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.

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 tail winds up to 20 mph, the best airspeed is within 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.

Lockheed Electra, Serial 1055, is a special ship with 1200 gallons of fuel and 74 gallons of oil. For extra tanks and equipment, see equipment list on page #4. The fuel and oil tanks are arranged as per the sketch on the preceding page.

The ship was weighed at the Lockheed factory on July 18, 1936 before Department of Commerce inspector L. H. Steward, as follows:

Reaction at hoist	7525	Tare on tail	729
Less net tail	-269	Gross tail	460
Ship as weighed	7256	Net tail	-269

C. G. located at $\frac{291.56 \times 269}{7256}$ = 10.8 inches forward of spar.

129.63 - 10.80 = 118.83 inches from the nose reference point.

The ship was weighed less the power unit - 44 pounds, also since the weighing it was decided to add a 51 gallon tank in the rear of the cabin. (See sketch).

Ship as weighed	7256	118.83	862,230
Power unit	44	76.0	3,344
Gas tank	40	221.00	8,840
Ship empty, gear down	7340	119.13	874,414

The present approved limits of center of gravity travel, from Aircraft specification 590, are:

Most Forward - 117.98 inches aft of reference line.

Most Rearward - 132.53 inches aft of reference line.

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EQUIPMENT LIST - #1055

Standard Equipment (from Aircraft Specification 590)

1.	2 engine ring cowls	93 lbs.
2.	2 exhaust collector rings	60
3.	2 oil radiators (U. A. P. 6")	38
4.	2 landing and 1 warning light	25
5.	position lights	
6.	flares (2 3-minute) and brackets	50
7.	2 flashlights and brackets	
8.	2 starters (electric)	64
9.	battery (Exide 6XT-13-12V)	65
10.	generator (50 ampere)	36
11.	pressure fire extinguisher	35
12.	35 x 15-6 wheels (Goodyear 6 HBM)	68
13.	35 x 15-6 tires (Goodyear heavy duty 6-ply) and plain tubes	109
14.	retracting landing gear, electric worm drive, 12-1/2 : 1 gear and E. D. C. #45040 electric motor (100 amp. fuse required)	275
15.	shock struts (Aerol S P-400 E)	96
16.	wing split trailing edge flaps, electrically operated, (30 ampere fuse required)	75
17.	rudder trailing edge tab and spring type bungee	3
18.	elevator balance weights	12
	auxiliary flap	3
	trimming tabs	2
21.	cabin heaters	40
26.	16 x 7-3 tail wheel (Goodyear 3 TW) with 4-ply tire	12
27.	tail wheel strut (Aerol 300 ET)	17
28.	instruments with panel	56

Items of Standard Equipment Which Have Been Removed

19.	radio	-75
20.	ventilating system	-20
22.	toilet equipment	-15
23.	container and one gallon water	-12
24.	cabin delux equipment	-19
25.	2 baggage straps (nose compartment)	- 4
29.	Pan American emergency equipment and container	-40
44.	(X) standard passenger seats removed	-200
	cabin upholstering	-45
	8 windows and frames	-25
	2 28 gallon gas tanks (wing)	~~-45~~

FORM 100

EQUIPMENT LIST - #1055
Continued

Special Equipment

31.	2	wheel fenders	8 lbs.
33.		control wheel lock	2
34.		tail wheel lock	3
37.		de-icers (permanently attached)	50
		Sperry pilot	120
	2	28 gallon oil tanks	45
	2	100 gallon gas tanks (in wing)	97
	2	118 gallon gas tanks (forward fuselage)	108
	3	149 gallon gas tanks (rear fuselage)	205
	1	70 gallon gas tank (rear fuselage)	35
	1	51 gallon gas tank (rear fuselage)	30
		Western Electric radio	128
		Cambridge fuel analyzer	12

INSTRUMENT LIST

		No. Req'd
641975	Sperry horizon	1
640540	Sperry gyro	1
864	Pioneer compas (Mark VIII)	1
176-01	Kollsman sensitive altimeter	1
743 B	Pioneer altimeter	1
354	Pioneer air speed indicator	2
385 B	Pionner bank and turn indicator	1
374 B	Pioneer rate of climb indicator	1
814 C	Pioneer manifold pressure gauge	2
8 DO 35SAA7	General Electric tachometer indicator	2
2 CM 4H2	General Electric tachometer generator	2
180	Kollsman fuel gauge	1
602A-16	Weston air temperature indicator	1
B/M 7225	Cambridge aero mixture indicator	1
	Chrysler gas gauge	1
NG 5508	Motometer fuel gauge	1
606A-46	Weston oil temperature indicator	2
763	Pioneer suction gauge	1
606	Weston carburetor air temperature indicator	2

The following table gives the items of useful load with their weight, moment arms, and moments in sequence.

Item	Wt.	Mom't. Arm	Moment
2 pilots	340	85.0	28,900
Standard wing gas (194 gal.)	1164	109.0	126,876
Forward fuselage gas (236 gal.)	1416	116.0	164,256
74 gal. oil (full) 80	555 600	134.4*	74,610 80,640
Wing tanks (baggage compartment) (200 gal) 204	~~1200~~ 1224	150.0	180,000 / 183,600
Rear fuselage gas (149 gal.)	894	144.0	128,736
Rear fuselage gas (149 gal.)	894	165.0	147,510
Rear fuselage gas (149 gal.)	894	186.0	166,284
Rear fuselage gas (~~121~~ gal.)	726	210.9†	~~153,078~~
70	420	202.0	84,840

* The C. G. of the oil was found as follows:

56 gal. oil - (wing)	420	150.0	63,000
18 gal. oil - (nacelles)	135	86.0	11,610
Full oil	555	134.43	74,610

† The C. G. of the two gas tanks in rear of cabin was found as follows:

70 gal. gas	420	202.0	84,840
51 gal. gas	~~306~~	~~223.0~~	~~68,238~~
Total	726	210.9	153,078

GROSS WEIGHT C.G.

Ship empty - gear down	7340	119.13	874,414
Moment - gear up	-	-	9,450
2 Pilots	340	85.0	28,900
Standard wing gas (194 gal.)	1164	109.0	126,876
Forward fuselage gas (236 gal.)	1416	116.0	164,256
74 gal. oil (full)	555	134.4	74,610
Wing gas tanks (200 gal.)	1200	150.0	180,000
Rear fuselage gas (149 gal.)	894	144.0	128,736
Rear fuselage gas (149 gal.)	894	165.0	147,510
Rear fuselage gas (149 gal.)	894	186.0	166,284
Rear fuselage gas (121 gal.)	726	210.9	153,078
Miscellaneous	277	130.0	36,010
Gross weight - gear up	15,700	133.13	2,090,124

It will now be necessary to formulate a procedure to be followed in using fuel from the various tank combinations in order to keep the C.G. within the approved limits.

Step #1

Starting with the full gross condition and removing the gas from the two rear most fuselage tanks (70 gal. and 51 gal.) which are interconnected:

Gross weight - gear up	15,700	133.13	2,090,124
Less 121 gal. gas	-726	210.9	-153,078
	14,974	129.36	1,937,046

Step #2

Removing the fuel from the rear 149 gallon fuselage tank:

From above	14,974	129.36	1,937,046
Less 149 gal. gas	-894	186.0	-166,284
	14,080	125.76	1,770,762

Step #3

Removing the fuel from the two forward fuselage tanks (118 gal. each):

From above	14,080	125.76	1,770,762
Less 236 gal. fuel	-1,416	116.0	-164,256
	12,664	126.86	1,606,506

Step #4

Removing the fuel from the two baggage compartment wing tanks (100 gal. each):

From above	12,664	126.86	1,606,506
Less 200 gal. gas	-1,200	150.0	-180,000
	11,464	124.43	1,426,506

At this point approximately 30 gallons of oil have been used:

From above	11,464	124.43	1,426,506
Less 30 gal. oil	-225	134.4	-30,240
	11,239	124.23	1,396,266

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Step #5

Removing the fuel from the four standard wing tanks (2 at 81 gal., 2 at 16 gal.):

From above	11,239	124.23	1,396,254
Less 194 gal. gas	-1,164	109.0	-126,876
	10,075	126.00	1,269,378

Step #6

Removing the fuel from the front 149 gallon fuselage tank:

From above	10,075	126.00	1,269,378
Less 149 gal. gas	-894	144.0	-128,736
	9,181	124.24	1,140,642

Step #7

Removing the fuel from the center 149 gallon fuselage tank:

From above	9,181	124.24	1,140,642
Less 149 gal. gas	-894	165.0	-147,510
	8,287	119.84	993,132
	8,287	119.84	993,132
Moment - gear down	-	-	-9,450
	8,287	118,70	983,682

GENERAL STRESS ANALYSIS DATA

	Empty weight	7340 lbs.
	Pay Load	8460 lbs.
W	Gross Weight	15800 lbs.
A	Wing Area	458.3 sq.ft.
HP	Total horsepower at sea level	900
s	Wing loading	34.5 lbs./sq.ft.
p	Power loading (900 HP)	17.6 lbs./HP
V_L	Design Level Flight Speed	172 mph 252 fps
q_L	Impact pressure at V_L	75.5 lbs./sq.ft.
	Total parasite drag coefficient (Pg. 1, Rep. 410)	0.0258
A_D	Total drag area (.0258 x 458.3)	11.82 sq.ft.
d	Drag Loading	1338 lbs./sq.ft.
V_m	Max. vertical velocity with zero thrust $29\sqrt{d}$	1060 fps 723 mph
K_g	Gliding Speed factor $= .08 + \left(\frac{1850}{15800 + 3000}\right)$	0.179
V_g	Design Gliding Speed $= V_L + K_g(V_m - V_L)$	397 fps
	but need not exceed $1.5\ V_L$ =	378 fps 258 mph
q_g	Impact pressure at design gliding speed	170 lbs./sq.ft.
R	Aspect ratio of wing (Pg. 0, Rep. 400-1)	6.6
	Airfoil section - Clark Y Modified Taper 18% to 9% thickness	
m	Slope of Lift Curve at aspect ratio 6.6 (Pg. 22, Rep. 406)	3.918
MAC	Mean Aerodynamic Chord (Pg. 2, Rep. 400-1)	105.39 inches
	Reference line to L.E. of MAC	100.25 inches
	Quarter chord point of wing to 20% point of tail (Pg. S-7, Rep. 400-1)	278.0 inches

FORM 100

Condition I & Condition II

Condition I

$\Delta n_{I_a} = \frac{.036 \times 252 \times 3.918}{34.5} = 1.03$

$\Delta n_{I_b} = \left[.77 + \frac{32000}{15800 + 9200}\right] \times .94 = 1.93$ not used. See page 1.

$n = 2.03$

$C_N = ns/q = 2.03 \times 34.5/75.5 = .927$

$C_c = -.2\ C_N = -.185$

C.P. = max.fwd. position = 32.5% (See page S-17, R.400-1)

Corresponding $C_m = .927(.250 - .325) = -.0695$

Reference line to C.P. of wing = 100.25 + (.325 x 105.39) = 134.5"

Reference line to C.G. = 133.1" Pg.

Reference line to C.P. of horizontal tail = 100.25 + (.25 x 105.39) + 278 = 404.6"

(See page S-7, R.400-1)

C.G. to C.P. of wing = 134.5 - 133.1 = 1.4"

C.G. to C.P. of tail = 404.6 - 133.1 = 271.5"

Applied wing load = 34.5 x 2.03 x 458.3 = 32,100#

Applied tail load = 32,100 x 1.4/271.5 = - 165#

(Small stalling moment due to C_c is conservatively ignored)

Condition II

$\Delta n = -1.03$

$n = -.03$

$C_N = C_c = 0$ nearly

$C_m = -.080$ (Page S-17, R.400-1)

Wing moment = $C_m\ A\ q\ C$ = -.080 x 458.3 x 75.5 x 105.39 = -292,000 in.lbs.

Tail load = -292,000/271.5 = - 1,075 lbs.

Condition III
&
Condition IV

Condition III

$$\Delta n_{III_a} = \frac{.018 \times 378 \times 3.918}{34.5} = .78$$

.772

$\Delta n_{III_b} = .6 \times 1.93 = 1.16$ not used. See page 1.

Applied load factor = 1.78

$C_N = ns/q = 1.78 \times 34.5/170 = .362$

$C_c = 0$

$C_m = -.083 - .01 = -.093$

C.P. = .25 + (.093/.362) = .25 + .257 = .507

Reference line to C.P. of wing = 100.25 + (.507 x 105.39) = 153.70"

C.G. to C.P. of wing = 153.7 - 133.1 = 20.6"

Applied wing load = 1.78 x 34.5 x 458.3 = 28,150#

Applied tail load = 28,150 x 20.6/271.5 = - 2,135#

See next page for calculations with most forward C.G. position. Tail load = -3,260#

Condition IV

$\Delta n = -.78$

Applied load factor = + .22

$C_N = ns/q = .22 \times 34.5/170 = +.045$

$C_c = 0$

$C_m = -.080 - .01 = -.090$

Reference line to quarter-chord of wing = 100.25 + (105.39/4) = 126.6"

Quarter-chord to C.G. = 133.1 - 126.6 = 6.5"

Wing load = .22 x 34.5 x 458.3 = 3,480#

Wing moment = (3,480 x 6.5) - (.090 x 458.3 x 170 x 105.39) = 22,600 - 740,000

= -717,400 in.lbs.

Tail load = -717,400/271.5 = - 2,640 lbs.