4th Part of Report No. A.& A.E.E./809.

5 Oct 1943

1102

AIRCRAFT AND ARMAMENT EXPERIMENTAL ESTABLISHMENT
BOSCOMBE DOWN

Hellcat F.N. 322
(Double Wasp R-2800-10)

Brief performance trials.

This report deals with the aircraft or equipment as tested. Action to remedy defects or decisions to accept items not in strict compliance with the specification are matters for decision & action by the Ministry of Aircraft Production.

A.& A.E.E. ref:- 4482/125 - AS.80.
M.A.P. ref:- RA.5381/04/R.D.N.3(a).
Period of tests:- July to August, 1943.

Progress of issue of report

Report No.	Title
1st Part of A.& A.E.E./809	F.N.323 - Weights and loading data.
2nd do.	F.N.323 - Carbon monoxide contamination tests.
3rd do.	F.N.323 - Flame damping trials with rearward facing multi exhaust pipes.

1. Introduction.

Performance trials have been made on the Hellcat aircraft. The tests were however confined to altitudes below 28000 feet due to the unsuitability of the magnetos for operation at higher altitudes.

Tests above that altitude will be made as soon as modification to the magnetos has been incorporated, and will form the subject of a further part of this report.

2. Condition of aircraft relevant to tests.

2.1. General. The Grumman Hellcat is a single seater, low wing fighter powered by a Double Wasp R-2800-10 engine, and intended for carrier based operations. It is of all metal construction except for the control surfaces, which are fabric covered. The following were the items of external equipment fitted:-

(i) Six 0.50" calibre machine guns, three in each wing, and with fairings around the gun barrels at the leading edge. The muzzles, but not the 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, just behind the pilot's hood, with an aerial running to a short mast on top of the tail fin.
The lead-in from the aerial enters the starboard side of the fuselage.

(iv) I.F.F. aerials from the tailplane tips to the fuselage.

(v) A whip aerial on the fuselage top approximately midway between the cockpit and the tail fin.

(vi) Cabin heater air intakes in the leading edge of the wing, just inboard of the armament.

(vii) A Kollsman type A.M.5816-2 pressure head carried on a strut from the leading edge at the starboard wing tip; details are given in Fig.1.

2.2. Engine installation and limitations. The Double Wasp R2800-10 engine has a two stage supercharger. The installation is shown diagramatically in Fig.2.

One stage of the supercharger, known as Main, is in operation at all times, the other known as Auxiliary can be employed in addition and has a two speed gear.

There is an intercooler between Auxiliary and Main stages. The carburettor is between the intercooler and the Main stage. When using Main stage the intake air passes through an air cleaner. When using Auxiliary stage however the air is not cleaned but can by selection from the pilot enter from the forward facing cold air intake or can be drawn in from the engine bay thus giving warm air.

/The pilot's

The pilot's supercharger control has three positions, Neutral, Auxiliary low, and Auxiliary high. The following table shows the results of having the lever in any of these positions and of having the air intake control at hot or at cold.

Pilot's supercharger control position	Supercharger engaged	Inter-cooler in or out	Air supply	
			With pilot's lever at cold air	With pilot's lever at hot air.
Neutral	Main stage only	Out	Cleaned warm air *	Cleaned warm air *
Auxiliary low	Main stage plus auxiliary at low speed	In	Cold air from forward facing intake - not cleaned	Warm air from inside cowling - not cleaned
Auxiliary high	Main stage plus auxiliary at high speed	In		

* Position of hot and cold air control has no effect when using main stage on i.e. pilots supercharger lever neutral.

The external air intake had a stone guard fitted.

The exhaust system consisted of ten individual pipes approximately 2" dia., eight of which each carried the exhaust from two cylinders, the remaining two pipes being each connected to a single cylinder. The system of F.N.323 was fully described and shown on a photograph in the 3rd Part of this Report. It was identical with that of F.N.322 used for these performance tests.

The following engine limitations applied at time of test:-

	R.P.M. (all super-charger gears)	Boost (Ins of Hg.)	
		Main	High and Low Aux.
Take-off (1000 ft. or 5 minutes limit)	2700	54	-
Climb (continuous)	2550	44	44
All-out level (5 mins. limit)	2700	52.5	52.5
Max. for cruising (rich mixture)	2550	44	44
" " " (weak ")	2200	32.5	32.5
Max. for diving	3050	52.5	52.5

The engine fitted bore the following numbers:-
Maker's:- 6115 A.M.:- A/59374

2.3. Propeller details :-

Make and type	: Hamilton Standard Hydromatic.
Type No.	: 23 E 50 - 499.
Serial No.	: 338777
No. of blades	: 3
Diam.	: 13' - 1"
Rotation	: R.H.
Material	: Metal
Pitch range	: 26° - 65°

2.4. Flap mechanism. The take-off and landing flaps which were of the slotted type, were operated by means of an electro-hydraulic system; manual control being available for emergency operation. Any intermediate position of the flaps could be selected as desired, the flap position being shown by an indicator connected to the port wing flap. There was however no mechanical interlinkage between port and starboard wing flaps, and it was thus possible for the flaps on one side to be at a different angle to the flaps on the other side. The calibration of the electrical flap position indicator is given below:-

Indicated setting		0°	15°	25°	35°	50°
Measured setting (Port side)	Inboard flap	0°	10°-0'	21°-0'	44°-35'	48°-5'
	Outboard "	0°	11°-20'	16°-50'	24°-35'	47°-10'

/The flaps

The flaps were spring loaded so that speed had to be reduced to 170 knots ASI before the flaps would start to lower. The flaps would not come down fully until speed was reduced to 93 knots ASI.

2.5. Loading. The aircraft was loaded to the normal typical Service load of 11400 lb. with the centre of gravity 27.8 ins. aft of the leading edge at Station 75.

3. Scope of tests.

The following tests were done:-

(i) Position error correction by the aneroid method in level flight with flaps and undercarriage up.
(ii) Climbs in both Main and Auxiliary Low Speed supercharger gears to 28,000 ft. at the best climbing speed as determined by partial climbs. The climbs had to be terminated at 28,000 ft., because of internal sparking in the magnetos experienced at altitude.
(iii) Level speed measurements at maximum permissible and maximum weak mixture cruise powers in Main and Auxiliary Low Speed supercharger gears between ground level and 24,000 feet.
(iv) Determination of the optimum flap setting for take-off; take-offs at various flap settings from 0° to 50° (full flap) being made from a grass airfield.

4. Results of tests.

The climb and level speed measurements have been corrected to standard atmospheric conditions, and the level speeds to a weight of 10850 lbs i.e. 95% of the take-off weight, by the methods of A.& A.E.E./Res/170.

The take-off results have been corrected to zero wind and standard atmospheric conditions by the methods of R & M 1172. The take-off run in zero wind has been corrected to that obtained in a 20 knot wind by the formula:-

$$S_{20} = S_0 \left(1 - \frac{20}{V}\right)^2 ,$$

where S_{20} = Take-off run in a 20 knot wind
S_0 = " " " a zero wind
V = Take-off speed in knots.

4.1. Position error correction. The position error correction, shown in Fig.3., was found to vary linearly from +14.2 mph at 300 mph ASI to +8.3 mph at 100 mph ASI. The correction to the altimeter, when connected to the static side of the airspeed system, is given in Fig.4.

4.2. Climb performance. The results are given in full in Table I and shown plotted in Fig.5. The following summarises the results obtained with cooling gills half open and oil cooler flap fully open.

Max. rate of climb in Main supercharger gear = 2260 ft/min at 5400 feet.
" " " " in Aux. Lowspeed " " = 1880 ft/min at 20500 feet.
Time to reach 10,000 ft. = 4.65 minutes
20,000 ft. = 10.0 minutes
Change gear height = 9200 feet.

4.3. Level speed performance. The following results given in Table II and shown graphically in Fig.6. were obtained in Main and Auxiliary Low speed superchargers with cooling gills and flap closed.

Max. T.A.S. at max. permissible power (rich mixture) = 315 mph (274 knots) at 2000 ft. in Main supercharger.

Max. T.A.S. at max. permissible power (rich mixture) = 371 mph (322 knots) at 18700 ft. in Aux. Low Speed supercharger.

/Maximum

Max. T.A.S. at max. weak mixture power = 288 mph (250 knots) at 11,10[illegible] ft., in Main supercharger.

True air Speed at 24,000 ft. at max. weak mixture power = 335 mph (291 knots) in Auxiliary Low Speed supercharger

4.4. Take-off performance. The take-off run and airborne path at varying flap angles in zero wind and standard atmospheric conditions are shown plotted in Fig.7., whilst the variation of take-off run with flap angle, and of the distance to clear a 50 foot obstacle, are given in Figs. 8 and 9 respectively.

The results (both obtained under the conditions of test and corrected to zero wind and standard atmosphere) are given below:-

Indicated flap angle δ	Atmospheric conditions			Under conditions of test			Corrd. to zero wind and standard atmosphere			Take-off run in 20 knot wind yds
	Ground temp °C	Ground press Ins Hg	Mean Wind mph	Take-off run yds	Dist. to clear 50' yds	Pilots ASI mph (knots)	Take-off run yds	Dist. to clear 50' yds	TAS at take-off mph (knots)	
0	+18	29.64	Zero	350	665	85 (74)	320	635	97 (84)	185
15	↓	↓	↓	325	610	79 (69)	305	580	93 (81)	175
25				305	585	78 (68)	290	580	95 (83)	165
35				280	545	77 (67)	275	540	88 (76)	150
50				285	470	69 (60)	265	455	84 (73)	150

It will be seen from above that full flap gives the shortest take-off run and distance to clear a 50 ft. obstacle.

4.4 1. Take-off characteristics and technique. There was a tendency for the aircraft to swing to port, but this was not serious, and was readily corrected by application of rudder. The tail wheel was locked during take-off. The tail of the aircraft was not raised during the take-off run, the aircraft being allowed to fly itself off. There was ample take-off power and the initial acceleration was high. It might prove dangerous to attempt to raise the tail on a bumpy grass airfield, as the propeller ground clearance is not large on this aircraft.

It was found desirable, when using full flap, to have the elevator trimmer set 4 divisions nose-up, to reduce the force required on the control column at take-off. Zero elevator trim was found best for the case of no flap, and at intermediate flap settings the elevator trimmer may be adjusted in proportion.

Immediately on becoming airborne when using full flap there was noticeable lateral instability and a tail heavy change of trim; these conditions quickly disappeared as speed was increased however. It is felt that this temporary change of trim may prove troublesome at night, especially if the centre of gravity were further back; under these conditions about 20° flap only should be used at take-off.

5. Further developments.

Further take-off trials using the optimum flap setting as determined above are to be made at the overload fighter loading; these, with engine cooling and fuel consumption trials, will form the basis of further parts of this report.

/Table I.

TABLE I

Performance on climb

Weight:- 11,400 lb. Cooling gills ½ open
Intercooler and oil cooler flap fully open.

Standard height feet	Rate of climb (Ft/Min)	Time from start (Mins)	ASI mph (knots)	TAS mph (knots)	R.P.M.	Boost (Ins of Hg)	Super-charger gear
0	2260	0	-	-	-	-	Main
2000		0.9	150 (130)	165 (143)	2550	44.0	
4000		1.8		170 (148)			
* 5400		2.4		173 (150)			
6000	2200	2.65		175 (152)		43.0	
8000	2000	3.6		180 (156)		40.1	
≠ 9200	1880	4.25		183 (159)		38.3 / 44.0	Auxiliary low speed
10000		4.65		186 (162)			
12000		5.7		192 (167)			
14000		6.75		198 (172)			
16000		7.85		204 (177)			
18000		8.9		211 (184)			
*20500		10.25		219 (190)			
22000	1670	11.1	146 (127)	219 (190)		41.2	
24000	1400	13.35	142 (123)	221 (192)		37.8	
26000	1120	13.95	138 (120)	222 (193)		35.0	
27000	980	15.0	136 (118)	223 (194)		33.7	
28000	840	16.1	134 (116)	224 (195)		32.7	

* Full throttle heights. ≠ Change gear height.

TABLE II

Level speed performance

Mean weight:- 10,850 lb. Cooling gills closed
Intercooler and oil cooler flap shut

Standard height feet	TAS mph (knots)	ASI mph (knots)	Corrections m.p.h. P.E.	Corrections m.p.h. C.E.	R.P.M.	Boost (Ins of Hg)	Mixture	Supercharger gear
* 2000	315 (274)	292 (254)	+14.0	-0.9	2700	52.0	Auto rich	Main
4000	314 (273)	284 (247)	+13.7	-1.0		48.6		
≠ 6000	314 (272)	275 (239)	+13.4	-1.4		45.5 / 52.0		Auxiliary low speed
8000	323 (280)	274 (238)	+13.3	-1.3				
10000	332 (288)	273 (237)	+13.3	-1.3				
12000	341 (296)	272 (236)	+13.3	-1.2				
14000	350 (304)	270 (235)	+13.3	-1.1				
16000	359 (312)	268 (233)	+13.2	-1.0				

/Table contd..

TABLE II contd.

Level speed performance

Mean weight:- 10,850 lb. Cooling gills closed

Intercooler and oil cooler flap shut

Standard height feet	TAS mph (knots)	ASI mph (knots)	Corrections m.p.h. P.E.	Corrections m.p.h. C.E.	R.P.M.	Boost (Ins of Hg)	Mixture	Supercharger gear
* 18700	371 (322)	264 (229)	+13.1	-0.9	2700	52.0	Auto rich	Auxiliary low speed
20000	370 (322)	258 (224)	+13.0	-0.8		49.4		
22000	369 (321)	248 (215)	+12.7	-0.7		45.8		
24000	367 (319)	239 (208)	+12.3	-0.6		42.6		
0	238 (207)	227 (197)	+12.0	-0.6	2200	33.0	Auto weak	Main
2000	247 (215)	228 (198)	+12.1	-0.6				
4000	256 (223)	230 (200)	+12.2	-0.6				
6000	265 (230)	231 (201)	+12.2	-0.6				
8000	274 (238)	231 (201)	+12.2	-0.6				
10000	283 (246)	232 (202)	+12.2	-0.6				
* 11100	288 (250)	232 (202)	+12.2	-0.6				
12000	287 (249)	228 (198)	+12.1	-0.5		31.8		
/ 13300	285 (248)	221 (192)	+11.8	-0.4		30.2 / 33.0		Auxiliary low speed
14000	288 (250)	221 (192)	+11.8	-0.4				
16000	298 (259)	221 (192)	+11.8	-0.3				
18000	307 (267)	220 (191)	+11.8	-0.3				
20000	317 (275)	220 (191)	+11.8	-0.2				
22000	326 (283)	219 (190)	+11.7	-0.1				
24000	335 (291)	217 (189)	+11.7	-0				

* Full throttle heights

/ Change gear heights

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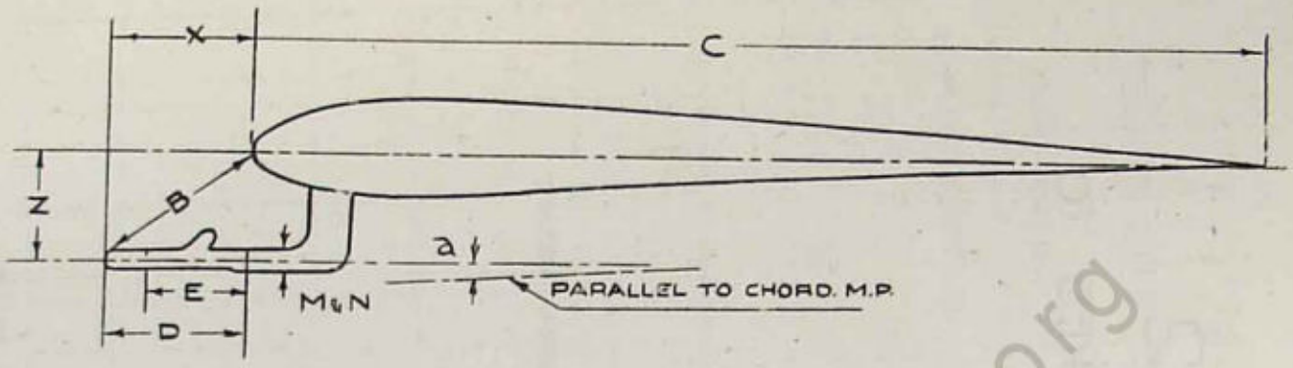
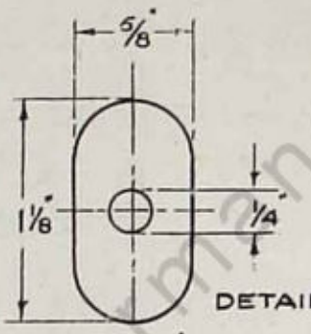
HELLCAT FN 322 Fig.1

PRESSURE HEAD POSITION





DETAIL OF APERTURE.

TYPE OF PRESSURE HEAD. AN 5816-2 24 VOLT SER. Nº 4904 KOLLSMAN.

RATIO OF APERTURE OF TUBE TO EXTERNAL DIA. OF STATIC TUBE SEE SKETCH

INCIDENCE OF MAIN PLANE (ADJACENT TO PRESSURE HEAD) 0° - 50'

a ANGLE OF STATIC TUBE TO CHORD OF MAIN PLANE + 1° - 50'

B NOSE OF STATIC TO MAIN PLANE (MINIMUM DISTANCE) 11"

D " " " " " SUPPORTING STRUT 9"

Z " " " " " CHORD LINE 6½"

X " " " " M.P. LEADING EDGE (PARALLEL TO CHORD) 9½"

E STATIC HOLES TO STRUT (MEAN) 5 7/16"

C LENGTH OF CHORD AT SECTION 5' - 3"

M MAJOR AXIS OF STRUT. 1¼" AT P.H. TO 3" AT WING

N MINOR " " " 1¼"

DISTANCE FROM PLANE OF SYMMETRY 20' - 10"

POSITION UNDERSIDE STBD. M.P.

SEMI SPAN 21' - 4"

RATIO OF THICKNESS TO CHORD OF AEROFOIL SECTION, ADJACENT TO PRESSURE HEAD. 8%

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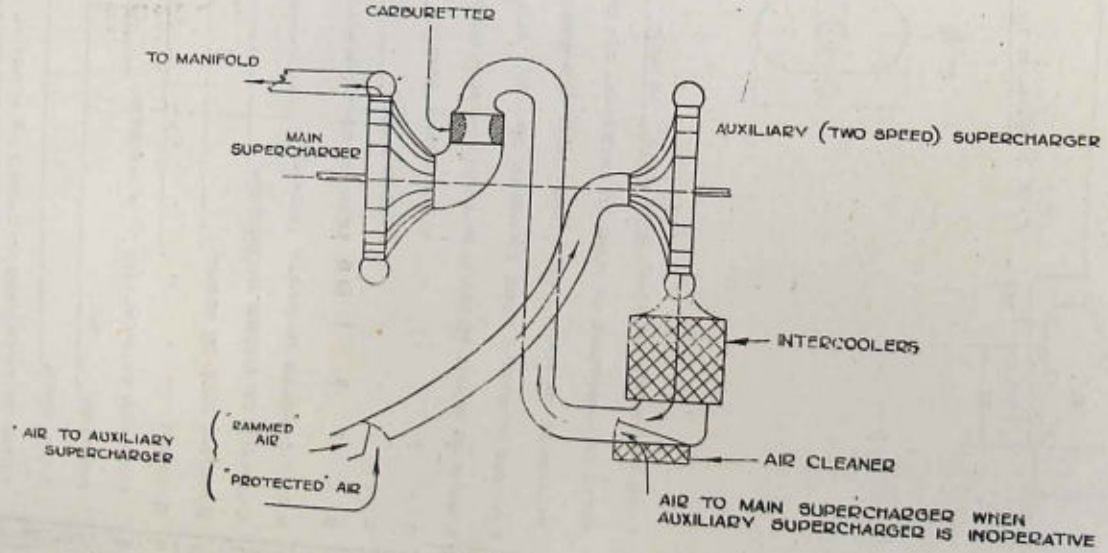
HELLCAT FN 322

DIAGRAMATIC ARRANGEMENT OF AIR INTAKES TO SUPERCHARGERS

Fig. 2



HELLCAT FN 322 (DOUBLE WASP R-2800-10)

PERFORMANCE ON CLIMB

COOLING GILLS ½ OPEN — WEIGHT ~ 11,400 lb — INTERCOOLED AND OIL COOLED FLAP OPEN

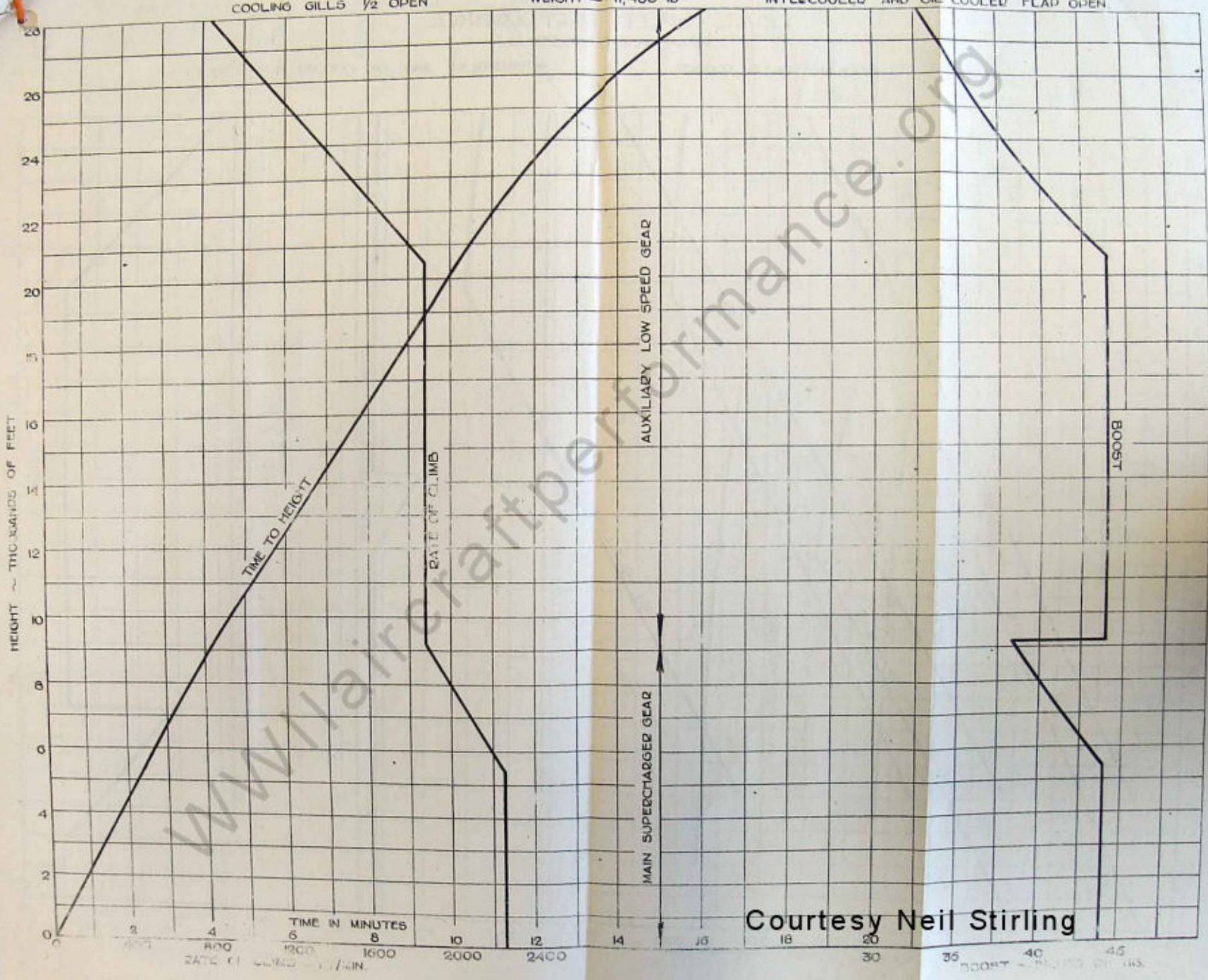


FIG. 6

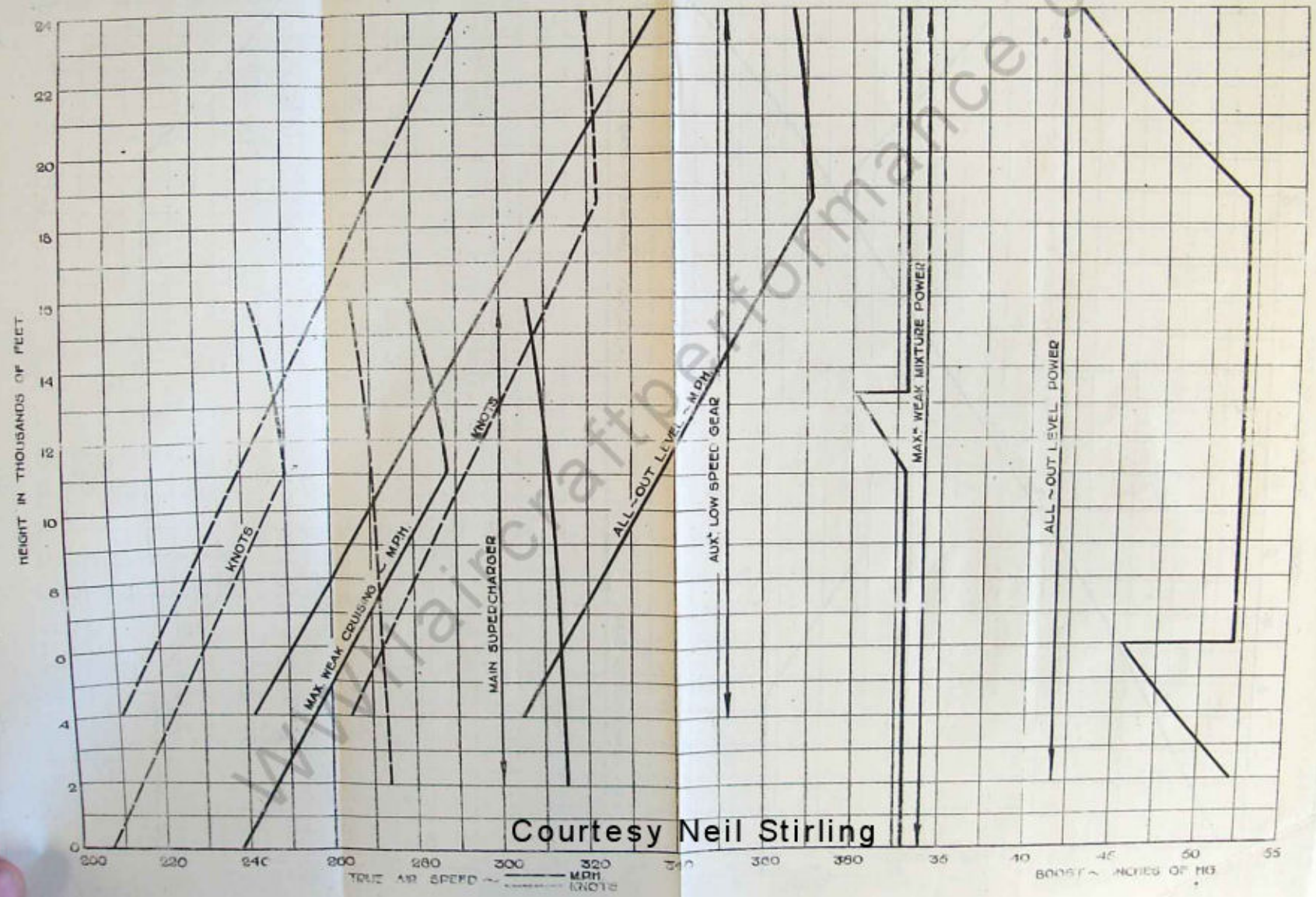
HELLCAT FN-322

(DOUBLE WASP R-2800-10)

LEVEL SPEED PERFORMANCE.

MEAN WEIGHT ~ 10,850 lb.

COOLING GILLS CLOSED. INTERCOOLER AND OIL COOLER FLAP CLOSED



HELLCAT FN 322

Fig.3

(DOUBLE WASP R-2800-10)

POSITION ERROR CORRECTION

WEIGHT ~ 11,400 lb

FLAPS AND UNDERCARRIAGE UP