TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 340

FULL SCALE DRAG TESTS ON VARIOUS PARTS OF FAIRCHILD (FC-2W2) CABIN MONOPLANE

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Summary

The drag due to the various parts of a Fairchild (FC-2W2) cabin monoplane was measured at air speeds varying from 50 to 100 m.p.h., in the Twenty-Foot Propeller Research Tunnel of the National Advisory Committee for Aeronautics.

It was found that the largest drag was due to the radial air-cooled engine. The measured drag due to the landing gear was also large, being about 4/5 of that due to the engine. Substituting Musselman type wheels for the standard wheels caused no change in the drag due to the landing gear. A small decrease in drag was effected by adding a turtleback to the airplane fuselage.

Introduction

Until recently, wind tunnel measurements of the drag due to airplane parts have been of questionable value principally because of the small scale at which it has been necessary to conduct the tests. The Twenty-Foot Propeller Research Tunnel (Reference 1) of the National Advisory Committee for Aeronautics has afforded a means of overcoming this difficulty, for full scale airplane parts may be tested in its air stream. Moreover, the drag due to these parts in the presence of the rest of the airplane can be measured, thereby determining the interference effects.

The Fairchild (FC-2W2) cabin monoplane (Fig. 1) was mounted in the tunnel primarily to determine certain propeller characteristics for use in connection with glide tests to be made with the airplane in flight. It was decided to extend the tests and measure the drag due to the various parts of the airplane. This was done without the presence of a propeller slipstream and with the airplane at one angle of attack. Since the air stream in the tunnel would include only 20 feet of the airplane's wing, the drag values measured with the wing in place do not represent the total drag of the airplane. A comparison of the results of drag tests made on various parts of the airplane with and without wing, does show, however, the effect of the presence of the wing upon the drag due to these parts.

Because there was a poor contour formed where the trailing edge of the wing center section intersected the fuselage, it was decided to find the effect of a turtleback extending from the thick part of the center section to the stabilizer.

The Musselman wheel has recently aroused much interest, because of the advantages claimed for it over the standard type. Therefore, it was thought important to measure the drag due to the landing gear with both types of wheels attached and obtain an indication of their relative aerodynamic merits.

Methods and Apparatus

The Fairchild (FC-2W2) airplane is a cabin monoplane (Fig. 1) with accommodations for four passengers and a pilot. It has an over-all length of 32 ft. 10-1/4 in., span of 50 ft., chord of 7 ft., split-axle type oleo landing gear, and a 425 hp 9-cylinder radial air-cooled Pratt and Whitney "Wasp" engine.

The airplane was mounted on the balance (Fig. 2) in the tunnel test chamber with its thrust line horizontal and in the center of the air stream. Due to the nature of the supporting arrangement which attached to the axles, it was found necessary to use dummy wooden wheels with cut-outs for the struts to the axles instead of the service wheels.

The factors investigated and described are as follows:

1. Drag due to the tail surfaces.
2. Drag due to the engine.
3. Effect on the drag of the airplane of adding a turtleback.
4. Drag of bare fuselage with nose faired.
5. Effect on the drag of the airplane of opening the cabin windows.
6. Drag due to the landing gear with both 13-inch by 30-inch Musselman wheels, and 8-inch by 36-inch standard wheels.

7. Drag due to the propeller (Design No. 1803, set 18.7 degrees at 42 inches radius) locked in a horizontal position. This was obtained with stabilizer full up (5.8 degrees above thrust line) and full down (1.2 degrees below thrust line).

8. Effect on the drag of the airplane of moving the stabilizer from full down to full up.

Unless otherwise stated, all tests were made with the landing gear in flying position, propeller off, engine shutters closed, windows closed, stabilizer full up, control surfaces floating in the air stream, and faired coverings over the wing and center-section fuel tanks. During all tests made with the wing on, there were fairings covering the intersection of the wing struts and fuselage. These fairings were taken off when the wing was removed. The drag forces were measured by the usual methods employed in such tests (Reference 1) and at air speeds varying from 50 to 100 m.p.h.

With the complete airplane, less wheels, mounted on the balance and the propeller locked in a horizontal position, the drag was measured with the stabilizer full up and full down. The propeller was then removed and the run repeated. Following this the airplane was altered, step by step, and each new set-up tested for drag. The wheels and a turtleback were first added (Fig. 2); the windows in both sides of the cabin were then opened; following this the windows were closed and the turtleback removed (Fig. 3); the tail surfaces were next taken off (Fig. 4); and finally, the engine was removed and the nose of the fuselage faired (Fig. 5)

The wing was next removed (Fig. 6) leaving only the faired fuselage, landing gear, and supports to be tested. The airplane was then reassembled part by part, with the exception of the wing, and tested for drag after each addition. First the engine was installed (Fig. 7); then the tail surfaces were attached (Fig. 8); and finally, the turtleback and wing-root fairings were added (Fig. 9).

The airplane was then disconnected from the landing gear and tail supporting post and suspended with a small clearance above them (Fig. 10). The drag due to the landing gear and supports was obtained with this set-up. The test was repeated after 13-inch by 30-inch Musselman wheels had been substituted for the 8-inch by 36-inch standard wheels (Fig. 11). Following this the landing gear was reattached to the fuselage, the supporting struts freed from the axles, and a run made to obtain the support drag. Finally, this test was repeated with the standard wheels replacing the Musselman wheels.

Results

The results observed are plotted (Figs. 12, 13, and 14) with drag in pounds against dynamic pressure $(q = \frac{1}{2} \rho V^2)$, in pounds per square foot. Scales of velocities in miles per hour have been added for convenience in using the data. Figures 12 and 14 show the results of tests made with the wing on, while Figure 13 shows those made with the wing off.

Derived curves taken from the foregoing results, showing the drags due to the individual parts are plotted in the same manner (Figs. 15, 16, and 17). Figures 15 and 17 are for tests made with the wing on, while Figure 16 is for tests made with the wing off.

Table I shows the drags at 100 m.p.h. due to all the parts tested. The figures are arranged so that the drag given for any condition is simply the sum of the drag values preceding it in the table.

The drags due to the various parts at air speeds from 50 to 100 m.p.h. are given in Tables II and III, together with the absolute drag coefficients $\left(C_D = \frac{\text{Drag}}{\frac{1}{2} \rho \, V^2 \, S}\right)$, where S is the wing area (336 square feet). This area includes that of the center section and ailerons in accordance with the definition of areas recently adopted by the Aerodynamics Committee. Table II is for tests made with the wing on, while Table III is for those made with the wing off.

Some of the principal structural dimensions of the airplane are given for ready reference in Table IV. These data may be of interest to designers who wish to convert the drag coefficients to some other basis.

Discussion

In Table I it is apparent that the drag due to the engine at 100 m.p.h., with the wing off is 19 pounds greater than with it on. This is explained by the blocking effect of the wing which slows up the air in front of it, thereby causing a reduced velocity in the region of the engine. In the same table it is shown that the increase in drag due to the tail surfaces is 9 pounds greater with the wing on than with it off. This increase is probably the result of a change in flow over the tail caused by the wing. The decrease in drag due to adding a turtleback is small under both conditions, being 10 pounds and 13 pounds at 100 m.p.h. (Table I).

Substituting Musselman wheels for the standard wheels does not alter the drag due to the landing gear (Table I), although the former have greater cross-sectional area. That the Musselman wheels do not increase the drag is probably accounted for by their better streamlined shape.

In Table I it can be seen that the drag due to the propeller locked in a horizontal position is 106 pounds at 100 m.p.h. when the stabilizer is full down, and 104 pounds when it is full up. The discrepancy between the two results is not significant since it is within the limits of accuracy of the tests.

In general, the drag coefficients (Tables II and III) for the various parts decrease as the free air velocity increases. This is the result of scale effect. However, the engine drag coefficients for the condition with the wing on show an opposite scale effect. This might be explained by the blocking effect, already referred to, of the wing behind the engine. It is probable that the decrease in velocity due to the blocking is less at the higher air speeds than at the lower. That the drag coefficients for the faired fuselage show the same characteristic is explained by the very irregular shape of the body. Although there is no wing present, the abrupt change in fuselage contour, due to the high, slightly inclined windshield, produces an effect very similar to that caused by the wing.

Conclusions

From the data collected in these tests it is concluded that:

1. The drag due to the engine is very large, and there are possibilities for its reduction by proper cowling (Reference 2).

2. The drag due to the landing gear is high, and full scale research on this subject would be valuable.

3. The substitution of 13-inch by 30-inch Musselman wheels for 8-inch by 36-inch standard wheels does not change the drag due to the landing gear. Such a substitution would probably give approximately the same results on other types of landing gear, providing the proper sized wheels are used.

4. The addition of a turtleback causes a small reduction in drag.

5. Opening the cabin windows increases the drag slightly.

6. The drag due to various parts may be altered by the presence of the wing. The results of tests made on fuselages alone are subject to modification when the wing is present.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 7, 1930.

References

1. Weick, Fred E. and Wood, Donald H. : The Twenty-Foot Propeller Research Tunnel of the National Advisory Committee for Aeronautics. N.A.C.A. Technical Report No. 300, 1928.

2. Weick, Fred E. : Drag and Cooling with Various Forms of Cowling for a "Whirlwind" Radial Air-Cooled Engine - I. N.A.C.A. Technical Report No. 313, 1929.

TABLE I

Drag Due to Various Parts of Fairchild

(FC-2W2) Airplane at 100 m.p.h.

lb. 100 m.p.h.	Airplane with Wing
307	Drag of airplane less tail and engine - 20 feet of wing in air stream.
100	Increase in drag due to engine.
28	Increase in drag due to tail surfaces.
435	Drag of airplane with 20 feet of wing in air stream.
13	Decrease in drag due to addition of turtleback.
422	Drag of airplane with turtleback and 20 feet of wing in air stream.
10	Increase in drag due to open windows.
432	Drag of airplane with turtleback, open windows, and 20 feet of wing in air stream.
lb. 100 m.p.h.	**Airplane without Wing**
104	Drag of bare fuselage with nose faired.
119	Increase in drag due to engine.
79	Drag due to landing gear with either standard or Musselman wheels.
19	Increase in drag due to tail surfaces.
321	Drag of airplane with either standard or Musselman wheels - no wing.
10	Decrease in drag due to turtleback and wing-root fairings.
311	Drag of airplane with standard or Musselman wheels, turtleback, root fairings and no wing.

TABLE I (continued)

lb. 100 m.p.h.	Airplane with Wing
106	Drag due to propeller locked horizontally - no wheels, stabilizer full down
104	Drag due to propeller locked horizontally - no wheels, stabilizer full up.
20	Increase in drag of airplane by moving stabilizer from full down to full up.

TABLE II

Drag and Drag Coefficient for Parts of Fairchild
(FC-2W2) Airplane with Wing On

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 S} \qquad S = 336 \text{ sq.ft.}$$

Air speed, m.p.h. (indicated)		50	55	60	65	70	75	80	85	90	95	100
Drag of airplane with 20 ft. of wing in air stream	Drag	114.7	136.1	162.0	188.6	217.0	248.8	282.2	316.7	354.0	391.6	435.0
Increase in drag due to engine	Drag	24.6	29.8	35.6	41.9	48.5	56.0	63.9	72.1	80.9	89.8	100.0
	C_D	.0115	.0115	.0115	.0115	.0115	.0116	.0116	.0116	.0116	.0116	.0116
Increase in drag due to tail surfaces	Drag	10.1	11.3	12.9	14.2	16.0	17.8	19.8	21.6	23.7	25.8	28.0
	C_D	.0047	.0043	.0042	.0039	.0038	.0037	.0036	.0035	.0034	.0033	.0033
Decrease in drag due to turtle-back	Drag	3.8	4.3	5.1	6.0	6.8	7.6	8.3	9.5	10.5	11.7	13.0
	C_D	.0018	.0017	.0017	.0017	.0016	.0016	.0015	.0015	.0015	.0015	.0015
Increase in drag due to open windows	Drag	3.8	4.2	4.9	5.1	5.8	6.5	7.1	7.9	8.7	9.1	10.0
	C_D	.0018	.0016	.0016	.0014	.0014	.0013	.0013	.0013	.0012	.0012	.0012
Drag of airplane less tail, engine, and turtleback	Drag	80.0	95.0	113.5	132.5	152.5	175.0	198.5	223.0	249.5	276.0	307.0

TABLE III

Drag and Drag Coefficient for Parts of Fairchild (FC-2W2) Airplane with Wing Off

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 S} \qquad S = 336 \text{ sq.ft.}$$

Air speed, m.p.h. (indicated)		50	55	60	65	70	75	80	85	90	95	100
Drag of airplane with wing off	Drag	90.7	105.6	123.7	143.3	163.5	186.8	210.8	235.9	262.9	290.5	321.0
	C_D	.0421	.0406	.0400	.0395	.0390	.0387	.0383	.0380	.0378	.0375	.0374
Increase in drag due to engine	Drag	32.9	38.4	45.1	52.5	60.1	68.8	77.8	87.1	97.1	107.6	119.0
	C_D	.0153	.0148	.0146	.0145	.0143	.0142	.0142	.0141	.0139	.0139	.0139
Drag of bare fuselage	Drag	24.8	30.0	36.1	42.9	49.9	57.9	66.0	74.6	84.0	93.4	104.0
	C_D	.0115	.0115	.0117	.0118	.0119	.0120	.0120	.0120	.0121	.0121	.0121
Drag of landing gear with either standard or Musselman wheels	Drag	22.1	26.0	30.5	35.1	40.2	46.0	52.0	58.2	64.8	71.5	79.0
	C_D	.0103	.0100	.0099	.0097	.0096	.0095	.0095	.0094	.0093	.0092	.0092
Increase in drag due to tail surfaces	Drag	10.9	11.2	12.0	12.8	13.3	14.1	15.0	16.0	17.0	18.0	19.0
	C_D	.0051	.0043	.0039	.0035	.0032	.0029	.0027	.0026	.0024	.0023	.0022
Decrease in drag due to turtle-back and wing-root fairings	Drag	2.9	3.2	3.9	4.6	5.0	5.9	6.5	7.2	8.0	9.0	10.0
	C_D	.0013	.0012	.0013	.0013	.0012	.0012	.0012	.0012	.0012	.0012	.0012

TABLE IV

Wings

Wing section	=	Göttingen 387
Wing area	=	336 sq.ft. (including center section)
Center section area	=	24 "
Wing span	=	50 ft.
Wing chord	=	7 "
Span x Chord	=	350 sq.ft.
Span/Chord	=	7.15

Fuselage

Maximum cross section area of fuselage	=	20.4 sq.ft.

Control Surfaces

Aileron area	=	34.0 sq.ft.
Stabilizer area	=	30.0 "
Elevator "	=	18.1 "
Fin "	=	4.5 "
Rudder "		10.2 "
Total tail surface area	=	62.8 "

Landing Gear

Two wheels, 8-inch by 36-inch standard, or
13-inch by 30-inch Musselman type.

Two streamline oleo strut fairings, each 3.2 in. thick, 7.8 in. deep, 43.4 in. long in flying position.

Two streamline diagonal front struts, each 2.2 in. thick, 5.8 in. deep, 43.4 in. long.

Two round rear struts, each 1.8 in. diameter, 54 in. long.

a, 50'0"

b, 3'4"

c, 7'5$\frac{1}{8}$"

d, 7'0"

e, 32'10$\frac{1}{4}$"

f, 5'0"

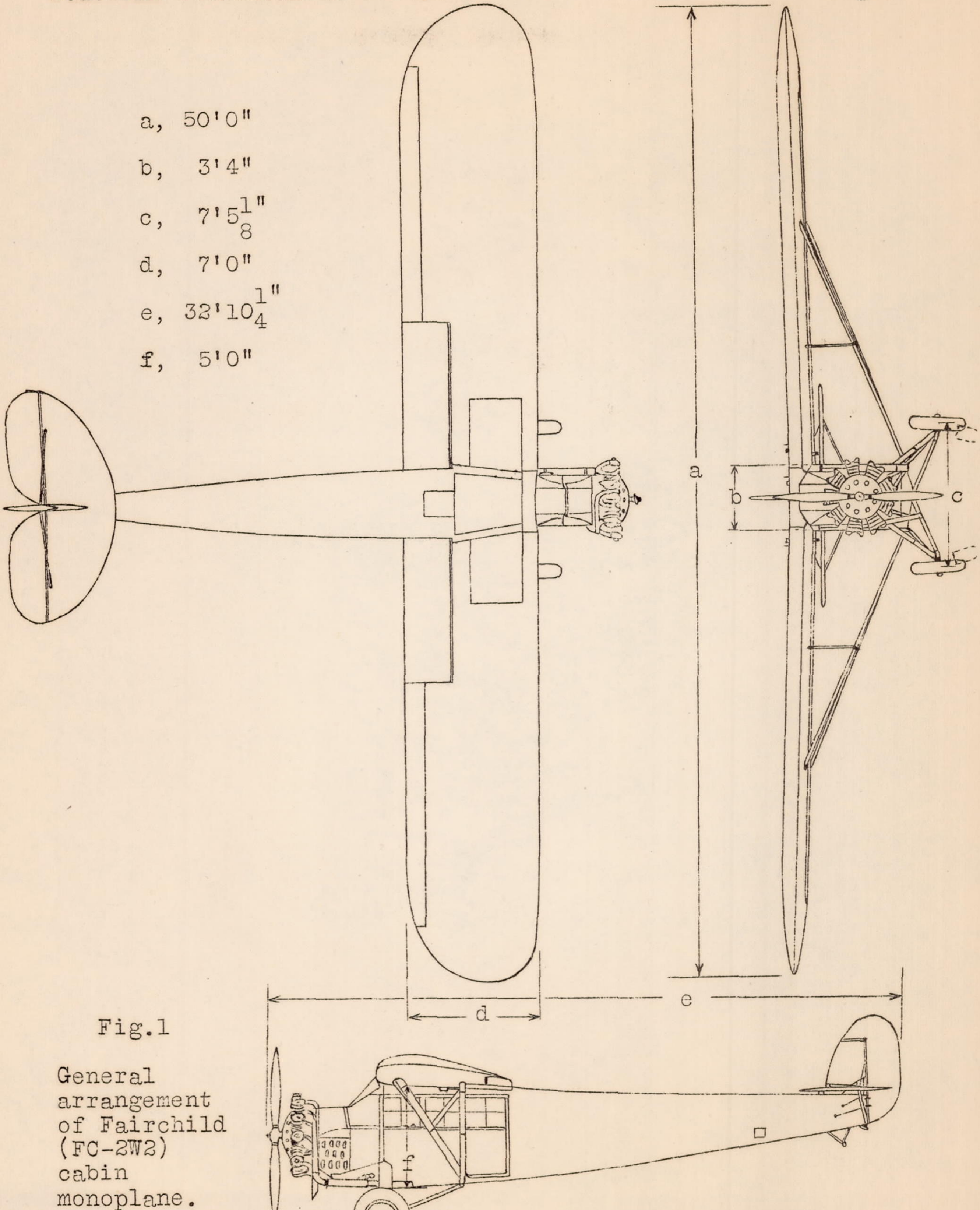


Fig.1

General arrangement of Fairchild (FC-2W2) cabin monoplane.

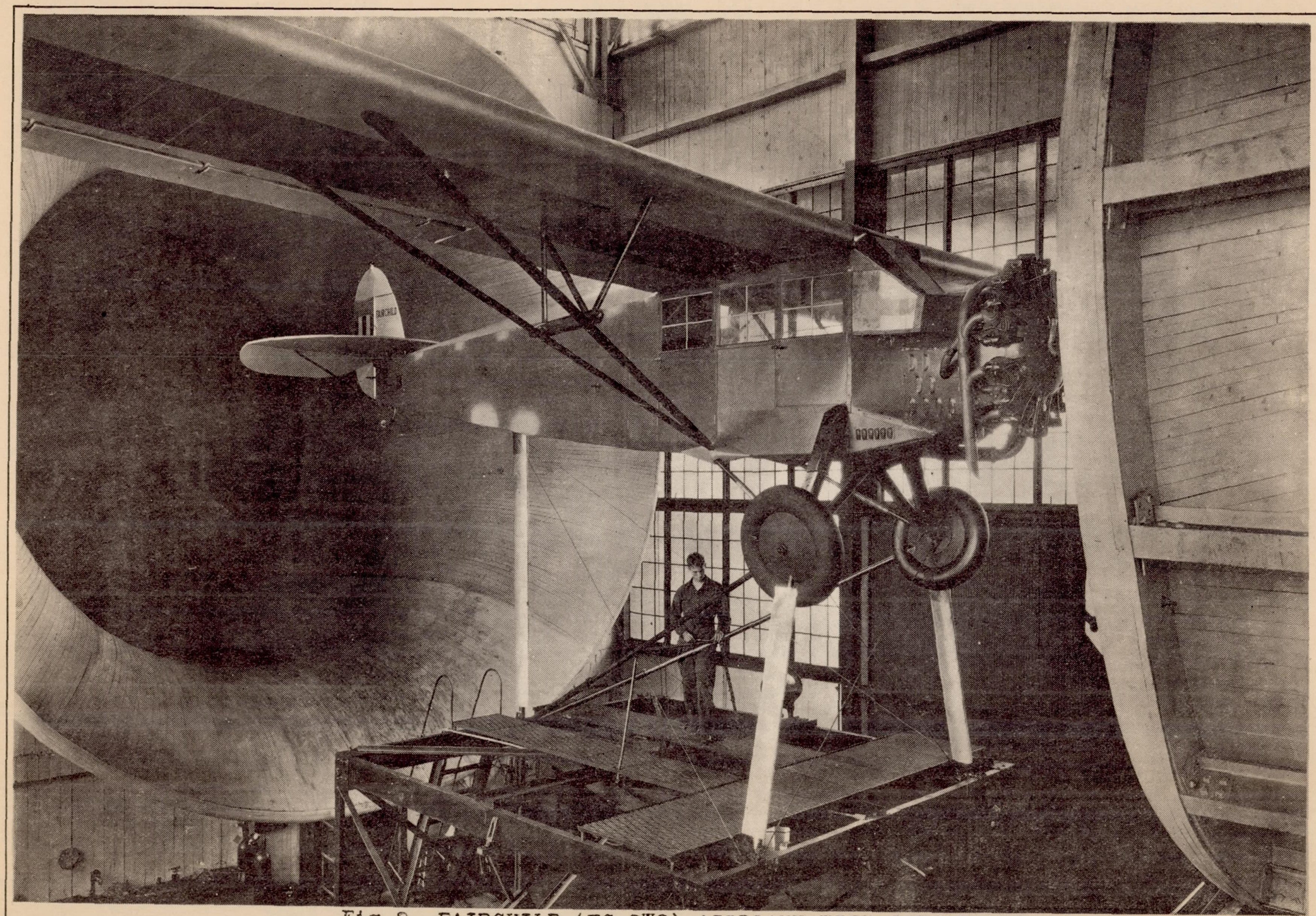


Fig.2 FAIRCHILD (FC-2W2) AIRPLANE WITH TURTLEBACK

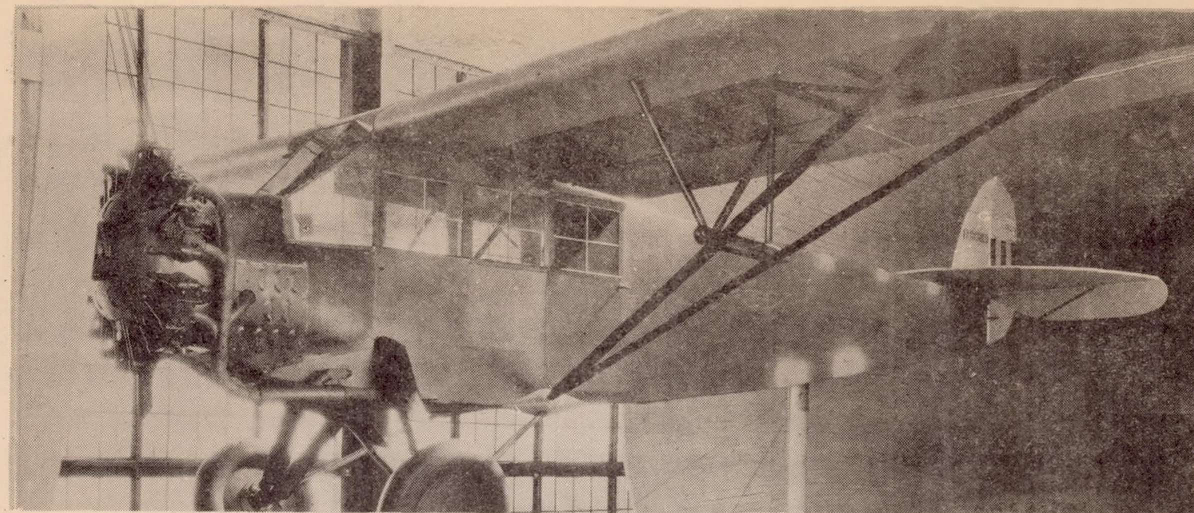


Fig. 3. TURTLEBACK REMOVED.

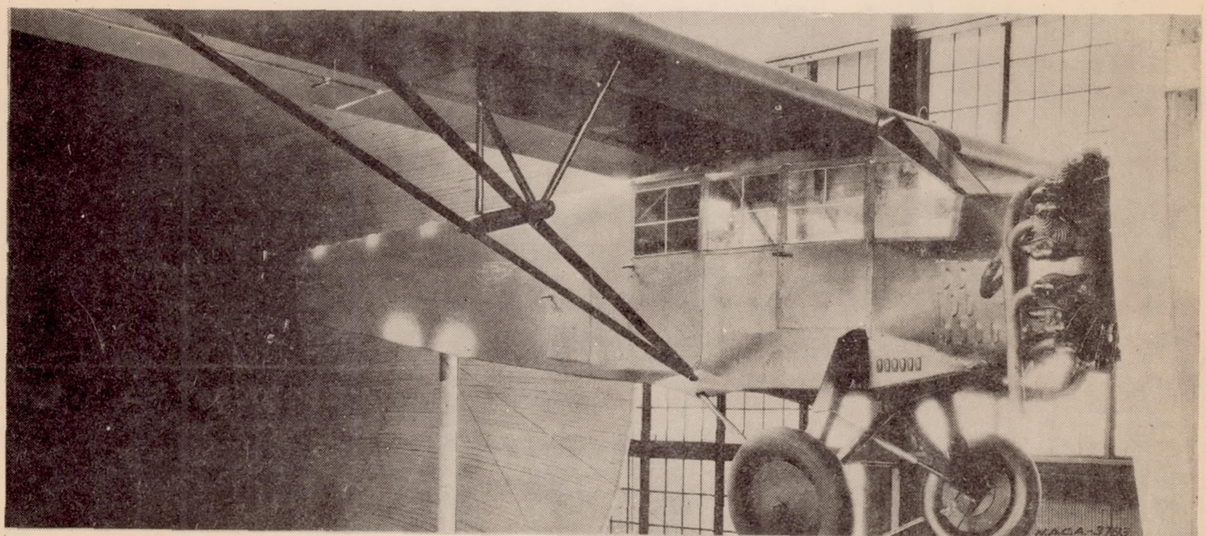


Fig. 4. TAIL SURFACES REMOVED.

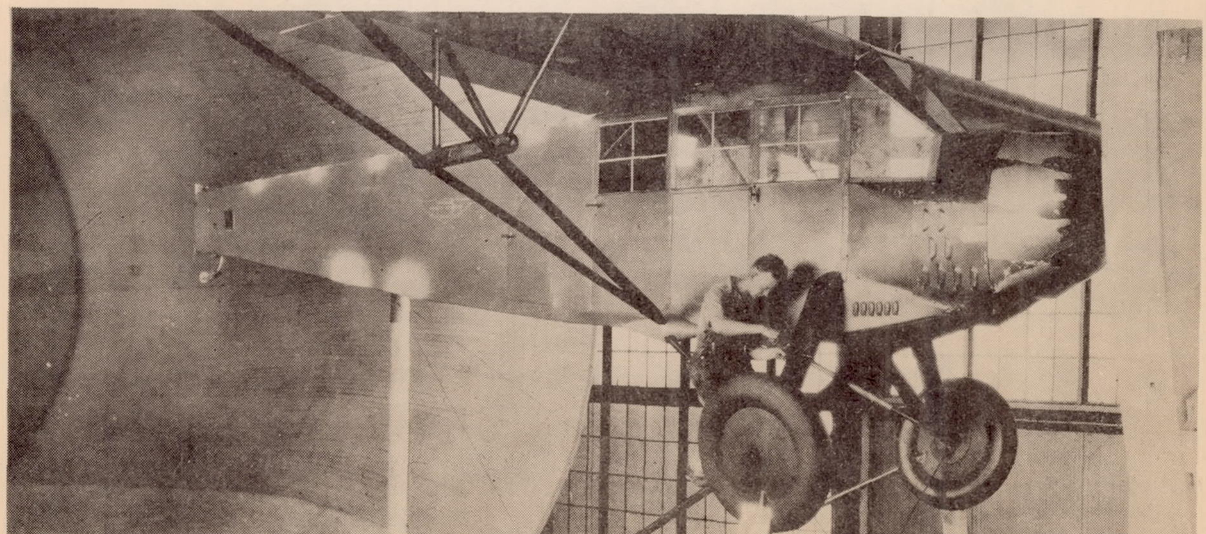


Fig. 5. ENGINE REMOVED AND NOSE FAIRED.

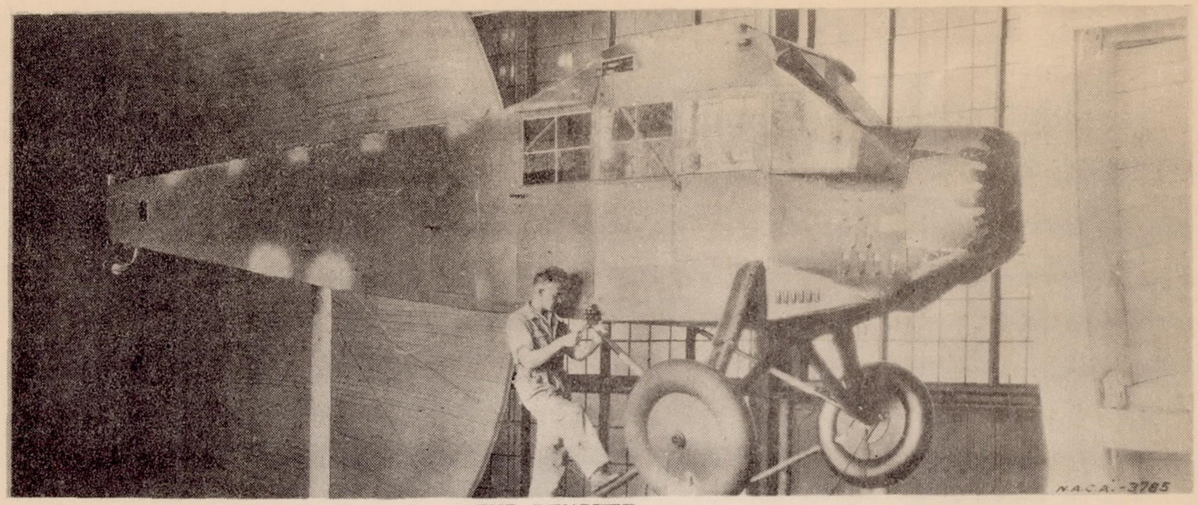


Fig. 6. WING REMOVED.

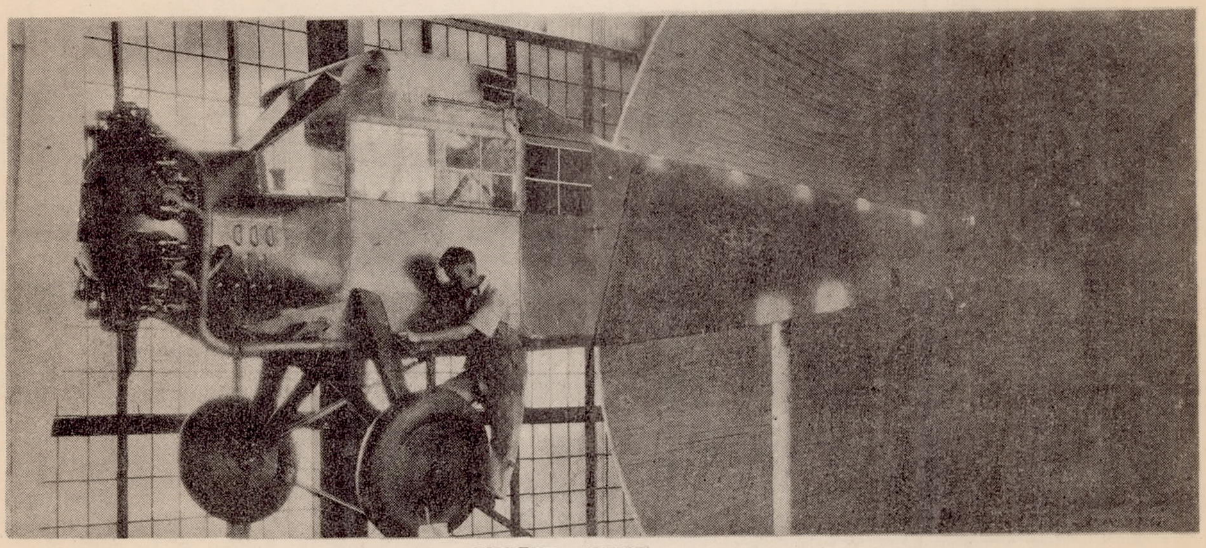


Fig. 7. ENGINE ADDED.

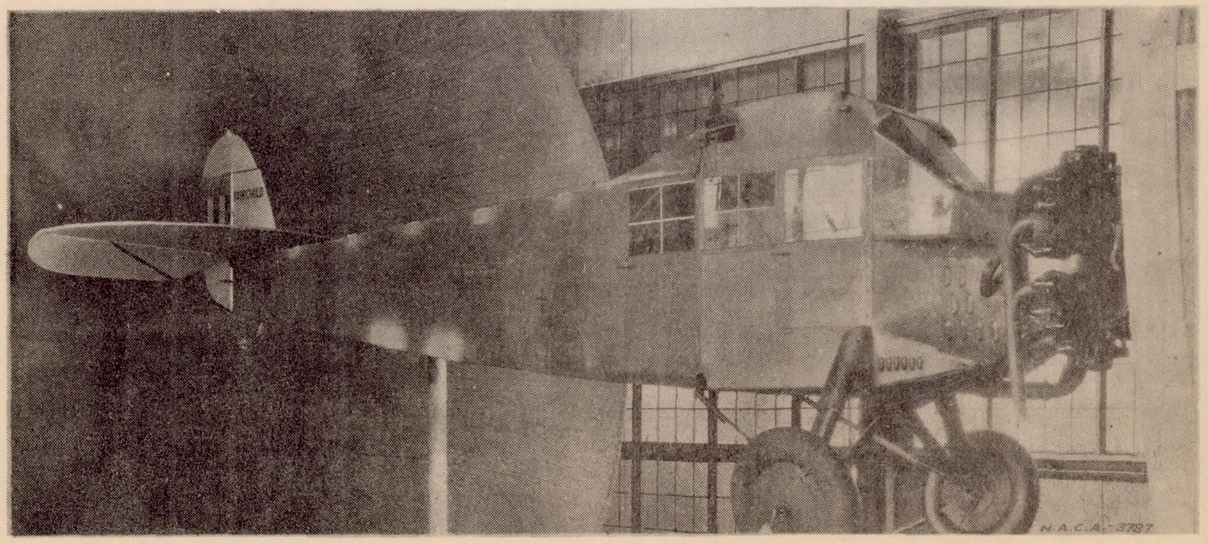


Fig. 8. TAIL SURFACES ADDED.

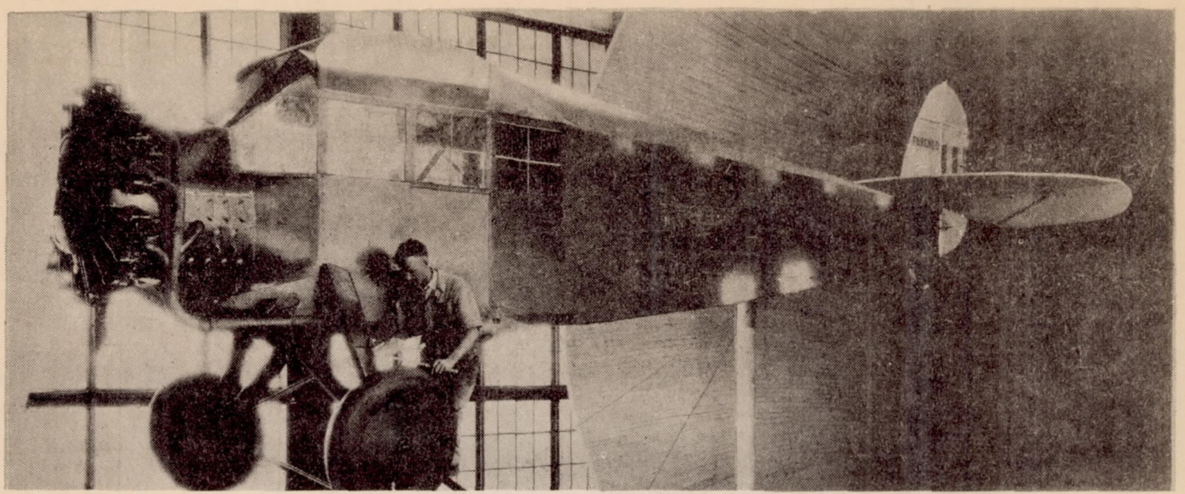


Fig.9. TURTLEBACK AND WING ROOT FAIRINGS ADDED.

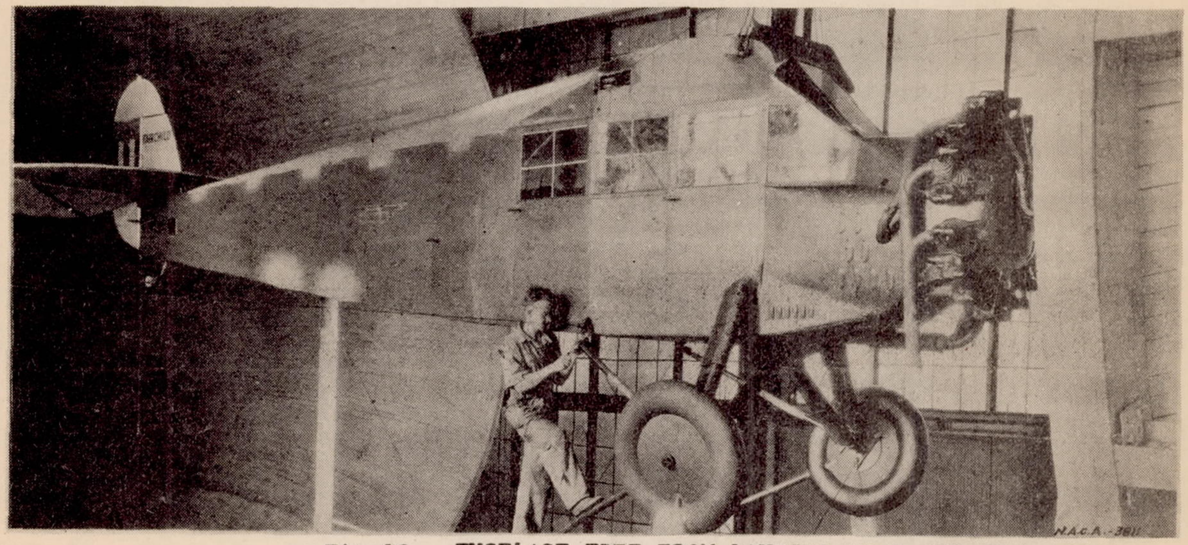
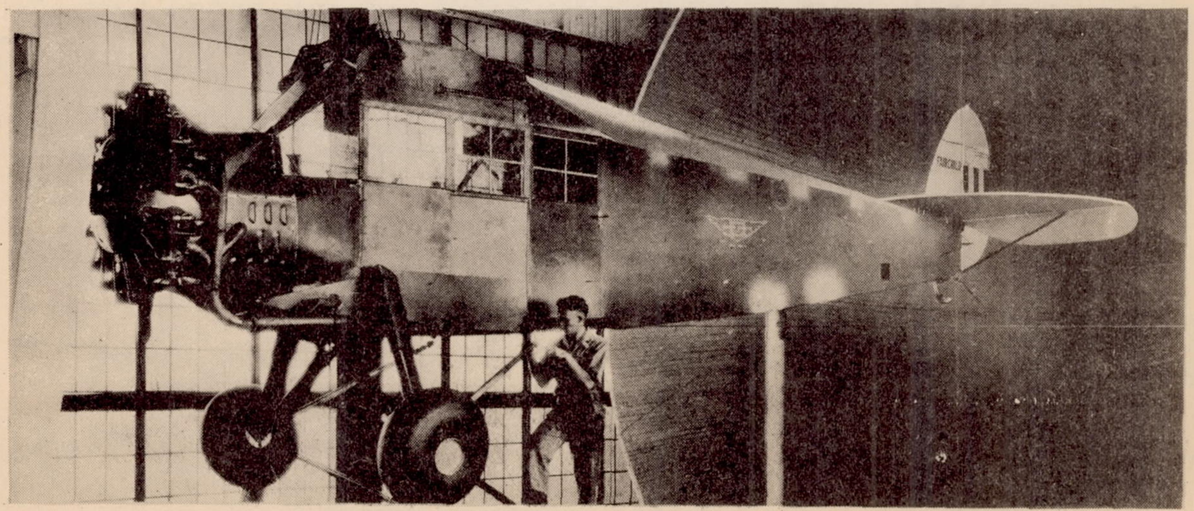


Fig.10. FUSELAGE FREE FROM LANDING GEAR AND SUPPORTS–STANDARD WHEELS.



Fig,11. FUSELAGE FREE FROM LANDING GEAR AND SUPPORTS–MUSSELMAN WHEELS.

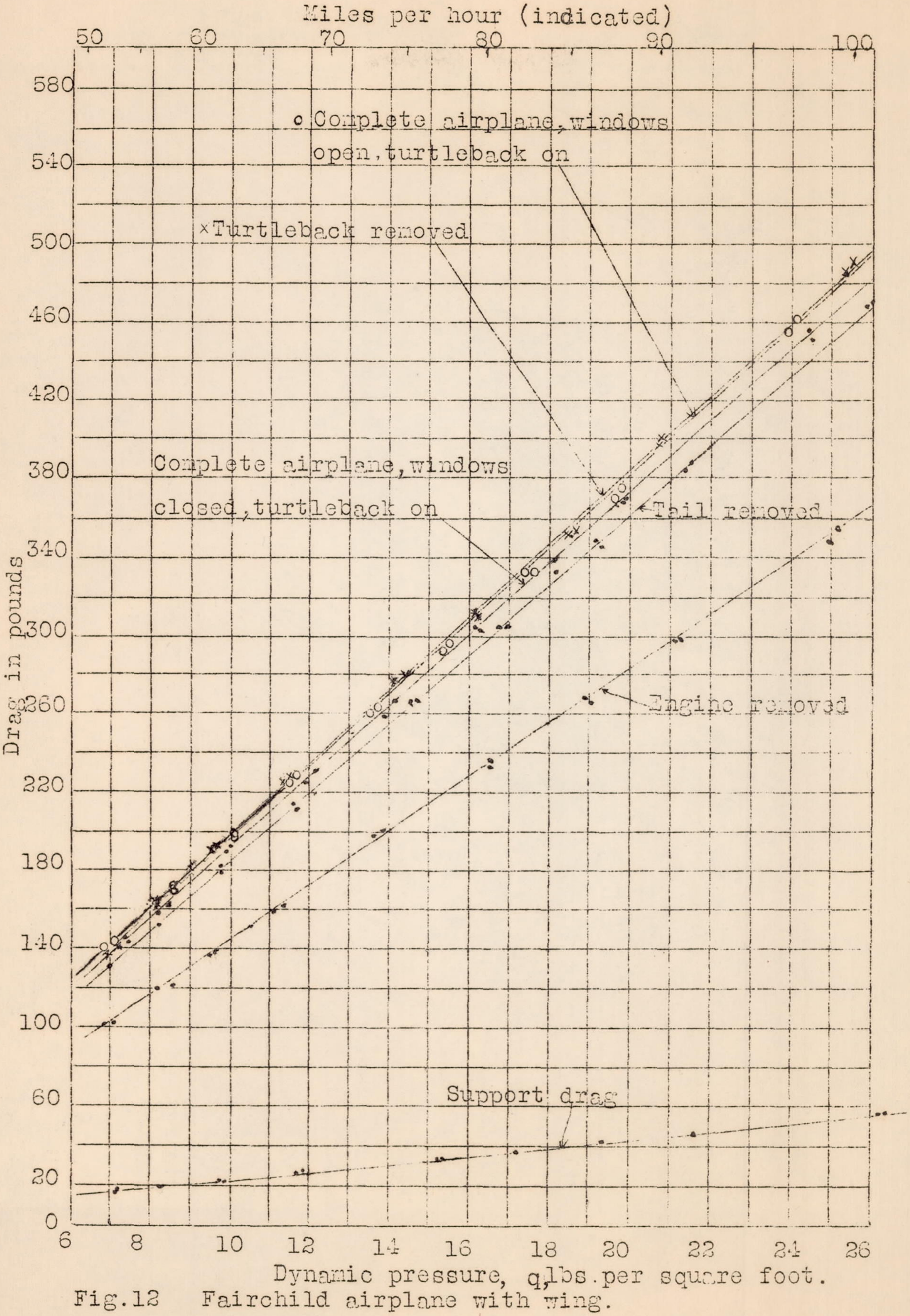


Fig. 12 Fairchild airplane with wing.

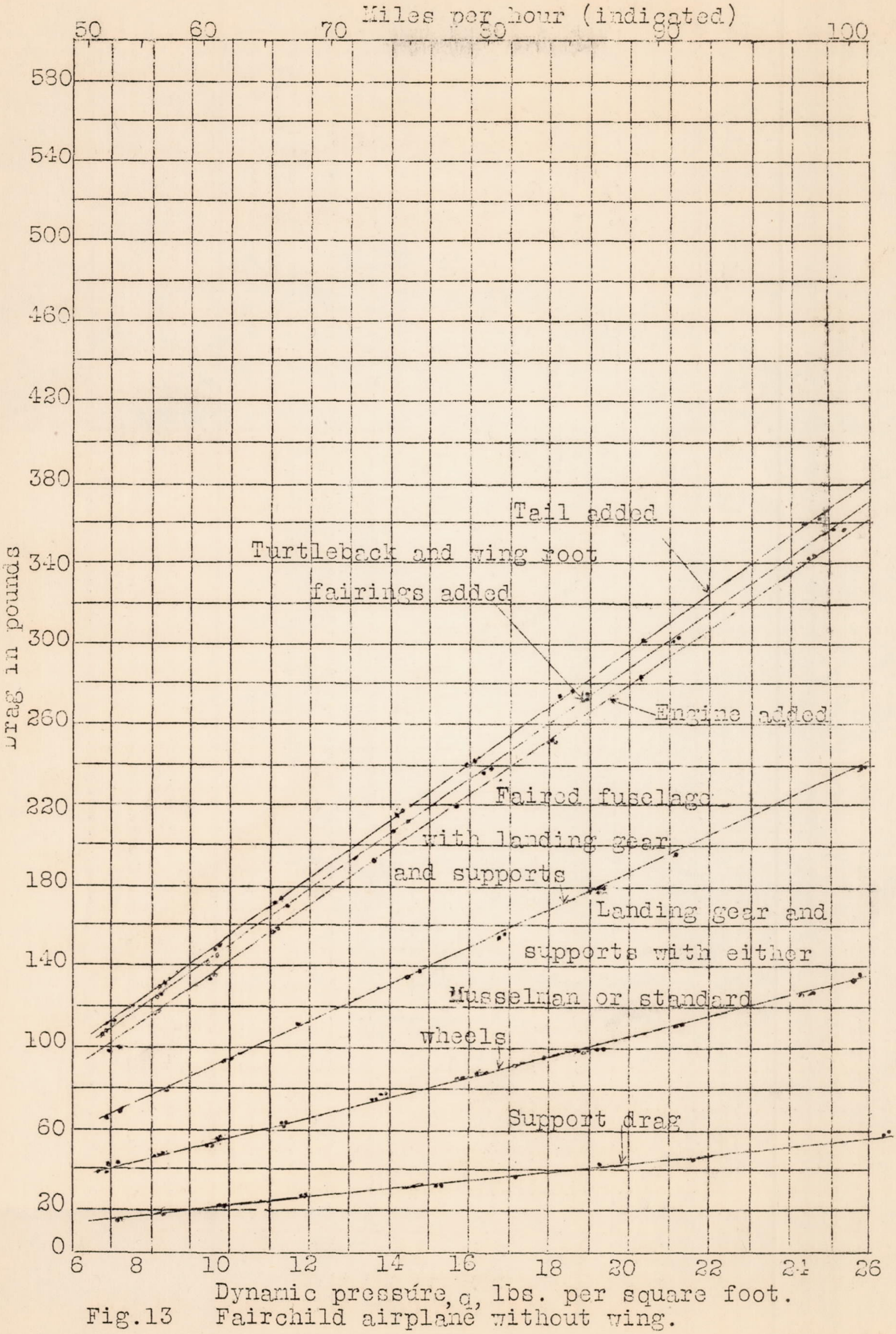


Fig.13 Fairchild airplane without wing.

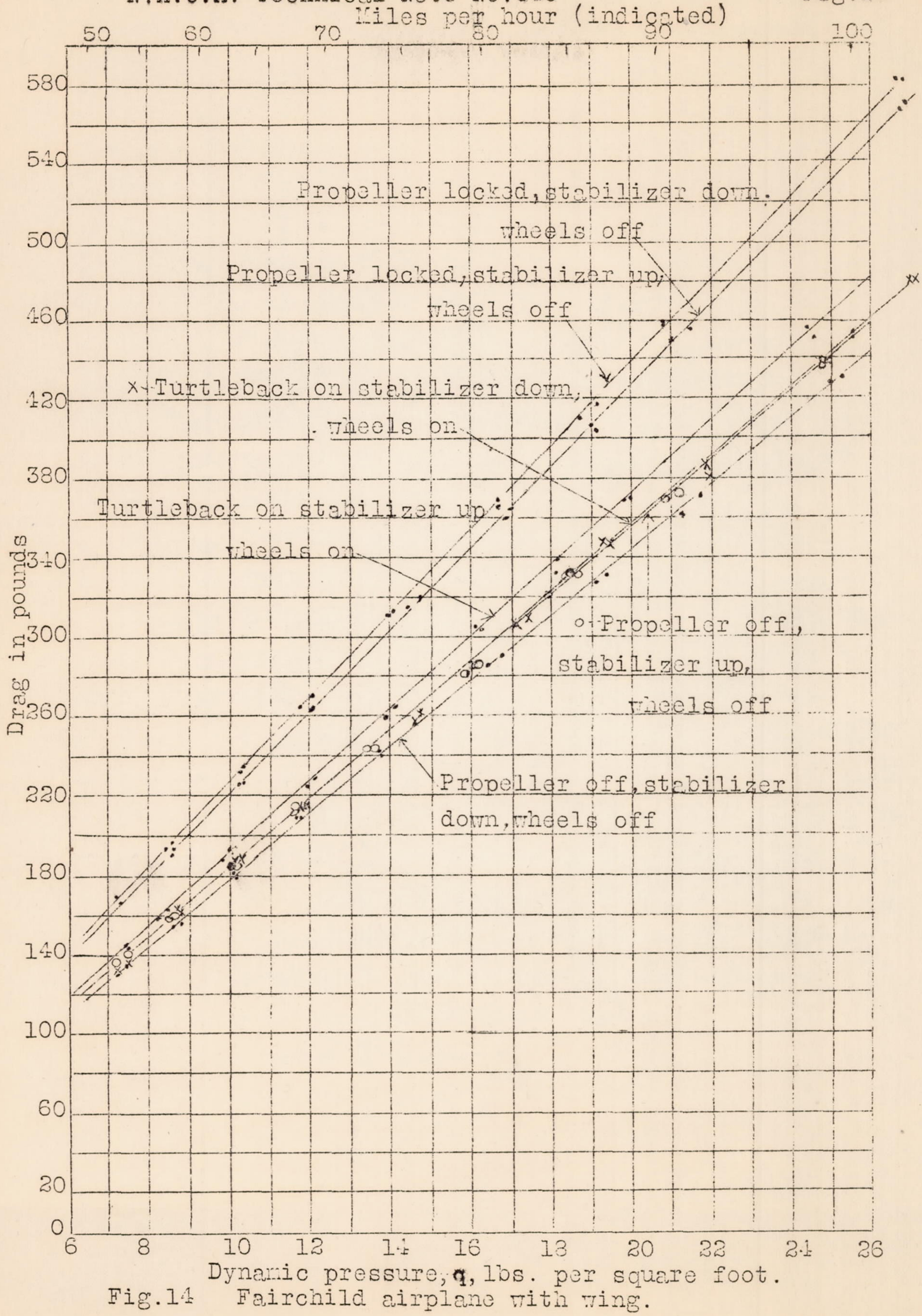


Fig.14 Fairchild airplane with wing.

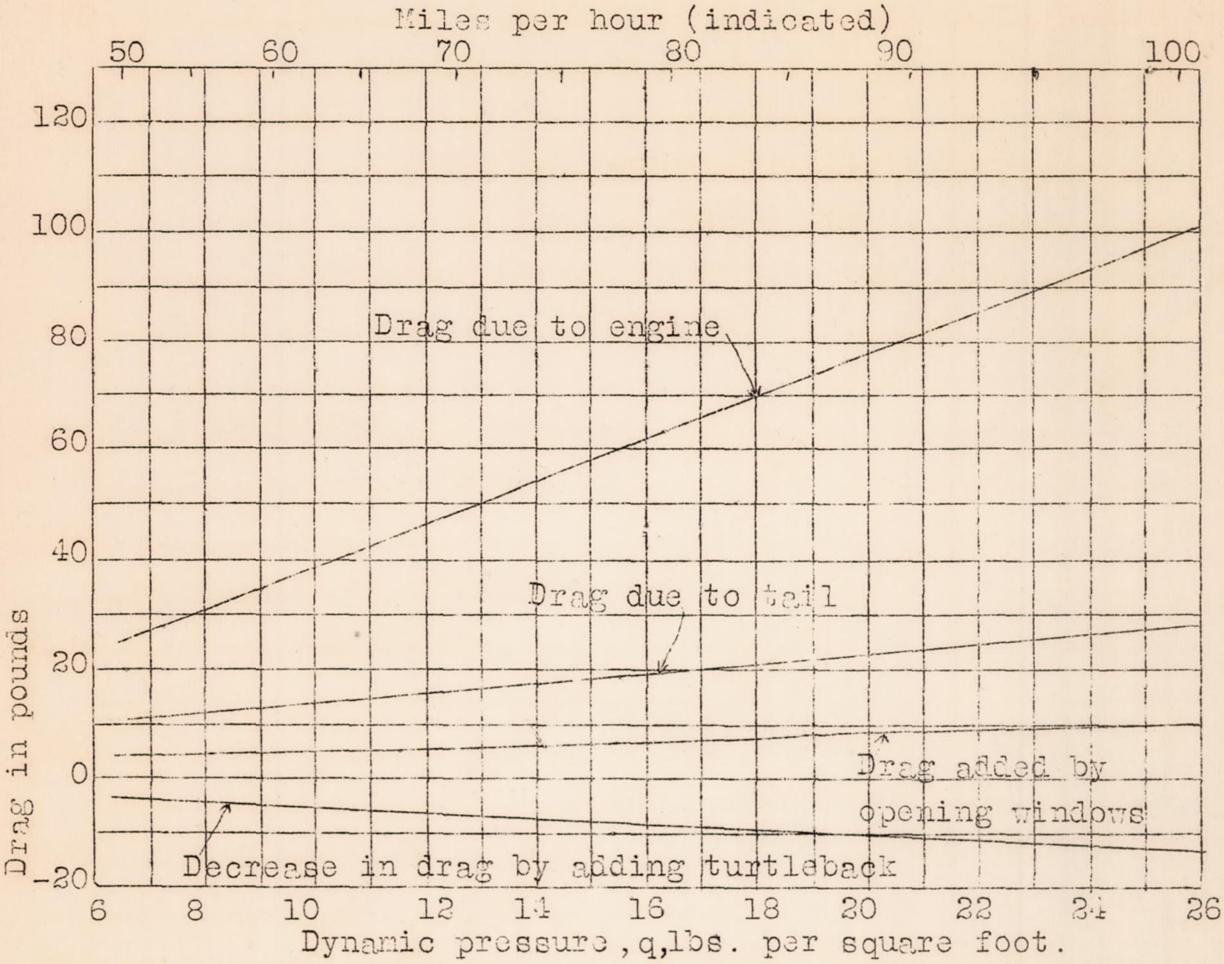


Fig.15 Fairchild airplane with wing. Drag of component parts.

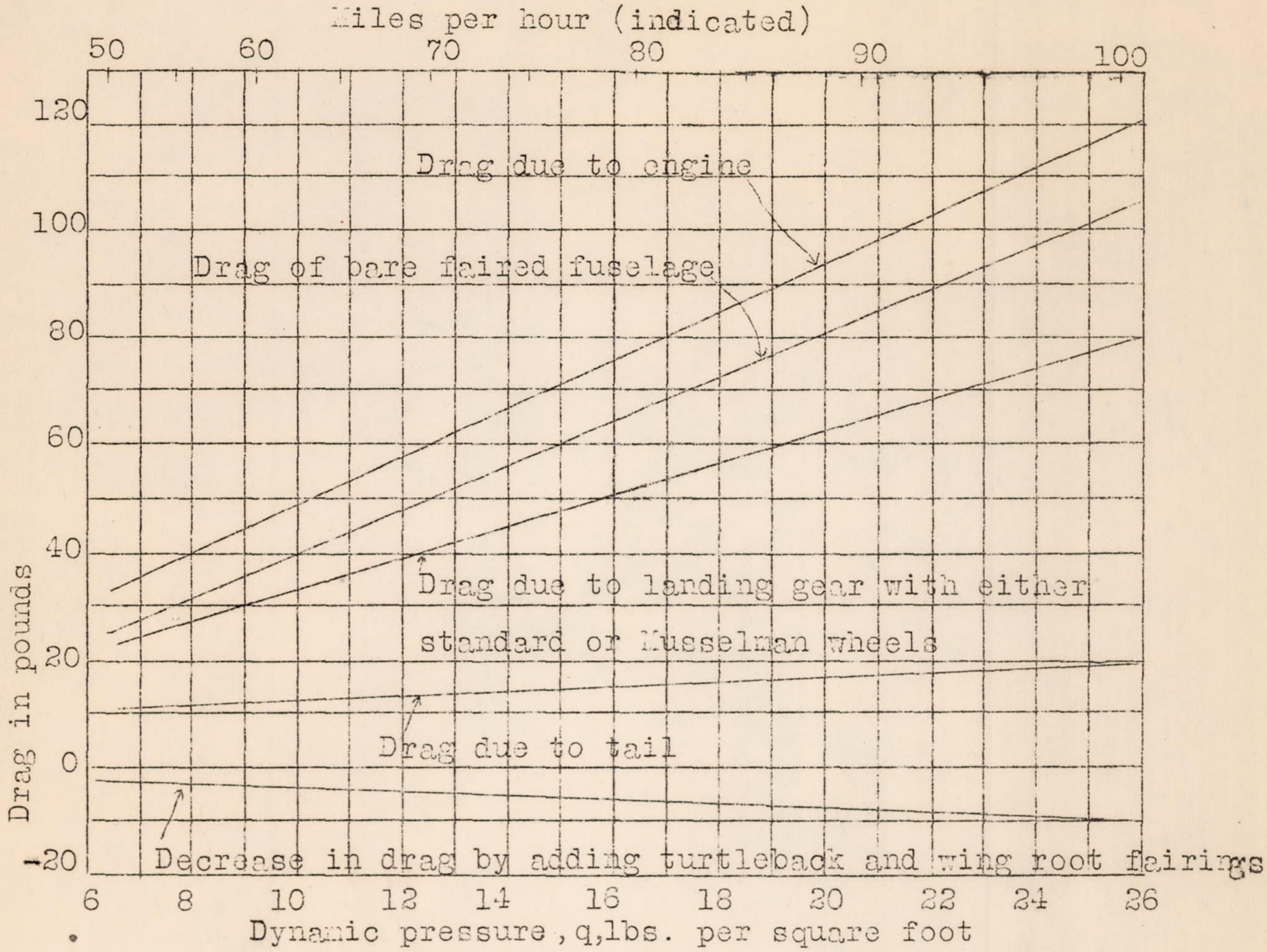


Fig.16 Fairchild airplane without wing. Drag of component parts.

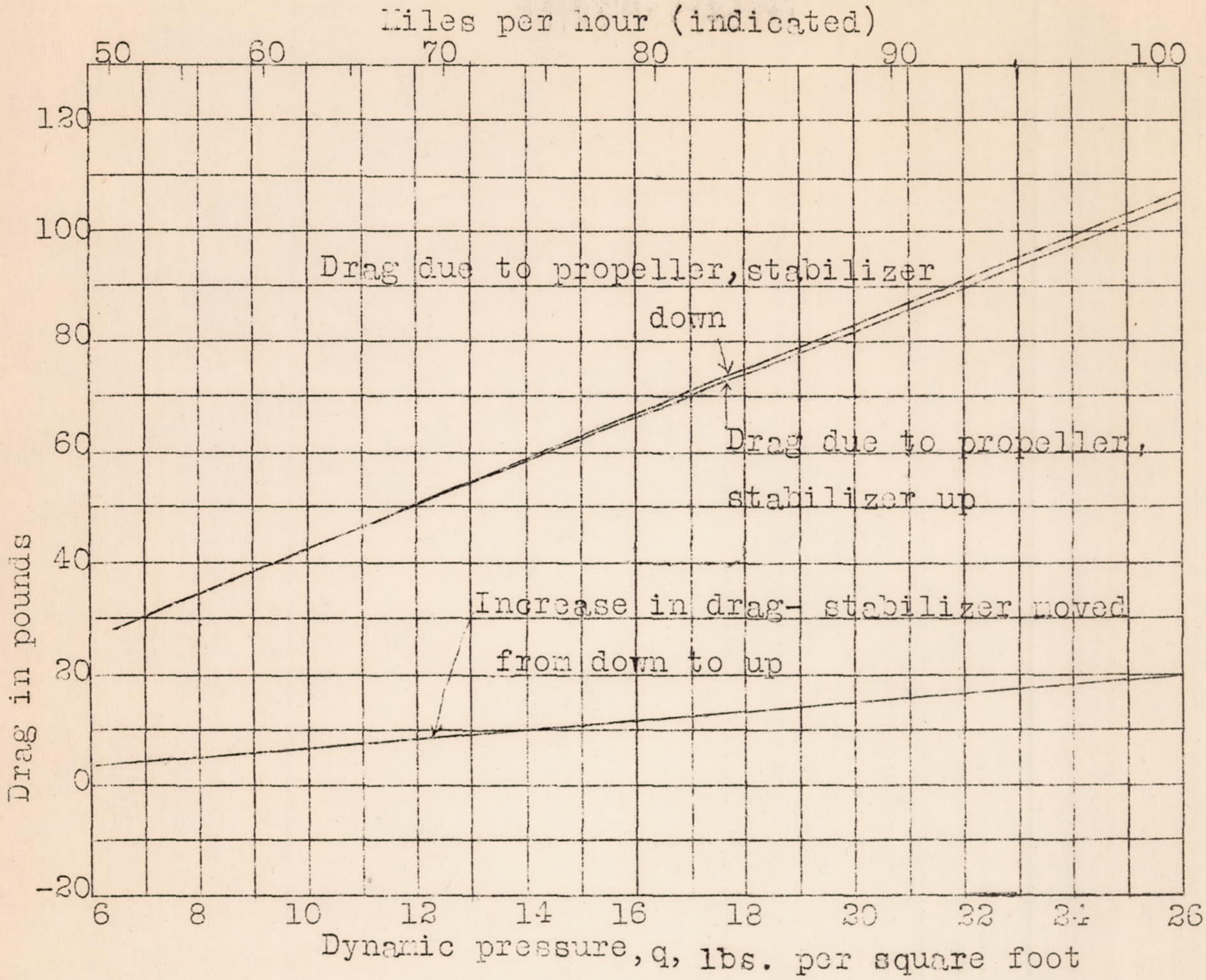


Fig.17 Fairchild airplane with wing. Drag of component parts.