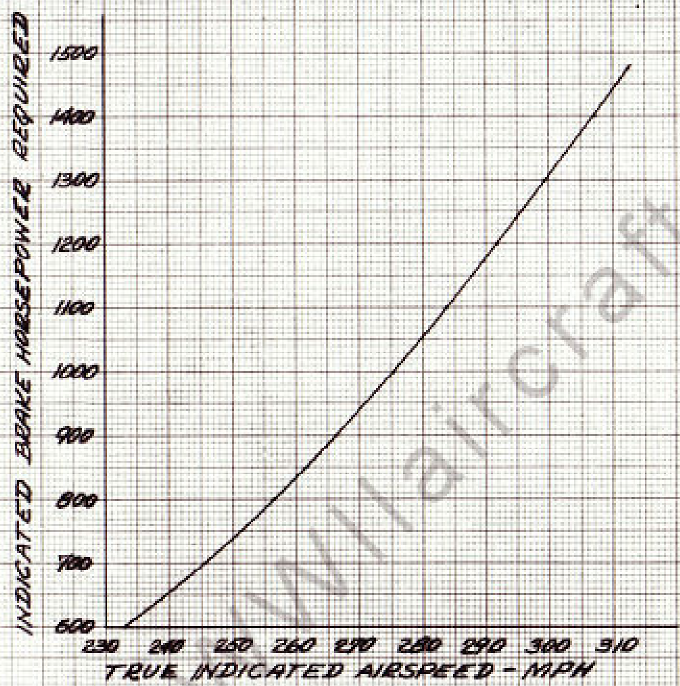


F.E.E.

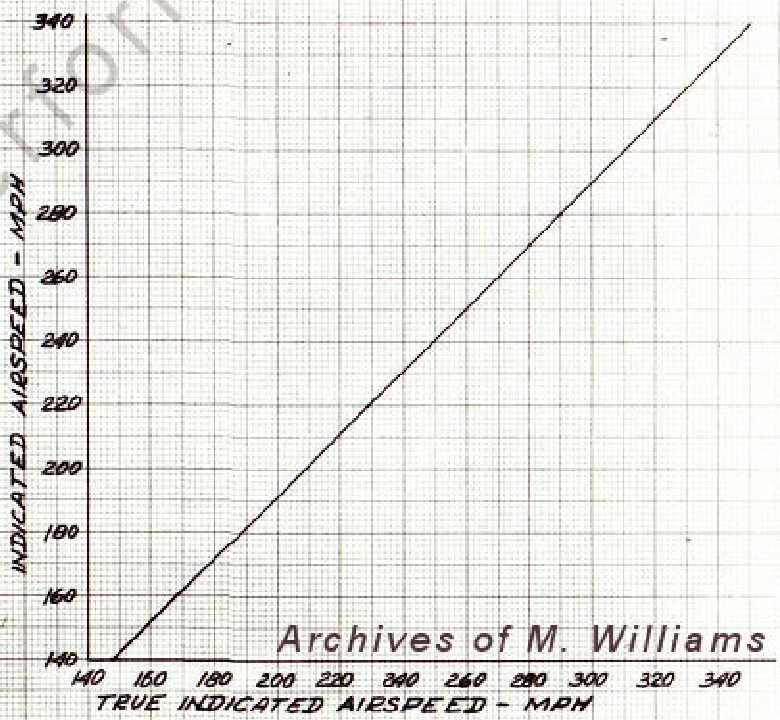
MODEL FM-2 AIRPLANE NO. 16169
PERFORMANCE CHARACTERISTICS AT MILITARY
AND WAR EMERGENCY POWERS (COMBAT)
NORMAL FIGHTER GROSS WT. = 7418 LBS.

PHOTO PTR 6748
5-9-44
FIG. 3

INDICATED BRAKE HORSEPOWER REQUIRED VS. MAXIMUM TRUE INDICATED AIRSPEED



AIRSPEED INDICATOR CALIBRATION



F.E.E.