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Wake surveys at the tail position of
the Avro CF-100 half model M - 0.6
to M - 0.9

D. G. Gould

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Avro - Mr. Chamberlin

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SUBJECT

WAKE SURVEYS AT THE TAIL POSITION OF THE AVRO CF-100 HALF MODEL, M = 0.6 to M = 0.9

PREPARED BY

D. G. GOULD

ISSUED TO

INTERNAL

A.V.ROE (CANADA)

R.C.A.F.

WAKE SURVEYS AT THE TAIL POSITION OF THE AVRO CF-100 HALF MODEL, M = 0.6 to M = 0.9

SUMMARY

Surveys of total head loss were made in the wake of the Avro CF-100 half model in the Mach number range from M = 0.6 to M = 0.9 at angles of attack of 0.5°, 2.5°, 4.5° and 6.5°.

At low angles of attack at all Mach numbers, the wing-nacelle junction seemed favourable in decreasing the wake width. At higher angles of attack and high Mach numbers a peak in the wake width occurred behind the wing-nacelle junction.

The first indication of the wake widening over the horizontal tail at low angles of attack and high Mach numbers was behind the fuselage - nacelle fillet. At the higher angles of attack the wake first spread over the tail behind the nacelle as the Mach number was increased.

1. INTRODUCTION

Measurements of total head loss were made in the wake of the Avro CF-100 half model, at the tail plane position, in order to determine qualitatively peak wake widths and regions of high loss.

2. SCOPE OF TESTS

A wake rake was used to determine the losses and extent of the wake behind the fuselage, fuselage-nacelle fillet, nacelle, wing-nacelle junction, and two outboard wing stations at model Mach numbers from $M = 0.6$ to $M = 0.9$ and at angles of attack of 0.5, 2.5, 4.5, 6.5 degrees. (Angle of attack was measured from the fuselage reference line).

3. APPARATUS

The N.A.E. transonic wing flow facilities were used to conduct the tests.

A photograph of the wake rake and the half model is shown in Figure 1. Fifty-five total head tubes, 0.04 inches I.D., were located in the model wake, and measurements of total head loss were made during six flights with an eleven channel pressure recorder. The plane of the leading edge of the total head tubes was located 1.02 $\bar{c}$ aft of the trailing edge of the jet pipe, i.e. at about the 0.25 $\bar{c}$ point of the horizontal tail.

The ratio of inlet to exit area of the nacelle was 1.56.

4. METHOD

A steady Mach number was established in the flow past the model and the model cycled through six degrees in two degree increments, with the model pausing $1\frac{1}{2}$ seconds at each angle.

All flights were carried out in level flight or in shallow dives so that lag effects were negligible.

5. RESULTS

The results are presented in two forms. In Figures 3 to 30, lines of constant loss are plotted in a transverse plane at the tail position for the four different angles of attack over the range of Mach numbers. The wake boundary position ($\frac{\Delta P_0}{q} = 0$) was estimated from the wake profiles plotted for each line of tubes. In Figures 31 to 37, $\frac{\Delta P_0}{q}$ vs. vertical height above and below the airplane reference line is plotted at six spanwise locations for the four angles of attack at each Mach number.

Figures 3 to 9 are contours of the wake at an angle of attack of 0.5° (relative to the fuselage reference line) for Mach numbers of 0.60, 0.65, 0.71, 0.77, 0.82, 0.86 and 0.90. The wake width does not increase appreciably with increasing Mach number until M = 0.77, where the wake generally increases. At M = 0.82 the wake behind the fuselage-nacelle fillet spreads over the inboard portion of the tail. No appreciable change in the wake takes place up to M = 0.90, where the wake spreads downward, probably due to shocks appearing on the lower surfaces. A common feature of all the Figures 3 to 9 is a narrowing of the wake behind the wing-nacelle junction.

Figures 10 to 16 are similar to Figures 3 to 9 except that the angle of attack is increased to 2.5°. The wake is generally wider than at 0.5° for the same Mach number. At Mach numbers up to M = 0.71, the wake behind the wing-nacelle junction and the wing widens slightly with increasing Mach number; the wake behind the nacelle and fuselage-nacelle fillet remaining essentially the same. Between M = 0.71 and 0.77 the wake width behind the wing and wing-nacelle junction increases considerably, and the wake behind the fuselage-nacelle fillet covers the inboard portion of the horizontal tail. Above M = 0.77 the wake behind the fuselage-nacelle fillet remains essentially the same; the wake behind the wing-nacelle junction and the wing, however, widens appreciably. At M = 0.86 the wake behind the nacelle covers a portion of the tail at about midspan. At M = 0.90 this peak is gone and the only portion of the wake covering the tail is inboard near the fuselage.

Figures 17 to 23 are a repeat of the above for an angle of attack of 4.5°. At all Mach numbers the wake is at least partially covering the horizontal tail. At M = 0.60 and 0.65 there are two peaks where the wake width is quite large, one behind the nacelle and the other outboard of the wing-nacelle junction. As the Mach number increases from M = 0.65 to M = 0.90 the peak outboard of the wing-nacelle junction disappears (at M = 0.71), and the peak originally behind the nacelle, moves outboard until at M = 0.82 it is behind the wing-nacelle junction. The wake completely covers the tailplane above M = 0.71, and the width generally increases with increasing Mach number.

Figures 24 to 30 are wake contours at an angle of attack of 6.5°. At these particular Reynolds numbers the aircraft is almost completely stalled at M = 0.60 and 0.65, and partially stalled from M = 0.71 to M = 0.90 (Reference 1). There seems to be a peak in the wake width behind the wing-nacelle junction at all Mach numbers at this angle of attack.

Figures 31 to 37 are plots of the wake losses vs. vertical height for six spanwise stations. Plots are made at angles of attack of 0.5°, 2.5°, 4.5° and 6.5° at each Number (M = 0.60, 0.65, 0.71, 0.77, 0.82, 0.86, 0.90). The trend from M = 0.60 to M = 0.71 is that the wake width increases appreciably in changing from an angle of attack from 2.5° to 4.5°. Above M = 0.77, the wake width increases more or less uniformly with increasing angle of attack. The peak losses at a given Mach number generally increase only slightly with increasing angle of attack. For all angles of attack the peak losses increase with increasing Mach number.

6. CONCLUSIONS

At low angles of attack ($\alpha = 0.5^{o}$), the wake behind the wing-nacelle junction is narrower than the wake behind the wing. The wake widens and covers a portion of the tail surface behind the fuselage-nacelle fillet as the Mach number increases beyond M = .82.

At $\alpha = 2.5^{o}$ the wake covers the inboard portion of the tail surface behind the fuselage-nacelle junction as the Mach number increases beyond M = .77. The wake widens behind the nacelle and covers the tailplane at M = .86.

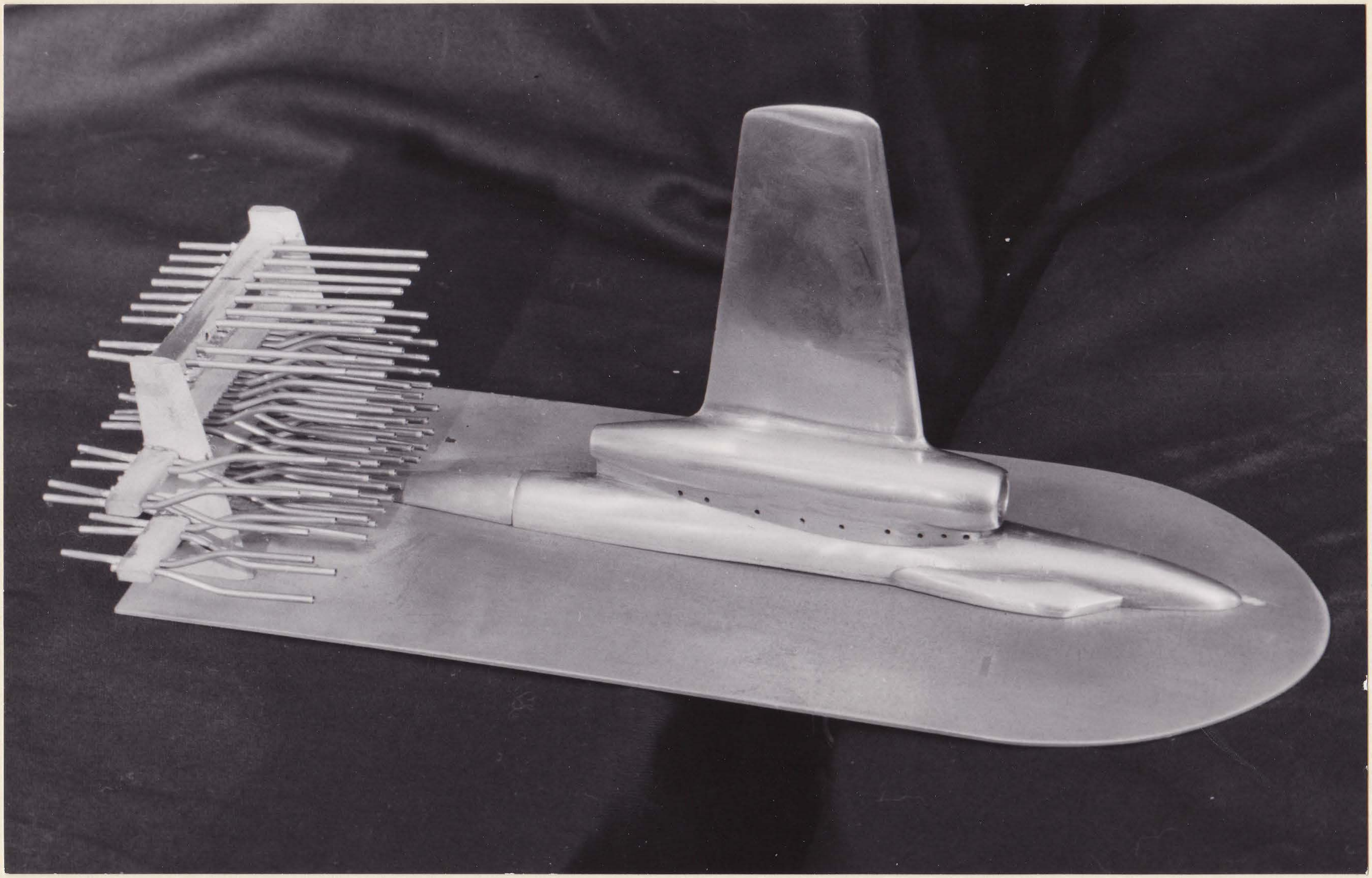
At $\alpha = 4.5$ there are two peak wake widths, behind the nacelle and behind a section of the wing just outboard of the wing-nacelle junction at M = .60 and .65. As the Mach number increases beyond M = .71, there is a single peak that moves outboard from behind the nacelle to a position behind the nacelle-wing junction;

At the highest angle of attack tested ($\alpha = 6.5^{o}$) the peak wake width is behind the wing-nacelle junction for all the Mach numbers.

It is difficult to assess the possible effects of the low Reynolds numbers since separation is probably associated with shock waves on the model surfaces at these particular test Mach numbers. No attempt was made to determine the effect of the jet on the wake since it is difficult to duplicate flight conditions. In any case the results are felt to be qualitatively good in indicating the regions of high loss and large wake widths.

REFERENCE:

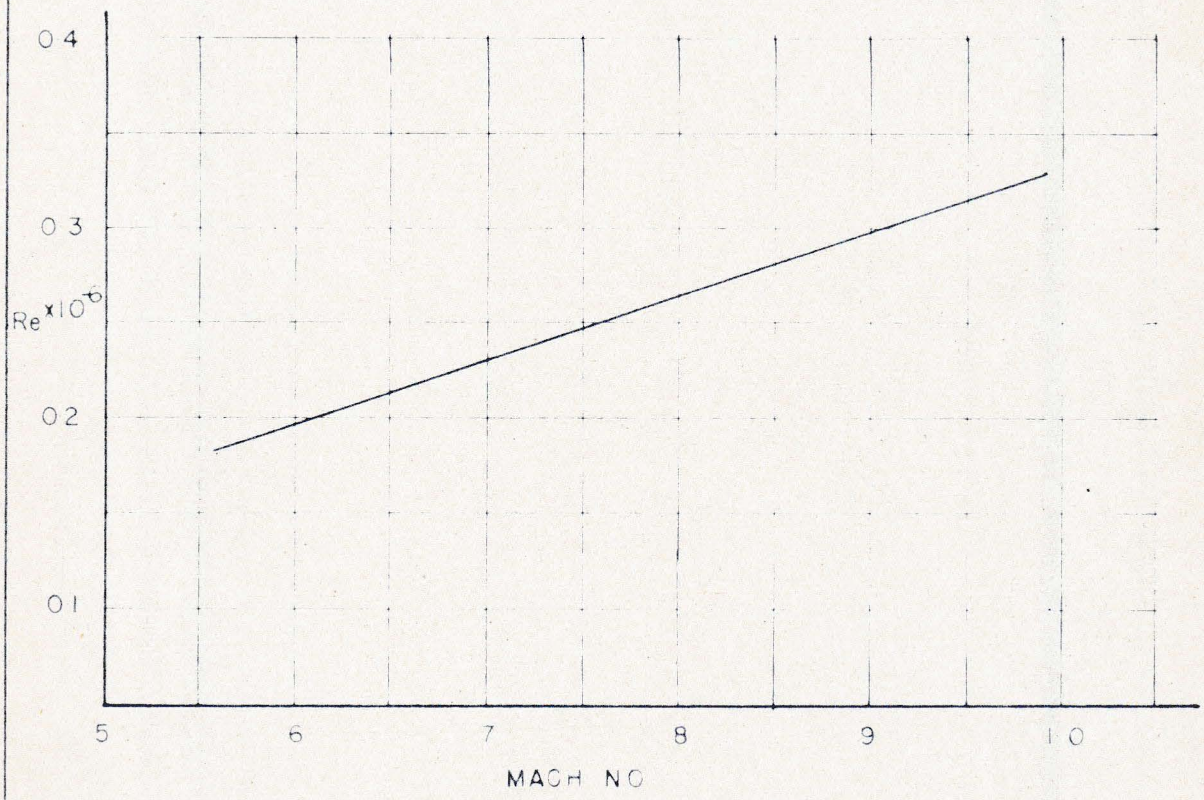
1. Lift and Pitching Moment Measurements of the Avro CF-100 Half Model, M = 0.3 to M = 1.0. D. G. Gould, N.A.E., Lab. Memo FR-10.



CF-100 HALF MODEL AND WAKE RAKE

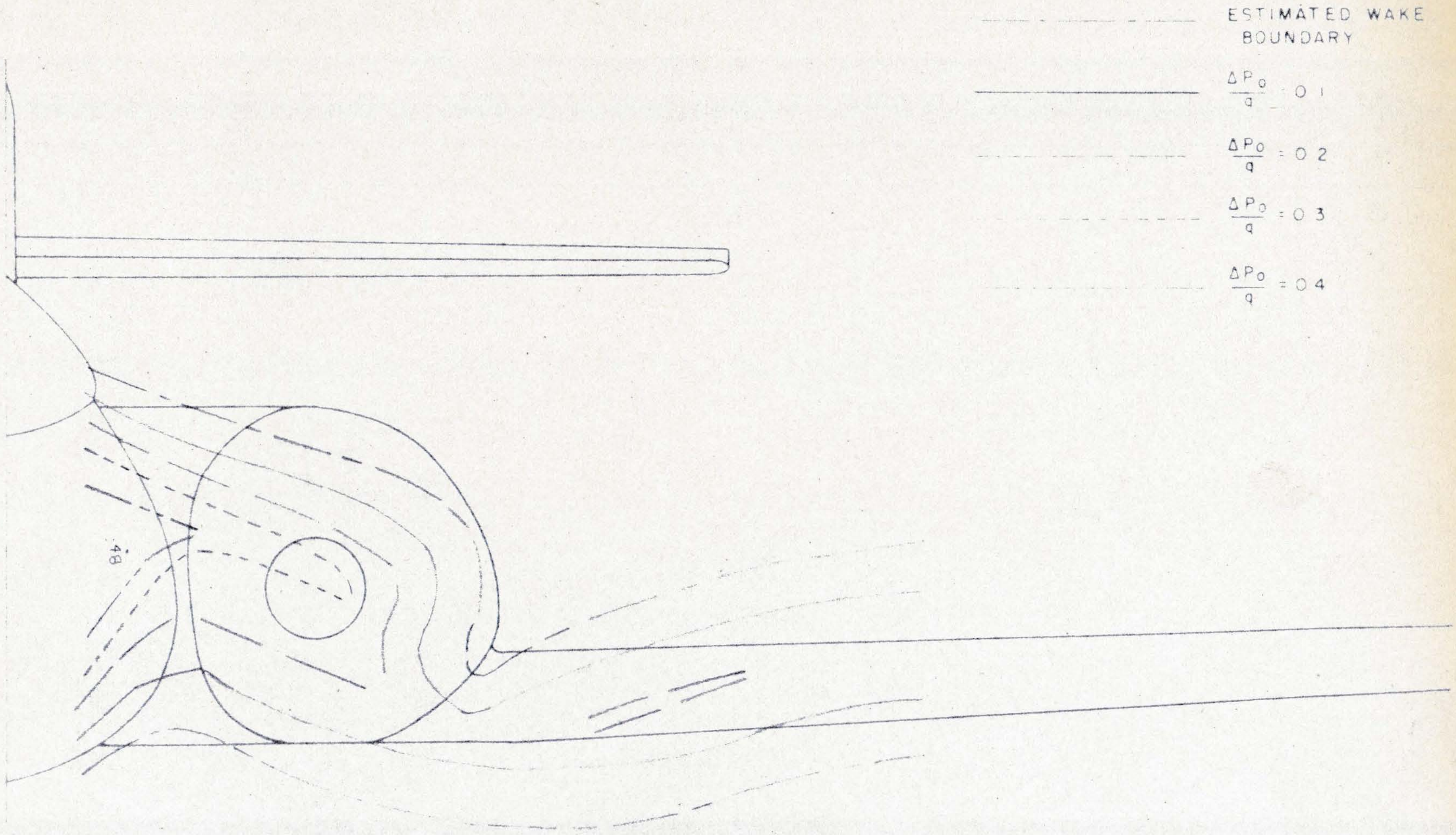
FIG. 1

FIG · 2



APPROXIMATE VARIATION OF REYNOLDS NUMBER

(BASED ON $\bar{c}$ = 1·56 IN·) WITH MACH NUMBER



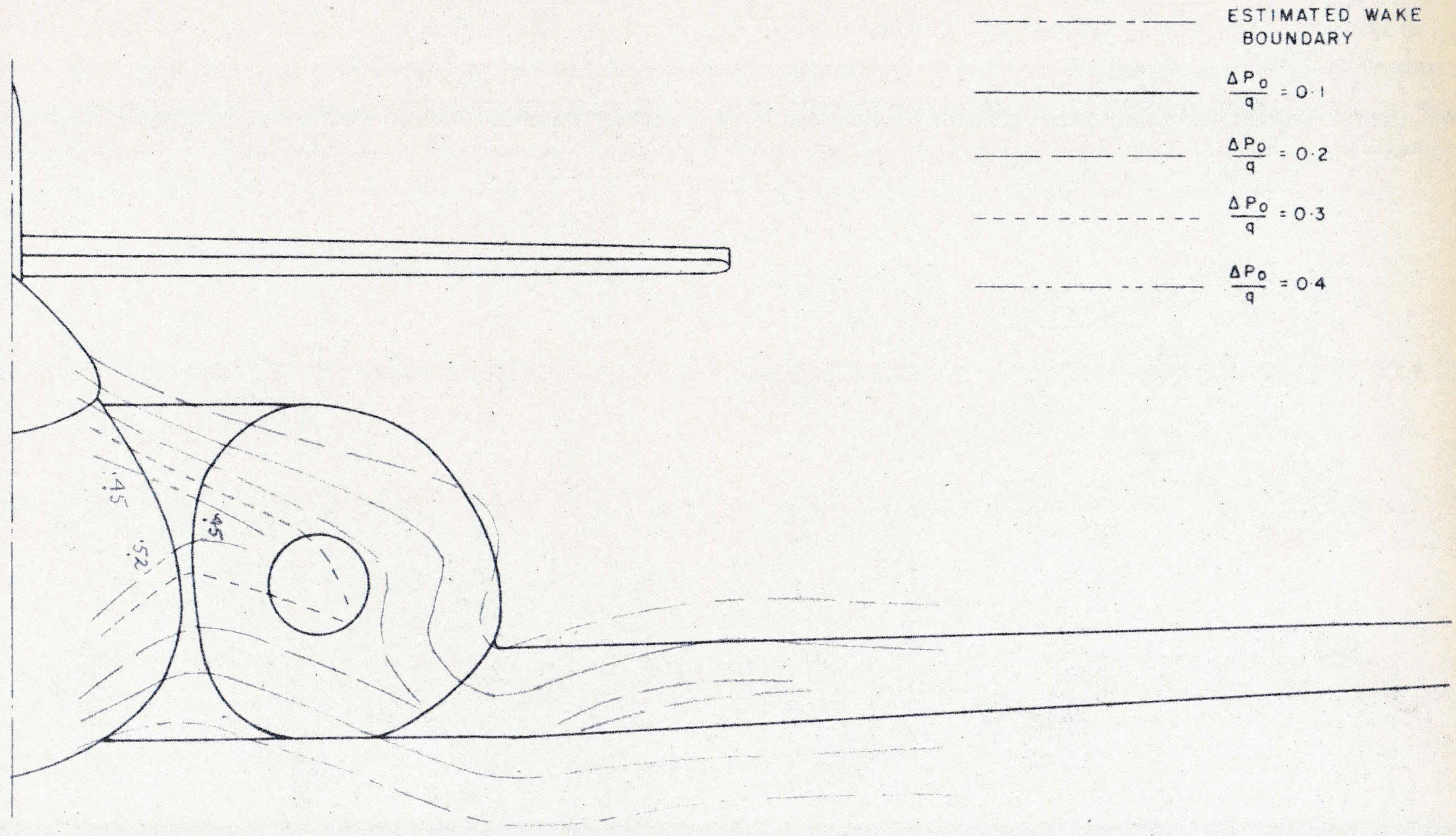
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = 0.60$ $\alpha = 0.5$ (FROM FUSELAGE REF. LINE)

$C_L = .145$

FIG 3



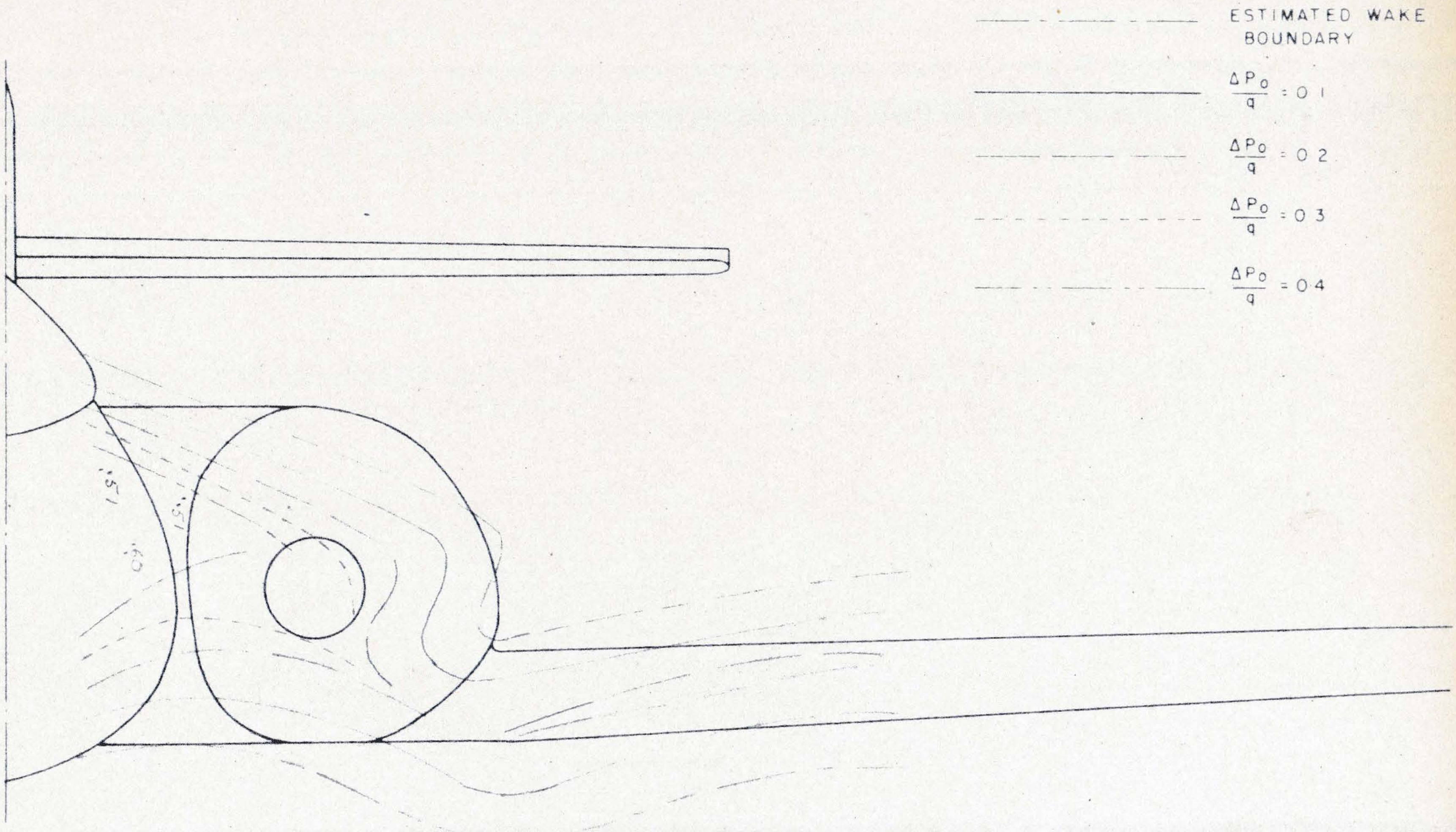
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = .65$ $\quad \alpha = 0{\cdot}5$ (FROM FUSELAGE REF. LINE)

$C_L = \cdot 155$

FIG. 4.



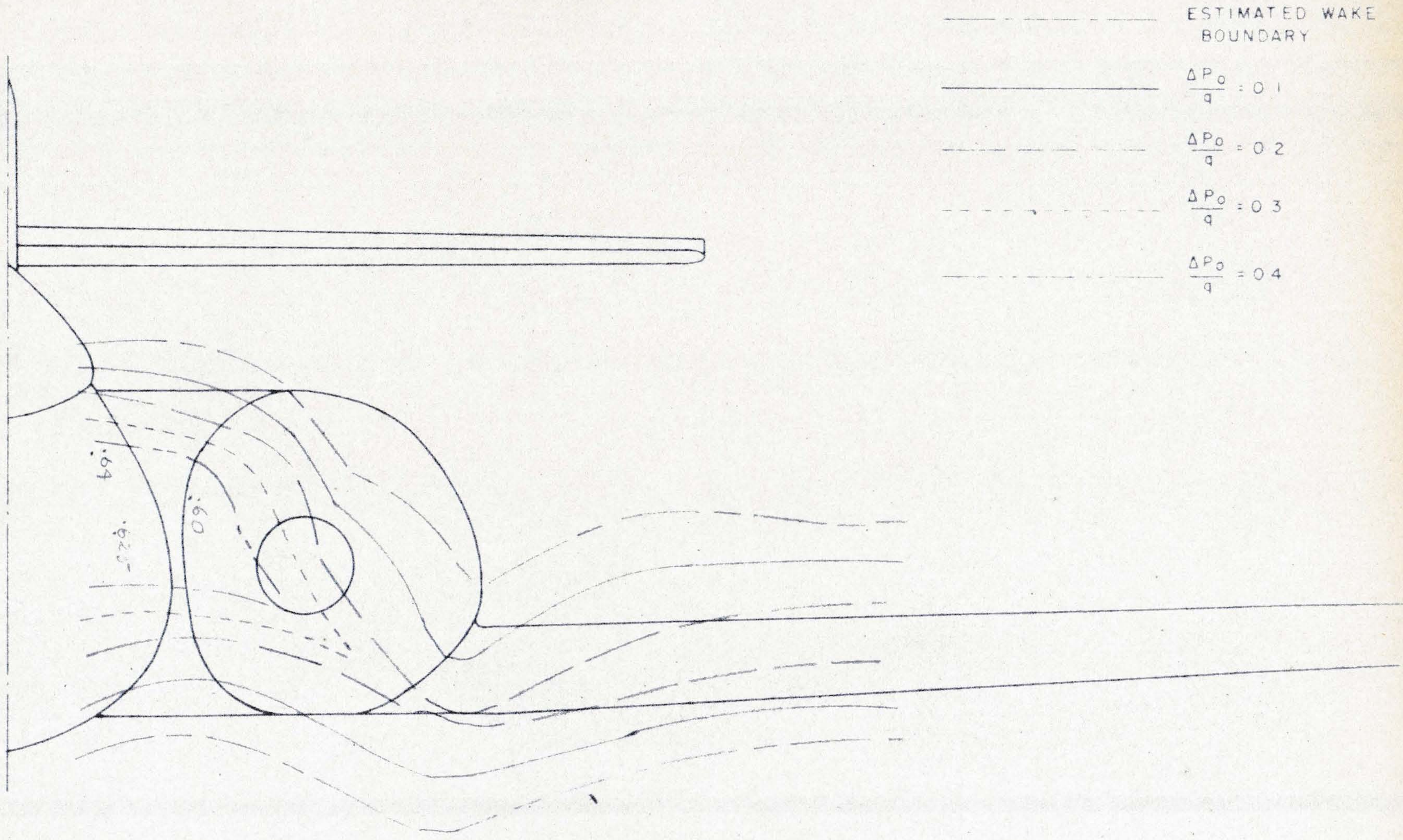
CF-100. CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = .71$ $\alpha = 0.5$ (FROM FUSELAGE REF. LINE)

$C_L = .15$

FIG 5.



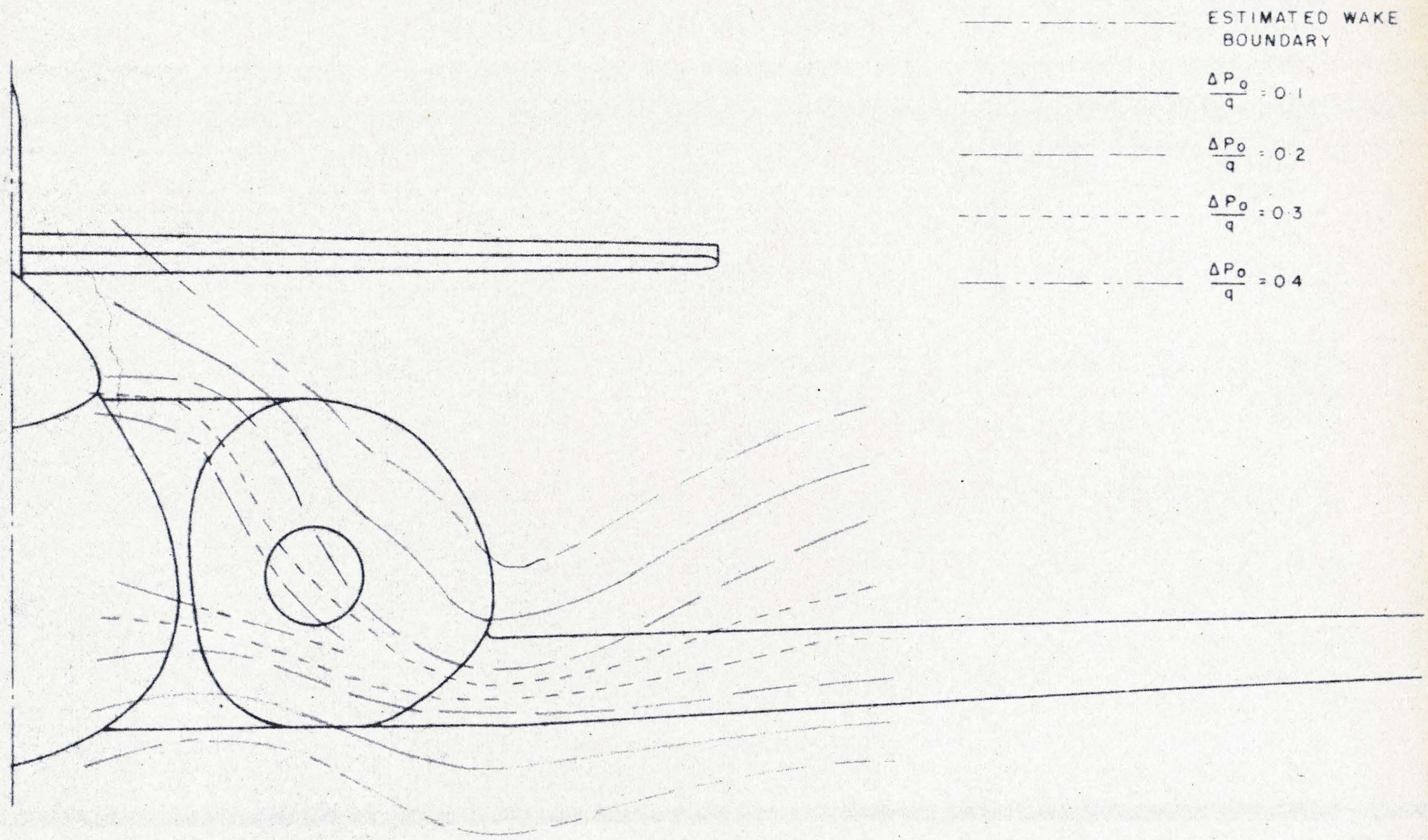
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = .77$ $\alpha = 0.5$ (FROM FUSELAGE REF. LINE)

$C_L = .12$

FIG 6



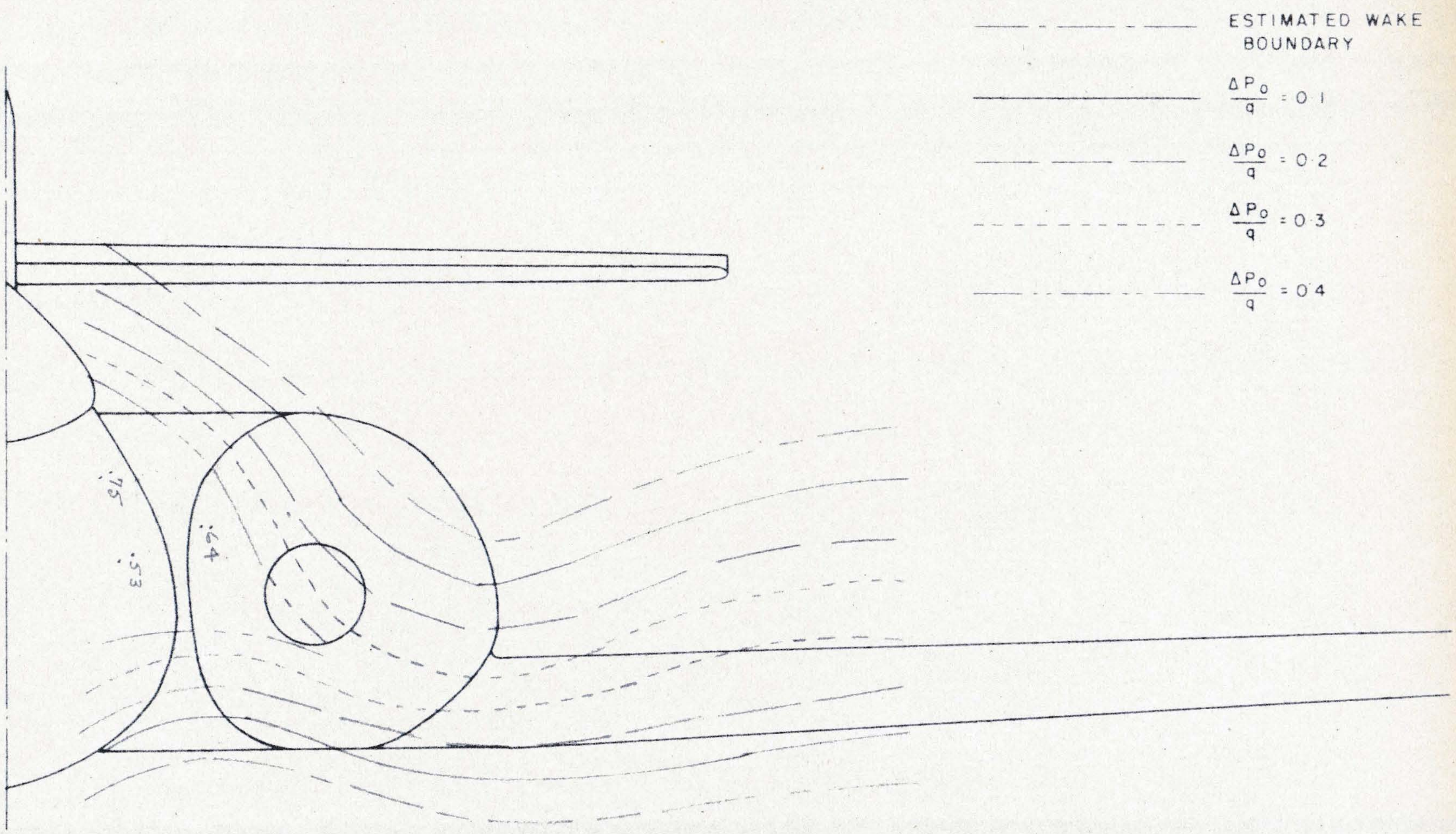
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = .82$ $\alpha = 0.5$ (FROM FUSELAGE REF. LINE)

$C_L = .11$

FIG. 7.



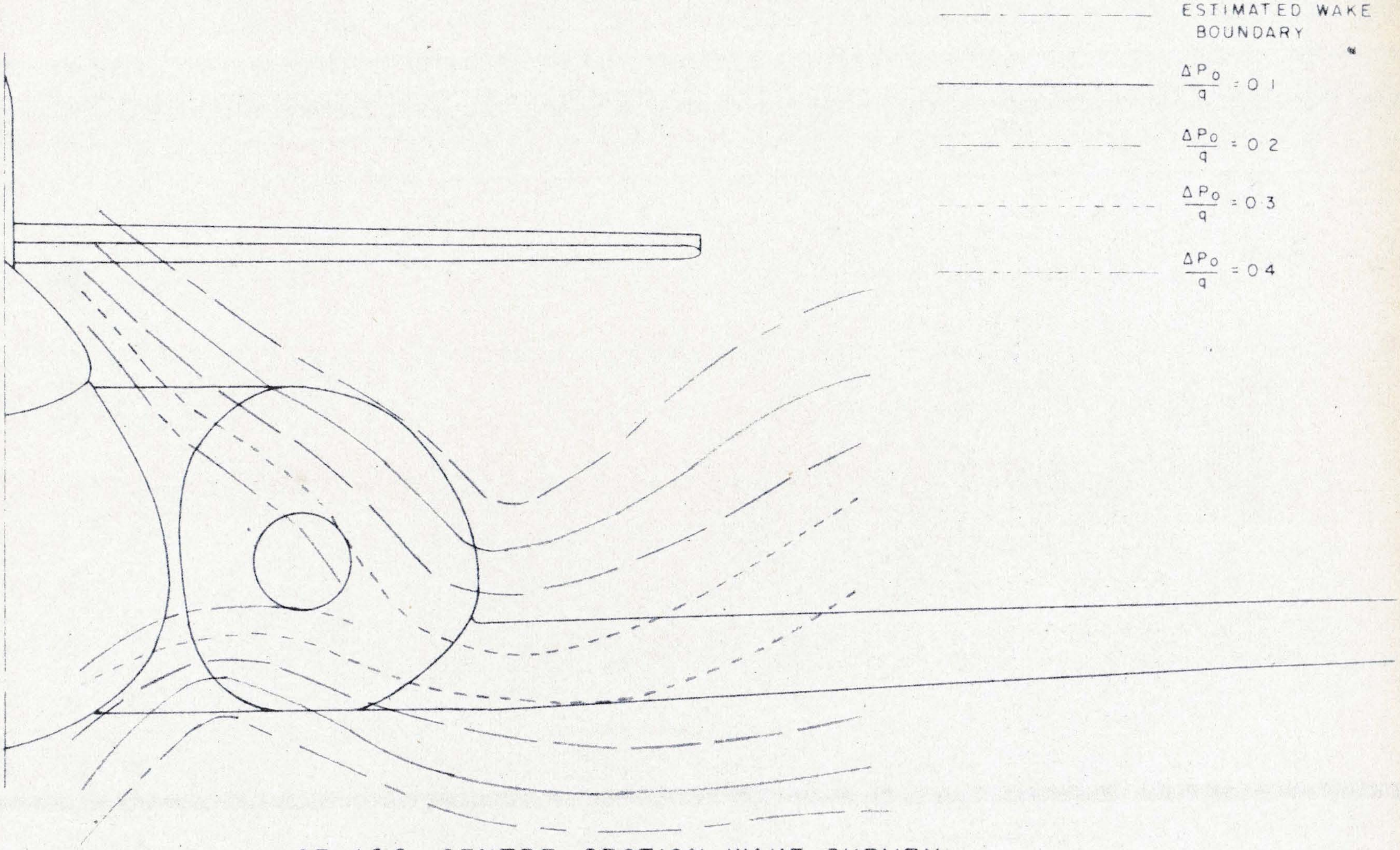
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = .86$ $\alpha = 0.5$ (FROM FUSELAGE REF. LINE)

$C_L = .10$

FIG 8



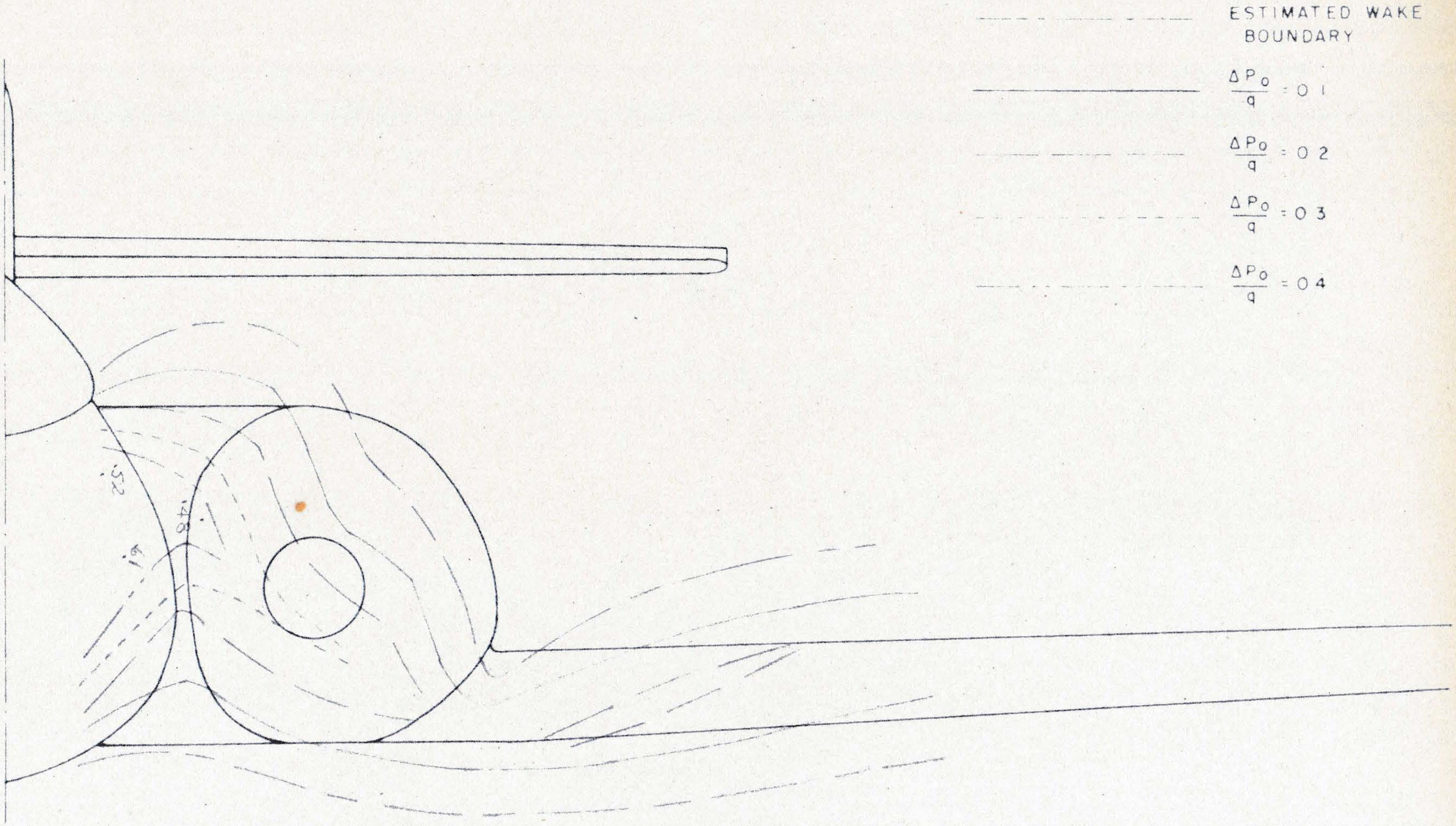
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = .90$ $\alpha = 0.5$ (FROM FUSELAGE REF. LINE)

$C_L = .105$

FIG 9



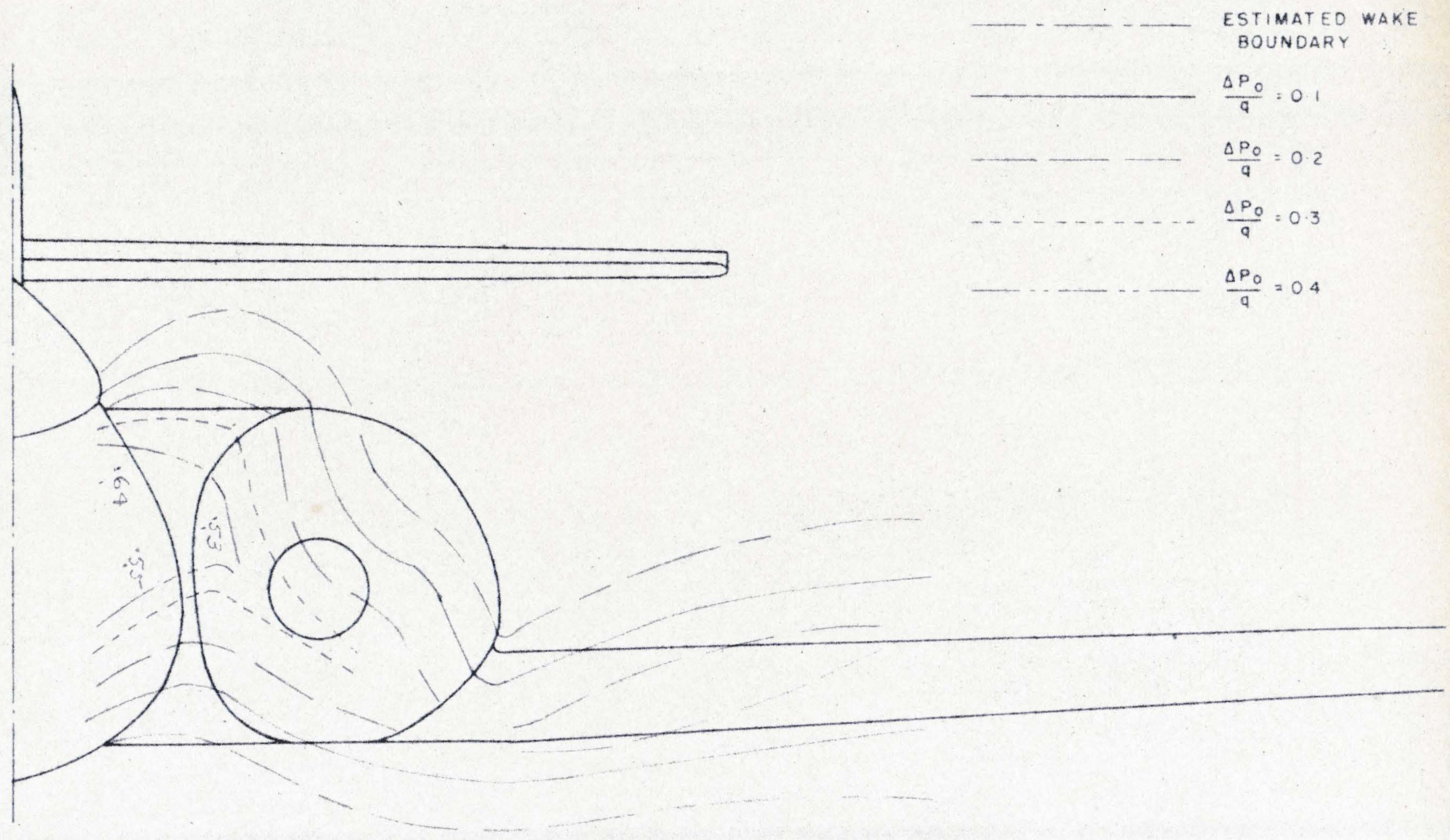
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = .60$ $\alpha = 2.5°$ (FROM FUSELAGE REF. LINE)

$C_L = .35$

FIG 10



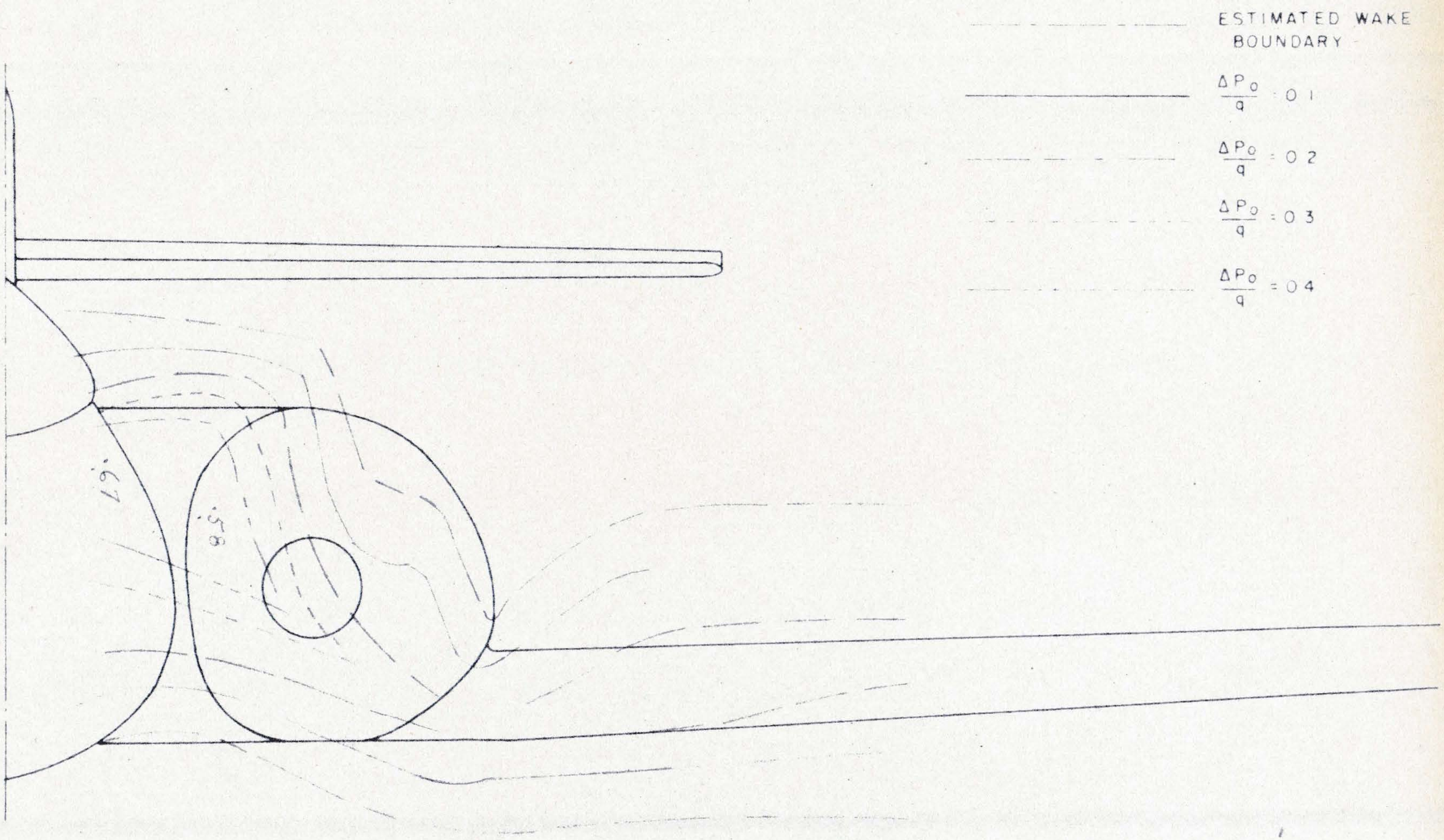
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = {\cdot}65$ $\alpha = 2{\cdot}5°$ (FROM FUSELAGE REF. LINE)

$C_L = {\cdot}35$

FIG. 11



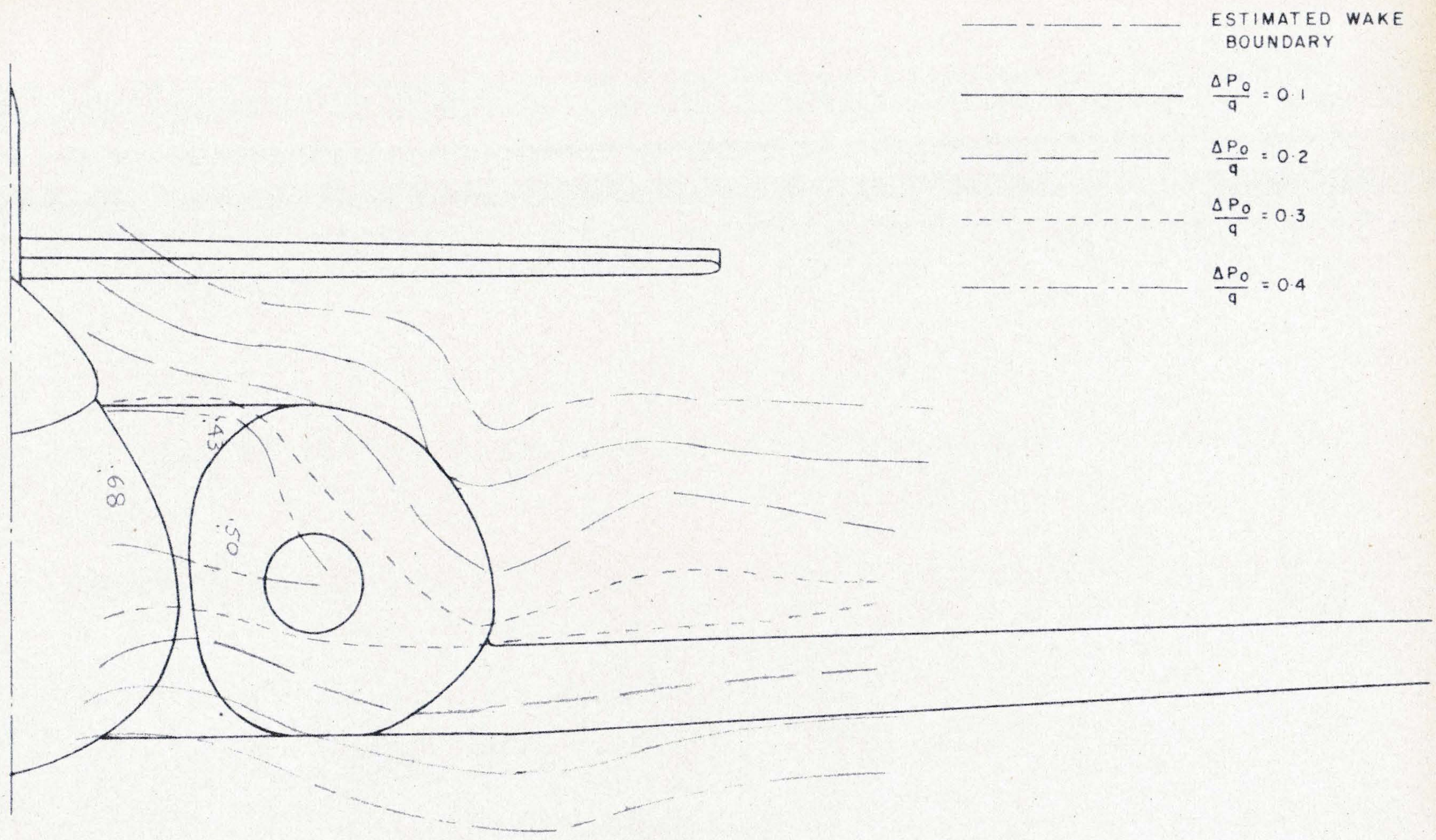
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = .71$ $\alpha = 2.5$ (FROM FUSELAGE REF. LINE)

$C_L = .36$

FIG. 12.



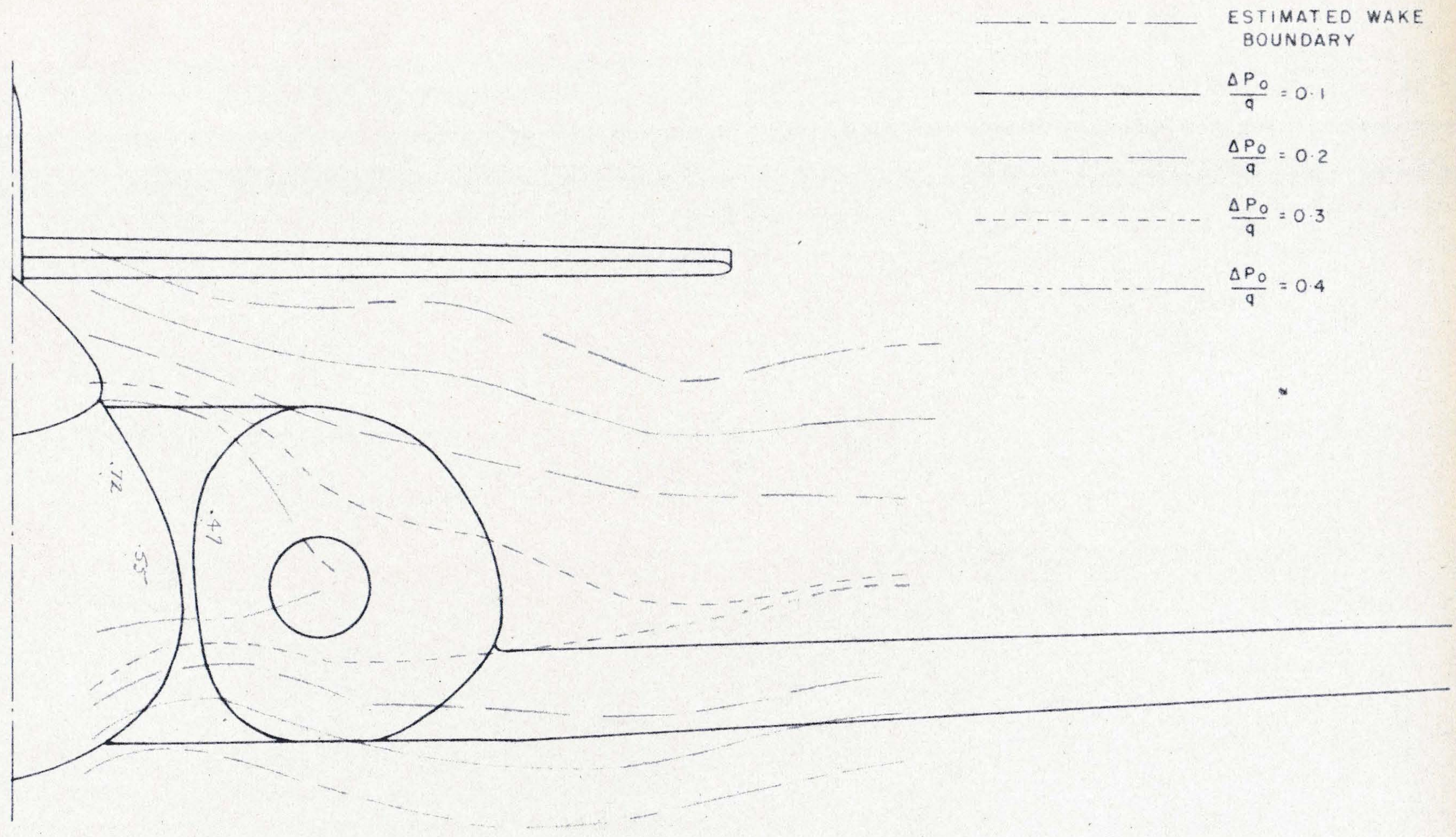
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = .77$ $\alpha = 2.5°$ (FROM FUSELAGE REF. LINE)

$C_L = .31$

FIG. 13



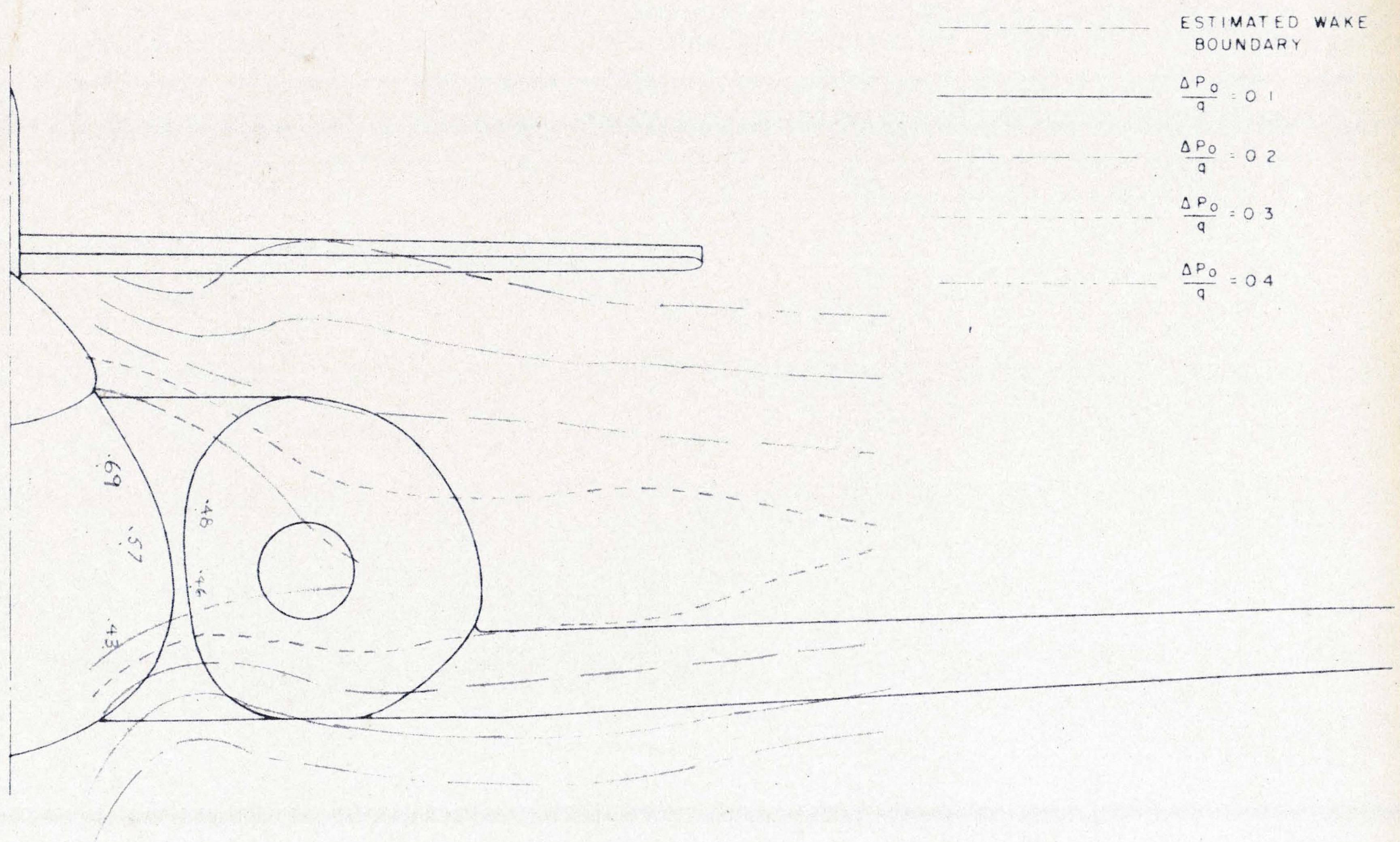
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

M = .82 α = 2.5 (FROM FUSELAGE REF. LINE)

C_L = .25

FIG. 14



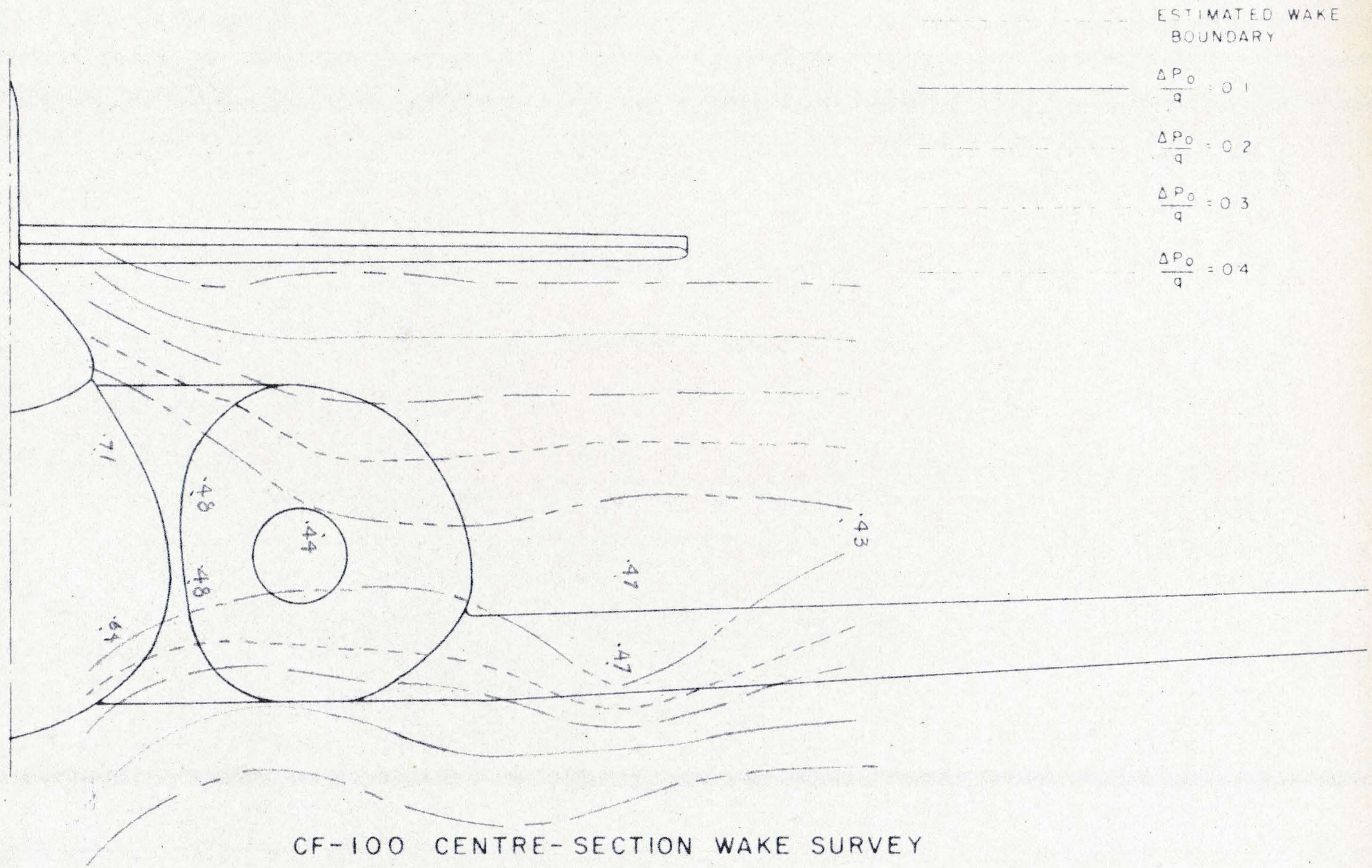
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = .86$ $\alpha = 2.5$ (FROM FUSELAGE REF. LINE)

$C_L = .23$

FIG 15.



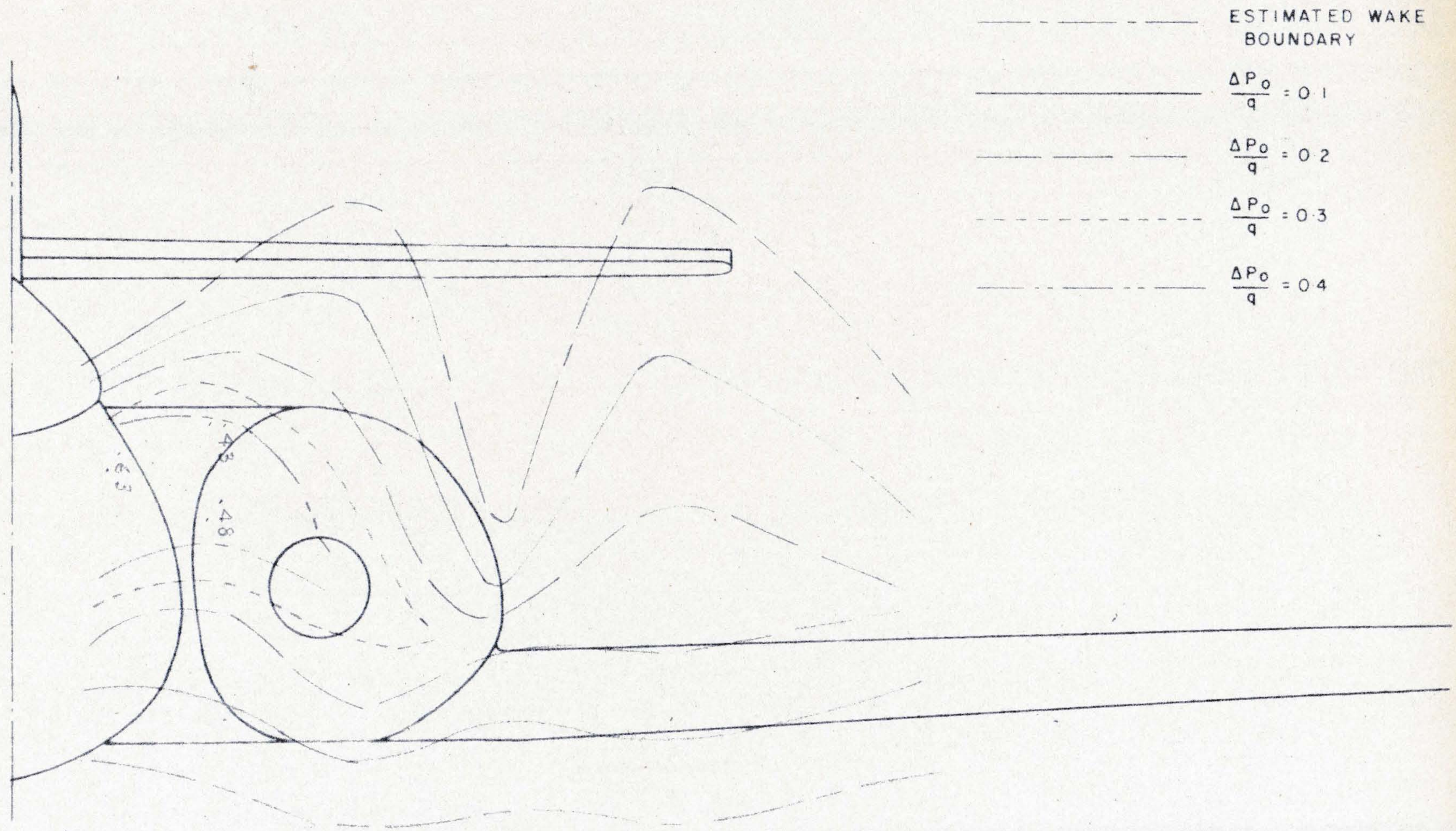
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = .90$ $\alpha = 2.5°$ (FROM FUSELAGE REF. LINE)

$C_L = .24$

FIG 16



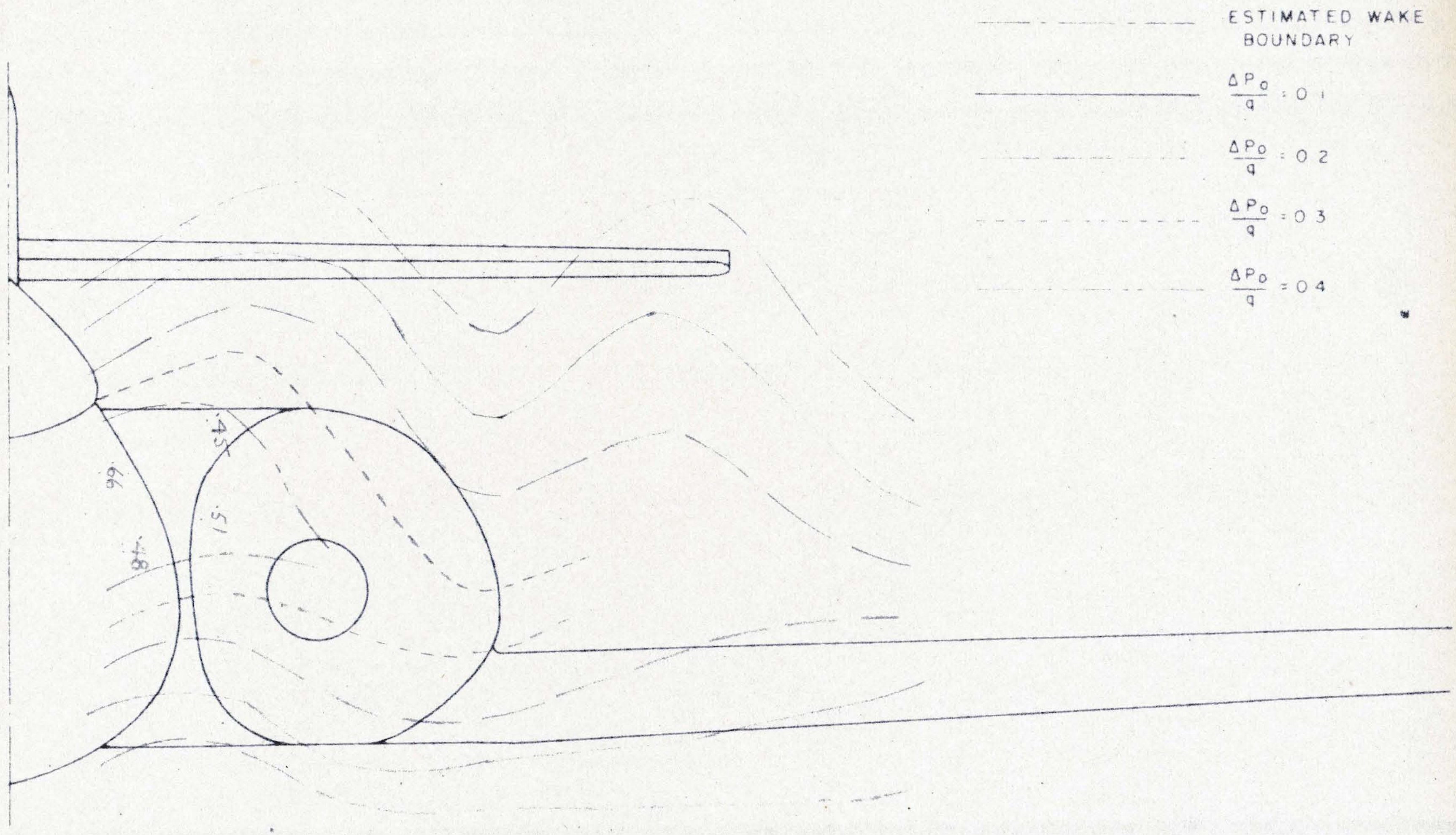
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = .60$ $\alpha = 4.5$ (FROM FUSELAGE REF. LINE)

$C_L = .485$

FIG. 17



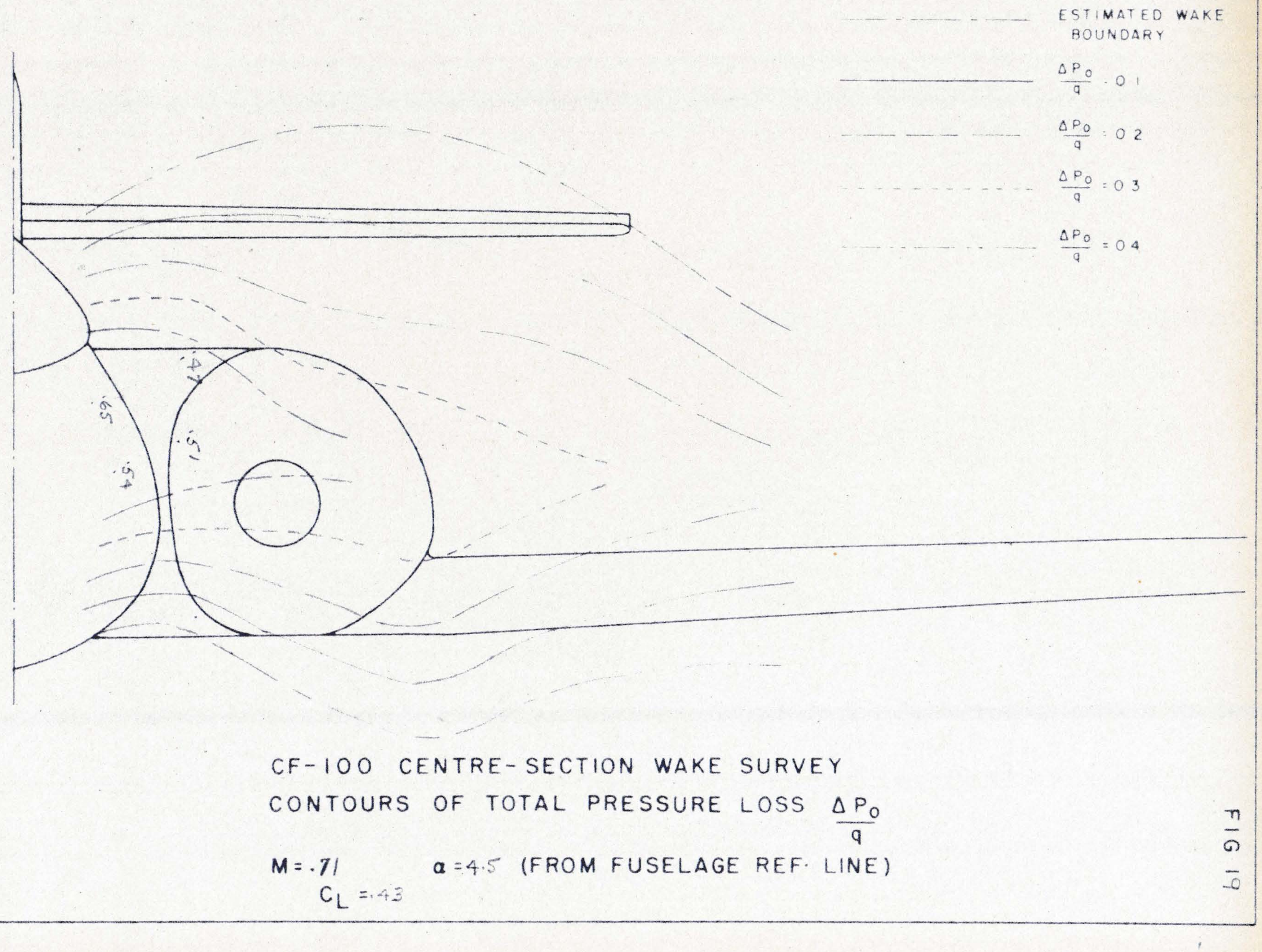
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = \cdot 65$ $\quad \alpha = 4 \cdot 5$ (FROM FUSELAGE REF. LINE)

$C_L = \cdot 46$

FIG 18



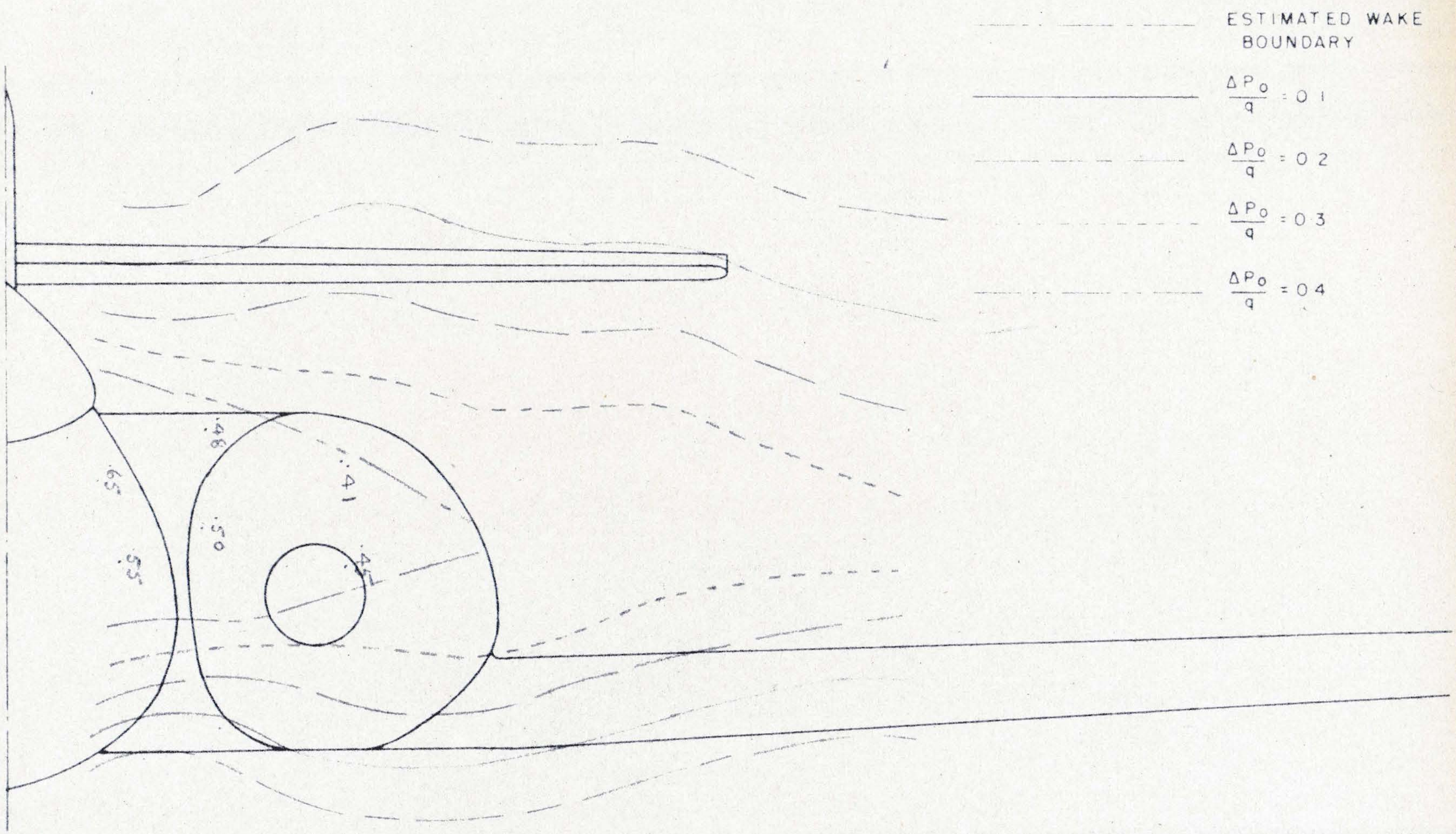
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = .71$ $\alpha = 4.5$ (FROM FUSELAGE REF. LINE)

$C_L = .43$

FIG 19



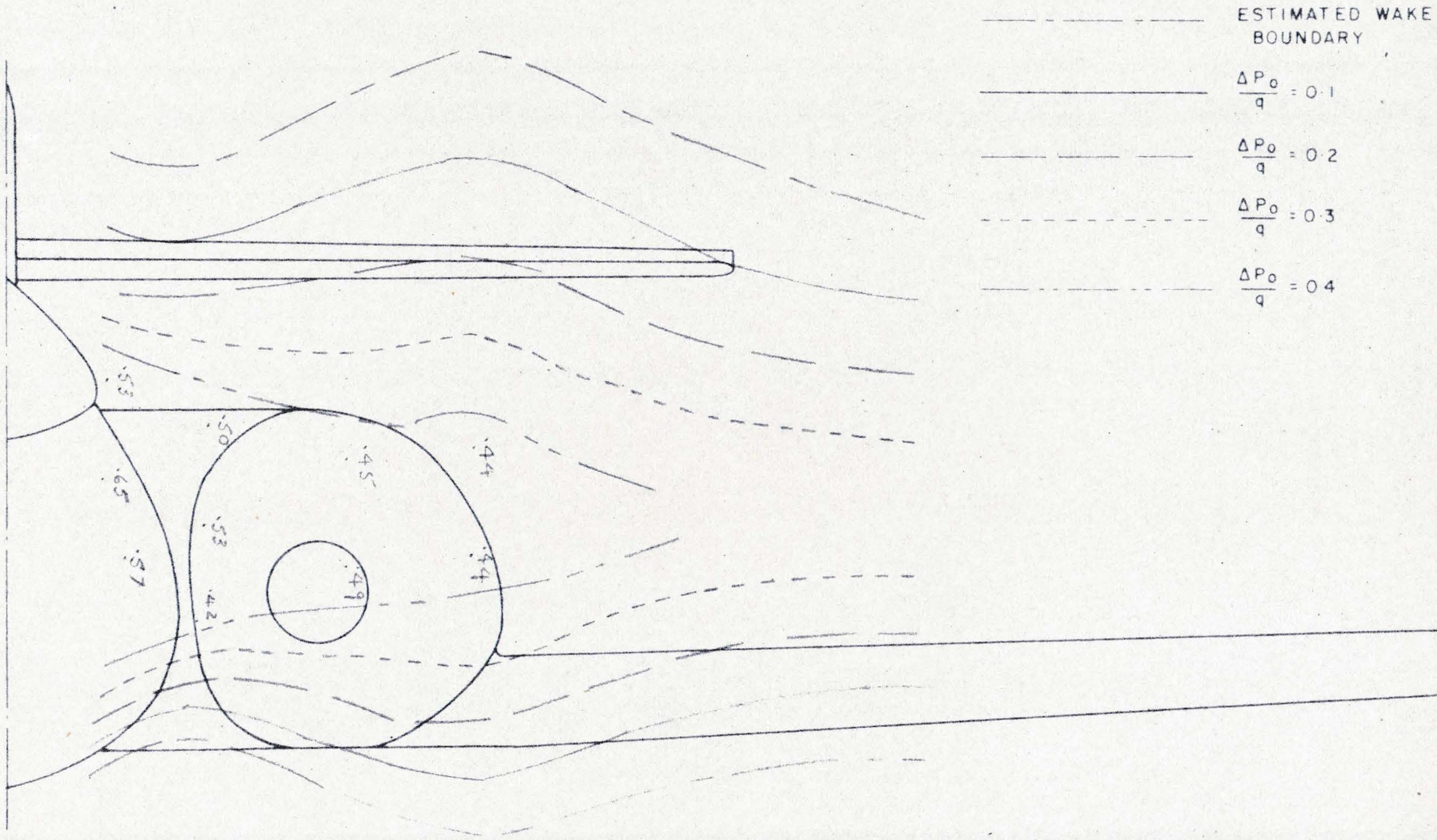
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = .77$ $\alpha = 4.5$ (FROM FUSELAGE REF. LINE)

$C_L = .40$

FIG. 20



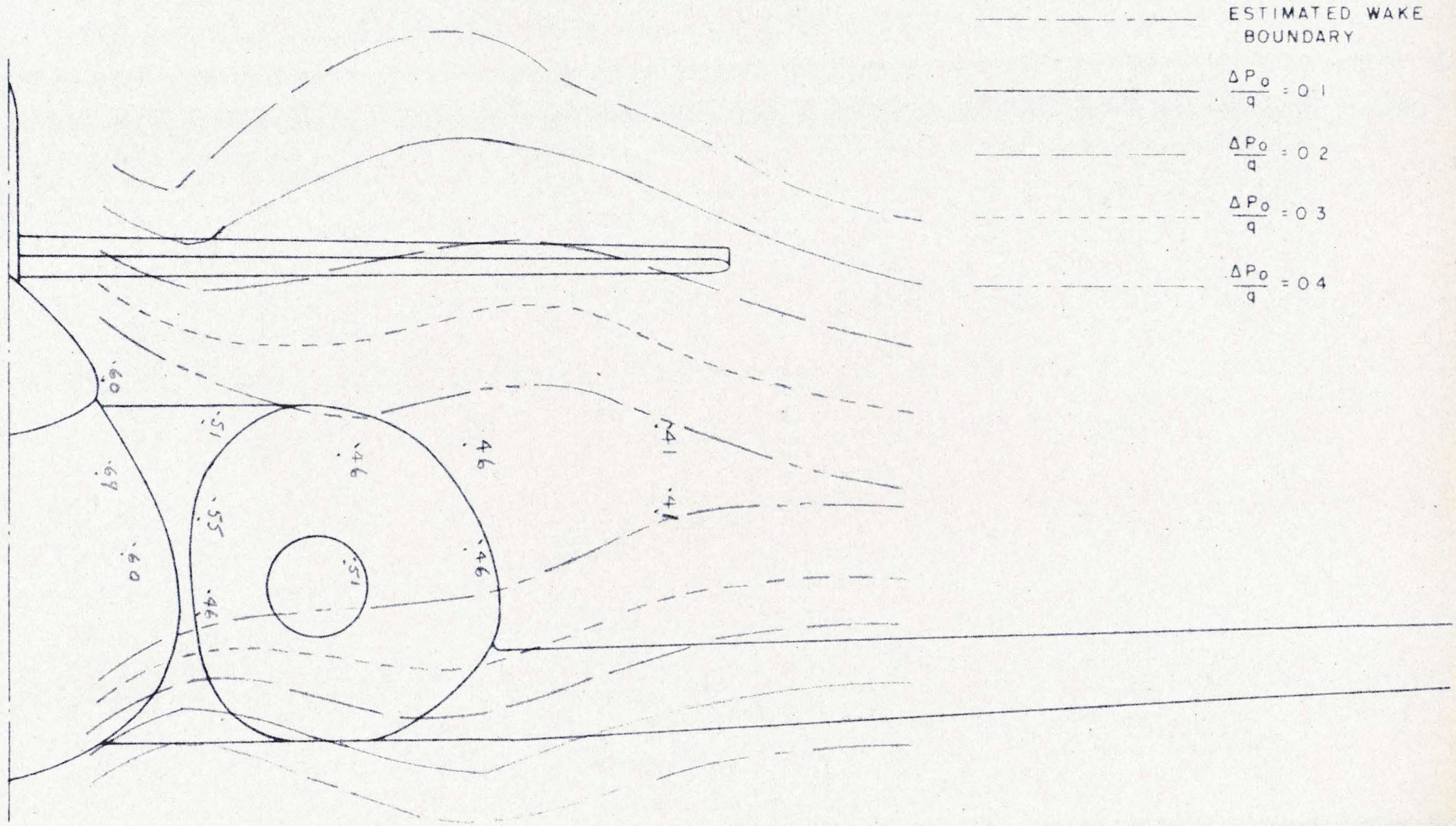
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = \cdot 82$ $\alpha = 4 \cdot 5$ (FROM FUSELAGE REF. LINE)

$C_L = \cdot 365$

FIG 21



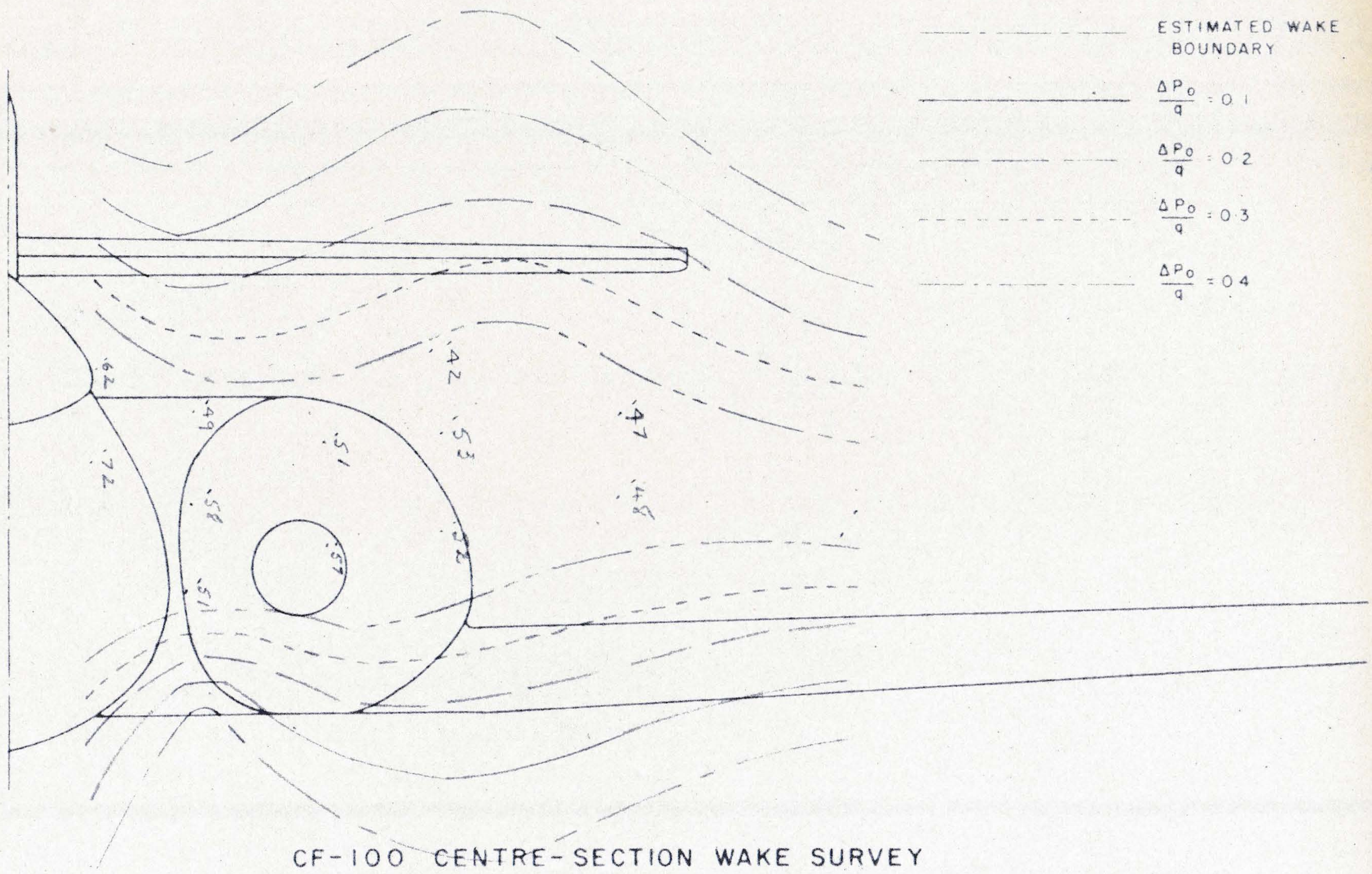
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

M = ·86 α = 4·5 (FROM FUSELAGE REF· LINE)

C_L = ·35

FIG 22



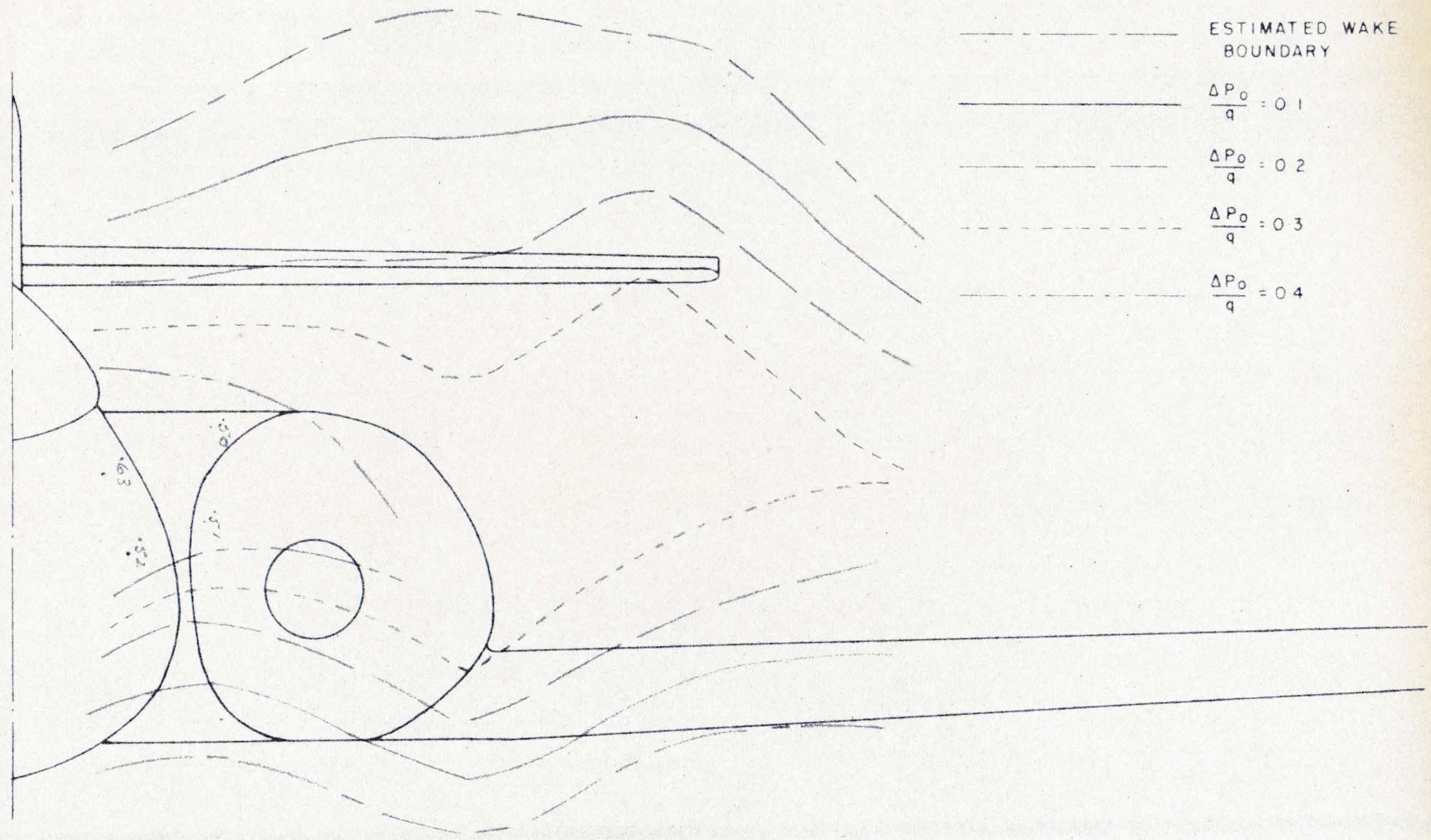
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = .90$ $\alpha = 4.5$ (FROM FUSELAGE REF. LINE)

$C_L = .345$

FIG. 23



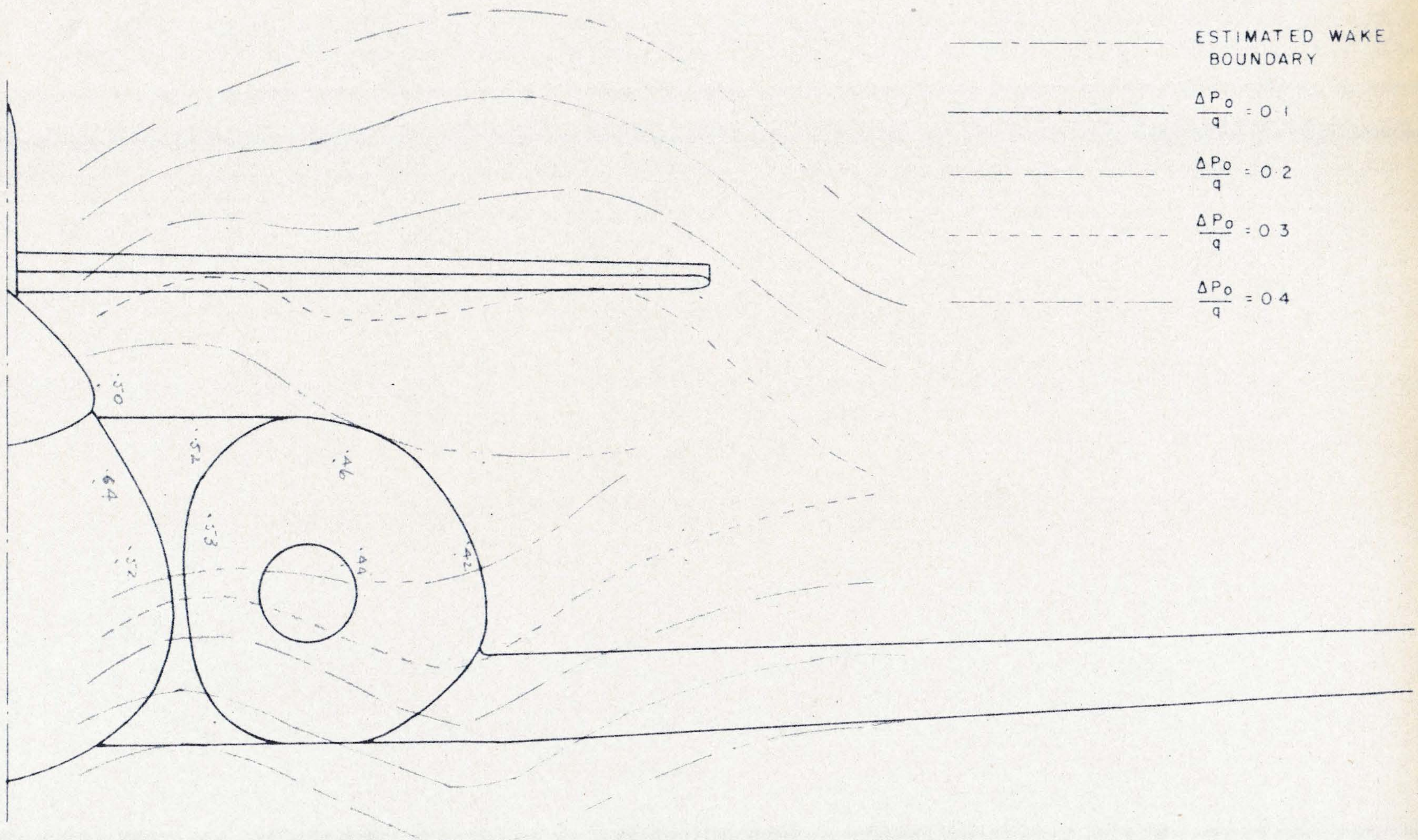
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = \cdot 60$ $\alpha = 6 \cdot 5$ (FROM FUSELAGE REF· LINE)

$C_L = \cdot 53$ (STALLED)

FIG·24



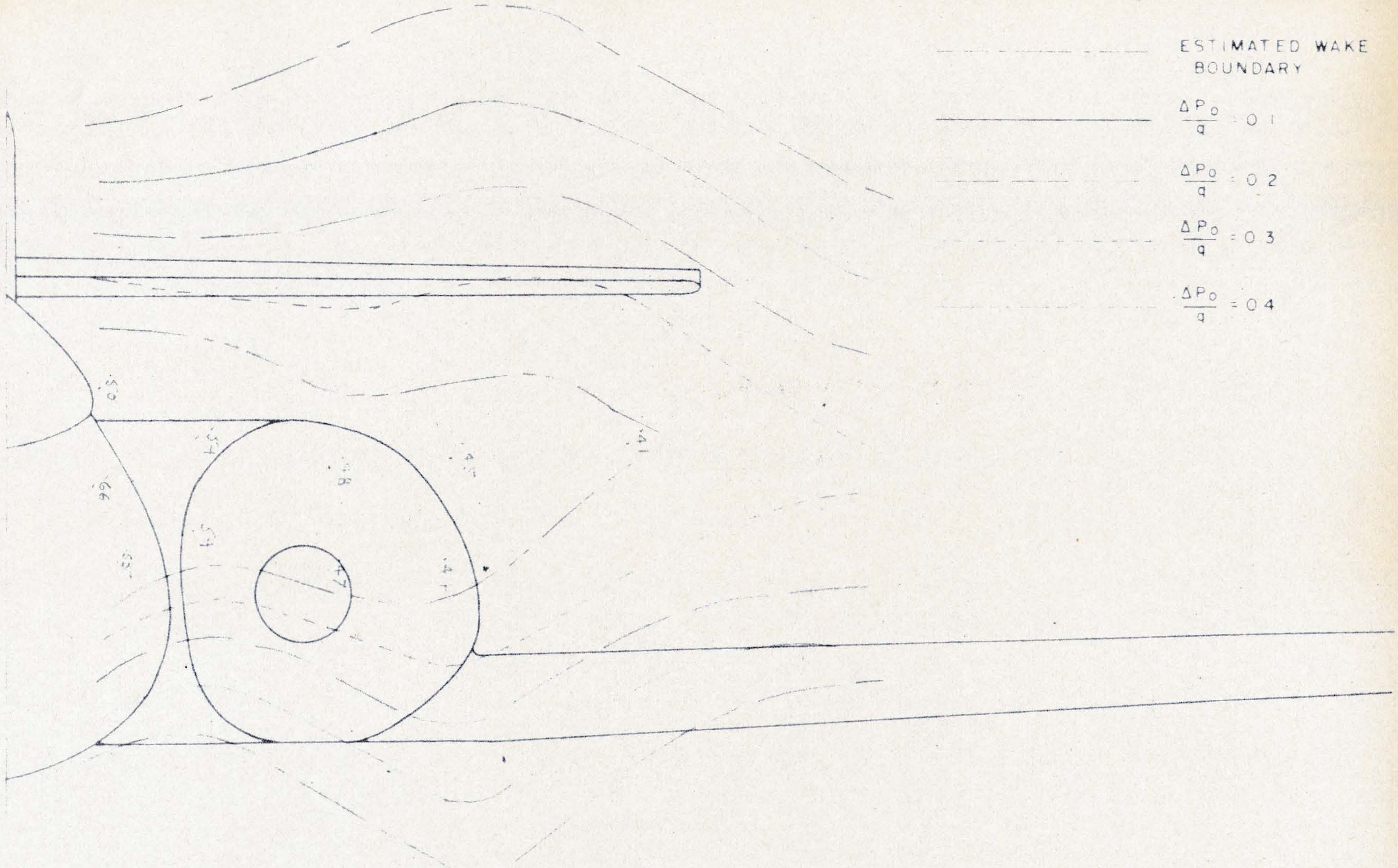
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

M = .65 α = 6.5 (FROM FUSELAGE REF. LINE)

C_L = .50 (STALLED)

FIG 25



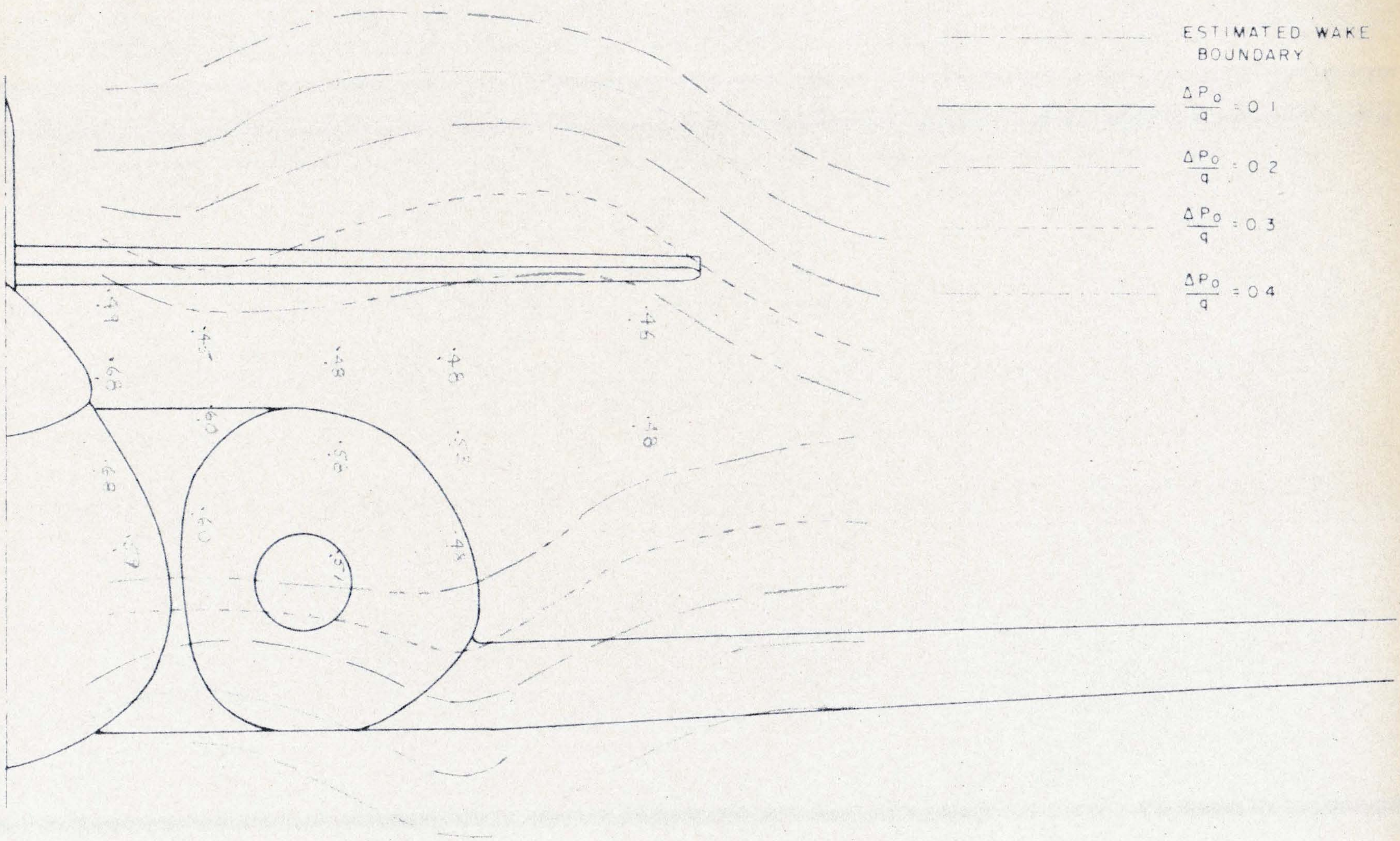
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = .71$ $\quad \alpha = 6.5°$ (FROM FUSELAGE REF. LINE)

$C_L = .51$

FIG 26



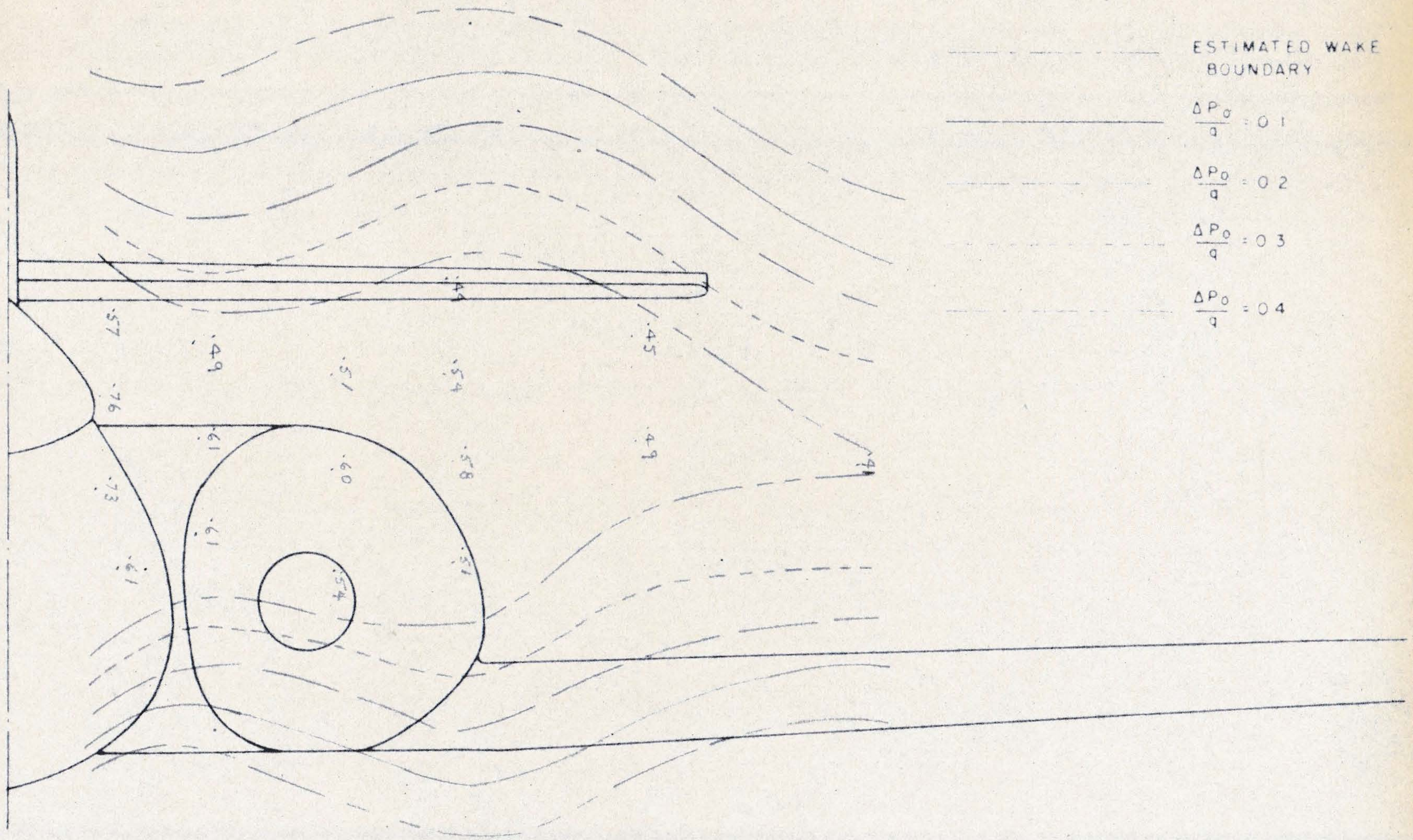
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

$M = .77$ $\alpha = 6.5$ (FROM FUSELAGE REF. LINE)

$C_L = .48$

FIG 27



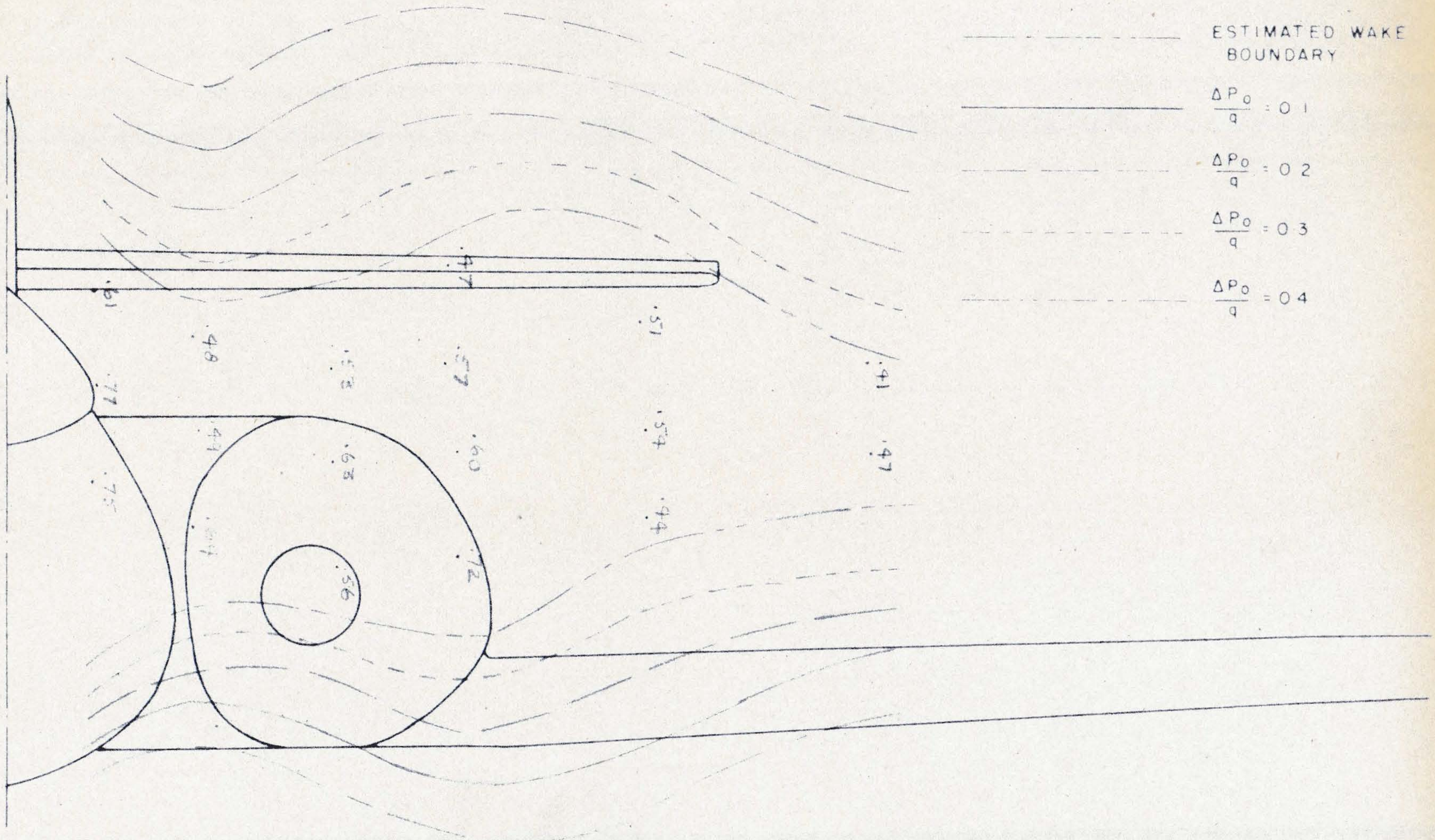
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

$M = .82$ $\quad \alpha = 6.5$ (FROM FUSELAGE REF. LINE)

$C_L = .455$

FIG 28



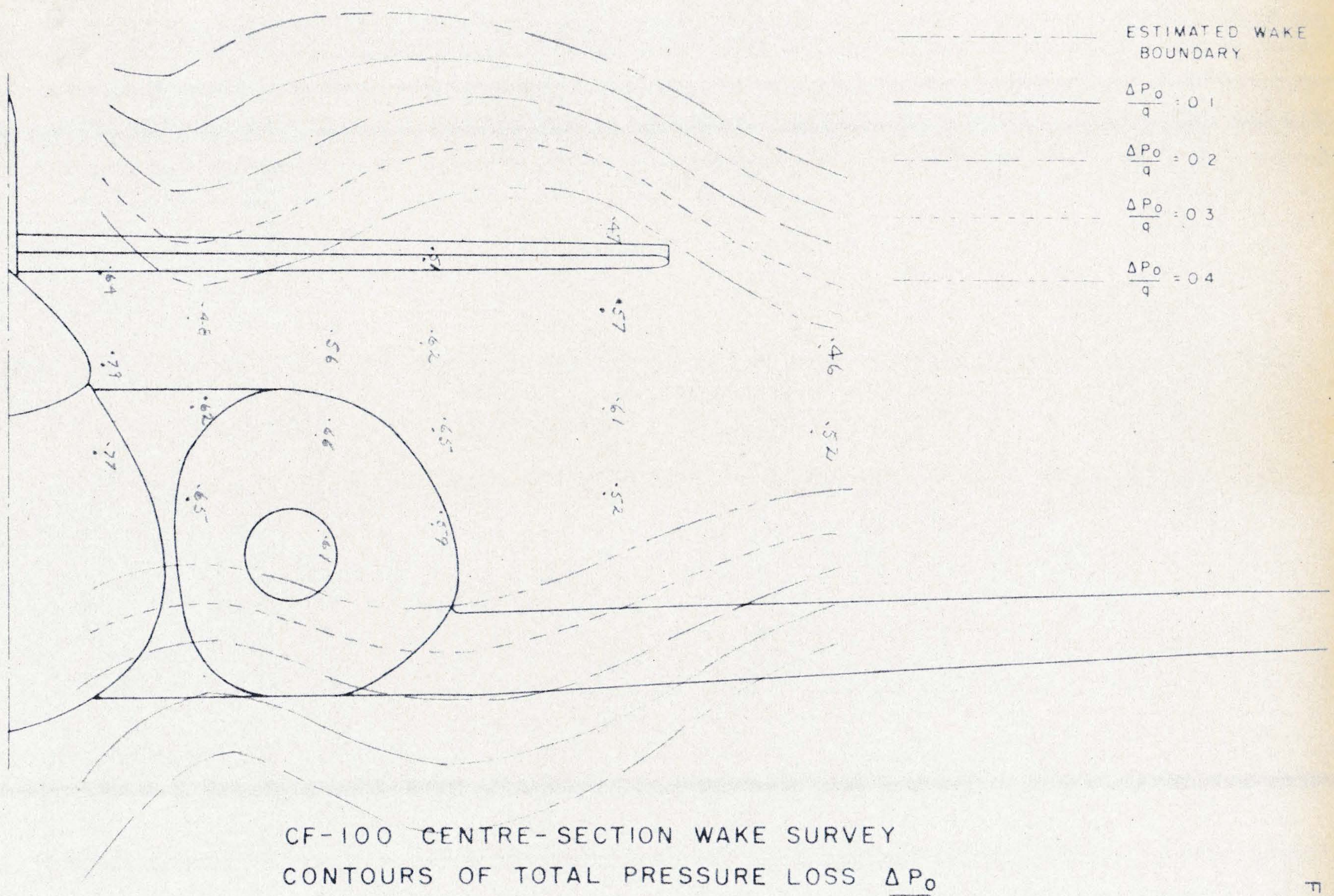
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_0}{q}$

M = ·86 α = 6·5 (FROM FUSELAGE REF. LINE)

C_L = 145

FIG 29



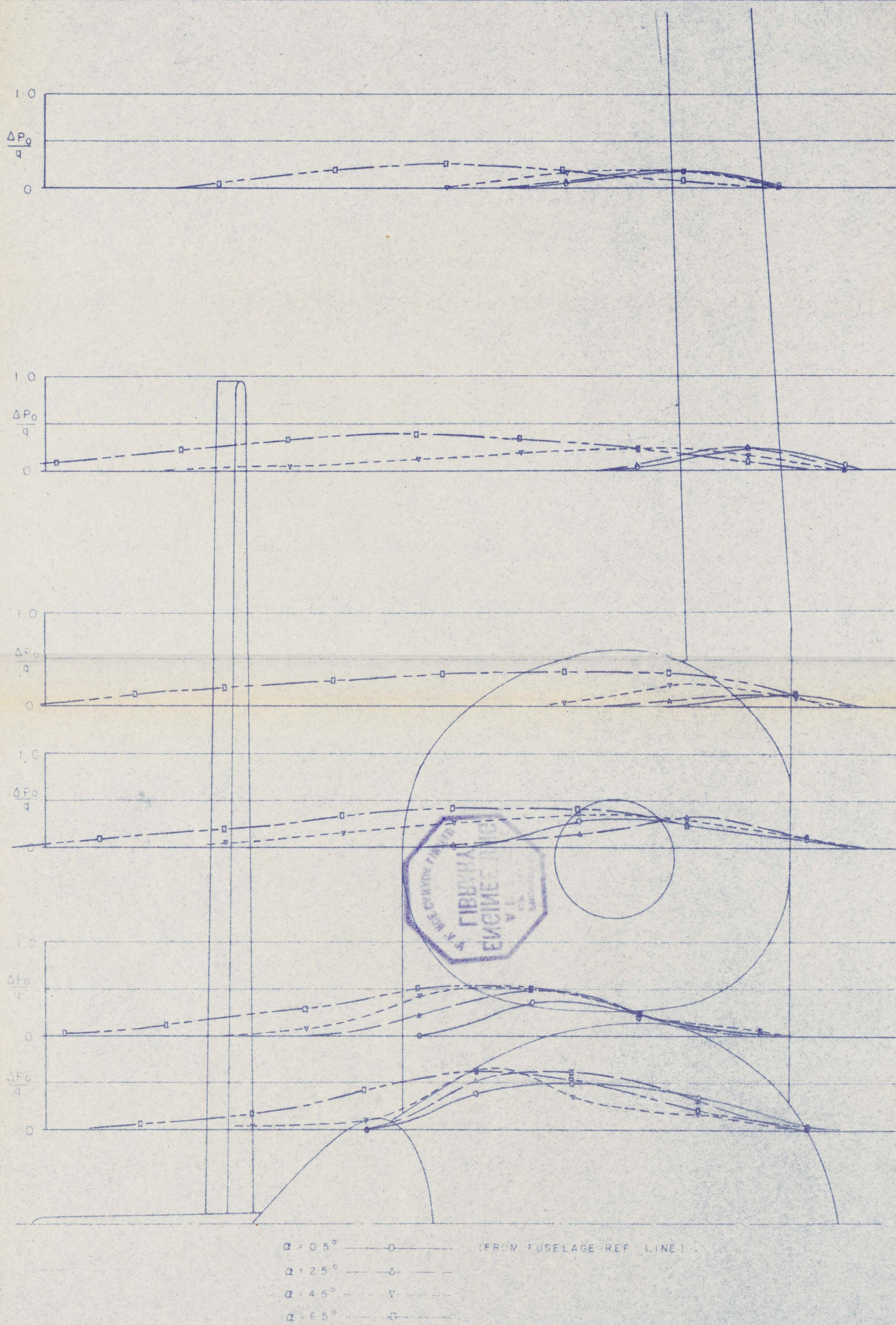
CF-100 CENTRE-SECTION WAKE SURVEY

CONTOURS OF TOTAL PRESSURE LOSS $\frac{\Delta P_o}{q}$

M = .90 α = 6 (FROM FUSELAGE REF. LINE)

C_L = .455

FIG 30

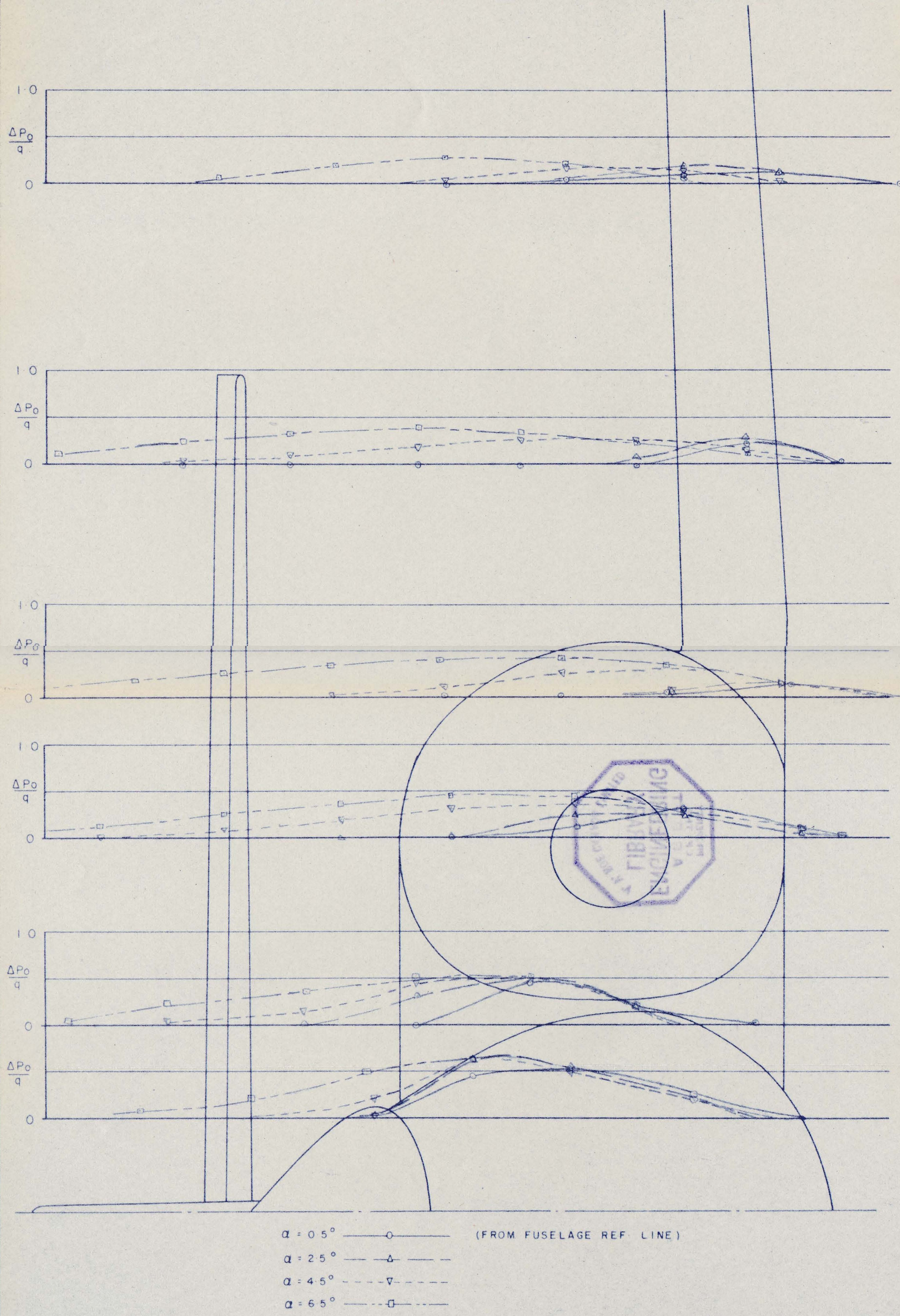


CF-100 CENTRE-SECTION WAKE SURVEY

VARIATION OF TOTAL PRESSURE LOSS WITH ANGLE OF ATTACK

M = 0.60

FIG. 31

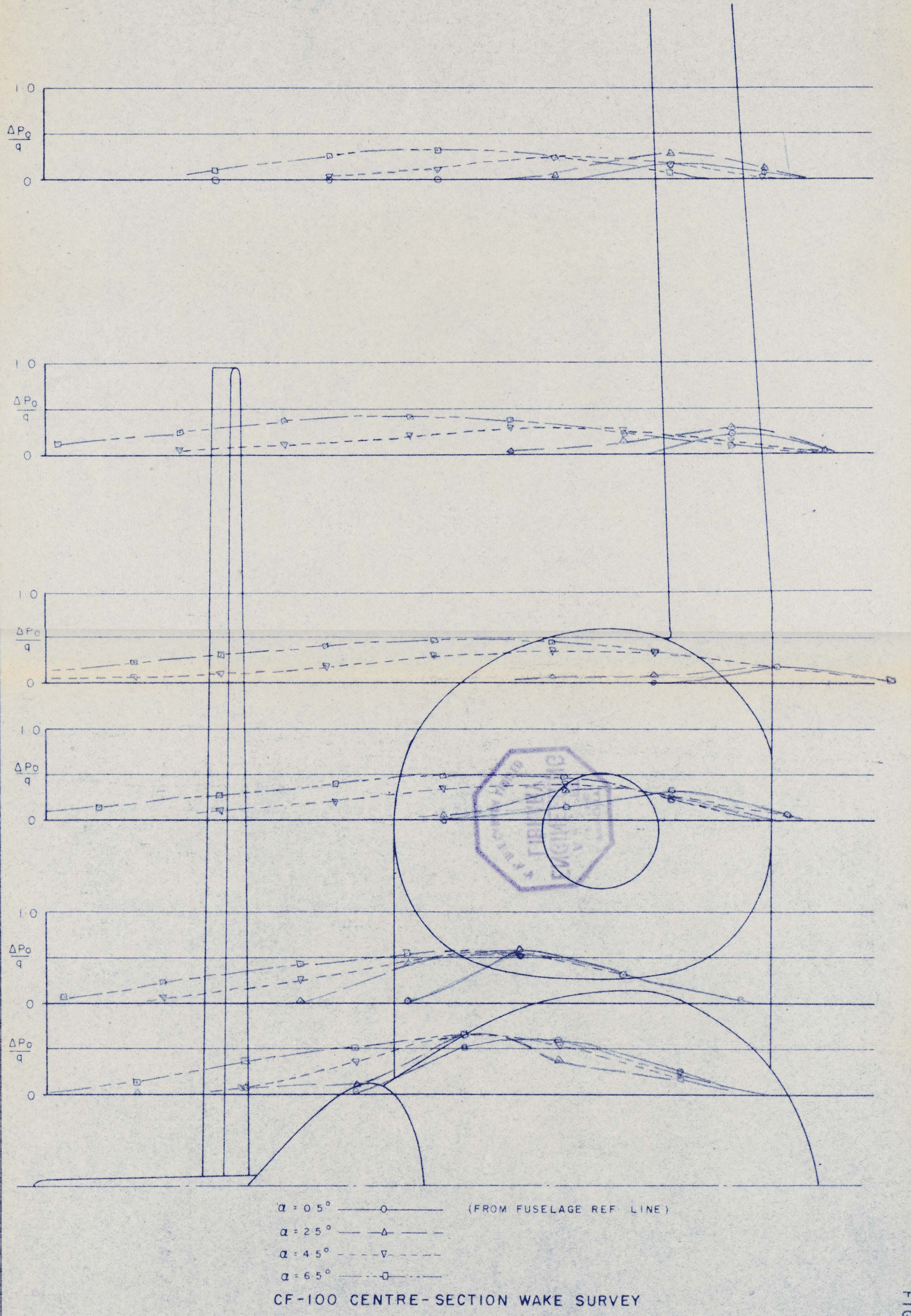


CF-100 CENTRE-SECTION WAKE SURVEY

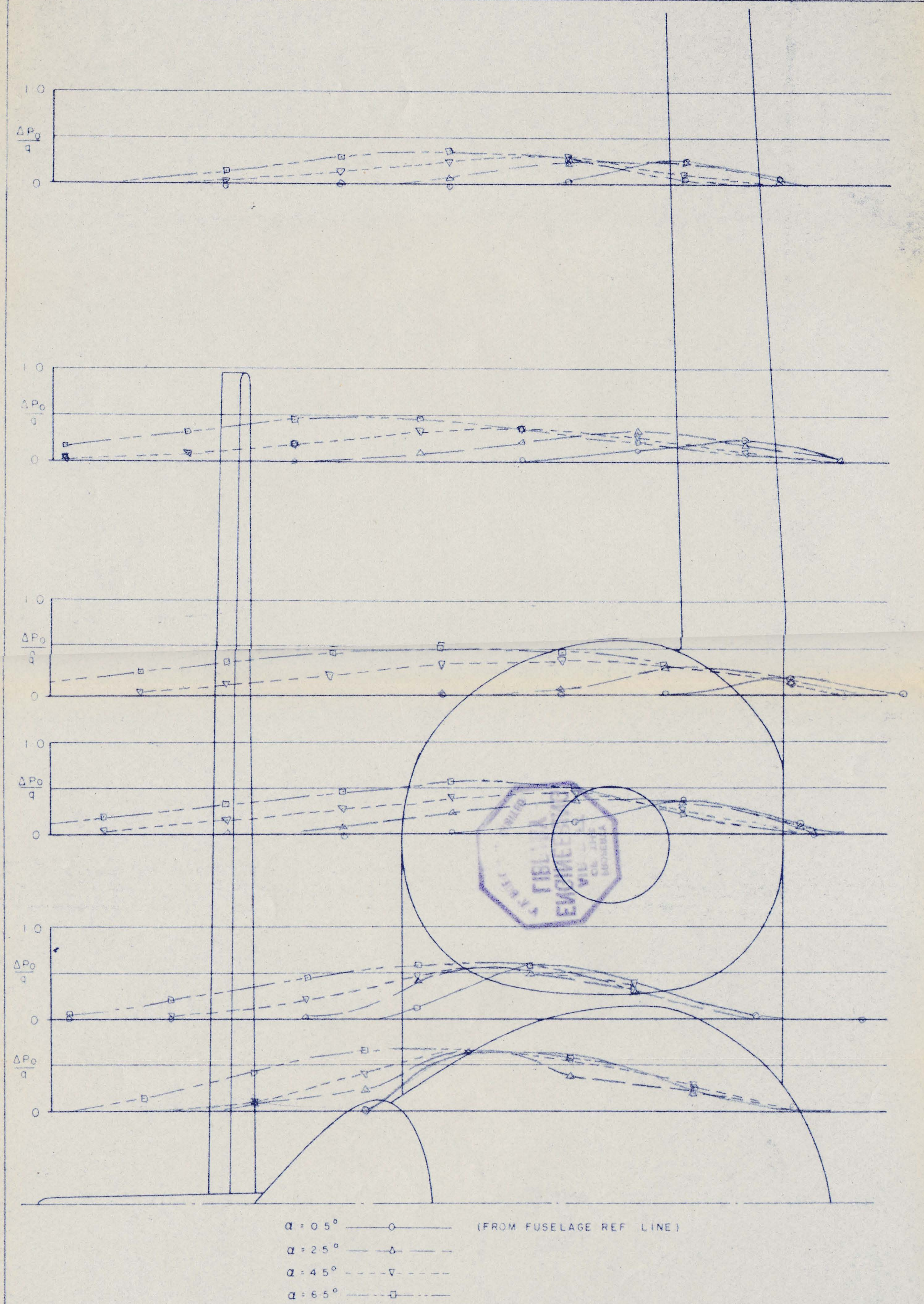
VARIATION OF TOTAL PRESSURE LOSS WITH ANGLE OF ATTACK

M = .65

FIG·32



CF-100 CENTRE-SECTION WAKE SURVEY
VARIATION OF TOTAL PRESSURE LOSS WITH ANGLE OF ATTACK
M = .71

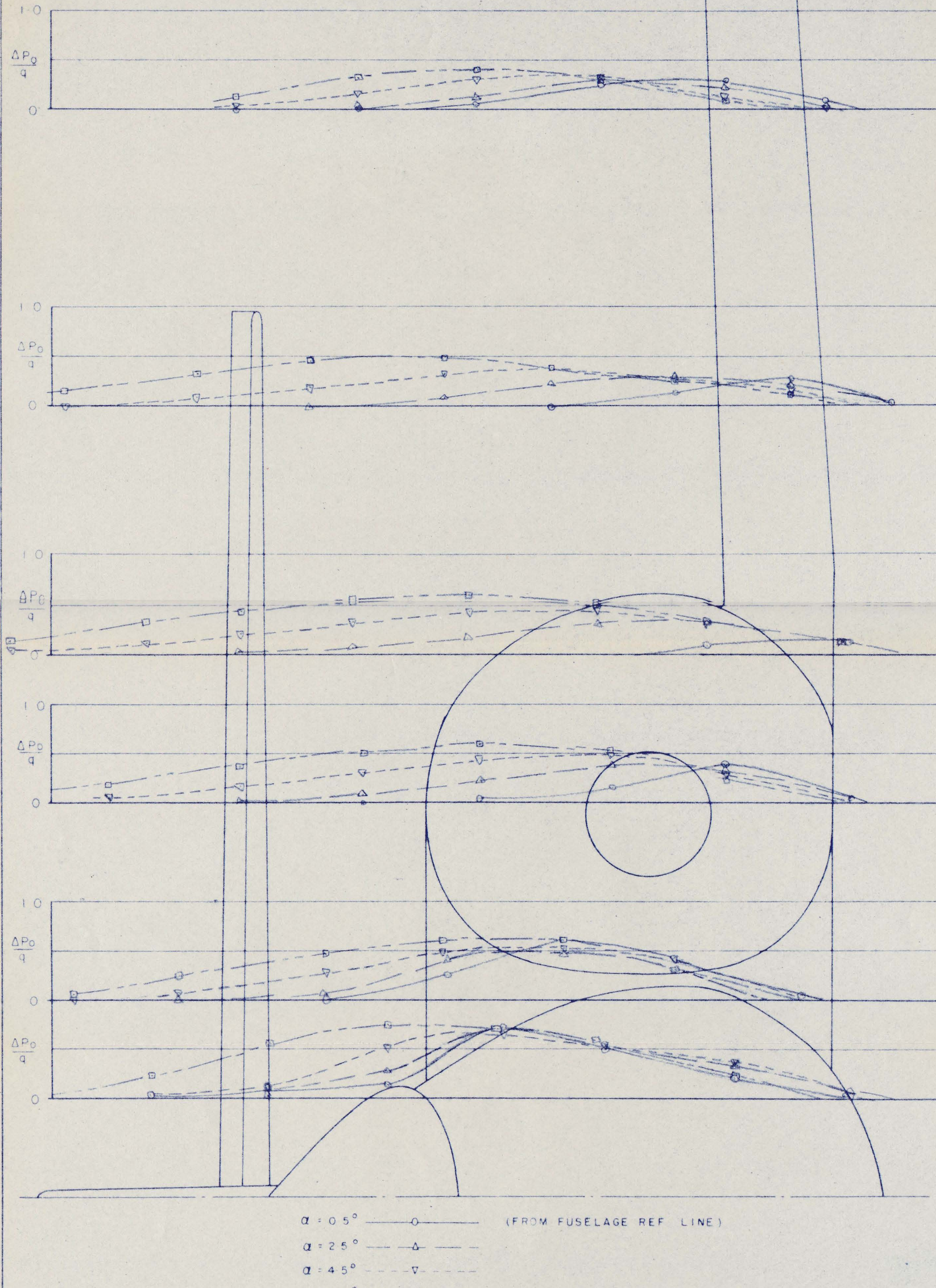


CF-100 CENTRE-SECTION WAKE SURVEY

VARIATION OF TOTAL PRESSURE LOSS WITH ANGLE OF ATTACK

M = .77

FIG. 34

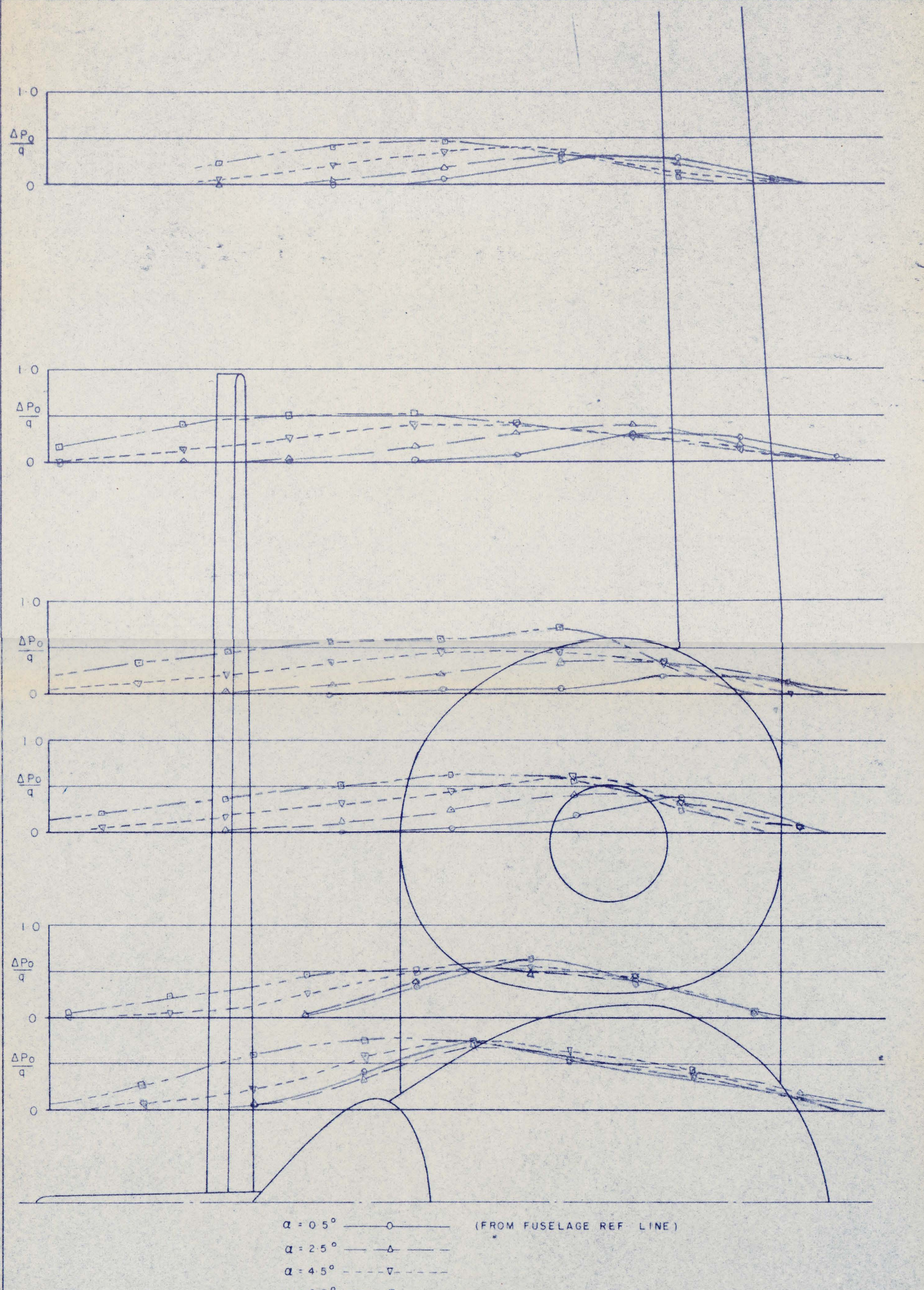


CF-100 CENTRE-SECTION WAKE SURVEY

VARIATION OF TOTAL PRESSURE LOSS WITH ANGLE OF ATTACK

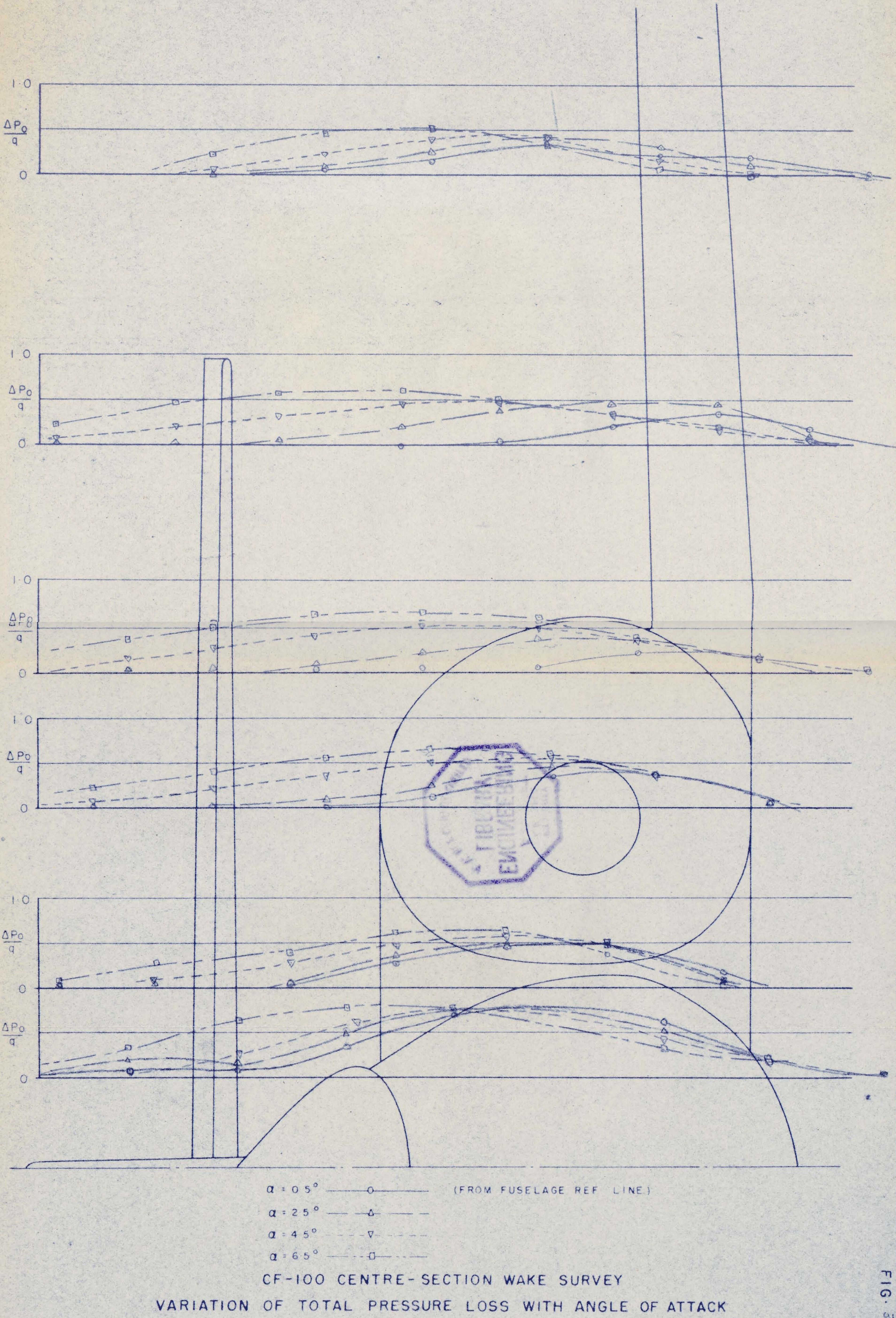
M = ·82

FIG·35a



CF-100 CENTRE-SECTION WAKE SURVEY
VARIATION OF TOTAL PRESSURE LOSS WITH ANGLE OF ATTACK
M = ·86

FIG·36



CF-100 CENTRE-SECTION WAKE SURVEY

VARIATION OF TOTAL PRESSURE LOSS WITH ANGLE OF ATTACK

M = .90