

4th Part of Report No. A&AEE/809, a.
AIRCRAFT AND ARMAMENT EXPERIMENTAL ESTABLISHMENT,
BOSCOMBE DOWNHellcat II JV.225
(Double Wasp R.2800-10W)Climb and level speed performance with
and without water injection.

A&AEE Ref:- 5707, f/5/SIRN.

M.A.P. Ref:- Res. Air. 5381/11/RDN5/NEW.

Period of tests:- September - October 1944.

This report deals with the aircraft or equipment as tested. Action to remedy defects or decisions to accept items not in at compliance with the specification are matters for decision and action by M.A.P.

Progress of issue of report

Report No.	Title.
1st Part of A&AEE/809, a.	JV.224 - Position error trials.
2nd " " " " "	JV.224 - Brief handling with spring tab ailerons.
3rd " " " " "	JX. 822 - Position error trials with repositioned static vent.

Summary.

This Report deals with the effect of introduction of water injection on climb performance in auxiliary low gear and on level speed performance in auxiliary high gear. The effect of the higher manifold pressure (60" Hg) allowed by the use of water injection, on performance is as follows:-

Climb: The rate of climb is increased by 650 ft./min. (from 2570 to 3160 ft/min) at all heights up to 11,200 ft., the full throttle height using water injection.

Level speed: The true level speed is increased by about 20 mph (17 knots) up to 18,600 ft., the full throttle height using water injection. At this height the true level speed is 377 mph (328 knots) compared with 367 mph (319 knots) at 21,800 ft., the full throttle height for the maximum manifold pressure permissible without water injection.

Some difficulty was experienced in obtaining the correct manifold pressure and water pressure but after adjustment of the boost capsule and the "Water Regulator Unit" the water injection system functioned satisfactorily.

1. Introduction.

Level speed performance has previously been measured in all three gears Main, Auxiliary Low and Auxiliary High, on Hellcat aircraft (See 4th and 20th Parts of Report No. A&AEE/809). This Report deals with the effect of the introduction of water injection on climb performance in Auxiliary Low gear and on level speed performance in Auxiliary High gear.

2. Condition of aircraft relevant to tests.

2.1 General. The Hellcat II is a single-seater low wing fighter powered by a Double Wasp R.2800-10W engine and is intended for carrier-based operations. It is of all-metal construction except for the control surfaces which are fabric covered. The following provides further details of the external features of the aircraft tested:-

- (i) Armament consisted of 6 x .50 in. Browning guns three in each wing and with no fairings around the muzzles at the leading edge. The muzzles and ejector chutes were sealed with fabric.
- (ii) Retractable main wheels, tail wheel and arrestor hook, the latter being stowed in the extreme rear of the fuselage.
- (iii) An aerial mast behind the pilot's hood, with an aerial running to a short mast on top of the fin. The lead-in from the aerial entered the fuselage on the starboard side.
- (iv) I.F.F. whip-type aerial underneath the fuselage a short distance behind the trailing edge of the wing.

- (vi) Sealed cabin heater air intakes in the leading edge of the wing, just inboard of the guns.
- (vii) Paired bomb rack situated on the starboard wing centre section just outboard of the wing root about three feet from the aircraft plane of symmetry. No bomb load was, however, carried during the present trials.

2.2 Airspeed system. The pressure head, a Kollsman Type AN.5816-2 was mounted on the starboard wing tip with the pitot and static sides connected to the airspeed indicator. (See 1st part of Report for details).

2.3 Engine number and limitations. The engine fitted to the Hellcat II tested was a Pratt & Whitney Double Wasp R.2800-10W, Makers No. DM13659, AM No. 205079. The following engine limitations applied at the time of test:-

Condition	R.P.M.		Man.press, In.Hg.		S/C gear
	With water	Without water	With water	Without water	
Take-off	-	2700	-	54"	Main
Combat (5 mins. limit)	2700	2700	60" (57" in Main)	52½"	Main Auxiliary Low Auxiliary High
Maximum cruising	-	2550	-	44"	Main Auxiliary Low Auxiliary High

2.4 Loading. The trials were carried out at fighter overload at a take-off weight of 12,220 lbs. C.G. 32.3 ins. aft of datum (u/c down).

2.5 Engine installation and water injection system.

2.51 General. The Pratt and Whitney Double Wasp R.2800-10W has a two-stage supercharger, one stage of which, known as Main, is in operation under all running conditions while the other, known as Auxiliary, may be employed in addition and has a two-speed gear. Further details of this system may be obtained from the 4th part of Report No. A&AEE/809.

2.52 Water injection system. The results of turning on the water supply in this installation are:-

- (i) a metered quantity of water is injected into the induction system with the fuel, at the impeller nozzle at the main blower throat,
- (ii) a decrease in the fuel/air ratio.

The use of water injection allows the increased manifold pressure to be used, see para. 2.3 above. This is obtained by opening the throttle beyond the gate after turning on the water supply.

The water storage tank fitted to Hellcat II aircraft contains 12.5 Imperial gallons.

When the water injection system is brought into action by operating a tumbler switch (marked "ADI" - anti-detonant injection) in front of the throttle lever on the left-hand side of the cockpit, the solenoid valve is opened and the water pump started. Water is then delivered to the "Water Regulator Unit".

This "Water Regulator Unit" controls the water pressure and the rate of water flow. The arrangement is such that water is metered to the engine at a rate which depends on the fuel and air flow through the carburetter.

The water pressure in the high-pressure chamber of the "Water Regulator Unit" should be, according to the makers, within the limits 17 lbs/sq.in. \pm 1 lb/sq.in.

To avoid freezing, a mixture (1:1) of pure water and alcohol to specification AN-A-18 is used.

3. Scope of tests.

The programme was arranged to obtain directly comparable tests with and without water injection during the course of each flight to minimise any possible discrepancy arising from varying corrections to ICAN atmospheric conditions.

3.1 Climb performance. Measurements were made at combat power with and without the use of water injection in Auxiliary Low gear with engine cooling gills half open and oil cooler and intercooler flaps fully open at the best climbing speed of 150 mph (130 knots) ASI (see 4th part of Report No. A&AEE/809) at heights between 2,000 ft. and 15,000 ft.

3.2 Level speed performance. Measurements were made with and without water injection in Auxiliary High gear at combat power with engine cooling gills and oil cooler and intercooler flaps closed at heights between 11,000 ft. and 25,000 ft.

3.3 Functioning of the water injection. Some notes on the mechanical aspects and behaviour of the water injection installation were made during the progress of the trials (See para. 5.)

4. Results of tests.

The results have been corrected to standard ICAN atmospheric conditions by the methods of Report No. A&AEE/Res/170, a supercharger constant of 0.002 being used and the level speeds corrected to a mean weight of 11,500 lb. (approximately 95 % of the take-off weight). Compressibility corrections to the indicated speeds have been made in accordance with the methods of Report No. A&AEE/208.

The position error correction used was that as measured on this aircraft and given in Curve No.2 of 1st part of Report No. A&AEE/809, and suitably corrected for weight.

4.1 Climb performance. The performance on climb is given in Table I and Fig. 1. The results are summarised as follows:-

Standard height (ft) and remarks.	Max. rate of climb (ft/min.)	
	With water injection	Without water injection.
2000-11, 200 (FTH in Aux. Low gear with water injection)	3160	(2510) 2460 ✕
15,000	2510	(2510) 2460 ✕

The rate of climb is increased by 650 ft/min. (from 2510 to 3160 ft/min.) at all heights up to 11200 ft. the full throttle height using water injection.

✕ (The nominal value of manifold pressure on climb without water injection (52½" Hg) was not obtained. The values given above in brackets are those corrected to the nominal value of manifold pressure and are indicated in Fig. 1 by a broken line).

4.2 Level speed performance. The level speed performance is given in Table II and Fig.2. The results are summarised as follows:-

Standard height(ft) and remarks.	Max. level speed TAS (mph(knots))	
	With water injection	Without water injection.
12000	354 (308)	335 (291)
18600	377 (328)	357 (310)
21800	367 (319)	367 (319)

The true level speed is increased by about 20 mph (17 knots) up to 18,000 ft., the full throttle height using water injection. At this height the true level speed is 377 mph (328 knots) compared with 367 mph (319 knots) at 21,800 ft., the full throttle height for the max. boost permissible without water injection.

5. Functioning of water injection installation during trials.

During the first part of the test flights, it was found that insufficient boost pressures were being obtained both with and without water injection. It was found that the auxiliary boost capsule, which controls a butterfly valve in the air inlet to the auxiliary supercharger, required some adjustment. Ground and air tests were made and after further slight adjustment, the correct values of the manifold pressures were obtained ($52\frac{1}{2}$ ins. Hg. without water injection and 60 in. Hg with water injection).

Trouble was also experienced with the water pressure. According to the makers specification, this ought to be 17 lbs/sq.in. \pm 1 lb/sq.in., but in the first flights, consistently high readings of the water pressure were obtained. After adjustment to the "Water Regulator Unit", the desired values were obtained.

After these adjustments had been made the climb and level speed performance tests were re-commenced and no further trouble was experienced with either the manifold pressure or water pressure.

The aircraft manufacturers state it is important that correct adjustment of these controls be made on individual aircraft by flight trials to ensure that the correct values of manifold and water pressure are obtained.

6. Discussion of results.

6.1 The manifold pressure curve (Fig.1) showing manifold pressures obtained during the climb indicates that the full throttle heights are approximately 3,000 ft. lower than might be expected according to the makers power curves which gave a full throttle height of approximately 14,000 ft. for this gear, at 60" Hg boost.

Since previous climb performance on Hellcat aircraft has not been measured at combat power, no direct comparison can be made.

6.2 The speed-height curve (without water injection) of Fig. 2 corrected to a mean weight of 11,500 lb. agrees favourably with points obtained in Auxiliary High gear on Hellcat I FN.360 (see 20th Part of Report No. A&AEE/809). The full throttle height as given by the results of the present trials also agrees reasonably well with the previous figure. The full throttle height (with water injection) as obtained now is in close agreement with that given by the makers power curves for the engine.

7. Conclusions.

The effect of the higher boost, allowed by the use of water injection, on performance is as follows:-

(i) Climb. The rate of climb is increased by 650 ft/min. (from 2510 to 3160 ft/min.) at all heights up to 11,200 ft., the full throttle height using water injection.

(ii) Level speed. The true level speed is increased by about 20 mph (17 kts.) up to 18,600 ft., the full throttle height using water injection. At this height the true level speed is 377 mph (328 knots) compared with 367 mph (319 knots) at 21,800 ft., the full throttle height for the maximum boost permissible without water injection.

TABLE I

Climb performance (Aux. low supercharger gear)

Fighter overload. Mean weight 11,500 lb. No external load carried.
Engine cooling gills half open, oil cooler shutters
and intercooler flap fully open.

Standard height feet	Rate of climb (ft/min)	Time to height (mins)	ASI mph (knots)	Manifold pressure (Ins.Hg)	R.P.M.	S/C gear
2000	3160	0.63	150	60	2700	Auxiliary Low
	2460	0.81	(130)	51.75		
4000	3160	1.26		60		
	2460	1.62		51.75		
6000	3160	1.89		60		
	2460	2.43		51.75		
8000	3160	2.52		60		
	2460	3.24		51.75		
10000	3160	3.15		60		
	2460	4.05		51.75		
11200*	3160	3.54		60		
	2460	4.55		51.75		
12000	3000	3.80		58.5		
	2460	4.88		51.75		
14000	2680	4.51		54.5		
	2460	5.68		51.75		
15000	2490	4.91		53		
	2460	6.09	V	51.75	V	V

The first set of values at each height is that obtained when water injection is employed.

* Full throttle height.

/Table II.

TABLE II

Level speed performance (Auxiliary high supercharger gear)

Fighter overload. Mean weight 11,500 lb. No external load carried
Engine cooling gills, oil cooler shutters and intercooler flap closed

Standard height feet	TAS mph (knots)	ASI mph (knots)	Corrections mph		RPM	Manifold pressure ins.Hg.	Mixture	S/C gear
			P.E.	C.E.				
12000	354 (308)	284 (247)	+14.7	-4.0	2700	60	Auto Rich	Auxiliary High
	335 (291)	269 (234)	+14.5	-3.5		52.5		
14000	361 (314)	282 (245)	+14.6	-4.4		60		
	342 (297)	266 (231)	+14.4	-4.1		52.5		
16000	368 (320)	278 (241)	+14.6	-4.7		60		
	348 (302)	262 (228)	+14.4	-4.5		52.5		
18000	375 (326)	274 (238)	+14.6	-5.4		60		
	355 (308)	258 (224)	+14.3	-4.8		52.5		
18600*	377 (328)	273 (237)	+14.6	-5.6		60		
	357 (310)	257 (223)	+14.3	-4.8		52.5		
20000	374 (325)	264 (229)	+14.4	-5.7		56.8		
	361 (314)	254 (220)	+14.2	-5.1		52.5		
21800/	367 (319)	251 (218)	+14.1	-5.2		52.5		
	367 (319)	250 (217)	+14.1	-5.2		52.5		
22000	366 (318)	249 (216)	+14.1	-5.4		52.1		
24000	353 (307)	242 (210)	+14.0	-5.0		47.5		

The first set of values at each height is that obtained when water injection is employed.

* F.T.H. with water injection.

/ " without " "

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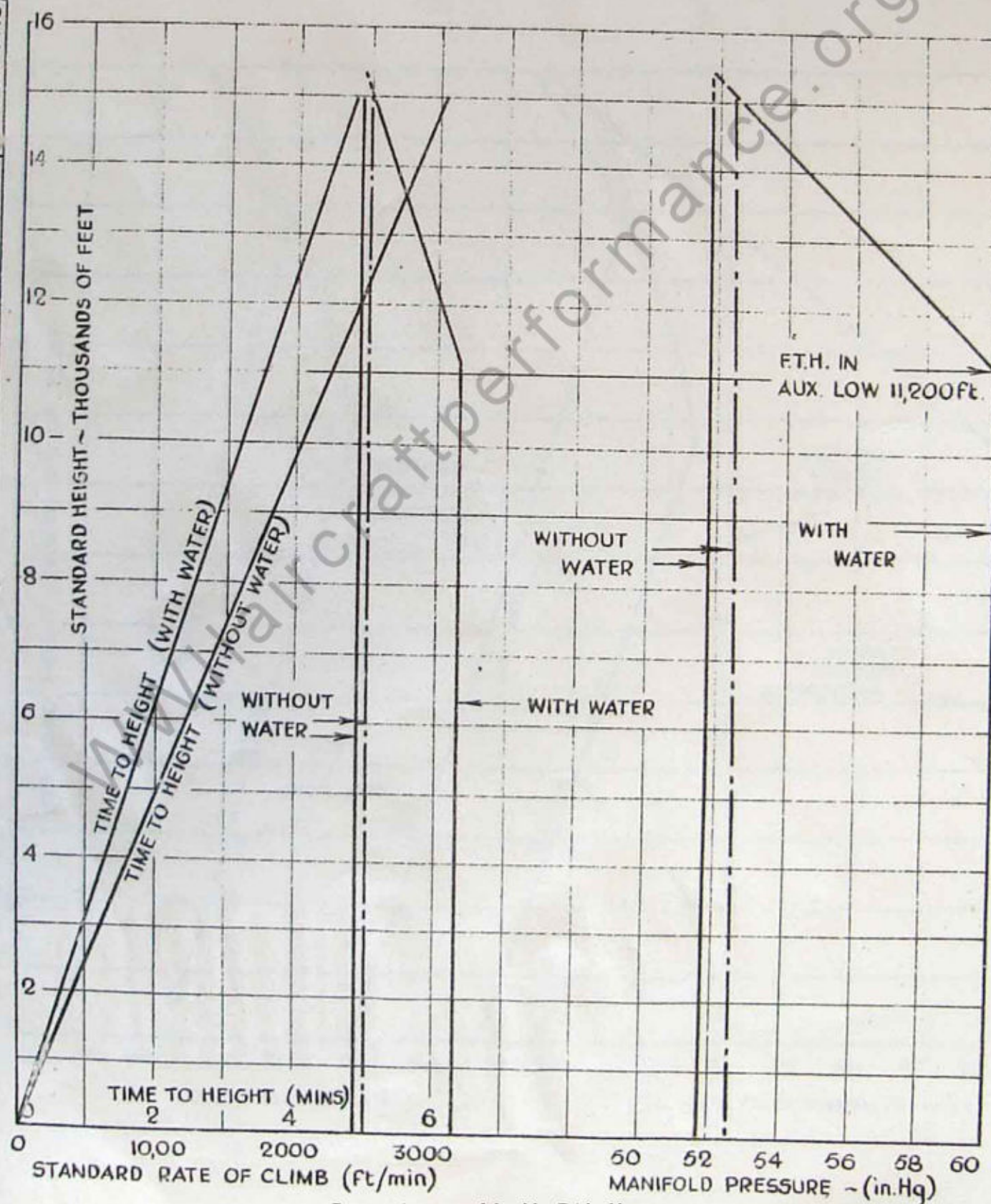
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PERFORMANCE CLIMBS

IN AUXILIARY LOW GEAR
WITH AND WITHOUT WATER INJECTION.

MEAN WEIGHT ~ 11,500 LB.
(NO EXTERNAL LOAD CARRIED)

----- ESTIMATED PERFORMANCE AT NOMINAL VALUES OF MANIFOLD
PRESSURE WITHOUT WATER INJECTION.
—— ACTUAL PERFORMANCE OBTAINED ON TEST.



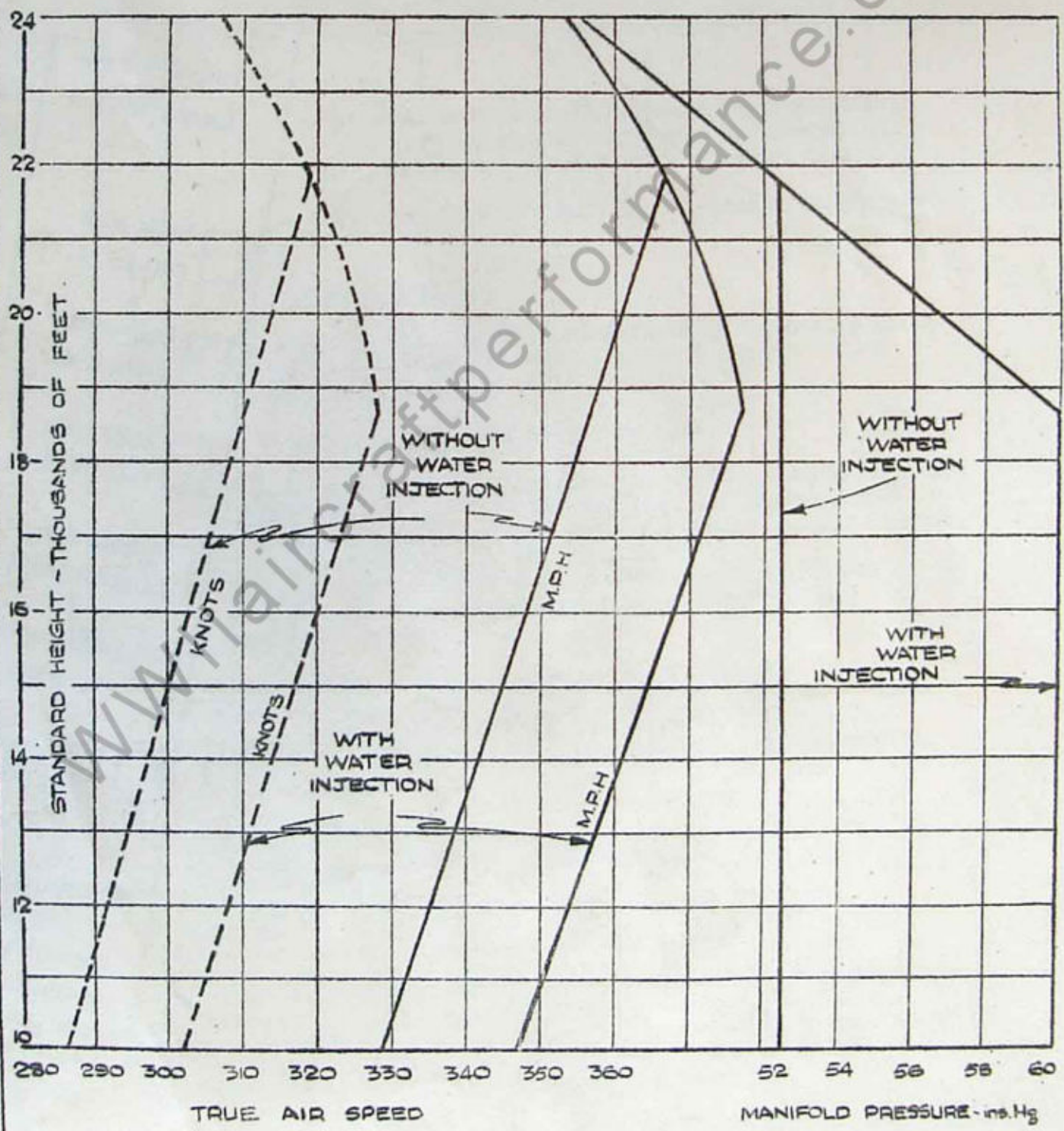
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FIG. 2

LEVEL SPEED PERFORMANCE

IN AUXILIARY HIGH GEAR
WITH AND WITHOUT WATER INJECTION
MEAN WEIGHT ~ 11500 lb.
(NO EXTERNAL LOAD CARRIED)



Courtesy Neil Stirling