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Flight Tests of a Simple Method of Measuring Pressure Distributions on a Wing

by

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FLIGHT TESTS OF A SIMPLE METHOD OF MEASURING PRESSURE DISTRIBUTIONS ON A WING

by

W. G. A. Port and J. C. Morrall

SUMMARY

Small-bore plastic tubes, stuck to the wing surface, and drilled for pressure measurements at selected points, are shewn to be a reasonably suitable basis for the measurement of pressure distributions in flight. Only a small fairing on each side of the tubes is required, but cross flow should be avoided as far as possible.

Results are presented for the pressure distributions around the wing centre-section on a Meteor aircraft, both in free air and near the ground.

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1 INTRODUCTION

A requirement arose in 1953 for a simple method of obtaining pressure distributions in flight over the wing of a 4-jet swept-wing transport aircraft (Comet 1). The equipment had to be capable of being easily installed and removed, with little or no modification to the wing.

It was suggested that satisfactory results could be obtained by sticking small-bore plastic tubes to the wing surface in a fore-and-aft direction, with holes drilled into the tubes at the required chord-wise positions. The tubes, sealed at their far ends, could be led externally along the wing and into the recording equipment in the fuselage.

As a preliminary, a flight test of such an installation was made on a Meteor 8 aircraft. Pressure distributions were measured both in free air and in the presence of the ground (as was required on the Comet 1). An investigation was also made of the effect of progressively reducing the width of the fairing on either side of the tubes, so that the simplest possible installation might result, consistent with acceptable accuracy.

2 DESCRIPTION OF INSTALLATION AND INSTRUMENTATION

It was decided to measure the pressure at 14 points, distributed chord-wise according to the positions shown in Table 1 and Fig.2. The region between the fuselage and the nacelle was chosen as the test section, the flow here being very nearly two-dimensional due to the effects of the "end plates" formed by the fuselage and nacelle. Since the application was to be to a swept-wing aircraft, on which cross flow, which could not be accurately assessed, would be present, it was decided to make the experiments in such a way that the effects of cross flow could be simulated. The tubes were therefore layed at an angle of about 25 degrees to the plane of symmetry, at least near the leading edge.

Fig.1 illustrates the chosen layout, showing how the tubes were wrapped around the leading edge to the undersurface, whence they were turned inboard towards the fuselage and led into the ammunition bay via the cartridge case ejection slot.

The fourteen tubes were of 3 mm outside diameter and were laid in a trough cut in a double layer of plywood, as shown in the detail sketch in Fig.2. The lower (continuous) sheet of plywood was stuck to the wing surface with Araldite, to form what was believed (at that time) to be a stronger bond than would be obtained by sticking the tubes directly to the metal skin. The tubes in the trough were embedded in Araldite which was smoothed and polished to form a surface continuous with the top surface of the plywood. A small hole was then drilled through the Araldite and into a buried tube at each of the chosen chord-wise stations so that each tube communicated with one pressure pick-up point. For simplicity, all the tubes extended rearwards over the top surface beyond the last hole position before being sealed off.

As a result of this installation, the wing surface locally was raised $\frac{1}{4}$" (0.19% of the local chord) relative to the original surface. Spanwise, the plywood fairing originally extended right from the fuselage to the nacelle, so that there was at least 15 inches of fairing beyond the outboard tube on the top surface (Fig.1), and at least 22 inches on the inboard side. In later tests, the fairing was reduced in width in four steps, ending with only 1 inch of tapering fairing on either side of the tubes. For the intermediate steps, the edges of the fairing were left at approximately 45° to the wing surface.

4.1 Ground effect

From the first series of tests in free air and near the ground, pressure distribution curves were obtained and plotted at a series of speeds. These curves were then cross plotted against lift coefficient, to give curves of pressure coefficient, C_p = (surface pressure-static pressure) $\frac{1}{2}\rho V^2$ against C_L for each pressure hole. Because the free air and the near-ground results were to be compared at the same geometric incidence, figures obtained from previous tests[1] on a Meteor, to measure ground effect on lift and drag, were used. These tests gave lift curves in free air and at a mean height of 0.75 of the local chord above the ground. With a small correction for the difference in height above ground in the two series of tests, the lift coefficients could be obtained for the incidences at which the comparison was to be made. The pressure distribution curves were then compared at the same geometric incidence and these are shown in Fig.3 at three angles of incidence, with wheels and flaps down and in Fig.4 at one incidence with flaps up, undercarriage down. The incidence range over which it is possible to compare pressure distribution is limited because of the small speed range over which the near ground flights could be made. Fig.5 shows two curves at the same lift coefficient (0.7), in free air and near the ground ($\frac{1}{4}$ chord point 0.6c above the ground). Since these two curves are almost identical it would appear that, over the leading 25% chord at least, the ground effect on Meteors is almost entirely a change in effective incidence.

4.2 Effect of reducing fairing size

The results of the flights to assess the effect of reducing the fairing size are given in Fig.6 (A-D), at four values of the lift coefficient and in Fig. 7 at a Mach number of 0.6. The extreme cases are compared in Figs.8A and 8B.

At a constant lift coefficient, no differences were shown between the results for the full width and the 7" fairings. With the narrowest fairing, the pressure distribution curves lie generally inside those for the full width fairing, except on the undersurface at the higher lift coefficients. The differences are small over the first 3% of the chord. Aft of this point, on both surfaces, some of the pressure holes were directly down-stream of the leading edges of the narrowest fairings, (Fig.1), since the tubes were deliberately laid to produce a cross flow. Fig.1 shows that this was the case with any fairing less than 6" in width, and it is not surprising that some change in pressure distribution was recorded. Even where the tubes themselves were laid streamwise, the fairing of the swept tubes near the leading edge could affect the readings.

At high speed (around M = 0.6) insufficient measurements were made to enable the full effect of reduction in fairing size to be determined at a constant lift coefficient, except for the $3\frac{1}{2}$", 2" and 1" fairings. Thus, the distribution curves (Fig.7) for the 7" fairing (the largest tested at this speed) are for a slightly higher lift coefficient than the others. There is no significant difference in the curves for the three smallest fairings, as shown in Fig.8B, but the effect of the reduction from the full width down to the $3\frac{1}{2}$" fairing is not known. The effect is, however, small over the C_L range 0.74 to 0.46.

It must be emphasised here that, although these very limited tests at M = 0.6 indicated that the fairing width had little effect, at higher Mach numbers with much more pronounced compressibility effects, fairing width may become very important.

TABLE 1

Positions of pressure tapping holes

	Hole No.	% chord	Dist. from leading edge, in inches
Bottom surface	1	6	7.98
	2	4	5.32
	3	2	2.66
	4	1	1.33
Leading edge	5	0	0
Top surface	6	$\frac{1}{2}$	0.67
	7	1	1.33
	8	2	2.66
	9	3	3.99
	10	4	5.32
	11	6	7.98
	12	10	13.30
	13	20	26.6
	14	25	33.0

NOTE Hole No.1 was in the outboard tube
Hole No.14 was in the inboard tube

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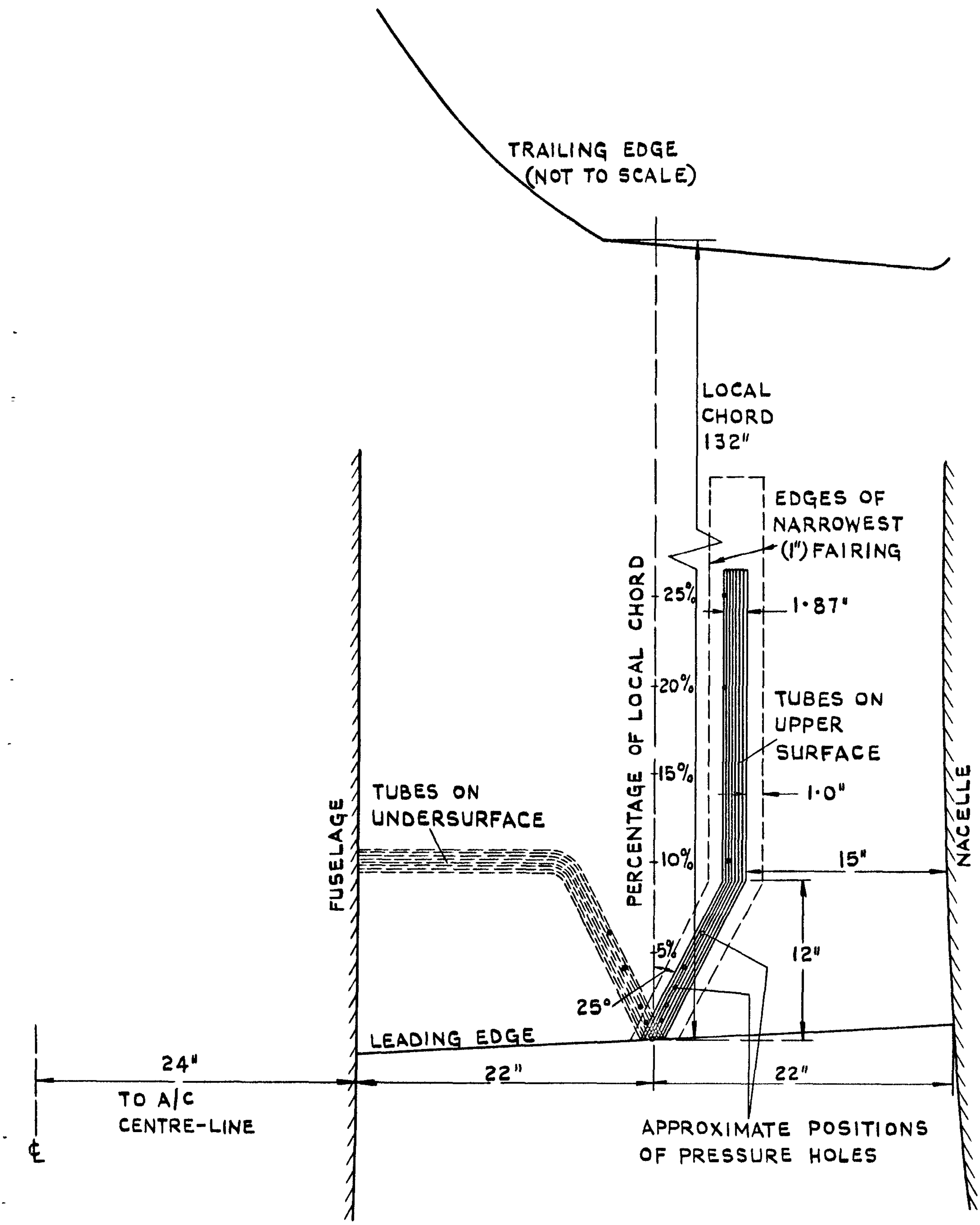

FIG.1. LAYOUT OF PRESSURE-PLOTTING TUBES ON PORT WING OF METEOR.

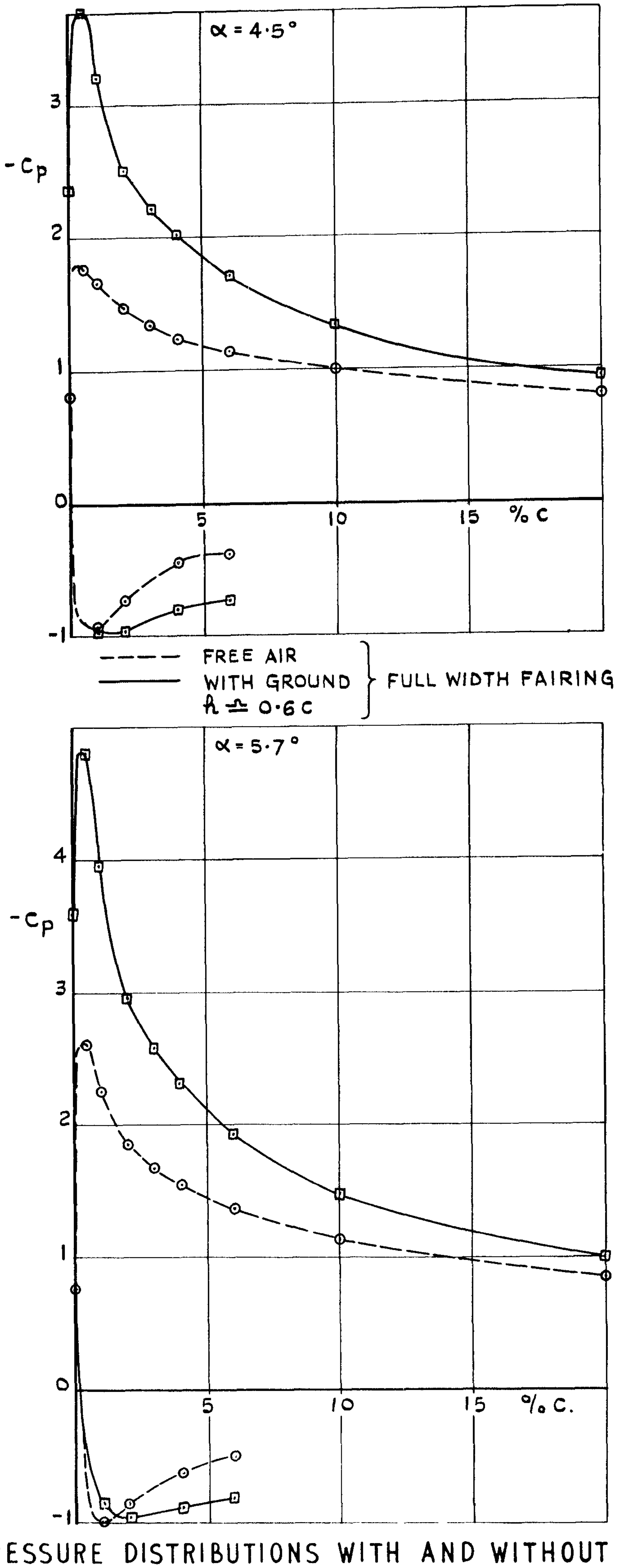

FIG.3. PRESSURE DISTRIBUTIONS WITH AND WITHOUT GROUND UNDERCARRIAGE AND FLAPS DOWN.

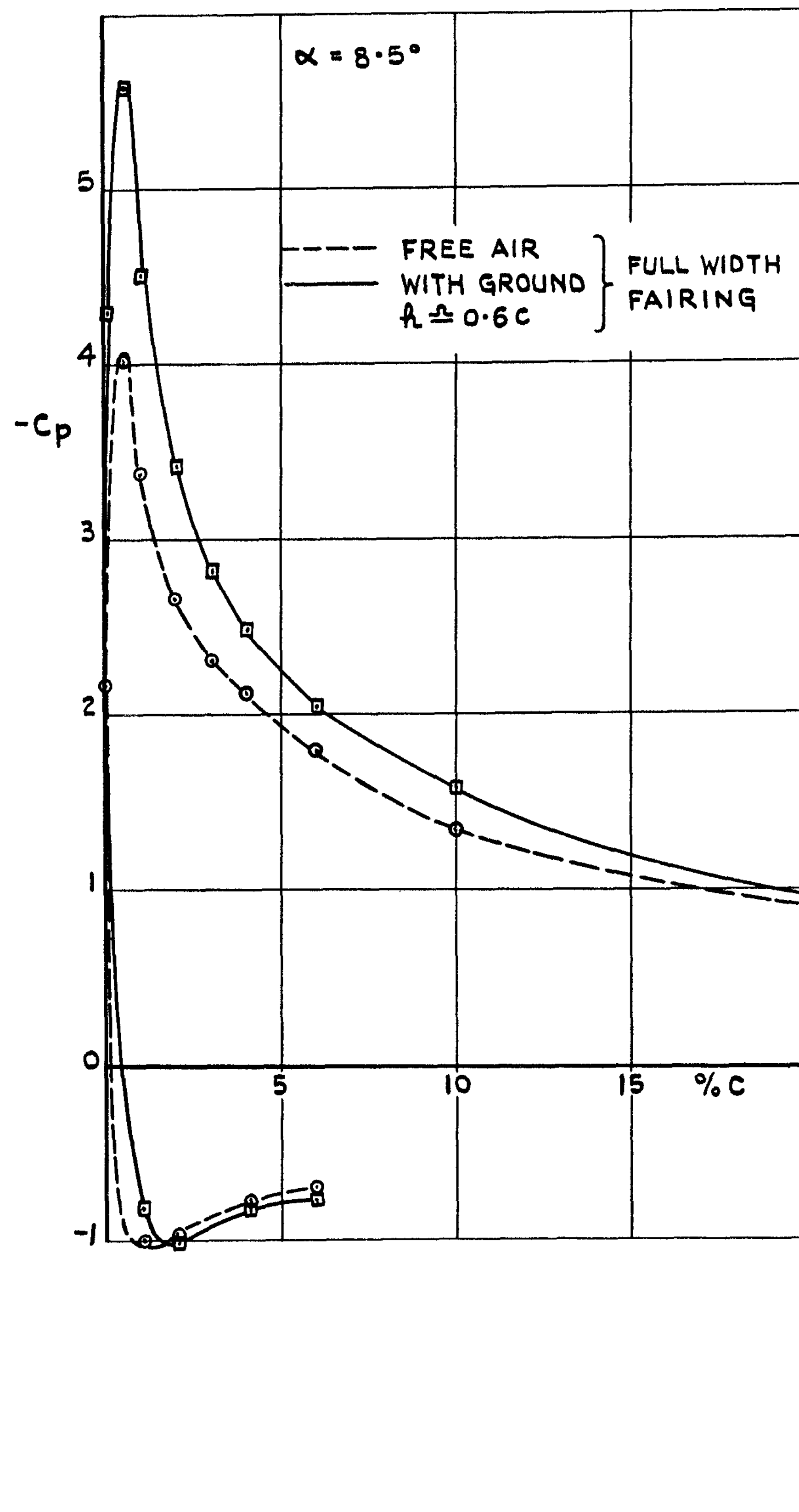

FIG. 4. PRESSURE DISTRIBUTIONS WITH AND WITHOUT GROUND UNDERCARRIAGE DOWN AND FLAPS UP.

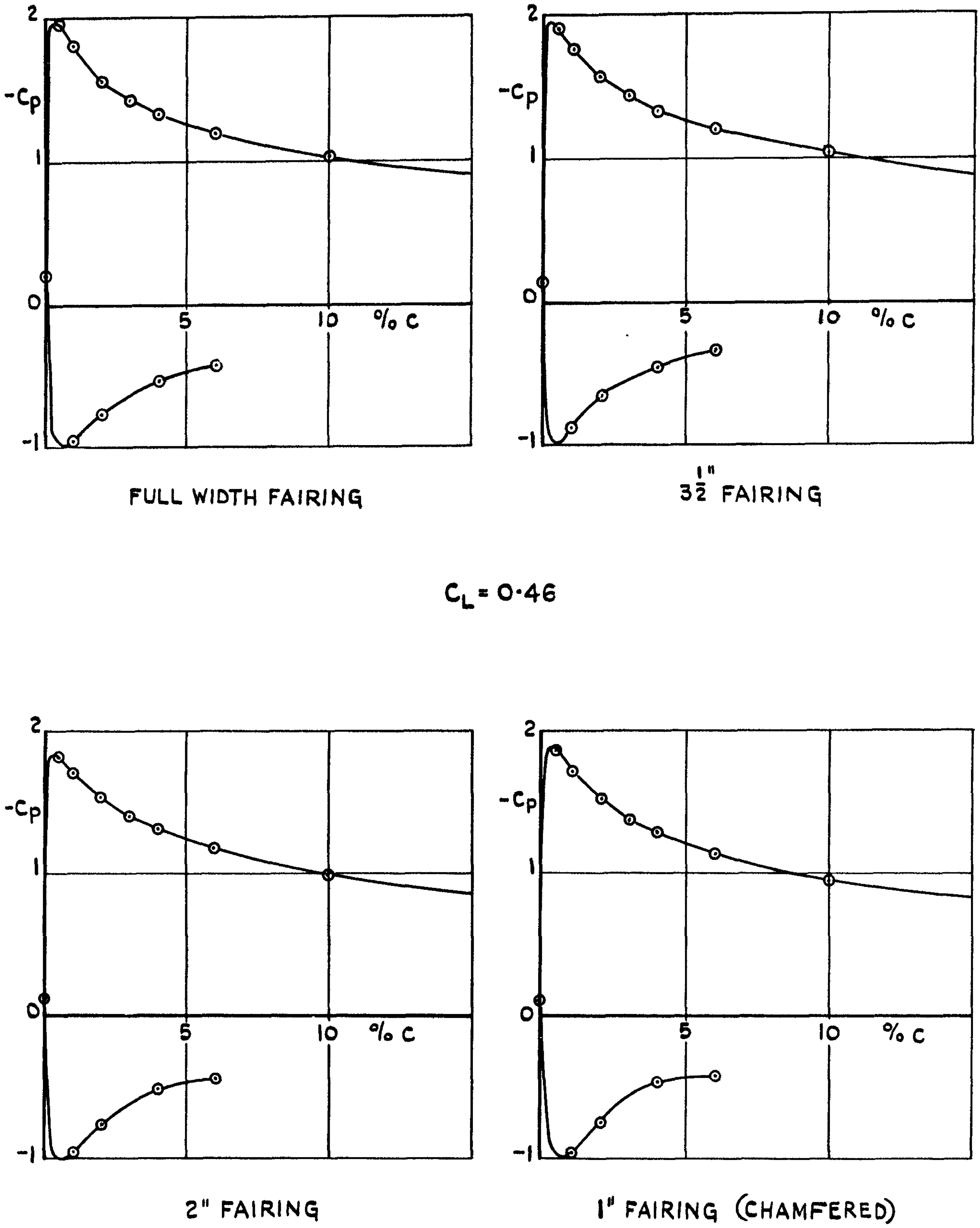

FIG. 6(a). PRESSURE DISTRIBUTIONS WITH VARIOUS FAIRINGS ($C_L = 0{\cdot}46$).

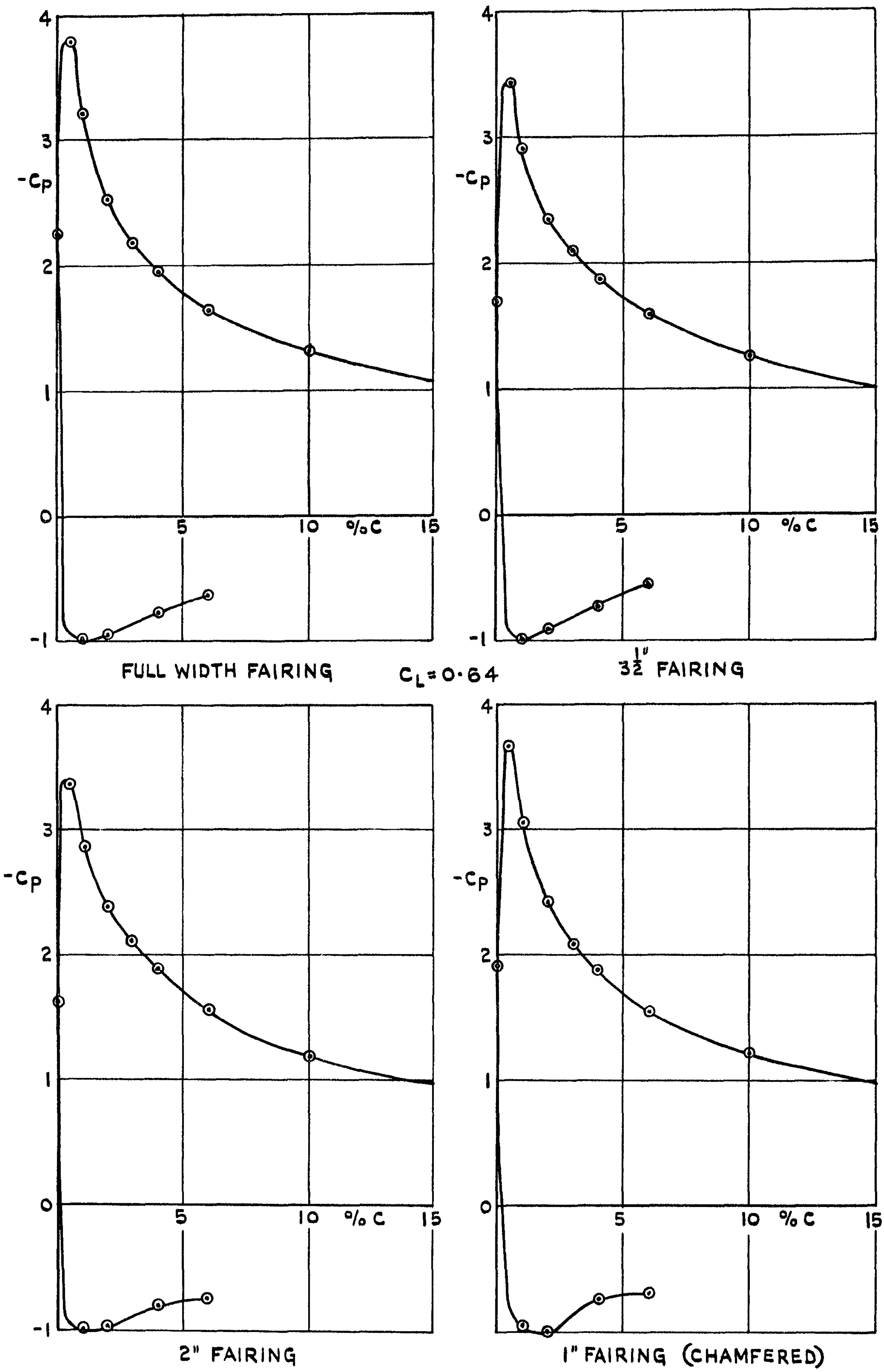

FIG.6 (c) PRESSURE DISTRIBUTIONS WITH VARIOUS FAIRINGS ($C_L = 0 \cdot 64$)

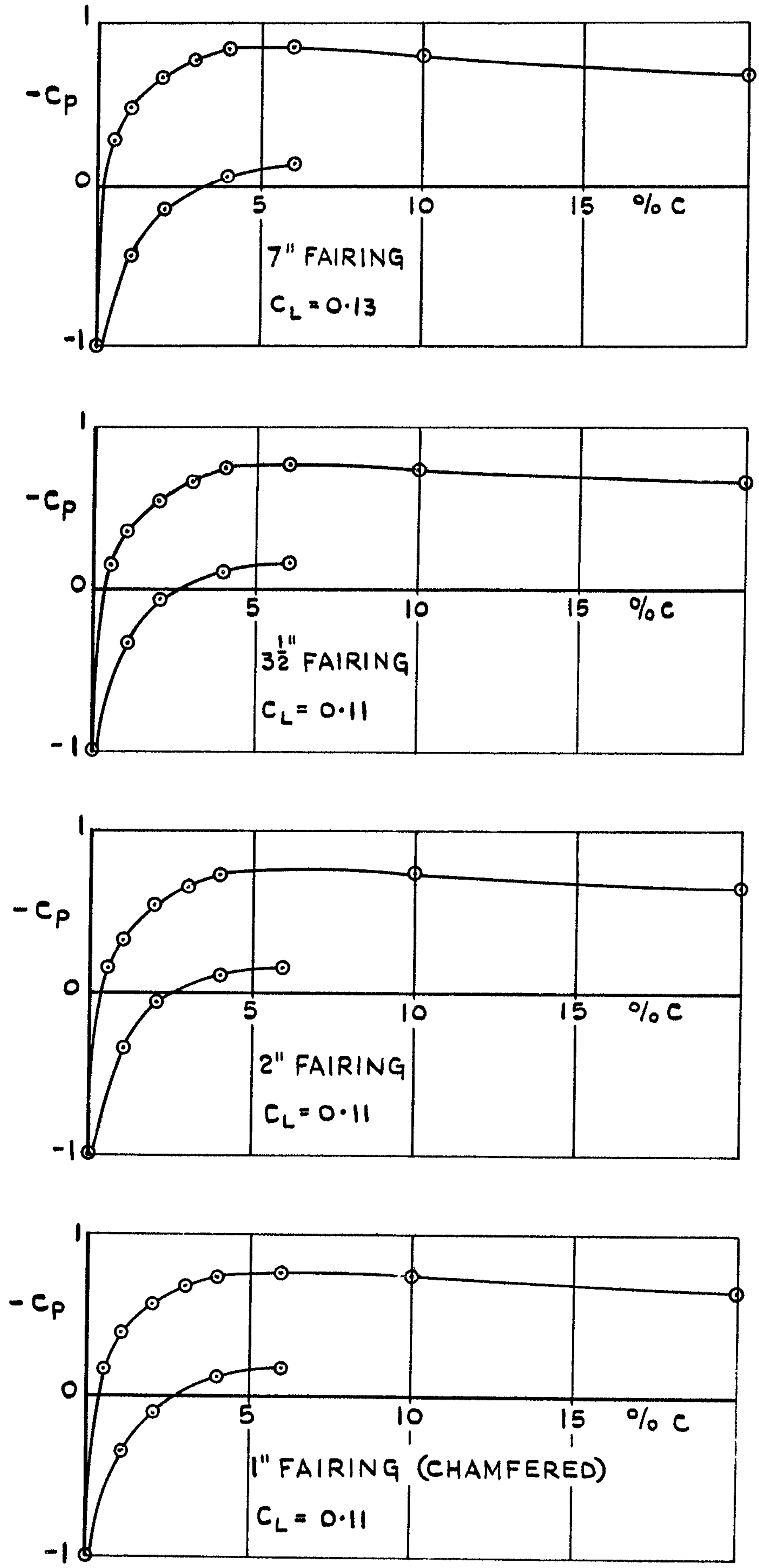

FIG.7. PRESSURE DISTRIBUTIONS AT M=0·6 WITH VARIOUS WIDTHS OF FAIRING.

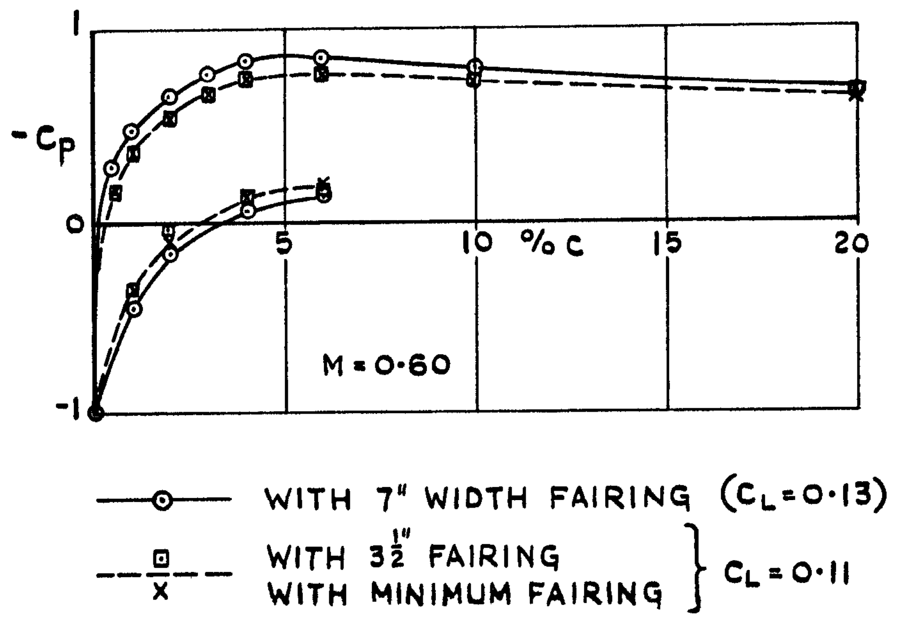

FIG. 8(b). EFFECT OF REDUCTION IN WIDTH OF FAIRING, AT HIGH SPEED.

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