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Preliminary Issue

A new method for measuring the pressure distribution on harmonically oscillating wings ~~of arbitrary planform.~~

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A new method for measuring the pressure distribution on harmonically oscillating wings ~~of arbitrary planform~~.

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Summary.

A method is described, enabling to measure the pressure distribution on oscillating wings with the aid of one pressure transducer, mounted inside a scanning valve. The scanning valve, located outside the testsection, is connected to the model orifices by equal pressure leads. Special measures are taken to simplify the correction procedure, necessary to eliminate the influence of the pressure leads. A short description of the equipment, developped to measure a large number of pressures automatically, is given. The usefulness of the technique is demonstrated by some examples.

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1 Introduction.

The last decade has shown an increased demand for pressure measurements on harmonically oscillating wings. The common way of using a large number of built-in transducers still has some disadvantages. In spite of the progress towards small transducers, they are in many cases still too large to be mounted at the desired points in thin model wings. On the other hand, application in large numbers as is necessary for low aspect ratio wings is prohibited often by the high cost involved.

At the NLR an other approach has been examined and developed. It is based on the idea to utilize pressure leads and to measure the various pressures with one transducer, mounted in a scanning valve outside the model. Although this is becoming common use for steady pressure measurements, it is obvious that in case of oscillating pressures the leads strongly affect the results. Therefore a suitable procedure has been developped to correct the measured values to "surface pressures", being the pressures at the model surface.

The purpose of the present report is to describe the method that has been used and to illustrate its usefulness. It may be remarked that the present result could be achieved only by the constant effort of a team of people.

2 The method.

Several authors [1,2,3] have considered the response to a sinusoidal input pressure $\bar{p}_i$ of a long capillar tube, connected at one end to the internal volume of a pressure transducer (fig.1). They have shown that the dynamic response, being the complex ratio of the volume pressure fluctuation p_v to the sinusoidal input is dependent on three non-dimensional quantities, viz.:

$$\frac{\omega L}{c}, \quad \frac{V_v}{V_t} \quad \text{and} \quad R\sqrt{\frac{\omega \rho}{\eta}}$$

with:

- ω frequency of pressure input
- L tube length
- c mean velocity of sound
- V_v transducer volume

V_t tube volume

R tube radius

ρ mean fluid density in the system

η absolute fluid viscosity

Thus for a given system, the dynamic response is not only a function of frequency but also of the mean temperature T and the mean pressure p. To illustrate the importance figs. 2 and 3 present theoretical results for the influence of resp. p and T on magnitude and phasedifference of the dynamic response of a typical combination. Using a multiple of tubes with transducers for windtunnelmeasurements on oscillating models without any precautions would mean that the mean temperature and the mean pressure in each tube should be determined in order to correct for the dynamic response of each tube. To avoid this difficulty and to simplify the correction procedure as far as possible, some special measures have been taken, viz.

1: All tubes are equal in geometric sense and connected to one transducer in the same way.

2: In each test, run at a constant frequency, the input pressure of one tube is measured directly with a second transducer, mounted in the model. In this way the dynamic response of a reference tube at test conditions is known.

For low speed measurements the mutual differences in mean pressure and mean temperature of the various tubes are so small that geometric equal tubes also have equal dynamic responses. And because the dynamic response of the reference tube is obtained in each test, the various measured pressure vectors may be corrected to the corresponding values at the model surface by dividing through that known response.

In case of higher speeds, in general the mutual temperature variations are still negligible but considerable differences in mean pressure may occur. Then the dynamic response of geometric equal tubes becomes different and an additional correction, depending on the difference between mean (i.e.static) pressure in each individual tube and in the reference tube has to be applied to each measured pressure. Thus the influence of mean pressure on the dynamic response of the reference tube and the static pressure distribution over the model have to be known. A proper selection of the tube-transducer combination with respect to the test requirements may be very helpful in order to keep the corrections small.

3 Practical information.

In each particular case, the most suitable dimensions of tube and transducers have to be chosen. This choice depends on many variables as model size, frequency range, windtunnelcharacteristics etc. For design purposes a computor program to calculate the dynamic response is very valuable.

In practice it may occur that minor discrepancies in dynamic response of similar tube exist due to small variations of length or diameter. These differences may be taken into account by using the ratio between the dynamic response of the tube considered and that of the reference tube. In general the variations are within a few percent, provided that the tubes are installed with care.

To prevent a non-linear behaviour of the dynamic response, it is advisable to avoid large discontinuities in tube diameter. As may be expected, non-linearities start to occur at frequencies, corresponding to peak values in the amplitude characteristic.

In case of thin models, it is not always possible to mount the reference tube and its transducer inside the model. Then the entrance of the reference tube and its transducer may be connected to any position where a sufficiently large pressure oscillation is generated under similar conditions, e.g. the tunnel wall in case of half-model measurements.

4 Equipment.

A semi-automatic measuring system has been developped, using commercial available components. It has been designed especially to enable a quick determination of a large number of pressures.

A block diagram of the equipment is shown in fig. 4. The model is excited by one or more electro dynamic vibrators, driven through a power amplifier by the oscillator. The pressure scanner, having 30 positions, passes the pressures one after the other to its transducer. The sequence of the various pressure and displacement signals is determined by the program switch. A normal program consists of: zero signal, overall calibration signal, displacement signals, signal of model pressure transducer, a sub-program of 30 scanned pressures, repeated displacement signals and repeated signal of model pressure transducer.

The passed signal is amplified and fed in the vector component resolver, that decomposes it into one component in phase with the 0 degree oscillator signal and one in quadrature to it. The resolver rejects all signals, except those having a frequency equal to that of the oscillator. The two components are measured one after the other by the digital voltmeter and finally fixed on paper tape in decimal code and on punch tape.

The complete measuring program operates automatically by means of the control unit. The time needed for one cycle of 30 scanned pressures and 8 other signals is 3 - 4 minutes. The number of pressure points may be extended easily with the aid of a hand-operated group selector, that gives the possibility to connect up to 7 different groups of 30 pressures leads to the scanner (fig.5).

5 Applications.

The developped measuring technique has been applied for various types of pressure measurements. Until now rigid models have been tested, but there exists no restriction for use on flexible models. In that case the mode of vibration has to be determined too.

An extensive programm to determine the unsteady aerodynamic forces on two-dimensional wing-flap combinations in incompressible flow has been carried out. [4] . One of the results, viz the pressure distribution due to oscillations of a 40 percent flap is shown in fig.6.

Similar results for a wing with a 25 percent flap in compressible flow are presented in fig.7. In stead of the pressure difference, the pressure oscillations at both sides of the model were measured [5] . The discrepancies between the pressures at both sides are due to a small deflection of the flap.

In incompressible flow a large number of pressure measurements has been carried out for the wing of the VJ 101 C of the "Entwicklungsring Süd". Experimental results, compared with three-dimensional theory have been given by B.Laschka [6] .

Results for a fin and a complete T-tail, both performing yawing oscillations are presented in the figs. 8 and 9. Since in both cases the fin is the same, a comparison of the pressures on the fin in corresponding sections shows the influence of the stabilizer. On the other hand, the interference aerodynamic forces on the stabilizer (section III of fig.9) are quite large.

An interesting phenomenon is shown in fig.11, presenting results for flapping motion of the stabilizer with different tip shapes. In contrary to the assumption in three-dimensional theory, the pressure difference at the tip in case of a clipped stabilizer tip is not becoming zero. The spanwise distribution of the aerodynamic force, shown in fig.12 stresses this phenomenon.

This might have an important effect on the flutter behaviour, because in general the large deformation amplitudes exist in that region.

6 Conclusions.

It has been shown by various examples, that the described technique leads to sufficiently accurate results.

Its special advantages are:

1: The possibility to measure at nearly each desired point of the model.

2: The reasonable cost and time involved with the measurements.

ΔC_p = pressure coeff. per eenheid v (dimensieloze) amplitude

7 References.

1 Iberall A.S. — Attenuation of oscillatory pressures in instrument lines. Journal of Research of the Nat.Bureau of Standards. Vol.45 pp.85 July 1950.

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5 Bergh H., Cazemier P.G., Siebert C.M. — Preliminary results of pressure measurements on a wing with oscillating flap in high subsonic and transonic flow (in Dutch) NLR. Int.rep.No.FF.5 1960.

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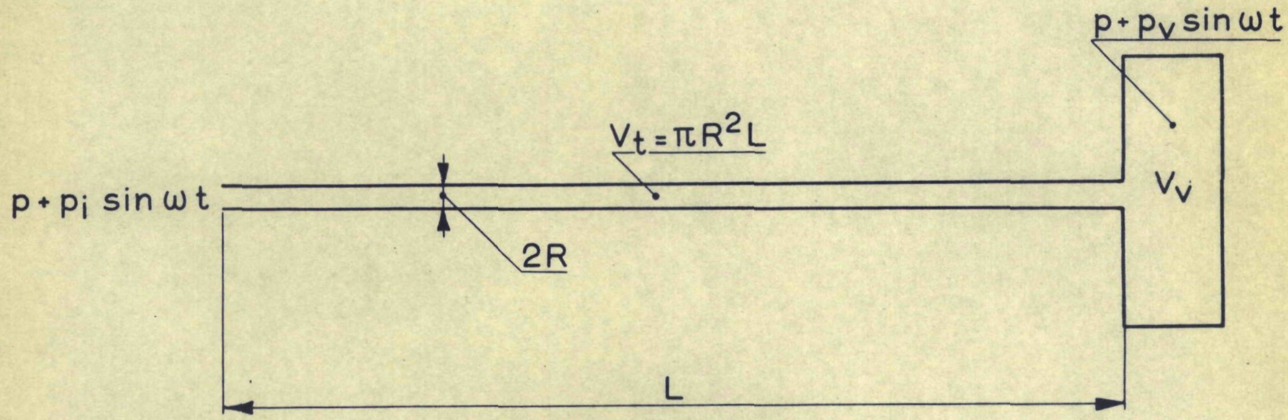
FIG. 1: SCHEMATIC REPRESENTATION OF TUBE WITH TRANSDUCER



PARAMETERS: $\frac{\omega L}{c}$, $\frac{V_v}{V_t}$, $R\sqrt{\frac{\omega \rho}{\eta}}$

FIG.2: INFLUENCE OF MEAN PRESSURE ON DYNAMIC RESPONSE

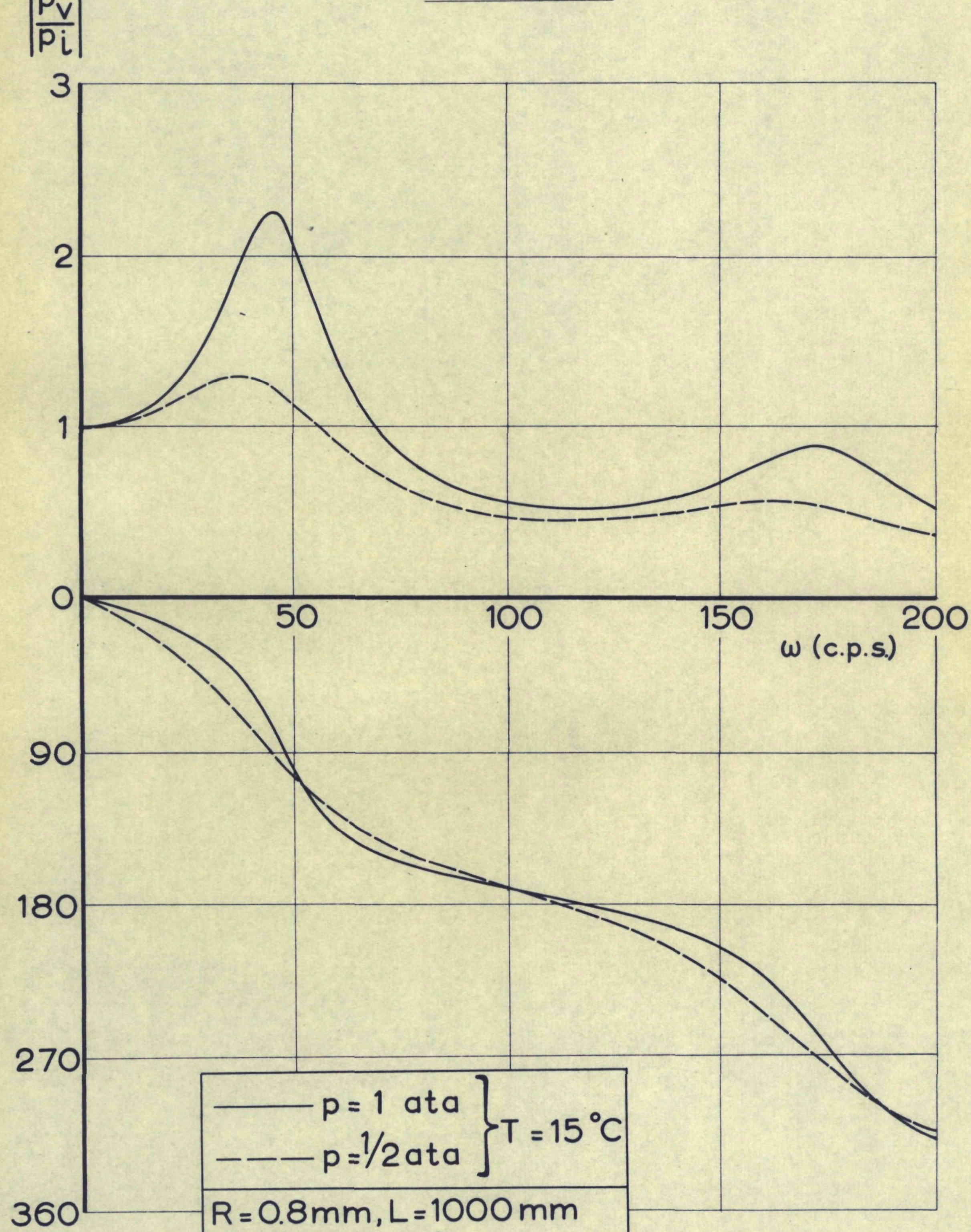


FIG. 3: INFLUENCE OF MEAN TEMPERATURE ON DYNAMIC RESPONSE

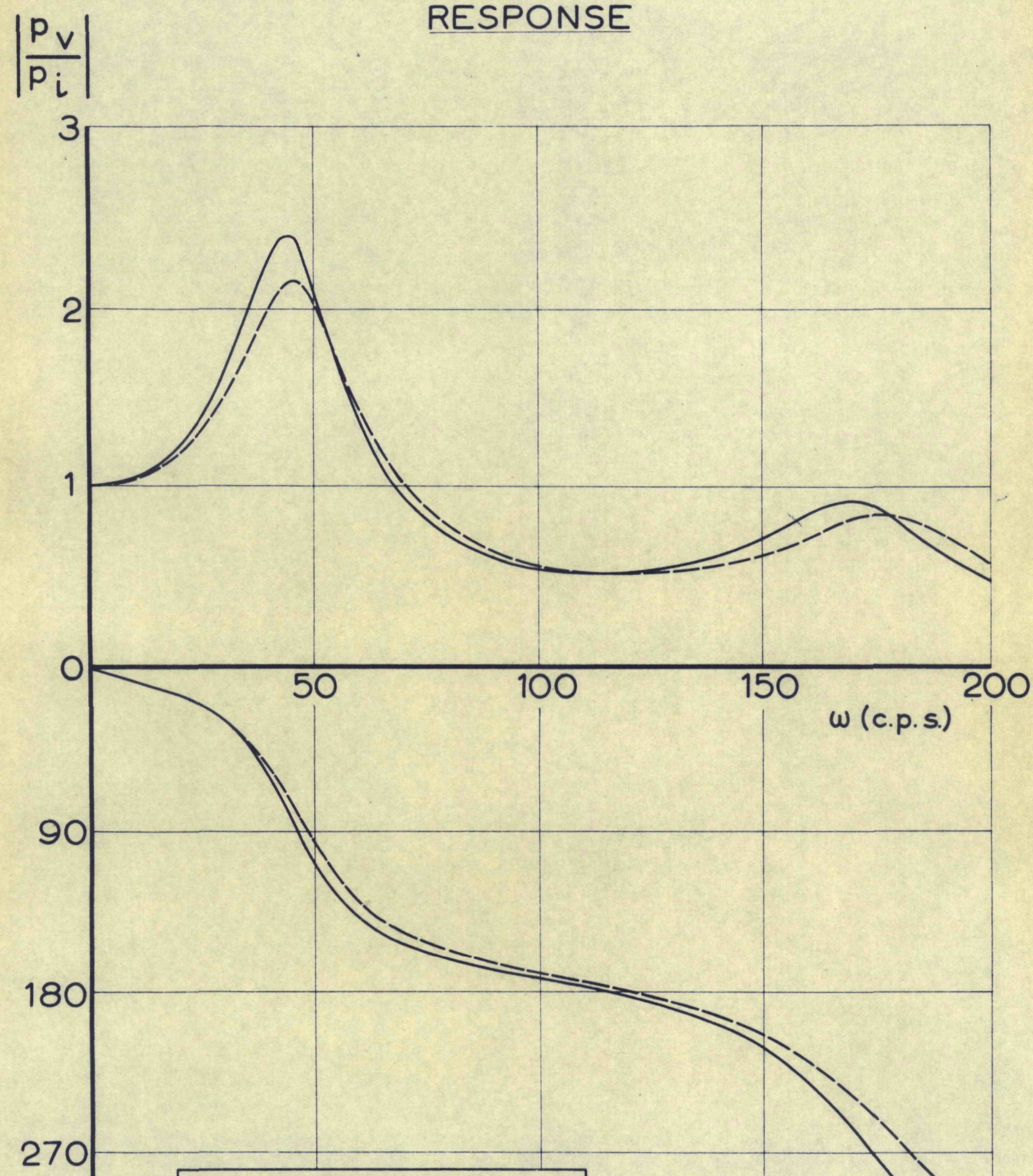


FIG. 4: BLOCK DIAGRAM OF EQUIPMENT

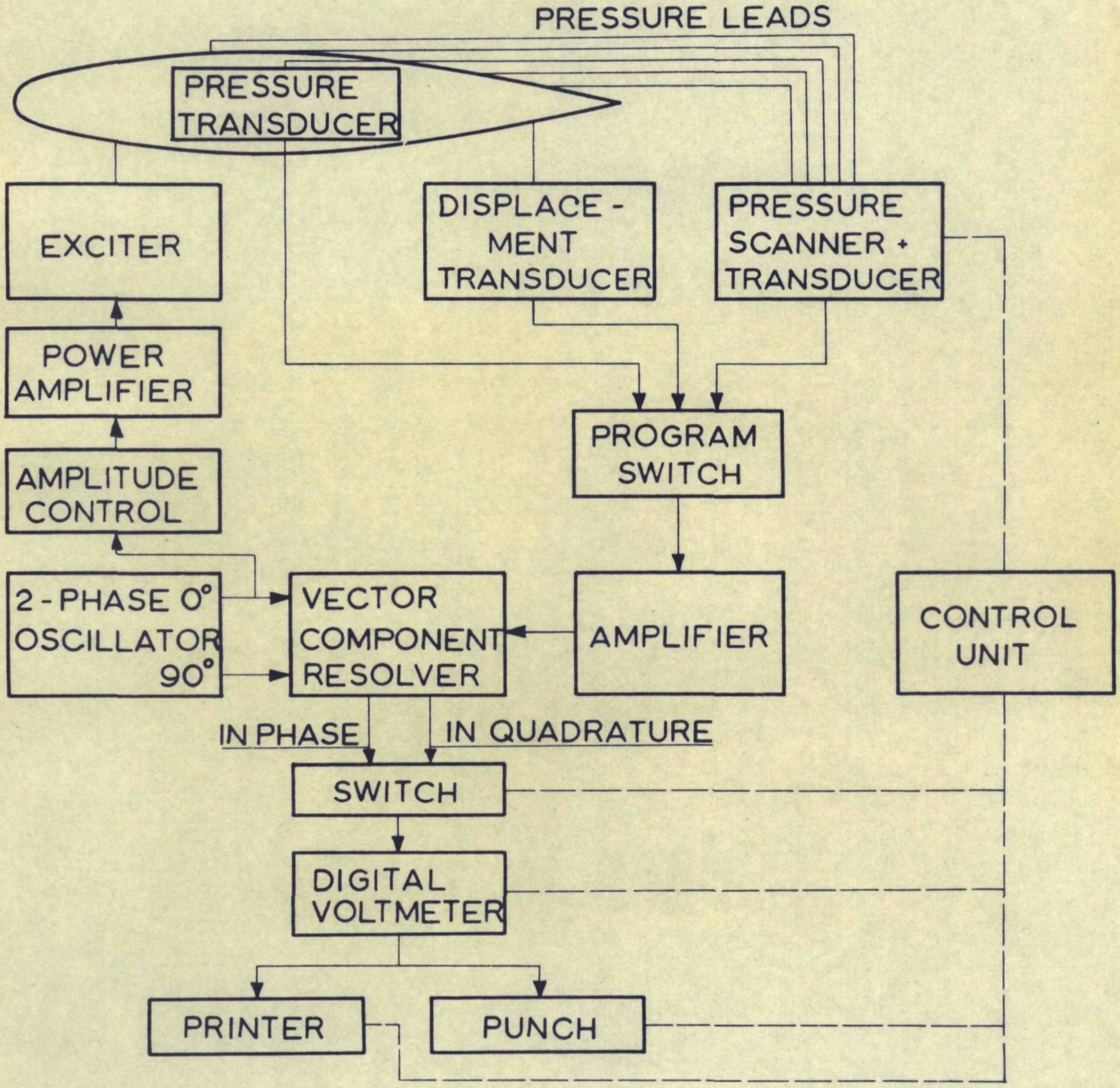


FIG. 5: GROUP SELECTOR AND PRESSURE SCANNER.

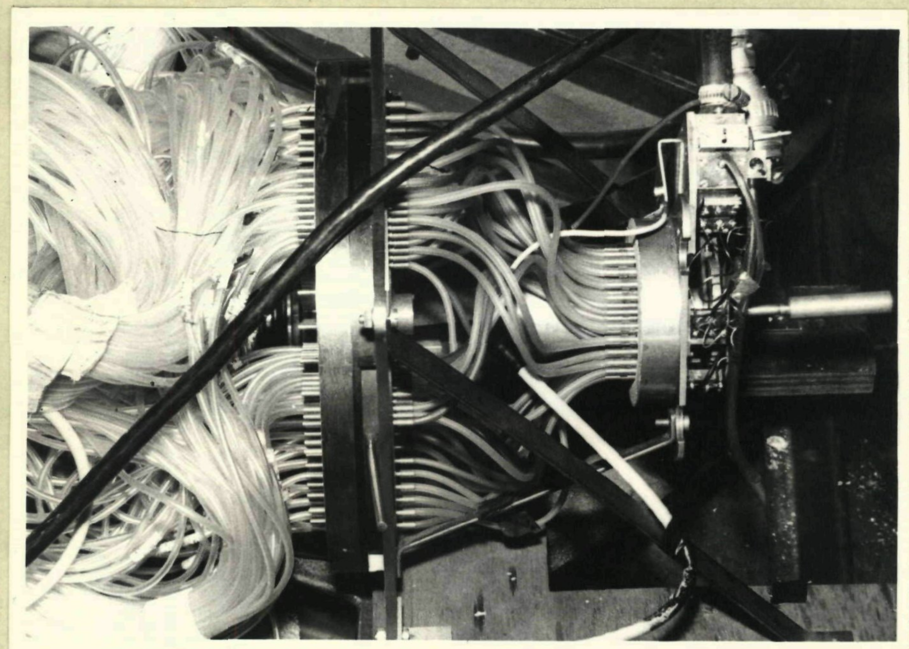
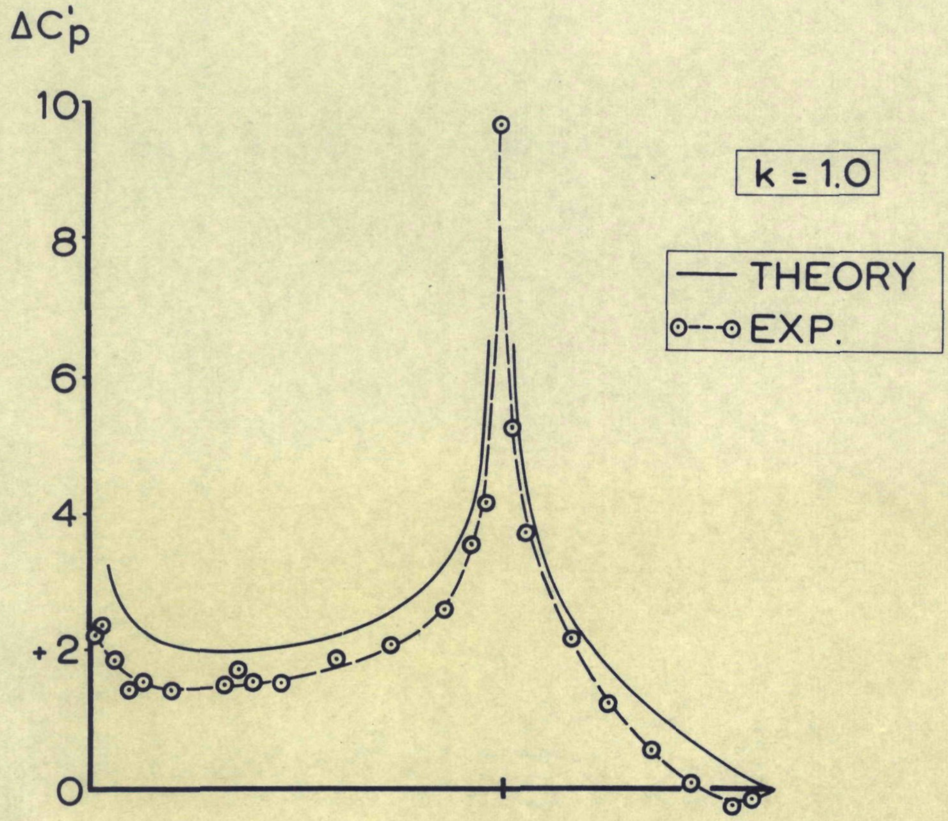


FIG. 6: PRESSURE DISTRIBUTION ON WING WITH OSCILLATING FLAP IN INCOMPRESSIBLE FLOW



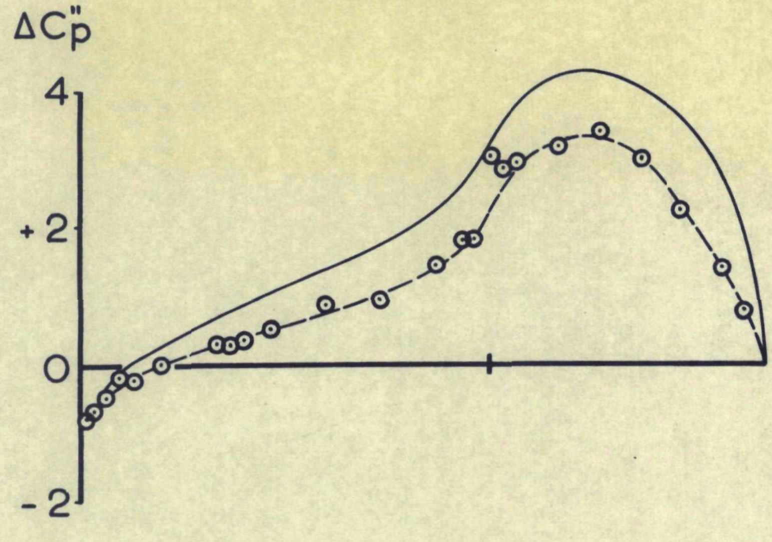


FIG. 7: PRESSURE DISTRIBUTION ON 2-DIMENSIONAL WING WITH OSCILLATING FLAP FOR M = 0.75 .

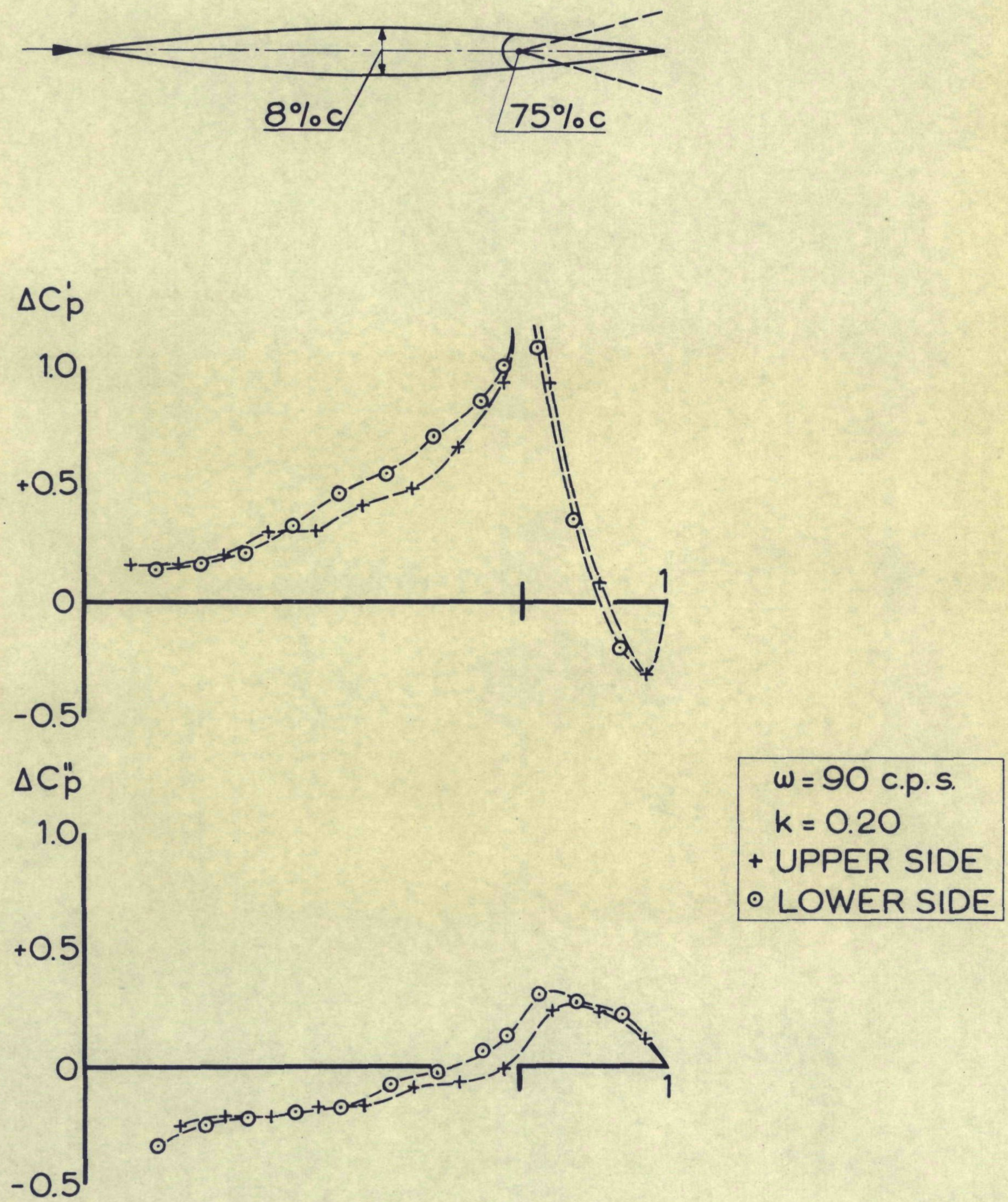


FIG. 8: PRESSURE DISTRIBUTION ON FIN (k = 0.35)

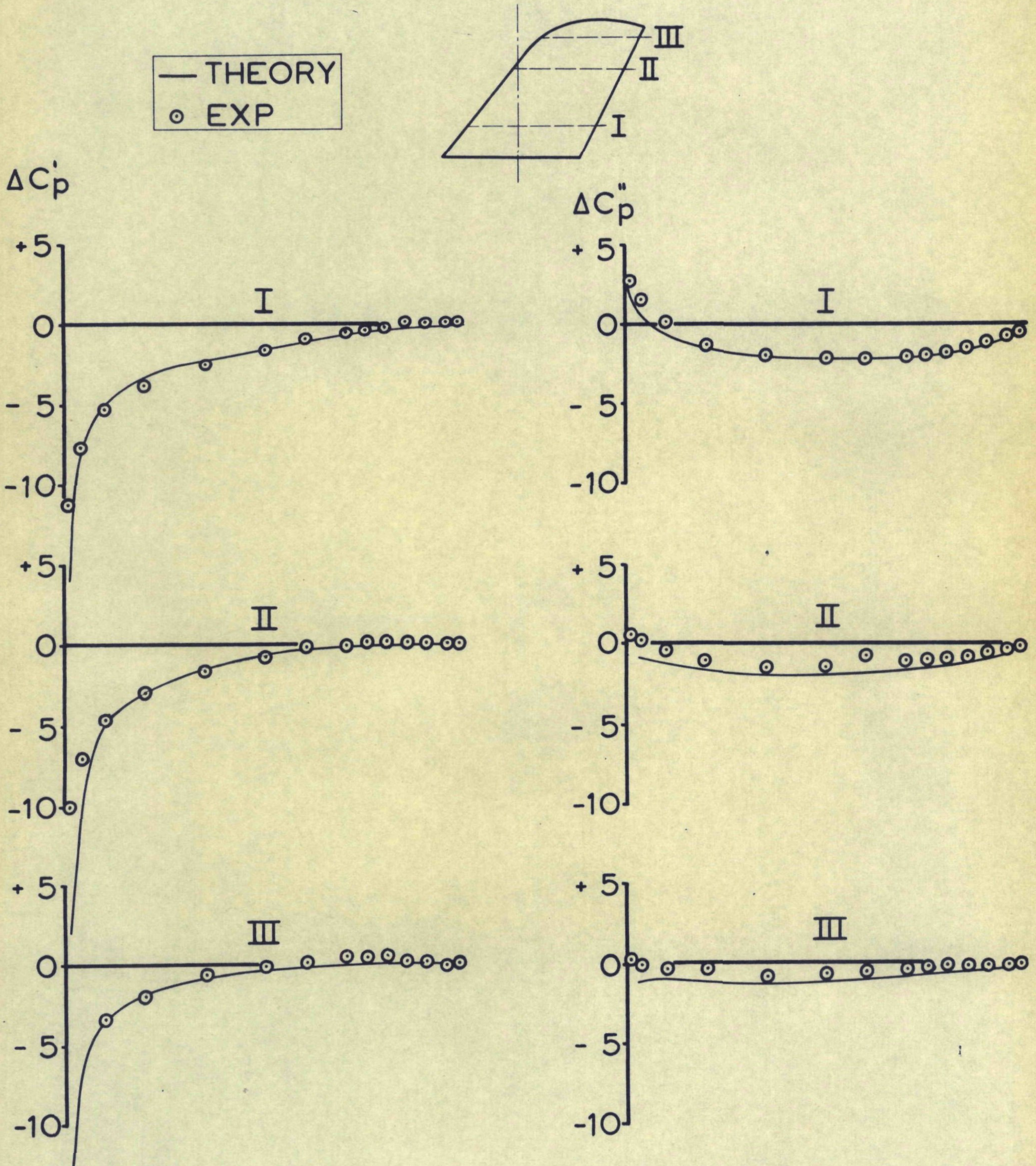


FIG. 9: PRESSURE DISTRIBUTION ON T-TAIL (k = 0.35)

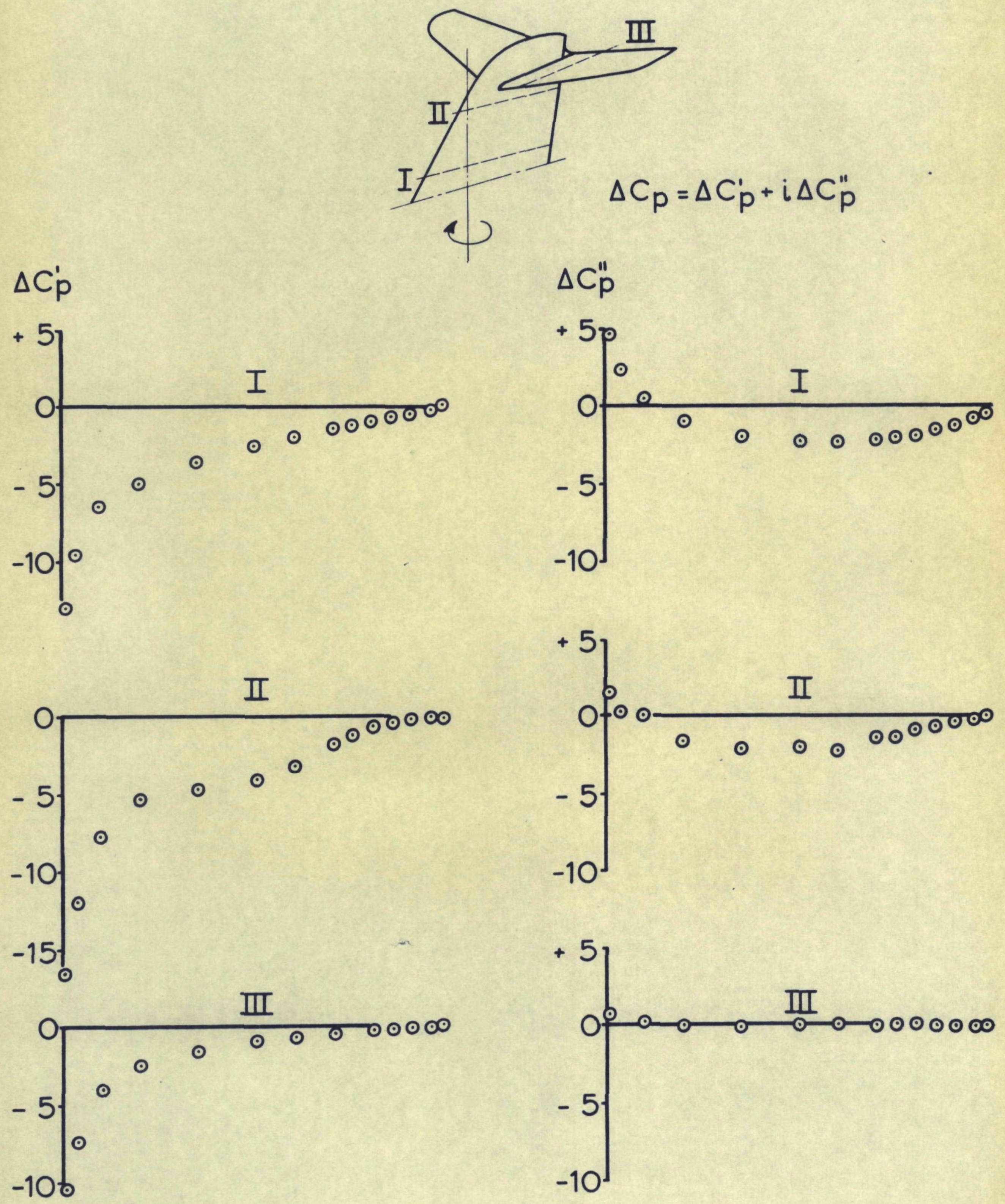


FIG. 10: T-TAIL MOUNTED IN WINDTUNNEL.

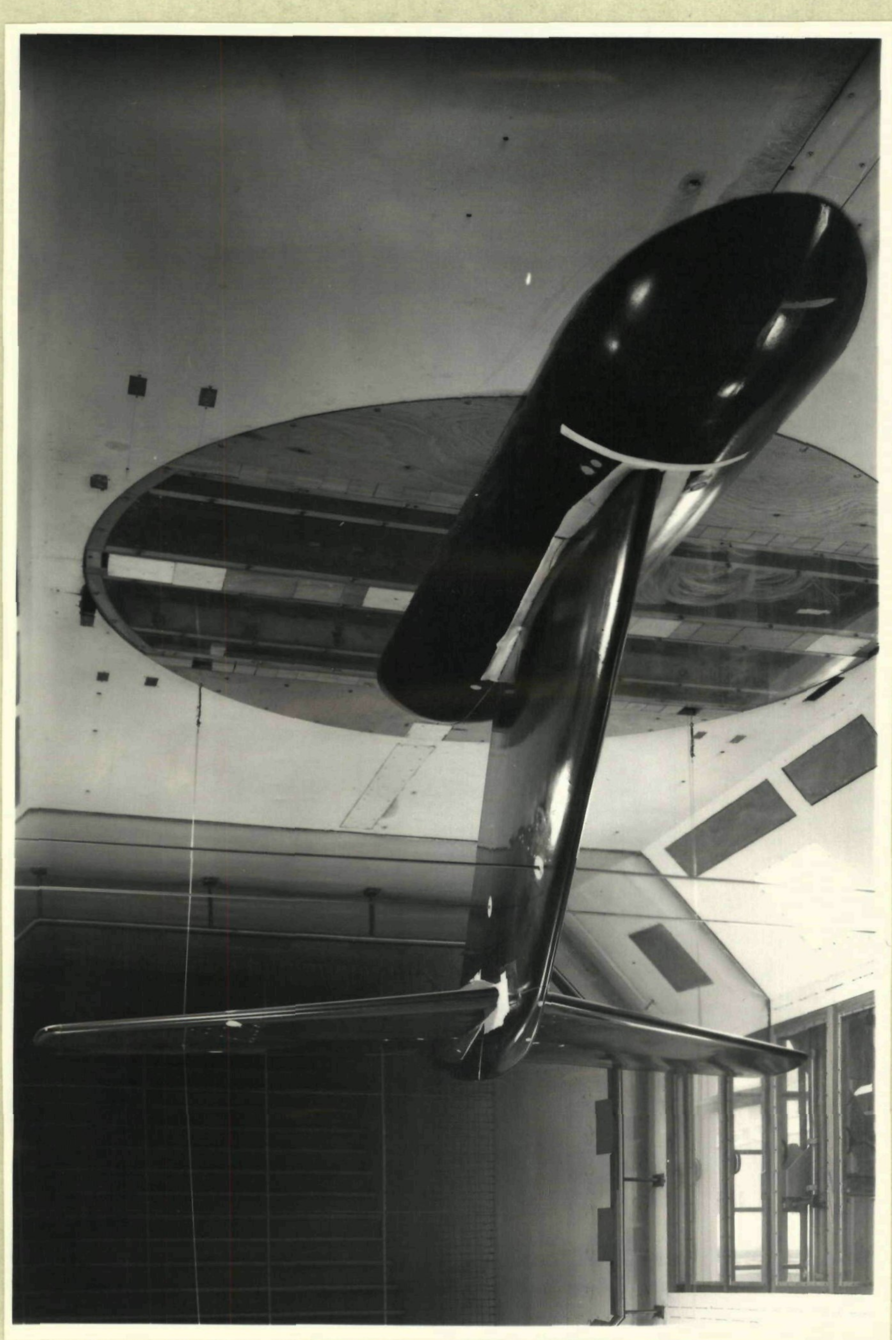


FIG.11: INFLUENCE OF TIP SHAPE (FLAPPING MOTION) (k = 0.43)

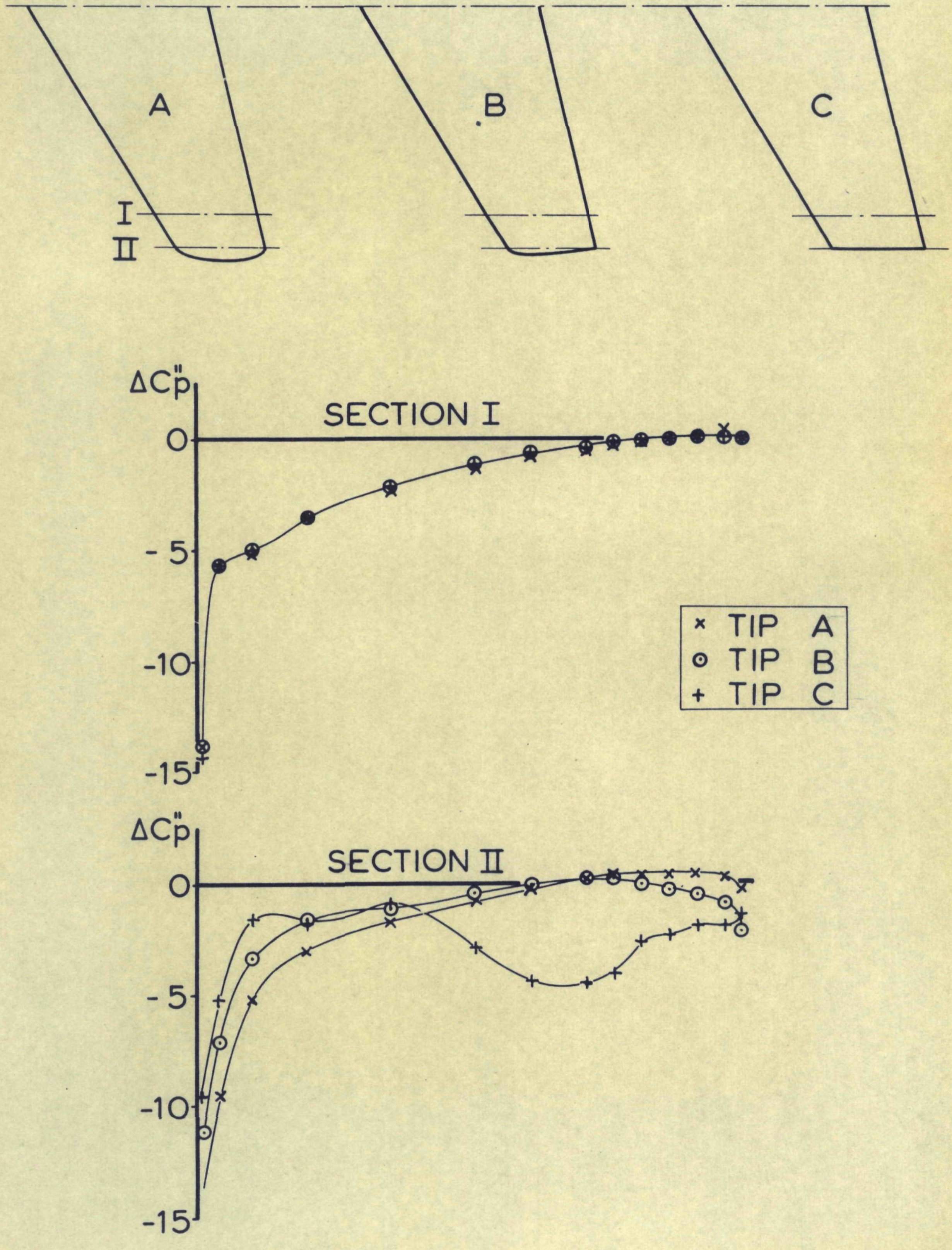


FIG.12: TIP EFFECT ON SPANWISE LIFT DISTRIBUTION (k = 0.43)