Lockheed Report 487.

This is a facsimile of an engineering report produced in June 1936 by Lockheed engineers Clarence L. "Kelly" Johnson and W. C. Nelson entitled "Report No. 487 – Range Study of Lockheed Electra Bimotor Airplane."

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RANGE STUDY OF LOCKHEED ELECTRA BIMOTOR AIRPLANE.

No. of Pages - 37

No. of Photographs - 0

By -
C.L. Johnson
W.C. Nelson

INDEX.
******

INTRODUCTION.
****

This report contains a complete study of the factors determining the maximum practical range of the Lockheed Electra Model 10E bimotor airplane. The problem is gone into in considerable length in order that complete recommendations may be made as to optimum methods of take-off, climb and level flight. Such factors as the effect of altitude, wind, variation of propulsive efficiency at constant forward speed, and variation of specific fuel consumption are all included in the study. As a summary, curves are given showing the recommended values of the above throughout a flight of the greatest possible range.

The airplane under consideration is a Model 10E Electra equipped with Pratt and Whitney S3H1 engines rated 600 BHP at 2300 rpm for take-off and not more than 412 BHP at 2000 rpm for cruising. To enable close control to be maintained over the mixture strength, a Cambridge gas analyzer is connected into the exhaust system. Hamilton Standard constant rpm, controllable pitch propellers are used. Added to this equipment is a Sperry Gyro-Pilot to lessen fatigue during long flights.

The engine operating conditions have been given careful consideration in recommending a flight procedure. Combinations of rpm and manifold pressure are chosen with regard to engine reliability and smoothness as well as optimum propulsive efficiency.

SUMMARY AND RECOMMENDATIONS.
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The complete performance has been computed conservatively based on actual flight test results on Model 10E*. Fuel consumption data is based on results which have been obtained in flight with careful mixture control. To get a range of 4500 miles it will be necessary to calibrate the Cambridge Analyzer so that the fuel consumption curve shown on page 13 can be obtained.

SUMMARY AND RECOMMENDATIONS.

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The important results from the report may be summarized as follows:

(1). Best take–off distance is obtained using a 30° wing flap setting. The tail of the airplane should be lifted off the ground as soon as possible and held up through the take–off run.

(2). On a hard run–way, using 600 BHP per engine, the take-off distance is 2100 feet at sea level.

(3). Climb after take-off with a gross weight of 16,500# is 500 feet per minute with wing flaps at 30° (using take-off power).

(4). After obtaining a safe altitude (50 to 100 feet), the flaps should be retracted and the engine power reduced to 550 BHP per engine at 2200 rpm.

(5). The climb should be continued at this power to an altitude of 2000'.

(6). At 2000', the power should be reduced to 380 BHP/engine and the flight continued at the values of altitude, power, rpm and speed shown on the inclosed curve.

(7). During the maximum range flight, the following considerations apply:

a. Variation of altitude from that specified by amounts as much as 2000' (except in the heavy load condition) has very little effect on the range.

b. With headwinds or tails winds up to 20 mph, the best airspeed is wthin 5 mph of that shown on the flight procedure curve.

c. When the wind increases with altitude, the load condition, and power conditions should be carefully considered when choosing an altitude different than that shown on the curves. No strict rules can be given covering the optimum flight procedure with varying wind gradients with altitude.

d. Increase the power output when climbing from one altitude to another. Climb at an indicated speed of 120 to 130 mph.

SUMMARY AND RECOMMENDATIONS.
****

Continuing the discussion of important factors during the maximum range flight -

e. Watch the mixture closely at all times. The engines must be run very lean.

f. In climb when the power output is increased, check the mixture and head temperatures.

g. When about 100 to 150 miles from the end of the flight, put the ship in a power glide losing about 250 to 300 feet of altitude per minutes while maintaining cruising power output.

h. The best average altitude at which to fly and the best power output are shown on the flight procedure curve. The lighter the load, the higher the density altitude for best range.

i. Standard carburetor air temperature has been assumed in choosing manifold pressures and rpm to obtain a given power. Normal deviations of carburetor air temperature likely to be encoucntered may be neglected.

j. If icing conditions are encountered, so that carburetor heat must be applied, the mixture may have to be richened somewhat to prevent detonation in the engines. Normally, the carburetor heat should be set to "FULL COLD".

DISCUSSION.
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The computations and most of the basic curves are given in an attached appendix. In attacking the problem, complete calculations of the altitude-speed-power characteristics of the airplane with three different gross weights were made to get the optimum operating conditions. Most of the final curves are derived using graphical integration of the basic curves.

Methods of computation are given in the Appendix and no further discussion on procedure will be given here. Perhaps the simplest way to give the results of the complete study is to comment on each of the final curves presented.

DISCUSSION OF CURVES DERIVED.

****

The various curves are denoted by figure numbers at the bottom of each sheet. The important points about each figure will be discussed in turn:

FIGURE I.

This is the curve sheet which summarizes the results of the maximum range study. Starting with a gross weight of 16,500# (1200 gallons of fuel), the elapsed time and distance in air miles is shown plotted against the optmum operating conditions of the airplane and engine. This curve should greatly simplify the pilot's duties.

FIGURE II.

The effect of head winds and tail winds on the optimum flight speed for a typical case is plotted. For a 20 mph head wind, the indicated airspeed should be increased about 4 mph for the heavy load conditioin. For the 20 mph tail wind, the speed should be decreased about the same amount. Values for other load conditions and wind speeds can be obtained from this chart. It applies exactly to sea level only, but the trends shown apply fairly well to the range of altitudes likely to be used.

FIGURE III.

The best speeds, power output and the elapsed time for the longest range flight using the most conservative fuel consumption curve is plotted against distance. This curve was modified and approximated to get Figure I. It is interesting to note that over a fairly wide range of power and speeds, the airplane efficiency is constant, so that the same range can be obtained with considerable difference in elapsed time. The flight procedure outlined in Figure I is based on the lower power output at the beginning of the flight and the higher power over the greater part of the flight so that a low elapsed time can be obtained with the engine operating at its best efficiency and reliability.

FIGURE IV.

Figure IV shows the variation of gross weight and best altitude in the maximum range flight.

DISCUSSION OF CURVES DERIVED.

****

FIGURE V.

Figure V shows the effect of altitude and power output on the air miles per gallon for the airplane at three different gross weights. Neglecting any wind gradient, it will be seen from the curves how little gain there is in flying at a high altitude over the major part of the distance considered. With the highest gross weight, there is a definite disadvantage in flying higher than 2000'.

FIGURE VI.

This curve was derived to show the minimum amoun of fuel necessary to go various distances less than the maximum range. It also shows the gross weight with the above amount of fuel. In order to increase the cruising speed for distances less than the maximum, more fuel than that shown will be taken along so that higher power outputs may be used. This curve is based on the conservative fuel consumption curve.

FIGURE VII.

Figure VII is a collection of various curves showing specific fuel consumption, optimum power and weight conditions and the effect of gross weight on best fuel consumption per mile. The fuel consumption curves are average propeller load curves which apply to the average pitch settings of the propeller and throttle setting of the engine during the flight. The higher curve has been referred to as the "conservative curve". The lower curve which reaches a minimum specific fuel conssumption of .42 #/BHP/Hr. is the one which must be obtained to get 4500 mile range.

The other curves shown on Figure VII are self explanatory.

FIGURE VIII.

Figure VIII is also a collection of curves used to derive the best flight procedure. The decrease in miles per gallon with increased gross weight, and the corresponding increase in speed for best range as the gross weight is increased are very interesting.

FIGURE IX.

Figure IX gives the engine and propeller data for take-off calculations and the effect of flap setting on take-off distance at sea level. The computations are based on having a good hard run-way and using the best take-off technique. The tail should be lifted as soon as possible for the minimum take-off run. The rate of climb after take-off is also shown for all flap settings.

ADDITIONAL DATA.

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Engine power curves of two types are included in Figures X and XI. The normal cruising chart at the ATC gross weight is also furnished on page 16. The increase in gross weight from 10,500# to the average weight throughout the maximum range flight (namely 12,900#) cuts down the high speed to 200 mph at 10,000' at 450 BHP output per engine. High speed at sea level with a gross weight of 16,500# and 450 BHP/engine is 177 mph.

CONCLUSIONS.

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As a result of the study just concluded, the following results are obtained:

(1). It is possible to fly a Lockheed Electra Model 10E non-stop for a distance between 4100 and 4500 miles starting out with 1200 gallons of gasoline and the proper amount of oil.

(2). The above range is for zero wind conditions. The procedure outlined in this report should be followed to get optimum results. This is especially true in regard to maintaining proper engine mixture control.

(3). The Cambridge Gas Analyzers should be carefully calibrated in flight to see if the fuel consumption data used in this analysis can be obtained. This should be done before attempting any long range flight.

(4). The airspeed indicator must be calibrated for pitot-static position error.

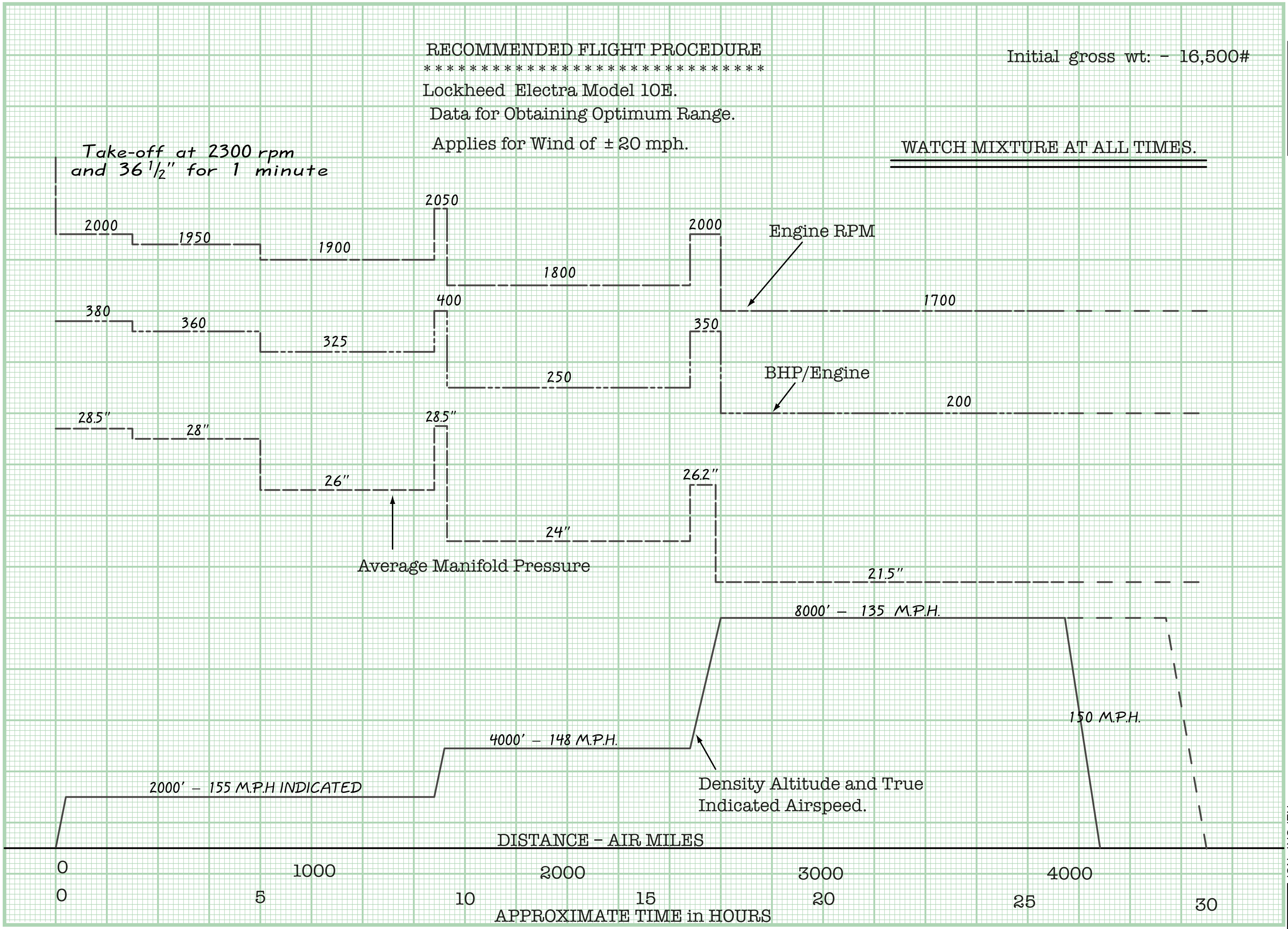
(5). Low power output flights should be made with the leanest mixture setting to be used to check the engine head temperatures. They may run too cool so that a shutter arrangement might have to be made so that the head temperatures can be kept up to the value giving best engine efficiency.

(6). Do not draw more than 600 BHP for one minute on the take-off. Cut back the power as soon as it is safe.

FORM 107

KEUFFEL & ESSER CO., N.Y. NO. 359-14
Millimeters, 10th line heavy.

FIGURE I.



ANALYSIS Range
PREPARED BY C.L. Johnson
DATE June 3, 1936

LOCKHEED AIRCRAFT CORP.

PAGE 7
MODEL 10E
REPORT NO. 487

LOCKHEED AIRCRAFT CORP.

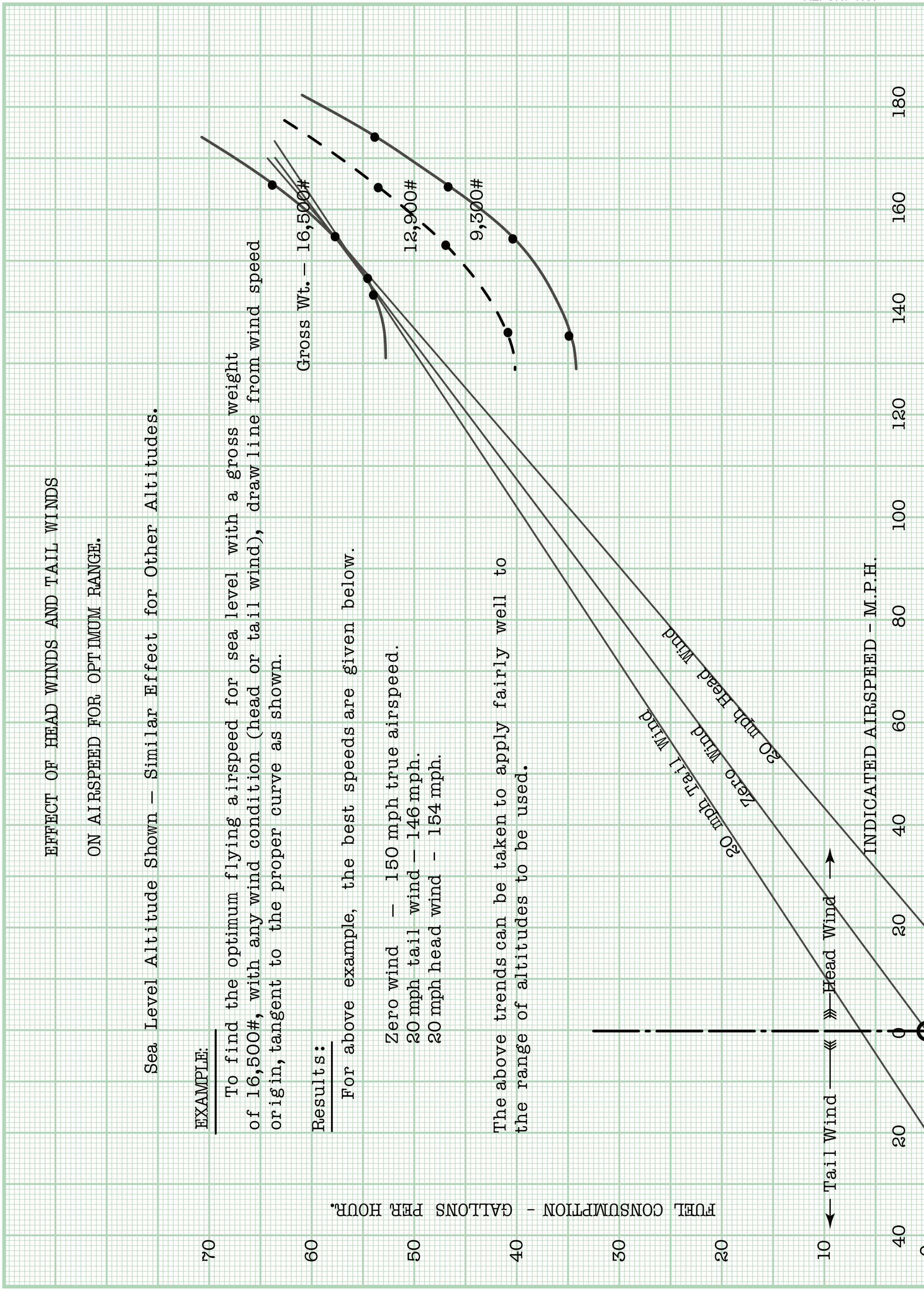


FIGURE II.

ANALYSIS Range
PREPARED BY W.C. Nelson.
DATE 5-18-36.

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PAGE 9
MODEL 10E
REPORT No. 487

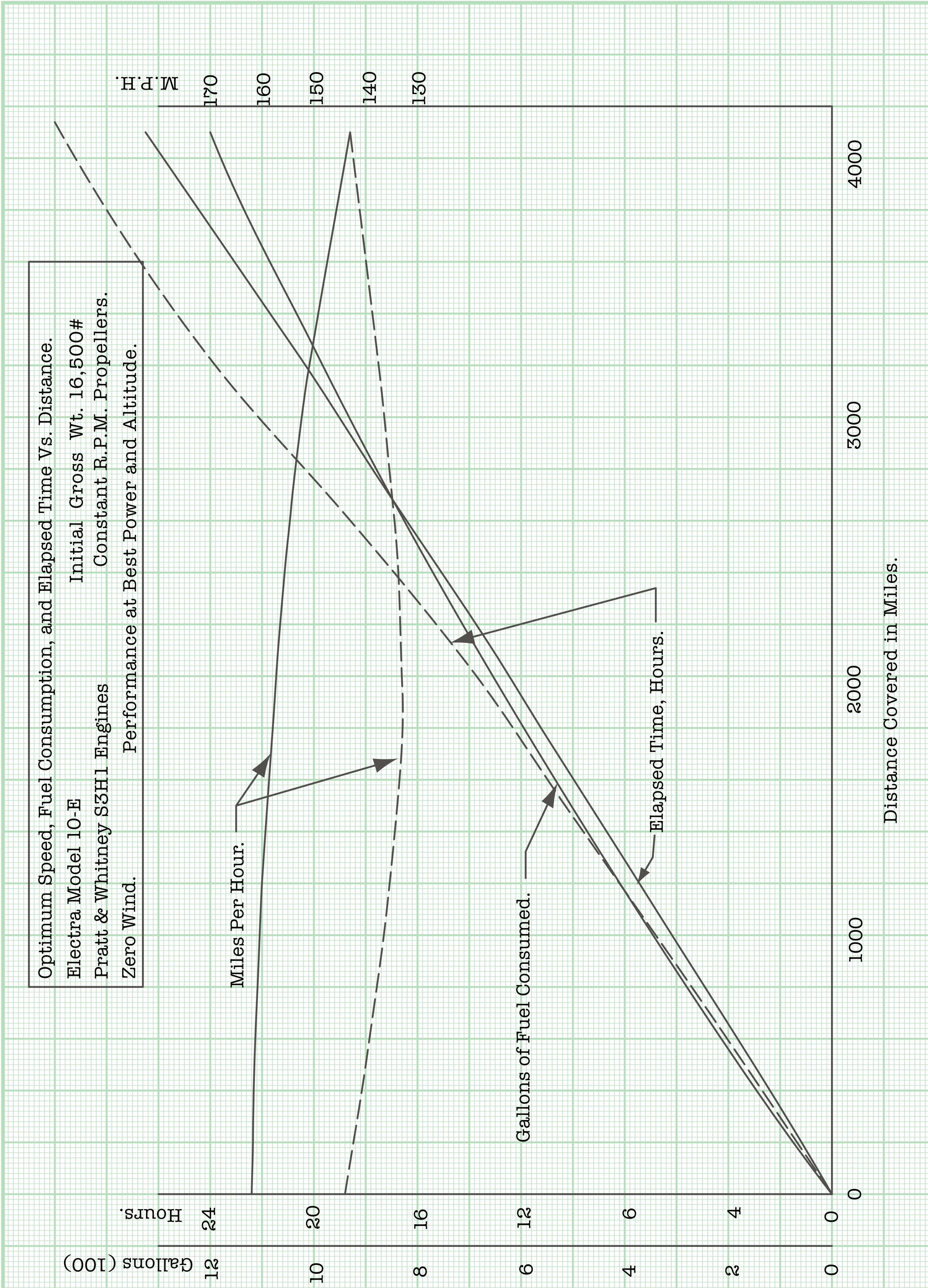


FIGURE III.

analysis Range
prepared by W.C. Nelson.
date 5-18-36.

LOCKHEED AIRCRAFT CORP.

model 10E
report no. 487

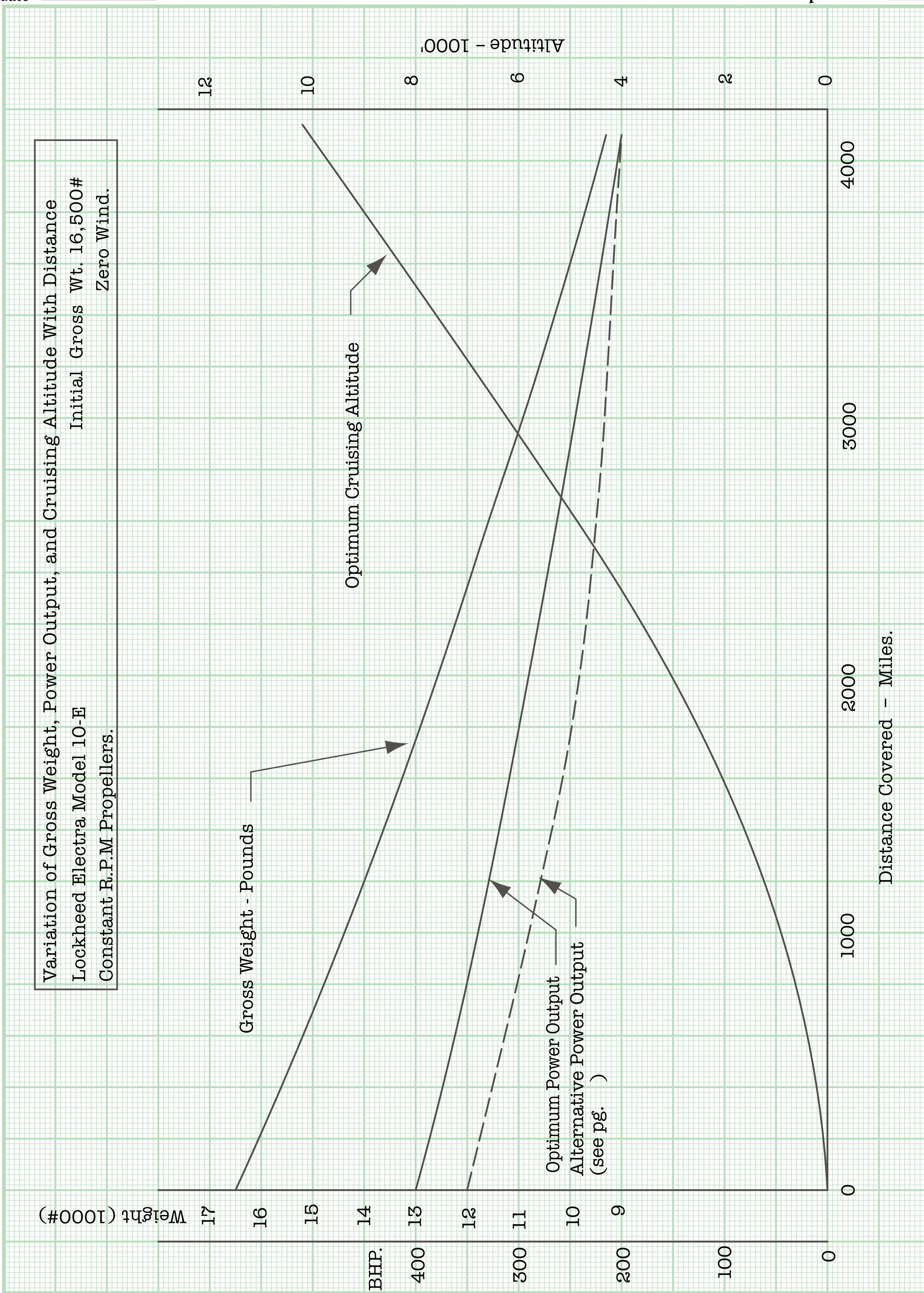


FIGURE IV.

KEUFFEL & ESSER CO., N.Y. NO. 359-14
Millimeters, 10th line heavy.

FORM 107

ANALYSIS Range
PREPARED BY W.C. Nelson.
DATE 5-18-36.

LOCKHEED AIRCRAFT CORP.

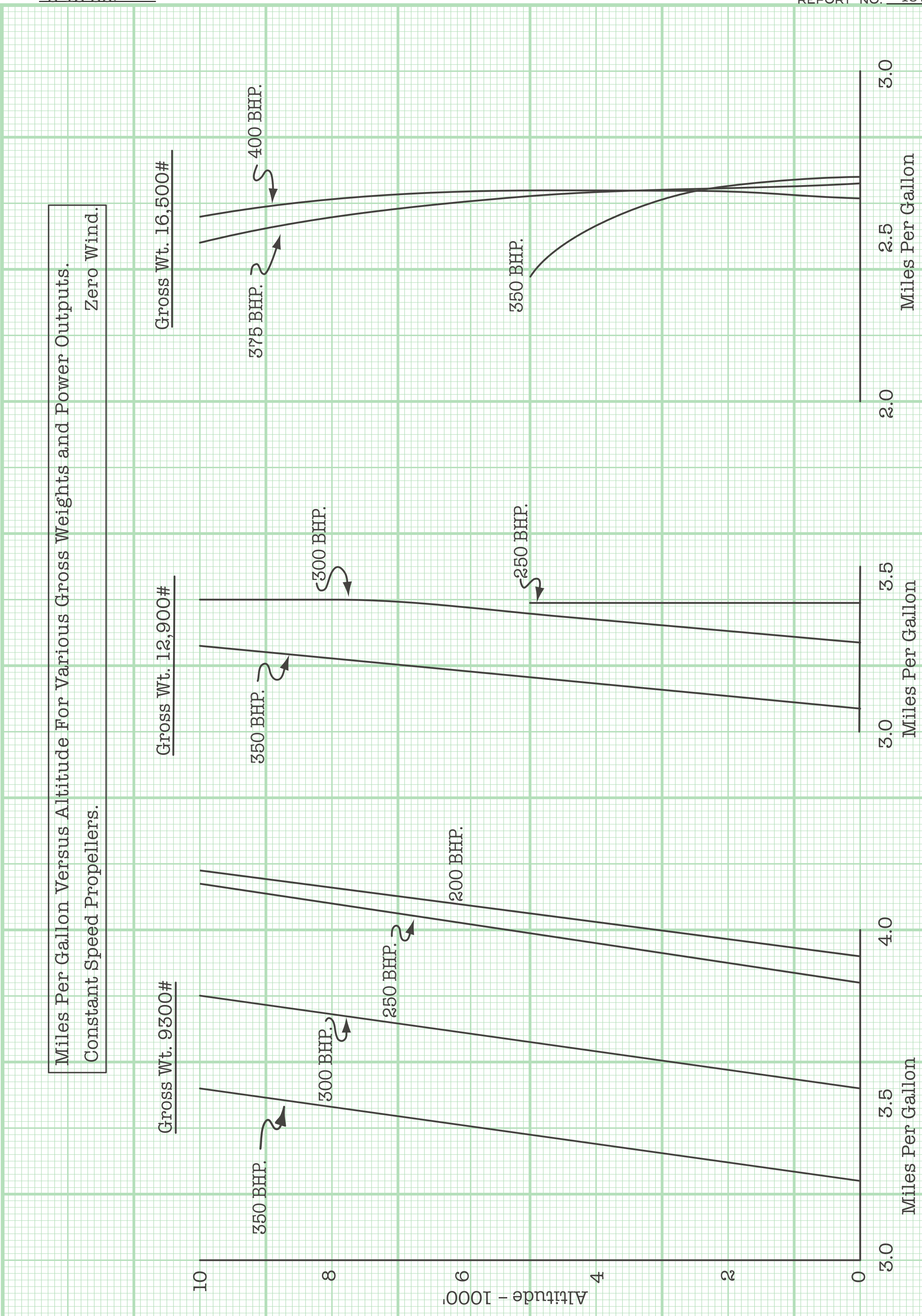


FIGURE V.

ANALYSIS Range
PREPARED BY W.C. Nelson.
DATE 5-18-36.

LOCKHEED AIRCRAFT CORP.

PAGE 12
MODEL 10E
REPORT NO. 487

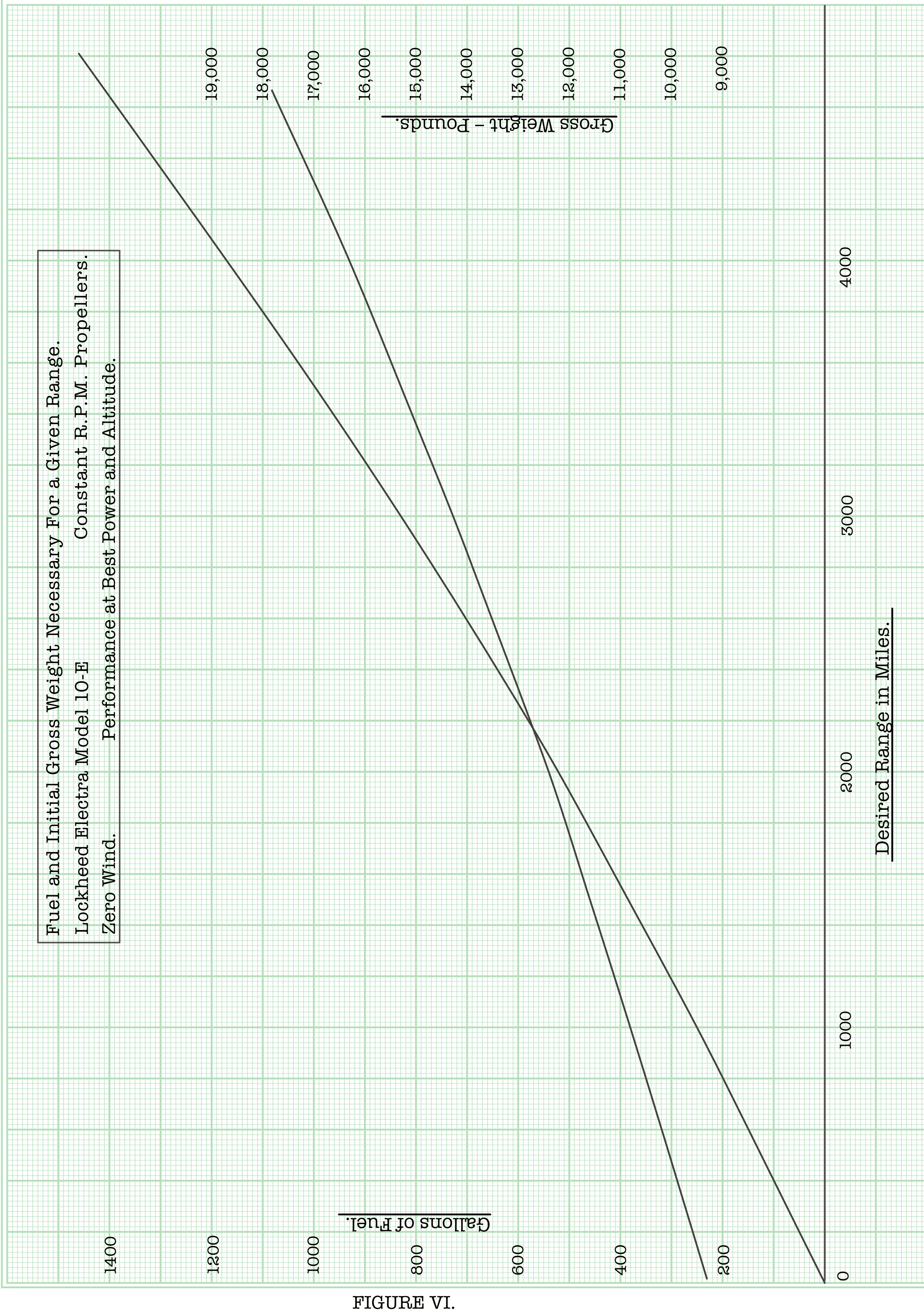


FIGURE VI.

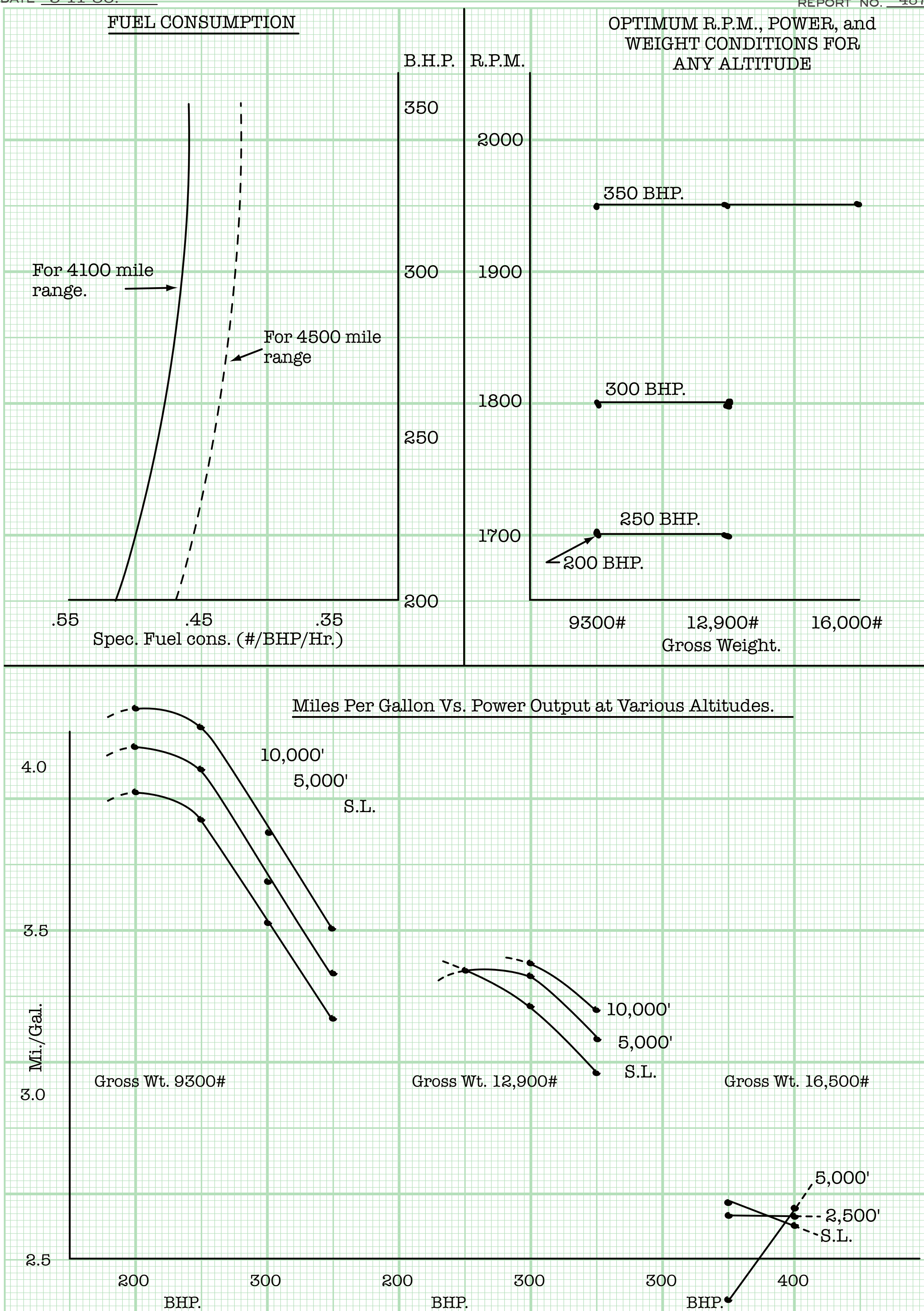

FUEL CONSUMPTION
B.H.P.
350
300
250
200
For 4100 mile range.
For 4500 mile range
.55
.45
.35
Spec. Fuel cons. (#/BHP/Hr.)
R.P.M.
OPTIMUM R.P.M., POWER, and WEIGHT CONDITIONS FOR ANY ALTITUDE
2000
1900
1800
1700
350 BHP.
300 BHP.
250 BHP.
200 BHP.
9300#
12,900#
16,000#
Gross Weight.
Miles Per Gallon Vs. Power Output at Various Altitudes.
4.0
3.5
3.0
2.5
Mi./Gal.
10,000'
5,000'
S.L.
Gross Wt. 9300#
Gross Wt. 12,900#
Gross Wt. 16,500#
2,500'
200
300
400
BHP.

FIGURE VII.

ANALYSIS Range
PREPARED BY W.C. Nelson.
DATE 5-18-36.

LOCKHEED AIRCRAFT CORP.

PAGE 14
MODEL 10E
REPORT NO. 487

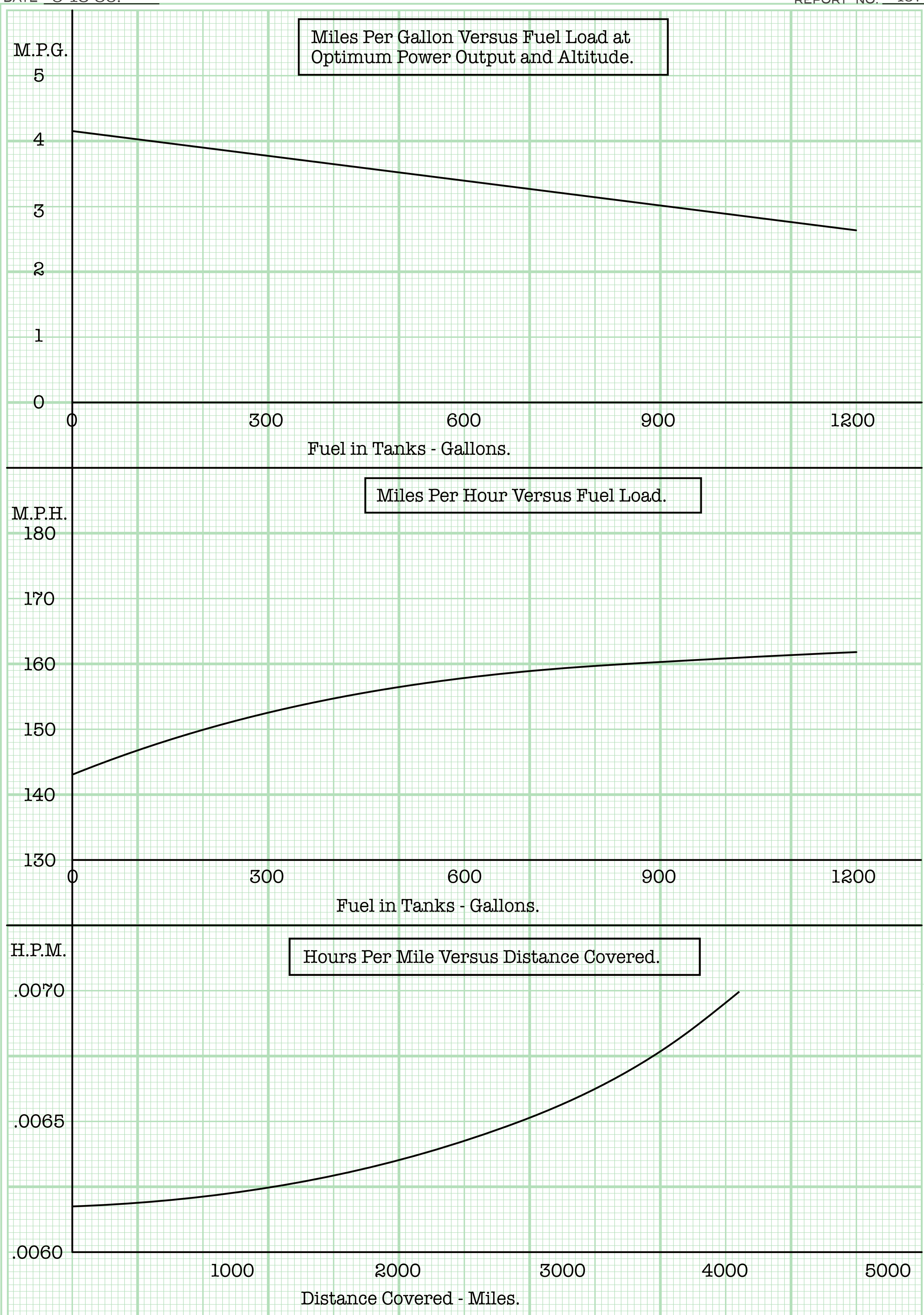
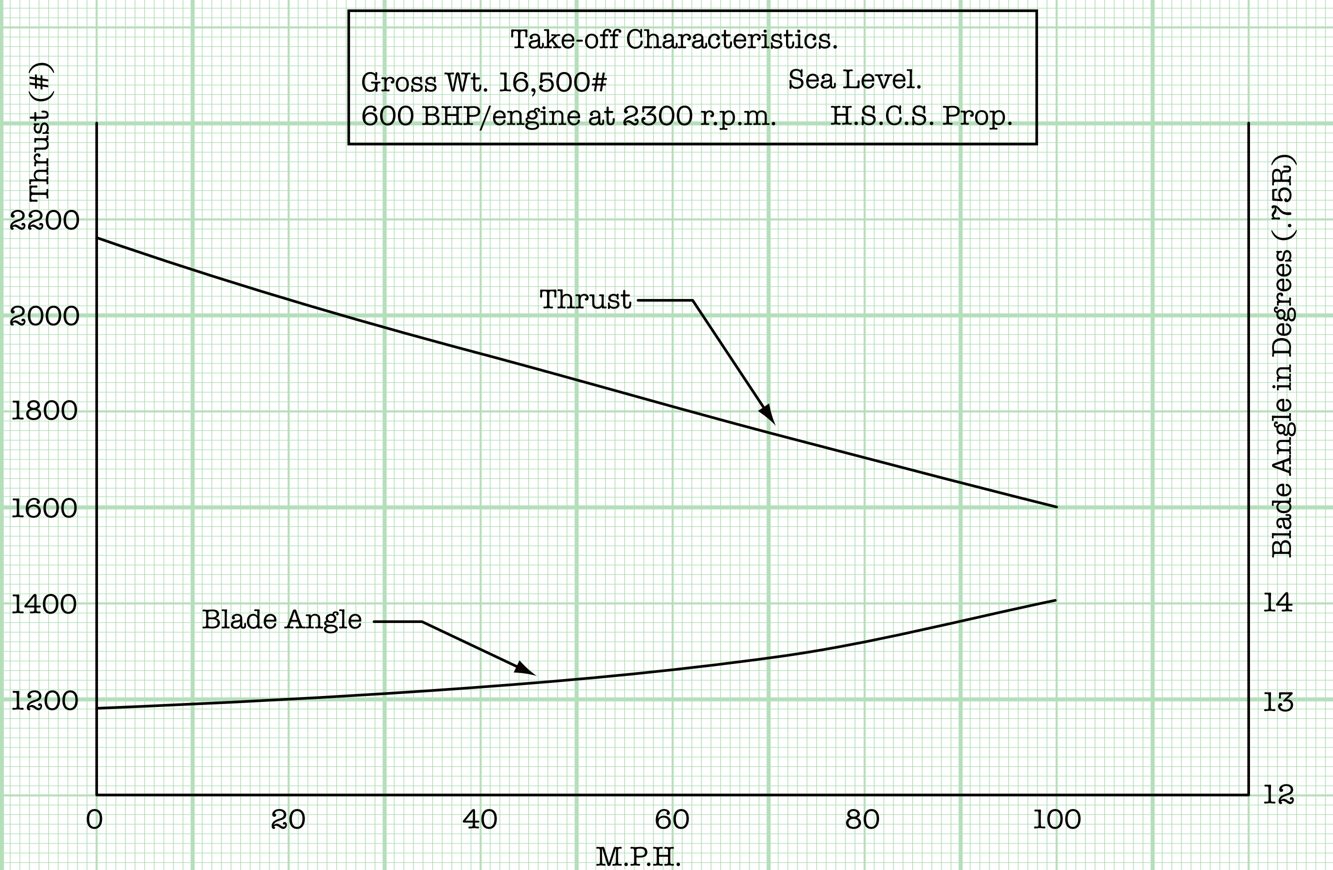
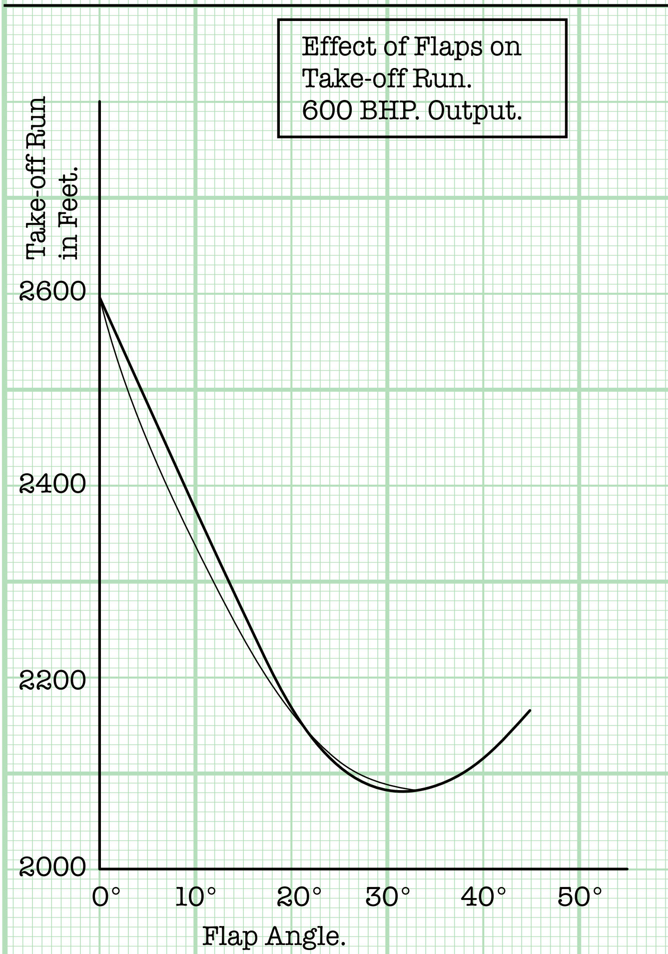


FIGURE VIII.


Take-off Characteristics.
Gross Wt. 16,500#
Sea Level.
600 BHP/engine at 2300 r.p.m.
H.S.C.S. Prop.
Thrust (#)
2200
2000
1800
1600
1400
1200
Thrust
Blade Angle
Blade Angle in Degrees (.75R)
14
13
12
0
20
40
60
80
100
M.P.H.


Effect of Flaps on
Take-off Run.
600 BHP. Output.
Take-off Run
in Feet.
2600
2400
2200
2000
0°
10°
20°
30°
40°
50°
Flap Angle.

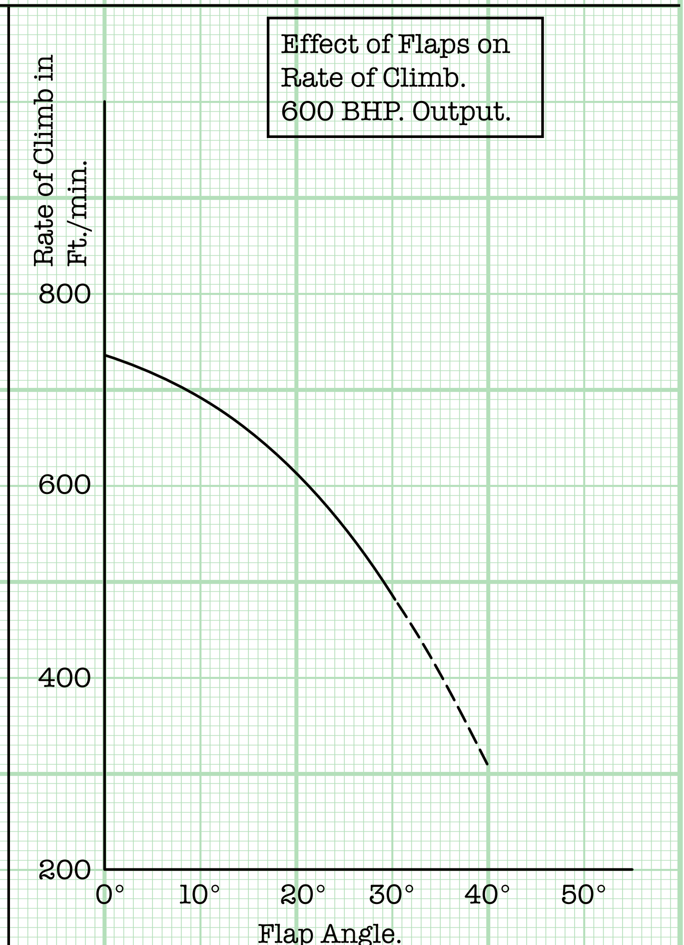

Effect of Flaps on
Rate of Climb.
600 BHP. Output.
Rate of Climb in
Ft./min.
800
600
400
200
0°
10°
20°
30°
40°
50°
Flap Angle.

FIGURE IX.

SEA LEVEL HP. REQUIRED CURVES FLAPS DOWN 30°

$V_{m.p.h.}$	q #/ft²	C_L	C_D	HP_{REQ}
87.5	19.5	1.85	.244	508
90	20.8	1.73	.218	498
95	23.1	1.56	.197	528
100	25.5	1.41	.179	556
105	28.0	1.29	.165	591
110	30.9	1.17	.151	626
120	36.8	0.98	.132	711
130	43.1	0.84	.119	815
140	50.0	0.72	.110	940
150	57.4	0.63	.104	1092
160	65.0	0.55	.100	1270

$$HP_{REQ.} = \frac{DV}{550} = \frac{C_D A q Y_{mph.}}{375} = 1.22\, C_D q V_{mph.}$$

SEA LEVEL HP. AVAILABLE – 600 B.HP. – 2300 r.p.m. – FLAPS 30°

V_{mph}	V/ND	C_S	β	η	T.HP.	HP_{REQ}	$HP_{ex.}$	R_C
90	.382	.72	15°	0.62	745	498	247	494 fpm
95	.403	.76	15°	0.64	769	528	241	482
100	.425	.80	16°	0.65	780	556	224	448
105	.446	.84	16.5°	0.665	780	556	208	416
110	.467	.88	17°	0.675	810	626	184	368
120	.510	.96	17°	0.70	840	711	129	258
130	.552	1.04	17°	0.72	865	815	50	100
140	.595	1.12	18°	0.74	889	940	-	-

FLAPS NEUTRAL

V_{mph}	T.HP	HP.REQ	HP.ex.	R_C
95	769	–	–	–
100	780	498	282	564 fpm
105	799	484	315	630
110	810	476	334	668
120	840	480	360	720
130	865	500	365	730
140	889	520	369	738
150	900	556	344	688

APPENDIX and COMPUTATIONS
****

METHOD OF COMPUTATION

The basic horsepower required curves are developed from flight test data and include an additional variation in "e" to account for the change in propulsive efficiency with angle of attack. Horsepower available curves are determined from the engine propeller characteristics. From these curves the cruising speeds at various power outputs and altitudes is determined and the optimum power - r.p.m. conditions selected for the engine.

Complete data on the fuel consumption of the engine was not available so generalized data on aircooled engines was used. (see pg.) From the known speeds and power outputs a chart of miles per gallon for various gross weights and alittudes was derived. From this chart the optimum power and altitudes for flight were selected and a graph of miles per gallon versus fuel load at any point during the trip was drawn up. Integration of this curve yields the range. Similarly, integration of the hours per mile versus miles travelled curve gives the elapsed time at any point during the trip.

Range, elapsed time, optimum speeds, power output, and altitude are then plotted on pgs. and . A curve of the gallons of fuel necessary for any given range is also presented on pg .

Recommended Sea Level Engine Conditions.

Gross Wt.	Power	R.P.M.	Man. Pr.
9300#	200 BHP.	1700	24.5 "Hg.
9300	250	1700	26.6
9300	300	1800	27.8
9300	350	1950	28.5
12,900	250	1700	26.6
12,900	300	1800	27.8
12,900	350	1950	28.5
16,500	350	1950	28.5
16,500	375*	2100	28.5
16,500	400*	2100	29.5

* Would only be used at altitude where max. cruising limitations of 2000 r.p.m. and 28.5" Hg. would not be exceeded.

COMPUTATIONS (continued)

Take-off will be considered with a gross weight of 16,500# and a power output of 600 BHP. per engine at 2300 r.p.m. at sea level. Schrenk's Method of analysis will be used. The following table of take-off relationships is then derived.

V	V/ND	C_P	β	C_T	Thrust	Thrust(Effective)
0 m.p.h.	0	.0418	12.9°	.102	2,320 #/prop.	2,160 #/prop.*
10	.030	.0418	12.9°	.100	2,270	2,110
20	.061	.0418	13.0°	.097	2,200	2,050
30	.091	.0418	13.1°	.093	2,120	1,970
40	.121	.0418	13.1	.092	2,090	1,950
50	.152	.0418	13.2	.090	2,050	1,910
60	.182	.0418	13.3	.086	1,960	1,820
70	.312	.0418	13.4	.082	1,860	1,730
80	.242	.0418	13.7	.080	1,820	1,690
90	.273	.0418	13.8	.078	1,770	1,650
100	.303	.0418	14.0	.075	1,710	1,590

* Effective thrust includes a 7% reduction factor due to tip losses.

Then:

$$S_1 = \frac{W}{g} \frac{q_1}{(P_o - P_1)} \log_e \frac{P_o}{P_1}$$

S_1 is the take–off run in ft.
W is the gross weight = 16,500#
g = std. air density = .0765 #/cu.ft.
q_1 = take–off impact pressure.
P_o is the initial accelerating force. P_1 the final.

$.9\ C_{L_{max.}} = 1.31 \qquad q_1 = 27.5$ #/sq.ft. (104 m.p.h.)

$C_D = 0.148$

$P_o = T_o - \mu W = 4320 - .04 \times 16{,}500 = 3650\#$

The coefficient of friction of .04 corresponds to a good field with hard turf.

$P_1 = T_1 - D_1 = 3180 - .148 \times 458 \times 27.5 = 1317\#$

$$S_1 = \frac{16{,}500}{.0765} \frac{27.5}{(3660 - 1317)} \log_e \frac{3660}{1317} = \underline{2590 \text{ ft.}}$$

COMPUTATIONS (continued)

Investigating the effect of flaps down 20°:

$0.9\ C_{Lmax.} = 1.57 \quad o_1 = 23$ #/sq.ft. (95 m.p.h.)

$C_D = 0.183$

$P_o = 3660\#$

$P_1 = 1620 \times 2 - 0.183 \times 458 \times 23 = 1310\#$

$$S_1 = \frac{16{,}500}{.0765}\ \frac{23}{2350} \log_e \frac{3660}{1310} = \underline{2180\text{ ft.}}$$

Flaps down 30°:

$0.9\ C_{Lmax.} = 0.9 \times 1.35 = 1.67 \quad q_1 = 21.6$ #/sq.ft. (92 m.p.h.)

$C_D = 0.21$

$P_o = 3660\#$

$P_1 = 2 \times 1660 - 0.21 \times 458 \times 21.6 = 1240\#$

$$S_1 = \frac{16{,}500}{.0765}\ \frac{21.6}{2420} \log_e \frac{3660}{1240} = \underline{2080\text{ ft.}}$$

Flaps down 45°:

$0.9\ C_{Lmax.} = 1.75 \quad q_1 = 20.6$ #/sq.ft. (89.5 m.p.h.)

$C_D = 0.243$

$P_o = 3660\ \#$

$P_1 = 2 \times 1660 - 0.243 \times 458 \times 20.6 = 1000\#$

$$S_1 = \frac{16{,}500}{.0765}\ \frac{20.6}{2660} \log_e \frac{3660}{1000} = \underline{2165\text{ ft.}}$$

COMPUTATIONS (continued)

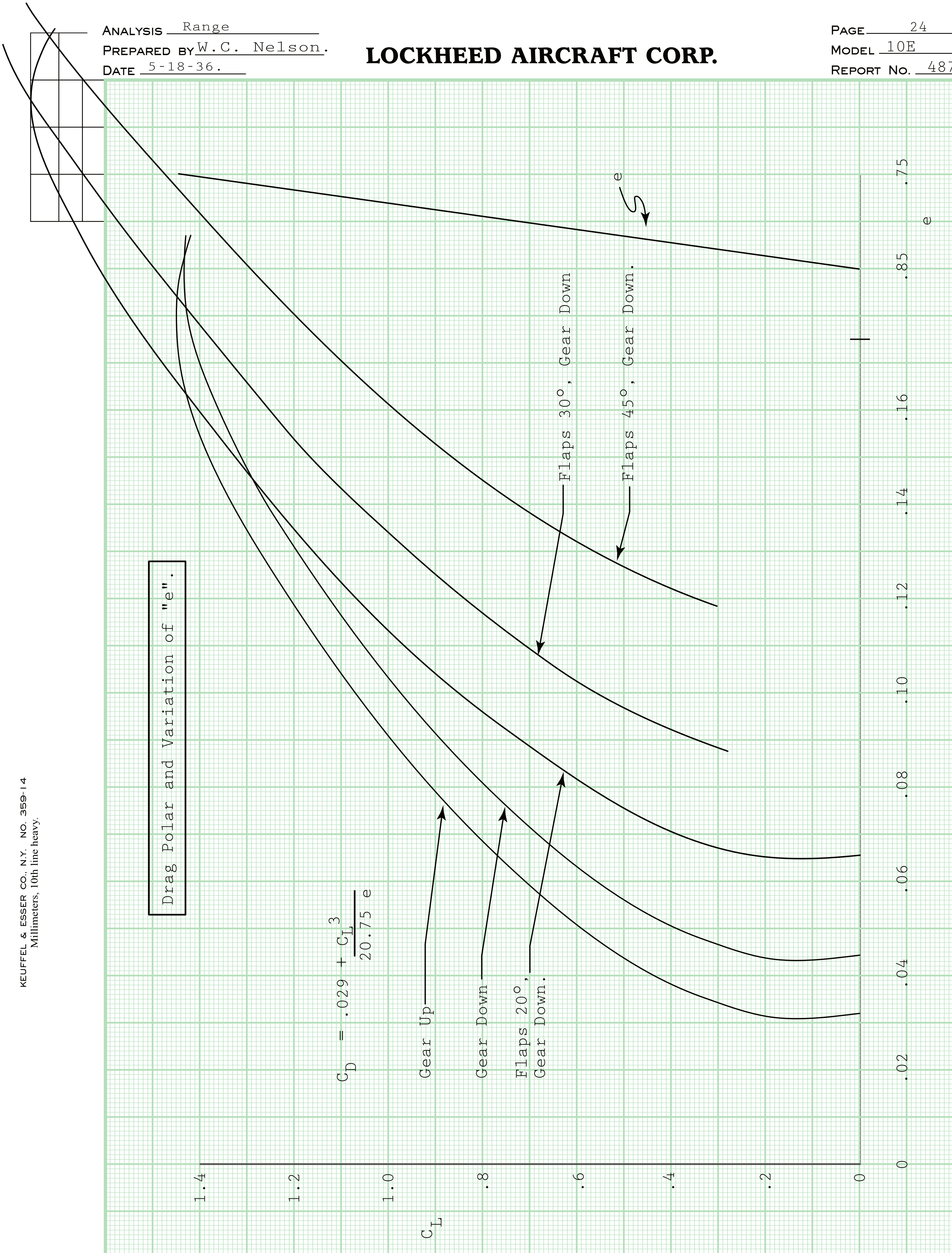
From the preceding calculations and graphs it is evidenct that the minimum take-off run occurs with the flaps set at approximately 30°, when it is reduced some 20% from the unflapped run.

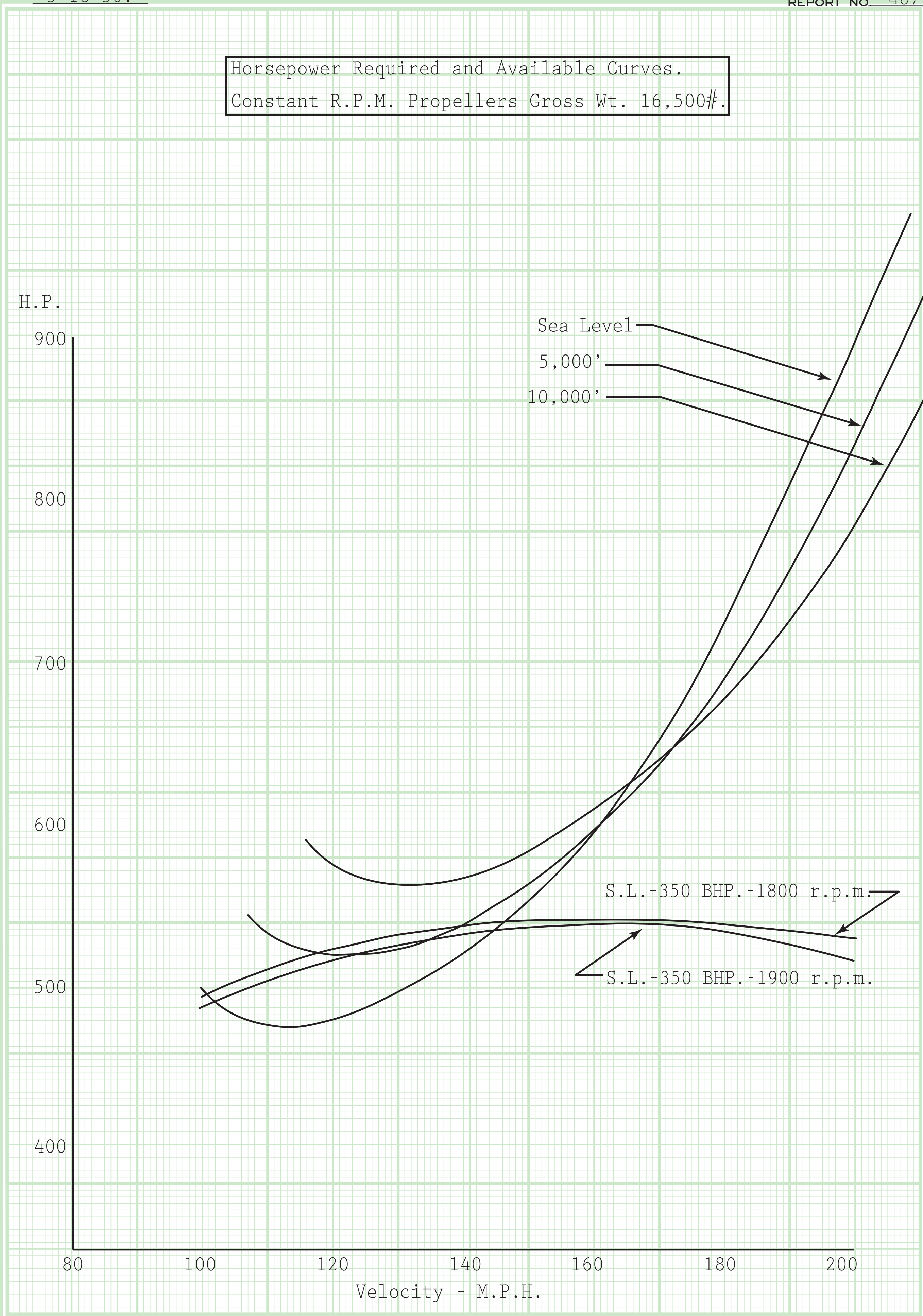
Computations for the rate of climb curves are included in the appendix, pg. .

Analysis Range
Prepared by W.C. Nelson.
Date 5-18-36.

LOCKHEED AIRCRAFT CORP.

Model 10E
Report No. 487




Horsepower Required and Available Curves.
Constant R.P.M. Propellers Gross Wt. 16,500#.
H.P.
900
800
700
600
500
400
Sea Level
5,000'
10,000'
S.L.-350 BHP.-1800 r.p.m.
S.L.-350 BHP.-1900 r.p.m.
80
100
120
140
160
180
200
Velocity - M.P.H.

ANALYSIS Range

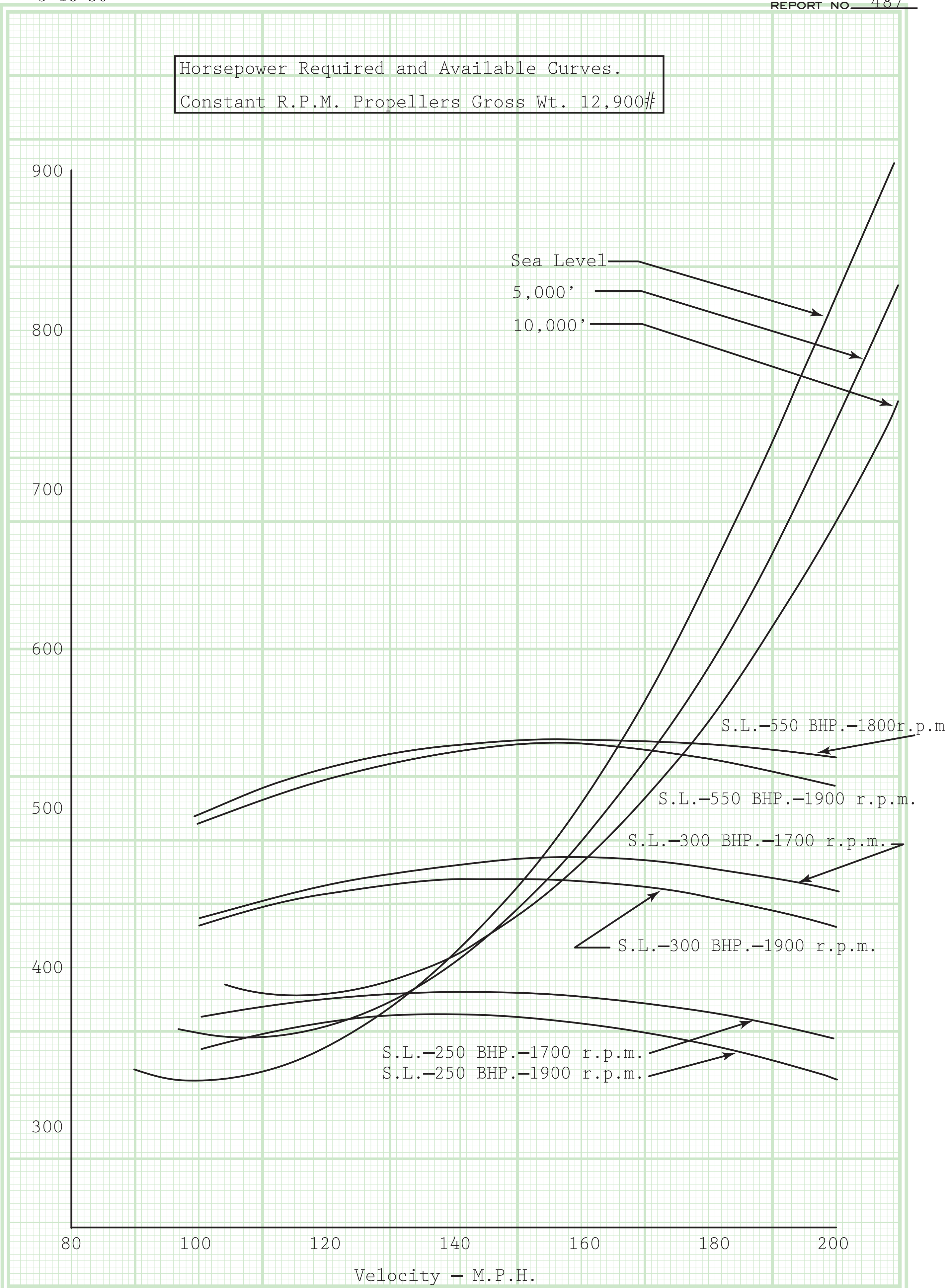
PREPARED BY W.C. Nelson

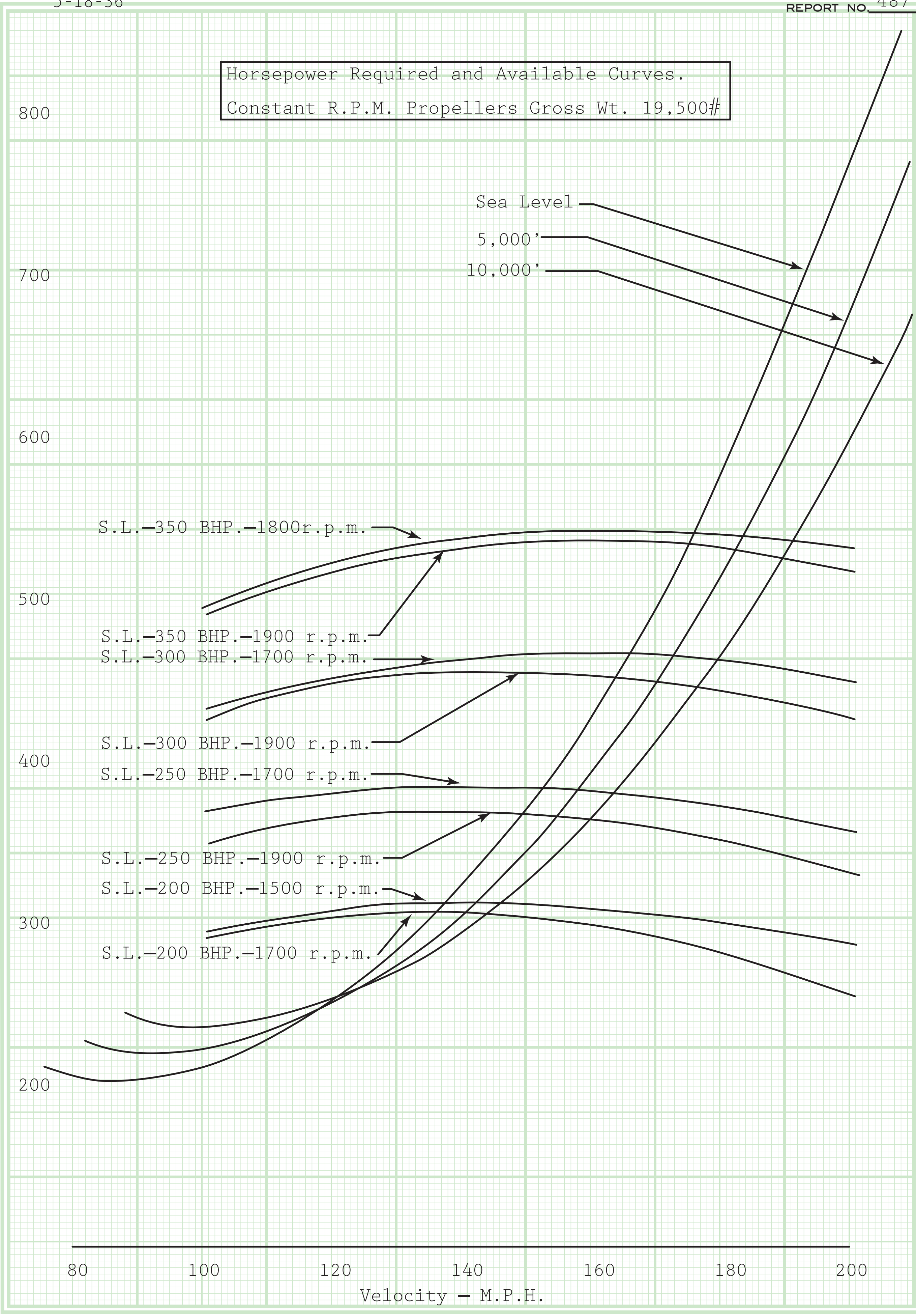
5-18-36

LOCKHEED AIRCRAFT CORP.

MODEL 10E

REPORT NO. 487

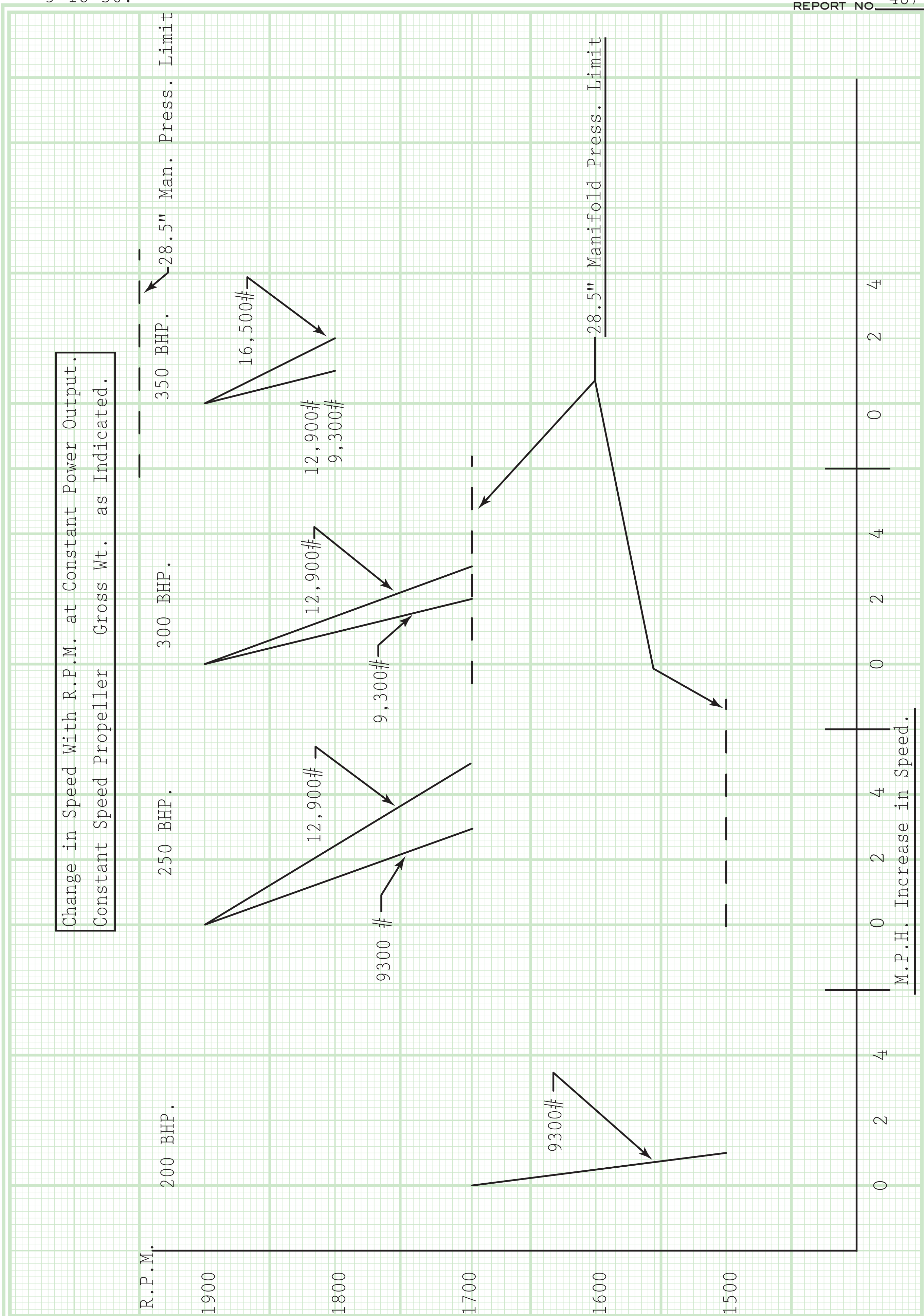



Horsepower Required and Available Curves.
Constant R.P.M. Propellers Gross Wt. 19,500#
Sea Level
5,000'
10,000'
S.L.—350 BHP.—1800r.p.m.
S.L.—350 BHP.—1900 r.p.m.
S.L.—300 BHP.—1700 r.p.m.
S.L.—300 BHP.—1900 r.p.m.
S.L.—250 BHP.—1700 r.p.m.
S.L.—250 BHP.—1900 r.p.m.
S.L.—200 BHP.—1500 r.p.m.
S.L.—200 BHP.—1700 r.p.m.
800
700
600
500
400
300
200
80
100
120
140
160
180
200
Velocity — M.P.H.

ANALYSIS Range
PREPARED BY W.C. Nelson 5-18-36.

LOCKHEED AIRCRAFT CORP.

MODEL 10E
REPORT NO. 487



SEA LEVEL HORSEPOWER REQUIRED CURVES

V_{mph}	q%		C_L				C_D				HP_{REQ}		
			16,500#	12,900#	9,300#		16,500#	12,900#	9,300#		16,500#	12,900#	9,300#
65	10.9												
70	12.5												
75	14.4				1.41				0.160				211
80	16.4				1.24				0.126				202
85	18.5				1.10				0.105				201
90	20.8			1.36	0.98			0.147	0.089			336	203
95	23.1			1.22	0.88			0.123	0.077			329	206
100	25.5		1.41	1.11	0.80		0.160	0.106	0.068		498	330	212
110	30.9		1.17	0.91	0.66		0.115	0.080	0.056		476	332	232
120	36.8		0.98	0.77	0.55		0.089	0.065	0.047		480	350	253
130	43.1		0.84	0.65	0.47		0.073	0.055	0.042		500	376	287
140	50.0		0.72	0.57	0.41		0.061	0.049	0.039		520	418	333
150	57.4		0.63	0.49	0.35		0.053	0.043	0.036		556	451	378
160	65.0		0.55	0.43	0.31		0.047	0.040	0.034		596	508	431
170	73.5		0.49	0.38	0.28		0.044	0.037	0.033		670	564	503
180	82.8		0.44	0.34	0.25		0.040	0.036	0.032		726	655	581
190	92.2		0.39	0.31	0.22		0.038	0.034	0.032		812	726	684
200	102.0		0.85	0.28	0.20		0.036	0.033	0.031		896	821	771

$W = C_L A q \qquad A = 458.3\,ft^2$

$C_L = \frac{36.0}{q}$ for 16,500#

$= \frac{28.2}{q}$ for 12,900#

$CL = \frac{20.3}{q}$ for 9,300#

$$HP_{REQ} = \frac{DV}{550} = \frac{C_D A q V_{mph}}{375} = 1.22\, C_D q V_{mph}$$

SEA LEVEL 200 B.H.P. 1500 R.P.M.

$V_{m.p.h.}$		V/ND		Cs		β		η		T.H.P.
100		.651		1.20		19°		0.74		148
120		.781		1.43		21°		0.77		154
140		.912		1.67		23°		0.785		157
160		1.042		1.90		25°		0.77		154
180		1.172		2.14		26.5°		0.74		148
200		1.302		2.39		28°		0.72		144
SEA LEVEL 200 B.H.P. 1700 R.P.M.										
100		.575		1.13		16°		0.73		146
120		.690		1.25		20.5°		0.76		152
140		.805		1.48		21.5°		0.77		154
160		.920		1.80		21.5°		0.72		144
180		1.035		2.03		23°		0.70		140
200		1.150		2.26		24.5°		0.64		128
SEA LEVEL 250 B.H.P. 1700 R.P.M.										
100		.575		1.09		17°		0.74		185
120		.690		1.30		19°		0.76		190
140		.805		1.51		21°		0.77		192.5
160		.920		1.73		22.5°		0.76		190
180		1.035		1.95		24°		0.745		186
200		1.150		2.16		25.5°		0.71		178
SEA LEVEL 250 B.H.P. 1900 R.P.M.										
100		.514		1.04		14°		0.70		175
120		.617		1.24		16°		0.73		183
140		.720		1.45		17°		0.74		185
160		.822		1.65		19°		0.72		180
180		.925		1.85		21°		0.70		175
200		1.030		2.06		22.5°		0.66		165
SEA LEVEL 300 B.H.P. 1700 R.P.M.										
100		.575		1.04		19°		0.72		216
120		.690		1.25		21°		0.76		228
140		.805		1.35		25°		0.765		230
160		.920		1.65		23.5°		0.78		234
180		1.035		1.87		25°		0.77		231
200		1.150		2.09		26°		0.75		225

SEA LEVEL 300 B.H.P. 1900 R.P.M.

$V_{m.p.h.}$		V/ND		C_s		β		η		T.H.P.	
100		.514		1.00		16°		0.71		213	
120		.617		1.20		17°		0.75		225	
140		.720		1.40		18.5°		0.76		228	
160		.822		1.60		20°		0.75		225	
180		.925		1.80		22°		0.74		222	
200		1.030		2.00		23°		0.71		213	
SEA LEVEL 350 B.H.P. 1800 R.P.M.											
100		.543		1.00		18°		0.71		248	
120		.651		1.20		19°		0.75		262	
140		.760		1.40		21°		0.77		270	
160		.869		1.60		22°		0.77		270	
180		.978		1.80		23.5°		0.77		270	
200		1.086		2.00		25.5°		0.76		266	
SEA LEVEL 350 B.H.P. 1900 R.P.M.											
100		.514		0.97		17°		0.70		245	
120		.617		1.16		18°		0.74		259	
140		.720		1.35		20°		0.76		266	
160		.822		1.54		21°		0.77		270	
180		.925		1.74		22°		0.75		262	
200		1.030		1.93		24°		0.74		259	
5,000' 200 B.H.P. 1700 R.P.M.											$\sigma^{1/5} = 0.972$
120		.690		1.32		18°		0.76		152	
140		.805		1.55		20°		0.76		152	
160		.920		1.75		22°		0.75		150	
5,000' 250 B.H.P. 1800 R.P.M.											$\sigma^{1/5} = 0.972$
120		.651		1.24		18°		0.76		190	
140		.760		1.46		19°		0.76		190	
160		.869		1.65		21.5°		0.76		190	
180		.978		1.85		23°		0.755		189	
5,000' 300 B.H.P. 1900 R.P.M.											$\sigma^{1/5} = 0.972$
120		.617		1.17		17.5°		0.75		225	
140		.720		1.36		19°		0.76		228	
160		.822		1.56		21°		0.76		228	
180		.925		1.75		22.5°		0.76		228	

10,000' 250 B.H.P. 1800 R.P.M.

$V_{m.p.h.}$		V/ND		C_s		β		η		T.H.P.	
											$\sigma^{1/5} = 0.943$
120		.651		1.21		18.5°		0.75		188	
140		.760		1.42		20°		0.77		193	
160		.869		1.60		22°		0.78		195	
180		.978		1.79		24°		0.78		195	
10,000' 300 B.H.P. 1900 R.P.M.											$\sigma^{1/5} = 0.943$
140		.720		1.32		20°		0.76		228	
160		.822		1.51		22°		0.78		234	
180		.925		1.70		23°		0.78		234	
SEA LEVEL 400 B.H.P. 2100 R.P.M.											
100		.465		0.90		15°		0.68		272	
120		559		1.08		19°		0.715		286	
140		.651		1.26		17°		0.76		304	
160		.745		1.44		18°		0.76		304	
180		.848		1.62		21°		0.75		300	
200		.930		1.80		22°		0.74		296	
5,000' 400 B.H.P. 2100 R.P.M.											$\sigma^{1/5} = 0.943$
140		.651		1.22		18.5°		0.75		300	
160		.745		1.40		20°		0.77		308	
180		.848		1.57		21.5°		0.76		304	
10,000' 400 B.H.P. 2100 R.P.M.											$\sigma^{1/5} = 0.943$
140		.651		1.19		20°		0.75		300	
160		.745		1.36		21°		0.77		308	
180		.848		1.53		23°		0.79		316	
SEA LEVE 375 B.H.P. 2100 R.P.M.											
120		559		1.102		15°		0.72		270	
140		.651		1.29		17°		0.76		285	
160		.745		1.47		18°		0.75		281	
180		.848		1.66		20°		0.74		278	

9300# GROSS WEIGHT

B.H.P./ENG.	R.P.M.	MAN. PR.	ALTITUDE	SPEED	S.F.C.	TOTAL FUEL CON. IN GAL. PER HR.	MILES PER GAL.	HR/GAL.
350	1950	28.5 "Hg	0 '	174 m.p.h.	0.46#/BHP.HR.	53.6	3.24	.0186
	1950	26.5	5,000	181	0.46	53.6	3.37	.0186
	1950	24.6	10,000	189	0.46	53.6	3.52	.0186
300	1800	27.8	0	164	0.465	46.5	3.52	.0215
	1800	25.8	5,000	170	0.465	46.5	3.66	.0215
	1800	23.7	10,000	177	0.465	46.5	3.80	.0215
250	1700	26.6	0	151	0.47	39.2	3.85	.0255
	1700	24.5	5,000	157	0.47	39.2	4.00	.0255
	1700	22.5	10,000	162	0.47	39.2	4.14	.0255
200	1700	24.5	0	135	0.515	34.3	3.93	.0291
	1700	22.5	5,000	139	0.515	34.3	4.05	.0291
	1700	20.5	10,000	143	0.515	34.3	4.17	.0291
12,900# GROSS WEIGHT								
350	1950	28.5	0	165	0.46	53.6	3.07	.0186
	1950	26.5	5,000	170	0.46	53.6	3.17	.0186
	1950	24.6	10,000	175	0.46	53.6	3.26	.0186
300	1800	27.8	0	152	0.465	46.5	3.27	.0215
	1800	25.8	5,000	156	0.465	46.5	3.36	.0215
	1800	23.8	10,000	158	0.465	46.5	3.40	.0215
250	1700	26.6	0	133	0.47	39.2	3.39	.0255
	1700	24.5	5,000	133	0.47	39.2	3.39	.0255
	1700	22.5	10,000	–	–	–	–	–
16,500# GROSS WEIGHT								
350	1950	28.5	0	144	0.46	53.6	2.68	.0186
	1950	26.5	5,000	128	0.46	53.6	2.38	.0186
	1950	24.6	10,000	–	–	–	–	–
400	2100	29.5	0	162	0.465	62.0	2.61	.0161
	2100	27.2	5,000	164	0.465	62.0	2.65	.0161
	2100	25.5	10,000	159	0.465	62.0	2.56	.0161
350	1950	27.5	2,500	141	0.46	53.6	2.63	.0186
400	2100	28.5	2,500	163	0.465	62.0	2.63	.0161
375	2100	28.5	0	153	0.46	57.5	2.66	.0174
	2100	26.5	5,000	151	0.46	57.5	2.62	.0174
	2100	24.5	10,000	143	0.46	57.5	2.48	.0174

Values Derived From Graphical Integration of Miles Per Gallon Vs. Fuel Load Curve.

FUEL USED	DISTANCE COVERED	OPTIMUM SPEED	HOURS PER MILE
300 gals.	846 mi.	160 m.p.h.	.00625
600	1812	153	.00633
900	2880	153	.00654
1200	4080	143	.00700
0	0	162	.00617

Values Derived From Graphical Integration of Hours Per Mile Vs. Distance Covered.

DISTANCE COVERED	ELAPSED TIME
1,000 mi	6.20 hrs.
2,000	12.49
3,000	18.94
4,000	25.68

DISTANCE DESIRED	FUEL NECESSARY	GROSS WEIGHT
0 MILES	0 GAL.	9,300#
500	120	10,020
1000	244	10,764
2000	520	12,420
3000	820	14,220
4000	1165	16,240