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R.A.A.F. HEADQUARTERS

DIRECTORATE OF TECHNICAL SERVICES

SPECIAL DUTIES AND PERFORMANCE FLIGHT

REPORT

ON

BRIEF PERFORMANCE TRIALS OF A SPITFIRE (F) - MK. VIII.

(MERLIN 66).

DATE OF ISSUE: January 1944.

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NO. 1 AIRCRAFT PERFORMANCE UNIT.

LAVERTON.

BRIEF PERFORMANCE TRIALS OF A SPITFIRE (F) - Mk.VIII (MERLIN 66)

Detail No.: 156/58/8.

R.A.A.F. File No.: 9/53/28.

SUMMARY.

The performance of the subject aircraft is summarised as follows:-

I.C.A.N. ALTITUDE	R.P.M.	BOOST	MAXIMUM SPEEDS	TIME TO ALTITUDE.	RATE OF CLIMB.
Feet.	NO.	lb/sq.in.	mph.	minutes.	ft/minute.
Combat Power Rating.					
S.L.	3000	+18 (m)	350	0	4600
10000	3000	F.T.(m)	363	2.3	3840
18500 ø	3000	+18 F.T.(s)	391	-	-
25000	3000	F.T.(s)	393	6.6	2880
30000	3000	F.T.(s)	389	8.6	2160
35000	3000	F.T.(s)	368	11.4	1440
Rated Power Rating.					
S.L.	2850	+18 m.	302	0	3640
10000	2850	+18 m.	347	2.8	3560
22050 ø	2850	+18 F.T.(s)	385	-	-
25000	2850	F.T.(s)	386	7.7	2460
30000	2850	F.T.(s)	380	10.1	1820
35000	2850	F.T.(s)	355	13.5	1160

ø ... denotes Full Throttle Height in 'S' gear in Level Flight.

Estimated Service ceiling : 41,000 ft. (Rated Power)

"Take Off" Distances on Concrete Runway:

240 yards to "unstick."
450 yards to clear 50 ft. screen.

1. INTRODUCTION.

At the request of T.S.7 brief performance trials of a Spitfire (F) Mark Vlll - Merlin 66 have been carried out. This report covers -

(a) Position Error Determination.
(b) Level Speed Performance.
(c) Climb Performance.
(d) "Take off" Path Determination.

2. CONDITION OF THE AIRCRAFT DURING TRIALS.

(a) AIRFRAME:

TYPE - Spitfire (F) Mk. Vlll.

Aust. Identification No. - A58-315.
English do. No. - J.F.-934.

This aircraft was manufactured in England and erected in Australia by the R.A.A.F. This aircraft was virtually a new one at the commencement of the trials.

The external details were as follows:-

(i) Overall finish was a fine matt camouflage paint. The wing loading edges were well fitted and finished, whilst the general flush riveting was of a good standard (superior to the Mark Vc previously tested.)

(ii) All external metal surfaces were flush riveted.

(iii) Mainplanes were of the same general shape as the Vc universal type (Span 36' 11").

(iv) The four .303 machine gun ports were fabric covered.

(v) The two unused cannon ports were covered with standard hemispherical caps.

(vi) Bubble type cockpit hood.

(vii) Dorsal radio mast.

(viii) Radio aerials from mast to fin and on each side from fuselage waist to tailplane tips.

(ix) Increased elevator balance area relative to Mark Vc.

(x) Increased rudder area relative to Mark Vc.

(xi) Retractable tail wheel.

(xii) Individual cylinder stub exhaust ducts.

Other external features and mechanical details were:-

(i) By passable Vokes air filter.

(ii) Thermostatically controlled radiator duct exit flaps.

(iii) Automatic supercharger gear change device, which operated at 13,500' pressure height on climb and at approximately 12,500' on descent.

See also the photograph at the end of the report.

(b) AIRSCREW.

Name:	Rotol.
Description:	4 bladed, external cylinder V.P. Propeller.
Type:	R12/4F5/4.
Blade Serial Nos:	89749, 89142, 89072 & 89079.
Diameter:	10' - 9½" (average).
Pitch Range:	35°
Chord c at 0.7R :	9.58"
Thickness:	0.91"
t/c :	0.095.
Blade angle limits:	High: 50°06' & 50°30' Low : 15°06' & 15°30' (opposite blades similar)
Rotation:	Right hand.
Weight:	290 lb. (Spinner 22 lb extra)

(c) ENGINE DETAILS. (Reference A.P. 1590 P & S Vol. I)

Manufacturer:	Rolls Royce Ltd.
Engine name:	Merlin 66.
Type:	Liquid cooled 12 cylinder "V" Engine fitted with 2 speed, 2 stage supercharger.
Weight:	1650 lb ± 2½% (dry).
Rotation:	Left Hand.
Specification:	Bore: 5.4 inches. Stroke: 6.0 " Capacity: 1648 cubic inches. Compression ratio: 6.0 : 1. Supercharger ratios: Low: 5.79 : 1. High: 7.06 : 1. Airscrew gear ratio: 0.477 : 1.
Carburettors:	Stromberg 8D/44/1 double entry.

STATIC CONDITIONS.

Power Ratings.	Supercharger Gear.	B.H.P.	R.P.M.	Boost.	Height.
		No.	No.	lb/sqin.	ft.
Take Off	M	1325	3000	+ 12	S.L.
Maximum for 5 minutes.	M	1680	3000	+ 18	S.L.
	M	1750	3000	+ 18	5500
	S	1630	3000	+ 18	16250
	S	995	3000	+ -	30000
Rated Pr. (1 hour)	M	1310	2850	+ 12	S.L.
	M	1410	2850	+ 12	9000
	S	1315	2850	+ 12	19000
	S	885	2850	-	30000
Maximum weak Mixture cruising.	M	985	2650	+ 7	S.L.
	M	1095	2650	+ 7	12000
	S	1030	2650	+ 7	20800
	S	716	2650	-	30000

Maximum diving engine speed (20 sec. limit) - 3150 r.p.m.

(d) WEIGHT. The weight sheet summary for the condition of full fuel is given in the Appendix Table III.

Corrections to performance results to an "all up weight" of 7690 lbs. have been made.

3. TESTS.

(A) POSITION ERROR.

Position error was determined by the altimeter-tower method, and together with pitot head position is given on Figures 1 and 2.

(B) SPEED TRIALS.

Speed trials were carried out at a number of heights from sea level to 35,000' using Combat and Rated Powers. Results are given in Table 1 and Figure 4. The maximum "all out" level speed is 393 mph. at 25,000' which is well above Full Throttle (18,500').

(C) CLIMBING TRIALS.

Climbing trials were also carried out at combat and Climbing Powers and full details are given in Table 2 and Figures 5 and 6. Optimum climbing speed data was not available when trials commenced, but considerable data on similar aircraft was found, from which the best climbing speed was estimated. For 3,000 R. P. M. the speeds were directly taken from a Boscombe Down report on a Spitfire IX (AAEE/692/m Part 16) whilst for 2,850 R.P.M. the speed estimated by the methods of Unwin given in Report No. AAEE/Res/141. From the pilot's experience, these speeds appear to be fairly close to the optimum. Maximum rate of climb is 4,600 feet per minute at sea level.

(D) TAKE-OFF PATH.

Take-off Path at 7690 lbs. weight, was determined by the C.S.I.R. "Take-off" camera. The results are given below and on Figure 7.

Engine R.P.M.	3,000
Boost	+ 12 lbs. per sq. in.
Flap	0
Distance from start to unstick	240 yards.
Distance from start to 50 foot screen	450 yards.

The results are corrected to standard atmosphere, zero wind and aerodrome slope on a concrete runway.

4. DISCUSSION AND FURTHER DEVELOPMENTS.

With the high rates of climb obtained in a Spitfire VIII, it is considered that the accuracy of rates of climb measured by a stop watch and altimeter is very limited. This is partly due to the limits of manually operating a stop watch and the lage in the altimeter. It is proposed to carry out some experiments to determine the relative effects of these items.

During the climbing trials, some difficulty was experienced with airscrew control at high altitudes, due, it is thought, to frothing of the oil as a result of "coring" in the oil cooler. A similar trouble has occurred with the Spitfire aircraft in service, this defect is under investigation. The remaining performance work consists of measuring fuel flows and speeds at cruising powers with the 90-gallon belly fuel tank installed. A height of 10,000 feet has been selected as the most useful ferrying altitude, and the fuel consumption tests will be carried out there.

5. ADDENDUM

As stated in the text the top speed for this model Spitfire was above the Critical Full Throttle Height - an unusual feature in level speed performance results. Because the results were checked several times and the speeds were inferior to those obtained from Boscombe down, further analysis of the results have been made to see if any explanation could be obtained.

In the first instance the results were reduced according to A & AEE/Res/170 and the following is added to indicate that is is not possible, on certain assumptions assumed valid for this engine installation, to obtain greater speeds than at the critical full throttle height.

Neglecting induced drag, we have at top speed (approximately.)

$$A\,P\,\eta\sqrt{\sigma} = Do\,Vi.^3 \qquad (A - \text{a constant})$$

or $$\frac{dp}{p} + \frac{1}{2}\frac{d\sigma}{\sigma} + \frac{d\eta}{\eta} = 3\frac{dV_t}{V_t} + \frac{3}{2}\frac{d\sigma}{\sigma} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

From ref(1) $P \propto (k\sigma - m)$ above F.T.H.

or $$\frac{dp}{p} = \frac{d\sigma}{\sigma - a} \quad \text{where } a = \frac{m}{k} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

From ref. (2) $$\frac{d\eta}{\eta} = \lambda\frac{dJ}{J}$$

$$= \lambda\frac{dV_t}{V_t} \quad \text{(constant R.P.M.)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

∴ (1) becomes on substituting from (2) and (3)

hence $$\frac{a\,d\sigma}{\sigma(\sigma - a)} = (3 - \lambda)\frac{dV_t}{V_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

For an increase in speed to occur above the Critical Full Throttle Height $\frac{a}{\sigma - a}$ must be -ve, since $d\sigma$ is negative for increase in height and σ is in the order of 0.2. The law given in reference (1) gives $a = +0.09$ hence $\frac{a}{\sigma - a}$ can only be -ve for altitudes in which $\sigma < 0.09$. i.e. heights well above 50000 ft. Hence the only conclusion which can be reached is that no increase can occur.

However as reference (1) refers to Merlin $\overline{XX}$ and $\overline{46}$, the law $P \propto k(\sigma)^{-m}$ may not be valid for the Merlin $\overline{66}$ which is a 2 stage 2 speed engine with an intercooler, and may have different characteristics above the Critical Full Throttle Height, although curves supplied by the manufacturer indicate a similar law holds, which will not therefore alter the approximate theory given above.

Checks on another Spitfire will be carried out when available.

REFERENCES.

(1) A & AEE/Res/190 -"The variation of power with height of a Merlin 46 engine as determined by flight tests on a Spitfire Vc" by G.S. Hislop, Ph.D., A.M.I.Mech.E.

(2) A & AEE/Res/170 -" British performance reduction methods for modern aircraft" by D. Cameron, Ph.D.

TABLE I.

SPEED TRIALS.

SPITFIRE (F) MK. VIII. 7690 lbs. WEIGHT.

A58-315.

STANDARD ATMOSPHERE.

I.C.A.N. Height	A.S.I.	P.E.C. Comp. E.	T.A.S.	Boost.	Supercharger Gear.
feet	mph	mph	mph	lb/sq.in.	M or S
5 MINUTE COMBAT RATING 3000 R.P.M.					
Sea Level	318	-11.8	330	+18	M (Low)
5000	311	-12.7	349	+18	M
ø 7550	309	-13.5	361	+18 F.T.	M
10000	298	-12.8	363	+15½	M
X 13500	283	-12.3	363	+12½	M
10000	293	-12.2	356	+18	S (High)
X 13500	287	-12.7	369	+18	S
15000	285	-13.0	376	+18	S
ø 18500	279	-13.3	391	+18 F.T.	S
20000	273	-13.3	392	+16	S
25000	251	-12.0	393	+10¾	S
30000	227	-10.9	389	+ 6½	S
35000	197	- 8.2	368	+ 3	S
60 MINUTE CLIMB RATING 2850 R.P.M.					
Sea Level	292	-10.0	302	+18	M
5000	289	-10.9	323	+18	M
10000	286	-11.8	347	+18	M
ø 11400	286	-12.0	355	+18 F.T.	M
X 13500	275	-11.5	354	+10	M
X 13500	273	-11.2	350	+18	S
15000	271	-11.3	356	+18	S
20000	262	-12.1	376	+18	S
ø 22050	259	-12.3	385	+18	S
25000	243	-11.2	386	+ 9	S
30000	222	-10.0	380	+ 5	S
35000	190	- 7.1	355	+ 1½	S

ø Full Throttle Heights.

X Automatic supercharger gear change Height.

NOTE.

Cold Carburettor air and closed Radiator Flap used throughout.

TABLE II.

CLIMBING TRIALS.

SPITFIRE (F) MK. VIII. — 7690 lbs. TAKE-OFF WEIGHT.

A58-315.

STANDARD ATMOSPHERE.

I.C.A.N. Height	A.S.I.	Rate of Climb	Time to Ht.	Boost	Supercharger Gear.
feet	mph	ft. per min.	Minutes	lbs/sq in.	M or S
5 MINUTE COMBAT RATING 3000 R.P.M.					
Sea Level	170	4500	0	+18	M
5000	170	4600	1.1	+18	M
Ø 5800	170	4600	1.2	+18	M
10000	170	3840	2.3	+13½	M
X 13500	170	3220	3.4	+10	M
X 13500	170	4160	3.4	+18	S
15000	170	4160	3.7	+18	S
Ø 16200	170	4160	4.0	+18	S
20000	160	3600	5.1	+13½	S
25000	148	2860	6.6	+19	S
30000	135	2160	8.6	+ 5	S
35000	123	1440	11.4	+ 1½	S
60 MINUTE CLIMBING POWER 2850 R.P.M.					
Sea Level	160	3640	0	+12	M
5000	160	3640	1.4	+12	M
9500	160	3640	2.6	+12	M
10000	160	3560	2.8	+11½	M
13500	160	3060	3.8	+ 8½	M
13500	160	3120	3.8	+12	S
15000	160	3120	4.3	+12	S
20000	160	3120	5.9	+12	S
20400	160	3120	6.0	+12	S
25000	148	2460	7.7	+ 7½	S
30000	135	1820	10.1	+ 3½	S
35000	123	1160	13.5	+ ½	S

Ø Full Throttle Heights.

X Automatic supercharger gear change Height.

TABLE III.

LOADING DETAILS AT "TAKE OFF."

ITEM.	Weight (lb.)	Arm. (in.)	Moment (lb.in.)
CREW.			
Pilot and parachute.	200	55.0	11,000
ARMAMENT.			
.303 in. Browning guns (4)	112	11.0	1,232
Ammunition (1400 rounds)	91	9.5	865
20 mm. Hispano guns (2)	294	- 2.0	- 588
Ammunition (240 rounds)	150	12.0	1,800
Reflector gun sight	4.5	39.5	178
WIRELESS.			
TR1143	93	109.0	10,137
A.1271	4.5	125.0	563
R.3002 and control unit	32.5	128.0	4,160
CAMERA.			
G.45	8.5	- 8.0	- 68
OXYGEN.			
Cylinder (Mk. Vc)	19.5	159.5	3,110
FUEL. (at 7.2 lb/gal)			
Main tanks (96 gals.)	691	14.0	9,674
Wing tanks (27 gals.)	194.5	- 9.0	- 1,751
OIL. (at 9 lb/gal.)			
8-1/3 gals.	75	- 57.5	- 4,313
TARE WEIGHT.	5772	0.065	378
TOTALS.	7742	4.70	36,377

$\bar{x}$ = 4.70 inches aft of datum.

C.G. limits 3.5 "to 5.5" aft datum see R.A.A.F. Pub. No. 311A.

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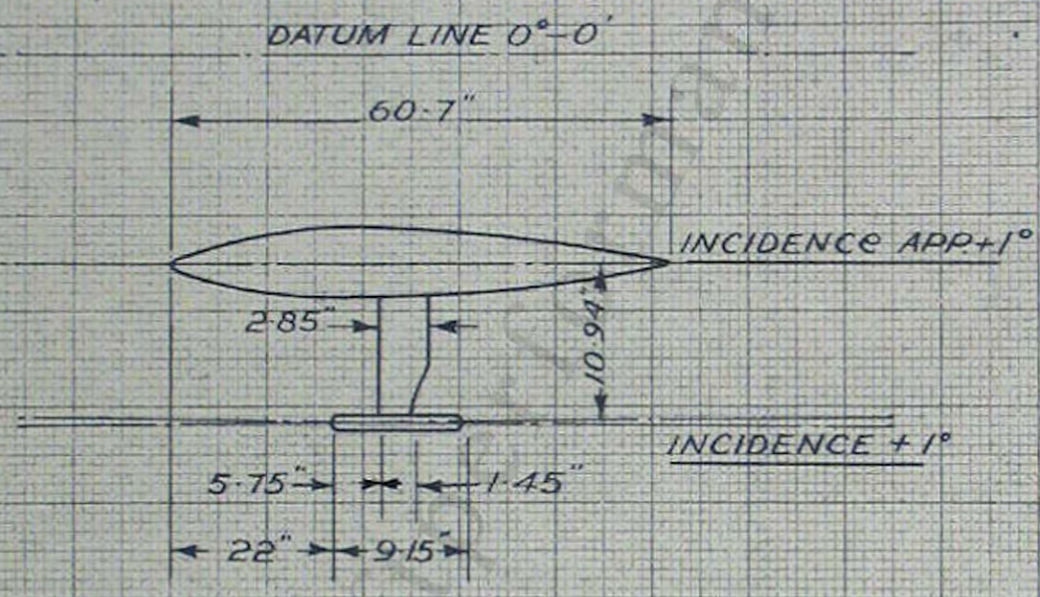
PREPARED BY	D.T.S. R.A.A.F. H.Q. T.S.7 SPECIAL DUTIES AND PERFORMANCE FLIGHT	FIG 1.
CHECKED BY	PRESSURE HEAD DETAILS	DATE 13-1-44

PITOT HEAD POSITION → A58-315.

SPITFIRE F. MK. VIII.



NOT TO SCALE

TYPE :- MK VIII C. ELECTRICALLY HEATED
REF. Nº 6A/730.
SERIAL Nº 35297/-.

POSITION :- UNDERSIDE OF PORT WING,
176" OUT FROM ℄ OF AIRCRAFT

MAINPLANE INCIDENCE :- AT ROOT = +2°
AT 176" = +1°

WING SECTION :- NACA 2210

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SPECIAL DUTIES AND PERFORMANCE FLIGHT

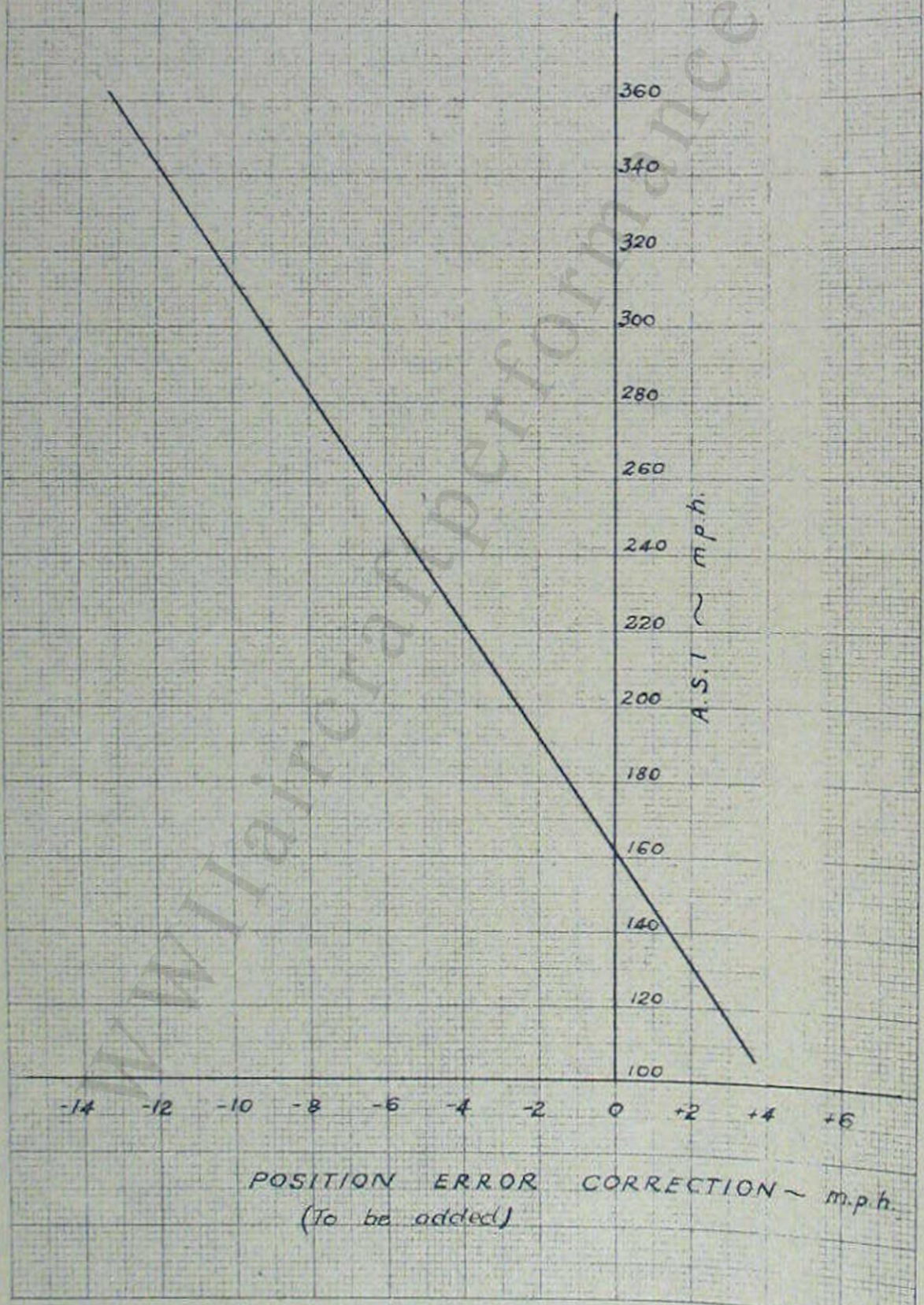
FIG 2

DATE 15-11-43

POSITION ERROR CORR'N.

SPITFIRE F Mk VIII

WT = 7690 lbs.



PREPARED BY	D.T.S. R.A.A.F. H.Q. T.S.7 SPECIAL DUTIES AND PERFORMANCE FLIGHT	FIG 3
CHECKED BY	ALTIMETER CORRECTIONS	DATE 17-11-43

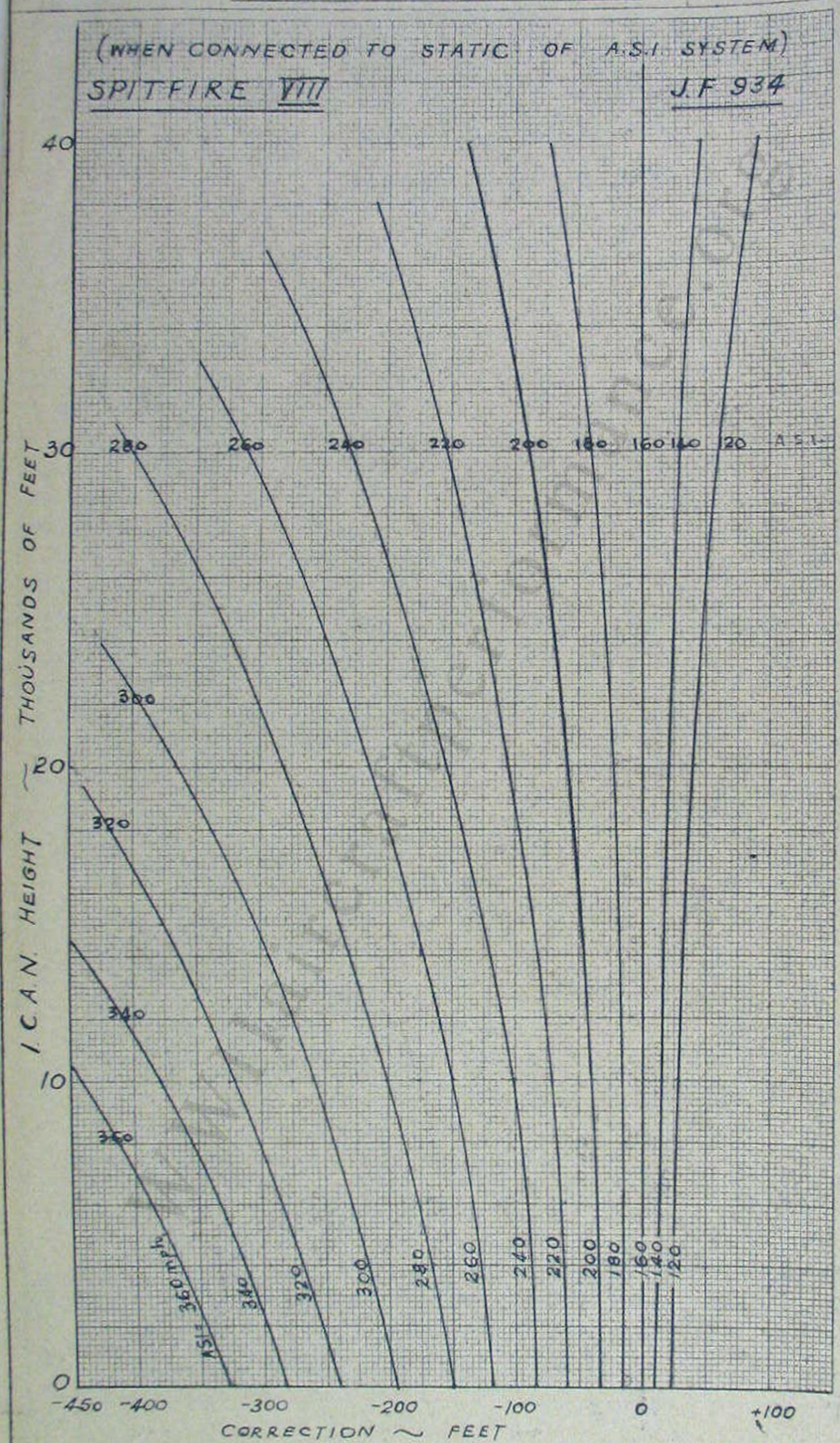


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FIG 4

LEVEL SPEEDS

DATE 21-12-43

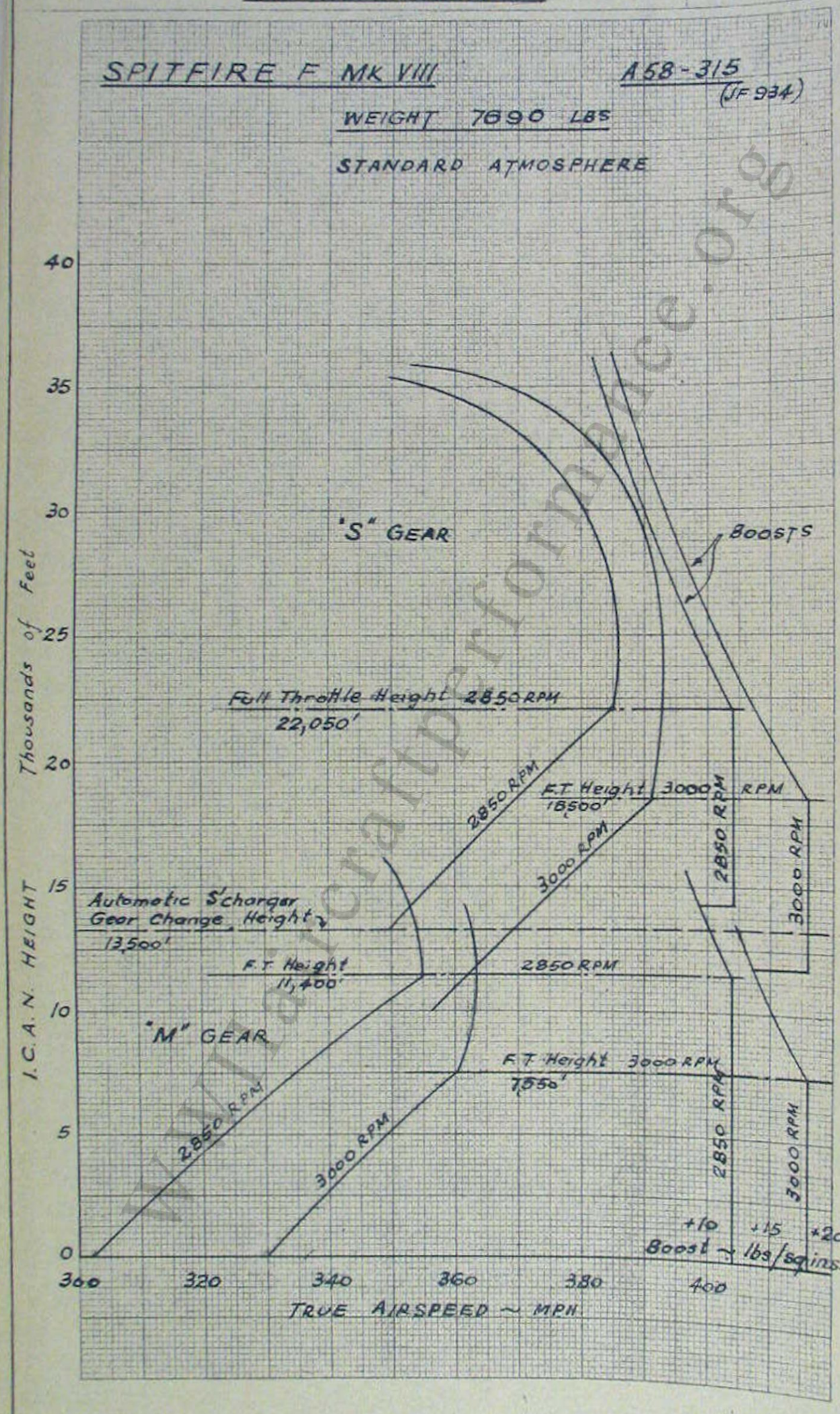

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FIG 5

CLIMBING TRIALS

DATE 30-12-43.

SPITFIRE F Mk VIII
A58-315

TAKE OFF WT 7690 lbs

STANDARD ATMOSPHERE

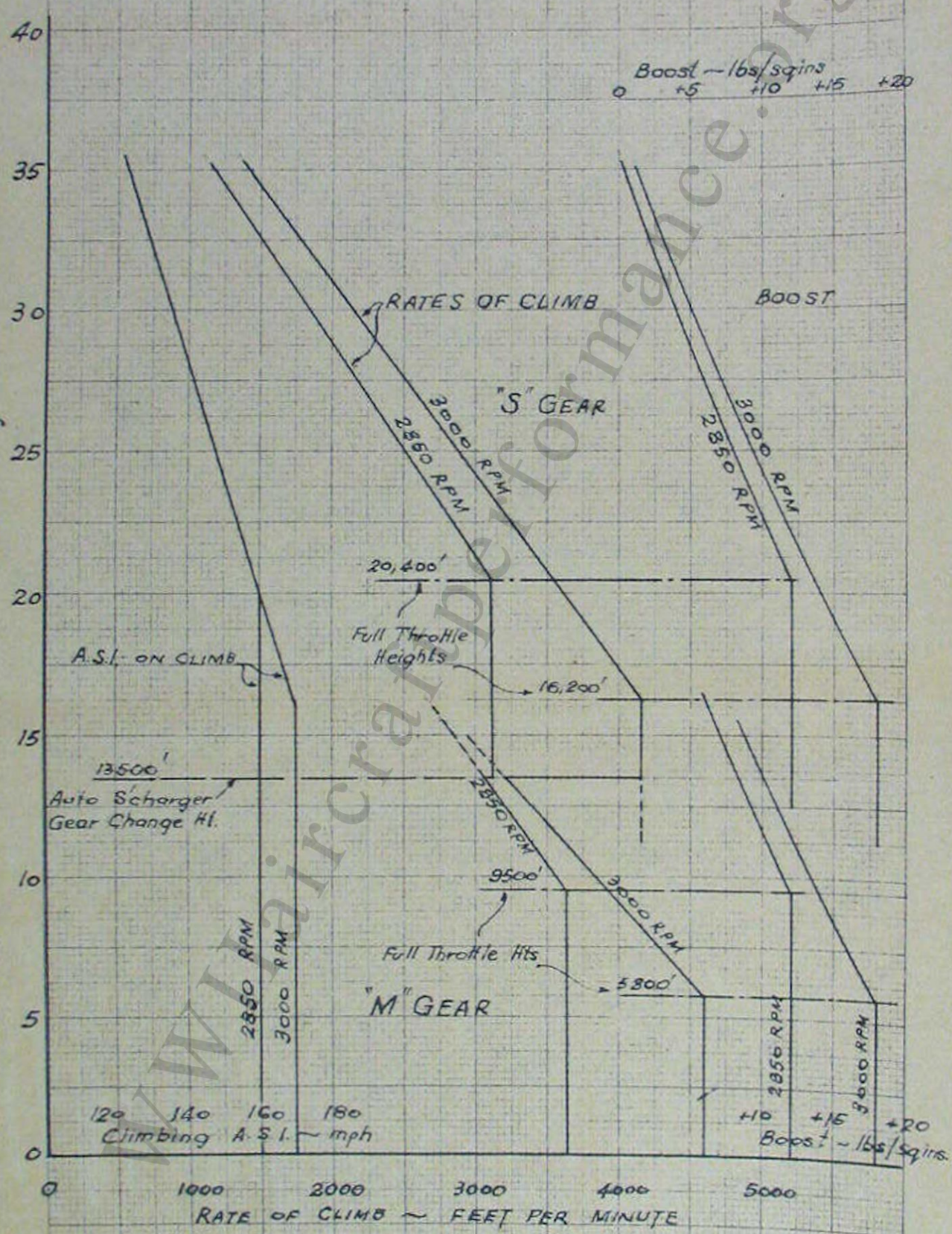

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FIG 6

TIMES TO HEIGHT

DATE 30/12/43

SPITFIRE F MK VIII
A58-315

TAKE OFF WT 7690 lbs.

STANDARD ATMOSPHERE

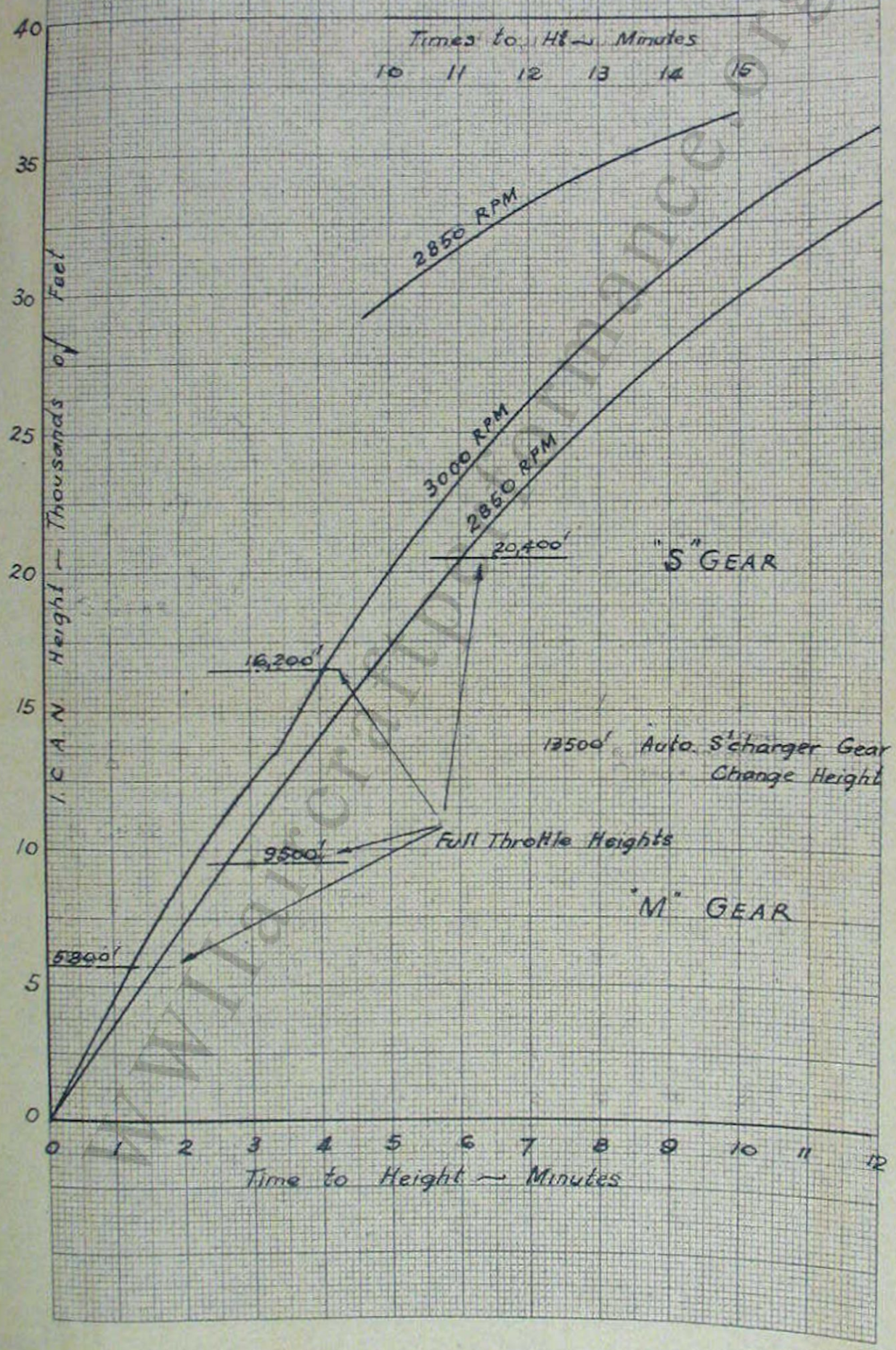

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FIG 7

DATE 21-12-43

TAKE OFF PATH

CORRECTED TO STANDARD SEA LEVEL CONDITIONS
ZERO WIND AND SLOPE. CONCRETE RUNWAYS

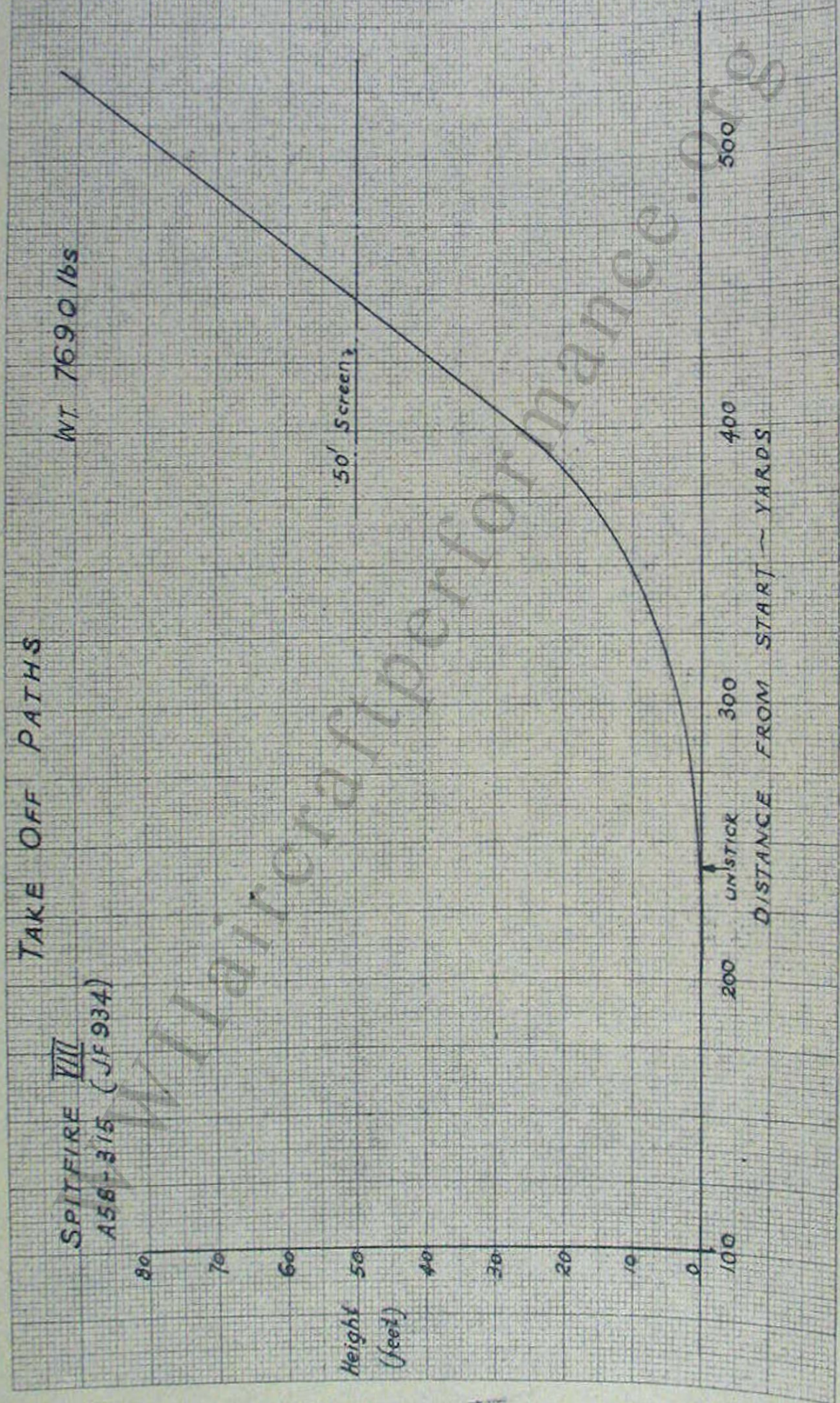

FIG. 8.

SIDE ELEVATION.

THREE QUARTER FRONT VIEW.

SPITFIRE MK. V111.