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The effect of compressibility on the drags of external stores carried on the F.W. 190.

- by -

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S U M M A R Y.

An analysis is made of the results of flight tests on the F.W. 190 equipped with two 65 gallon drop tanks and a 500 Kg. bomb. The drags deduced for the stores rise very rapidly with increasing Mach number, above M=0.4 (see Fig. 5); moreover, it is estimated that the increases of drag occur prior to the development of shock waves on the stores. The results emphasize the need for careful aerodynamic design of external stores carried on high speed aircraft.

Brief description of tests.

The long-range equipment of the F.W. 190 includes a 500 kg. bomb carried under the fuselage, and two under wing airship-shaped drop tanks each of about 65 gallons capacity. Photographs of the bomb and a drop tank in position are shown in Figs. 1 and 2. Corresponding sketches showing the principal dimensions of the stores are given in Fig. 3. The interesting feature of the drop tank installation is that, contrary to British practice, the fairing between the tank and the wing is retained after the tank has been jettisoned.

The flight tests included maximum level speed measurements at engine combat rating, up to an altitude of 30,000 ft.,

(a) With the aircraft in its standard condition

(b) With the 500 kg. bomb attached

(c) With the bomb and drop tank fairings, but with no tanks

(d) With the bomb, drop tank fairings, and drop tanks

Curves showing the variation of the true airspeed with altitude, for these four conditions, are plotted in Fig. 4.

Results and discussion.

The drags of the separate components, shown in Fig. 5, were deduced from the top speed measurements in the usual way, allowance being made for changes in the induced drag; the drag of the standard aircraft was assumed to be 65 lb. at 100 ft/sec. This figure was suggested by previous flight tests on the aircraft, but as there appears to be some

exact B.H.P. developed by the engine this figure may be about ± 8% in error; the drags deduced from the present tests will therefore be subject to errors of the same order. However, since the value of the results lies primarily in demonstrating the variation of the drag with increasing Mach number, rather than in the absolute magnitude of the drag, this order of accuracy is acceptable.

It will be seen from Fig. 5 that compressibility effects begin to be important at Mach numbers as low as 0.4. Thus, the drag of the bomb at 100 ft/sec increases from about 10 lb. to about 22 lb. between M=0.4 and M=0.49; the drag of the two drop tanks at 100 ft/sec rises from 18 lb. at M=0.39 to 26 lb. at M=0.45.

A rough estimate of the theoretical critical Mach number for the tank installation is 0.5; the critical for the bomb is probably appreciably higher*. It has been generally noted that, with increasing Mach number, thick wings or bodies show large compressibility effects earlier than is indicated by the critical Mach number derived from the low-speed pressure distributions. This is believed to be due to the fact that even at low speeds the adverse pressure gradients on such bodies are large; with increasing Mach number these gradients increase rapidly and boundary layer separation develops before the appearance of a shock wave. It follows that for such bodies the estimated critical Mach number is no longer reliable as a warning of impending adverse aerodynamic changes. In the case of external stores, such as we are considering in this note, the flow breakaway is probably augmented by interference effects between the stores and the wing and fuselage, and in consequence the breakaway probably spreads over parts of the wing and fuselage.

The above arguments emphasize the need for careful strut fairing design of drop tanks, the principles of which are discussed in Ref. 1.✓; further more, the external carriage of bombs of poor aerodynamic design on high speed aircraft should be avoided.

The drag of the fairings alone does not show any considerable change with increasing Mach number. This can be attributed to the fact that probably there is an almost complete flow breakaway from the concave undersurface of the fairing even at low speeds, and compressibility, therefore, has little further effect on the drag.

It may be noted that the drag estimates of a store were based on the differences in top speed of the aircraft with and without the store. Since the top speed of the aircraft alone is greater than that of the aircraft with the store, any compressibility effects on the aircraft due to this difference of speed would result in the estimate of the drag of the store being on the low side. Hence, in such a case, the rise in the values of the store drag with increasing Mach number shown in Fig. 5, is less than the true rise.

The low-speed drag of the tanks is considerably higher than that suggested by British wind tunnel tests[2] on a similar tank arrangement. This is probably due to the very poor shape of the fairing, and particularly to the spoiling effect of the leak between the tank and fairing (see Fig. 2).

A rough estimate of the drag of the bomb alone, using the data of Ref. 3, is about 6½ lb. at 100 ft./sec; of this, same 3 lb. is contributed

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* Excluding the circular bracing for the fin.

✓ In this connection it may be noted from Fig. 3 that the thickness-chord ratio of the strut fairing is about 35%; Ref. 1 recommends 15% as the maximum thickness-chord ratio for fairings of this type.

by the circular bracing for the fin. On the assumption that there is no interference between the bracing and the fuselage, it would appear from this estimate that the interference between the fuselage and bomb amounts to about 100% of the bomb drag. Wind tunnel tests on British 250 lb. and 500 lb. G.P. bombs, mounted beneath a 12½% thick Spitfire wing(4), showed a considerably greater percentage interference. This reduction of interference on stores in the underfuselage position as compared with the underwing position agrees with the results of American tests on drop tanks reported in Ref. 2.

The very large drag of 5 lb. at 100 ft/sec. for each of the fairings agrees fairly well with some unpublished results of tests on similar fairings made in the R.A.E. 5 ft. wind tunnel. It is probably due to the excessive drag of these fairings that the Germans have tended to abandon their use on more recent installations(5).

Conclusions.

The increase of drag with Mach number at fairly low speeds, suggests that flow breakaway develops prior to the formation of shock waves; this is to be expected on thick bodies, and on bodies of poor aerodynamic design. For such bodies the prediction of compressibility effects based on the critical Mach number will be of little value. Consequently, the need is emphasized for careful aerodynamic design of external stores carried on high-speed aircraft.

REFERENCES.

No.	Author.	Title, etc.
1	P.R. Owen.	Strut fairings for drop tanks on high speed aircraft. R.A.E. Tech. Note No. Aero 1243. July, 1943.
2	P.R. Owen, H.V. Becker and H. Hogg.	Note giving a survey of wind tunnel tests on auxiliary fuel tanks. R.A.E. Report No. Aero 1846. Aug. 1943. ARC 7165.
3	M.A. Morrison and R. Hills.	Wind tunnel tests on bombs: a collection of data on drag. R.A.E. Tech. Note No. Aero 1304. Oct. 1943.
4	R.L. Maltby	24 ft. wind tunnel tests on bombs and bomb containers. R.A.E. Tech. Note No. Aero 1201. May, 1943.
5	W.A.P. Fisher	Examination of German 65 gallon metal drop tank. S.M.E. Tech. Note No. 182. (E.A.M/106). Oct. 1943.

Attached:

Neg. No. 49178	Fig. 1.
Neg. No. 49179	Fig. 2.
Drg. No. 14099 S	Fig. 3.
Drg. No. 14100 S	Fig. 4.
Drg. No. 14101 S	Fig. 5.

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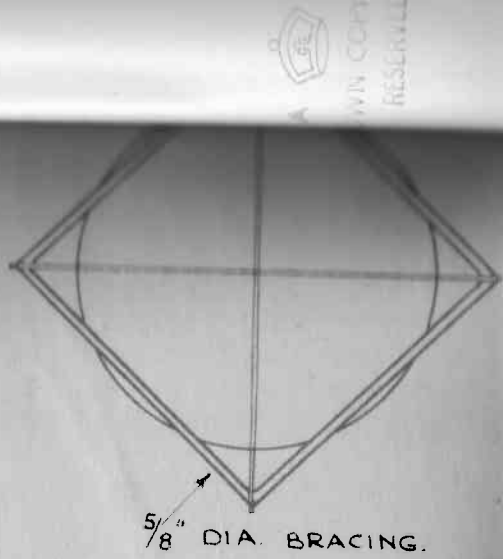
FIG.1.

FIG.2

SECTION OF TANK

500 KG. BOMB.



SCALE 0 5 10 INS.

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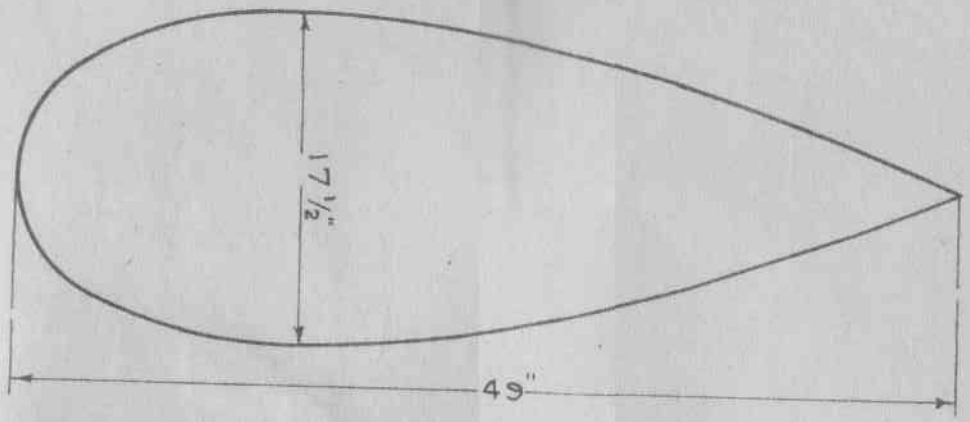
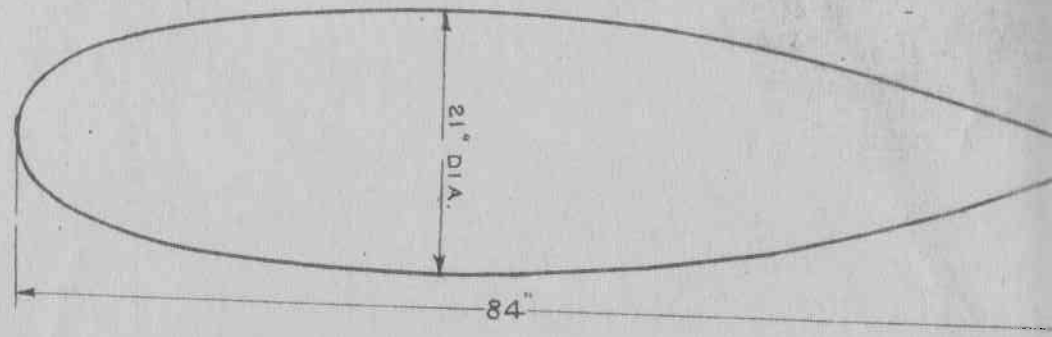


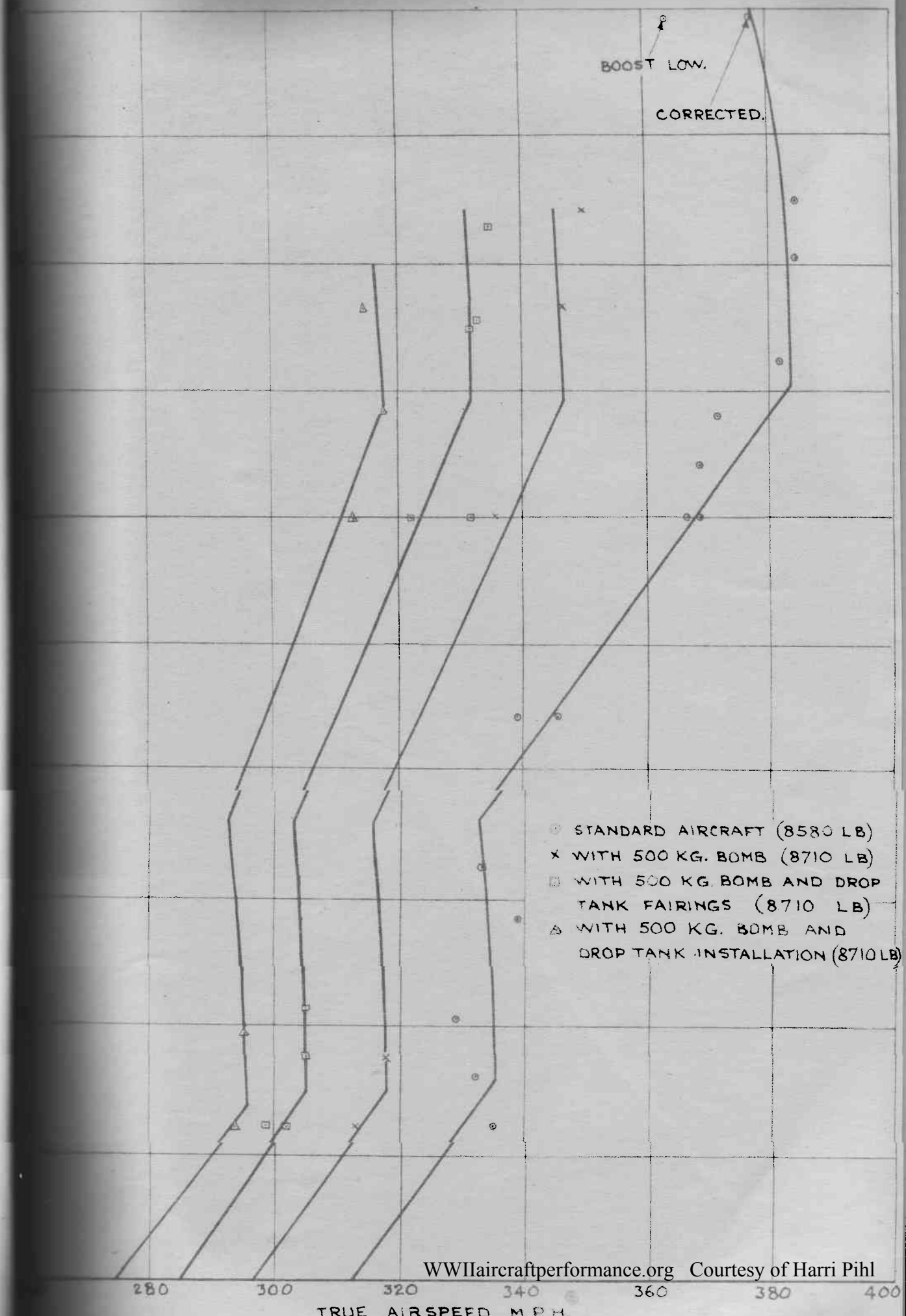
SECTION OF TANK FAIRING AT WING-FAIRING JUNCTION.

SCALE: 0 5 10 INS.



PROFILE OF DROP TANK.

SCALE: 0 5 10 15 INS.



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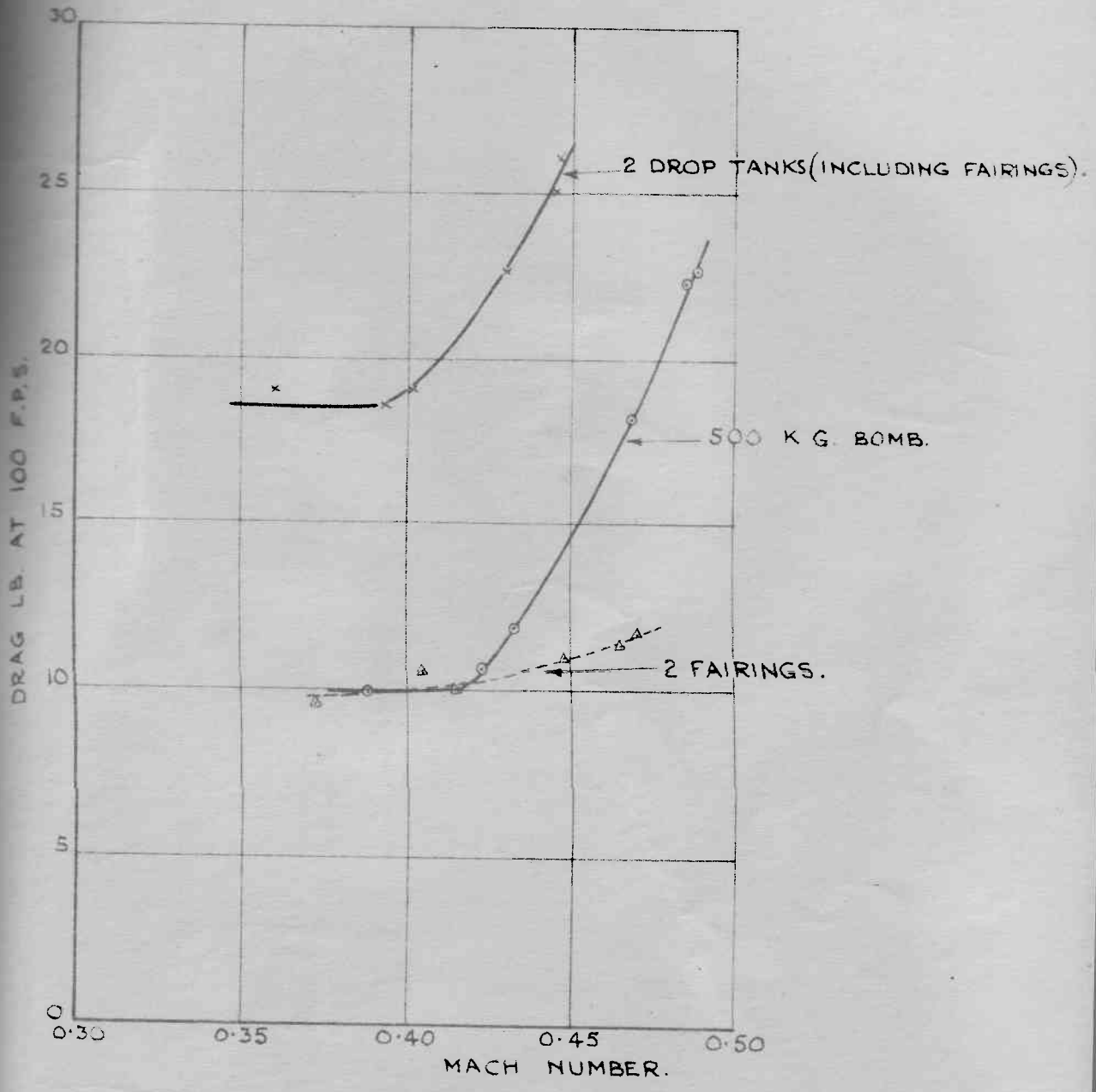
VARIATION OF MAXIMUM LEVEL SPEED WITH ALTITUDE.

MACH NUMBER = $\frac{\text{FORWARD SPEED}}{\text{SPEED OF SOUND AT THE SAME ALTITUDE.}}$



MEASURED VARIATION OF DRAG OF STORES WITH MACH NUMBER.