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A LOW-CONSTRAINT, HIGH-PRESSURE AIR FEED SYSTEM FOR WIND TUNNEL BALANCES

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A low-constraint, high-pressure air feed system for wind tunnel balances

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SUMMARY

A high-pressure air feed system, suitable for use with blowing models mounted on a six-component virtual-centre balance, is described. Air is supplied to the balance by a flexible ring-main feed so that no air is lost as with an air-bearing system. Constraints on the balance are very low; at an internal pressure of 30 p.s.i. gauge with a mass flow of 0.5 lbs/sec. all force corrections were less than 1 lb., and the pitching moment correction less than 0.5 lb.ft. Rolling and yawing moment corrections were 2.0 lb.ft. and 2.7 lb.ft. respectively. The constraints were measured using a calibrator which enabled the desired mass flow to be passed through the system without additional constraints.

Contents

List of symbols

B_o	gauge pressure of air measured at orifice plates
ℓ	calibrator gap

1. Introduction

The extension of wind-tunnel testing in recent years to include the effects of jets has caused problems associated with the air feed and its effect on the balance system. Tests in which full jet engine thrust has to be simulated involves passing quantities of air of the order of 1 lb/sec., and constraints must be fairly small and accurately known, particularly when the forces or moments to be measured are small and of the same order as the correction.

The two main types of air feed employed are the flexible hose and the air bearing and are adequately described in reference 1. With a badly designed feed using flexible hose, constraints tend to be large and not repeatable, and for larger and semi-permanent rigs the tendency has been to employ air bearings. Despite the additional complication, however, constraints can still be of appreciable magnitude and there can be variations in mass flow due to losses or gains at the air bearing faces. The present rig was designed to supply air at mass flows of up to 1 lb./sec. to models mounted on a six component virtual centre balance (see reference 2). Since most systems are calibrated at the appropriate pressure by sealing off the supply at a convenient point downstream of the flexible hose or air bearing, it was felt that a more accurate calibration could be obtained if mass flows similar to those used in the model tests were passed during the calibration. This was achieved by the use of a calibrator (§ 2) which discharged the air from the balance virtual centre in such a way that the direct jet forces were very small and distinguishable from balance constraints due to movement of the flexible hoses under pressure. The scheme has been in operation for some four years and has worked very satisfactorily.

2. Description of apparatus

Figure 1 shows the general layout of the system, with details of yaw and incidence adjustment in figures 2a and 2b. The main feed pipe to the tunnel is 3 in. inside diameter, branching from a 6 in. inside diameter ring main fed by one or two reciprocating compressors each capable of delivering approximately 1 lb./sec. of air at 100 p.s.i. gauge. In addition, there was storage space for another 3000 cu.ft. so that the nominal rate of mass flow could be exceeded for a short time if necessary. An activated alumina dryer was used to dry the air.

The airflow was controlled by a Hale Hamilton R.L.6 reducing valve using an L.15 controller. This arrangement proved very satisfactory and very little adjustment was necessary, even over long periods. The rate of mass flow was measured using standard sharp-edged orifice plates situated sixteen diameters downstream of the reducing valve and six diameters upstream of the T junction so as to avoid interference (reference 3).

The 'earthed' pipes downstream of the T junction were 2 in. inside diameter and the ring main was 2 in. inside diameter canvas backed rubber hose. The clover leaf shape was found to give lower constraints than a circular arrangement. The annular seal at the top of the hollow balance strut is shown in detail in figure 2a. Unfortunately the leather washer used as a seal was too stiff and recalibration was necessary when the yaw angle was changed. Experience has shown that a lighter and more flexible washer could be used with advantage. The circular hollow steel model support tapered from 2 in. inside diameter at the balance to 1.5 in. inside diameter at the model. A simple T junction with O ring seals enabled the model to pitch about the balance virtual centre (figure 2b).

The calibrator is shown in figure 3. It consists of a short length of pipe feeding air to the adjustable gap between two circular plates. Thus the air is emitted radially from the balance virtual centre and under these conditions the only forces and moments induced on the balance should be those due to distortion of the rubber hose (see also § 3).

3. Calibration and discussion

In order to calibrate the system, the model was removed and replaced by the calibrator. The gap was adjusted until the mass flow through the system was the same as that through the model at a given control pressure B_0. Balance readings were then taken over a suitable range of pressures corresponding to the proposed tests. In order to allow for slight inaccuracies in manufacture, two calibrations were always made, firstly with the calibrator in its normal position and secondly with the calibrator rotated through 180°. The average of the two sets of readings was taken to be the balance constraint correction.

Changes in calibration with time were negligible and only yaw changes called for recalibration, although even then the maximum changes, which occurred on roll and yaw corrections, were less than 0.5 lb.ft. Larger changes in calibration occurred when the system was reassembled, after having been dismantled for other tunnel tests, due to slight changes in the position of the rubber hoses. The time taken for a calibration was only about one hour.

A typical set of results is shown in figures 4a and 4b. With the exception of the cross-wind force changes due to rotating, the calibrator model was within experimental accuracy and the difference between results with increasing and decreasing pressure was small. At the maximum pressure of 30 p.s.i. gauge, the mass flow was about 0.5 lb/sec. Lift, drag, and pitching moment corrections are very small compared with normal loads, and although the other corrections are larger comparatively, the accuracy with which they can be measured indicates that possible inaccuracies are only about twice those associated with a normal (unblown) balance system. The corrections compare favourably with those obtained on a comparable air bearing system, (reference 1), with the added advantage that measurement of mass flow is not complicated by possible losses or gains at the air bearing faces.

A comparison was made between the results obtained with the calibrator, (figures 4a and 4b), and those using a tap (no mass flow). Although the differences were small, < 0.1 lbs. on forces and < 0.15 lbs.ft. on moments, there was a tendency for the differences to increase with increasing pressure and for systems where either the mass flow or pressure loss is large, the use of a calibrator is certainly advisable.

4. Conclusions

The air-feed system described in this report has been in use for some four years and has proved very satisfactory in operation. The constraints are very small, even for comparatively large mass flows, and do not change with time. The constraints are comparable with those of air bearings although the system is simpler and does not have the disadvantage of possible changes in mass flow as there are no air leaks in the system.

5. References

1.	Butler, S.F.J., and Williams, J.	Further comments on high-lift testing in wind tunnels with particular reference to jet blowing models. AGARD Report 304. March 1959.
2.	Alexander, A.J.	Experimental investigation on a cropped delta wing with edge blowing. CofA Report 162, 1963.
3.	Pankhurst, R.C. and Holder, D.W.	Wind tunnel technique. Pitman.

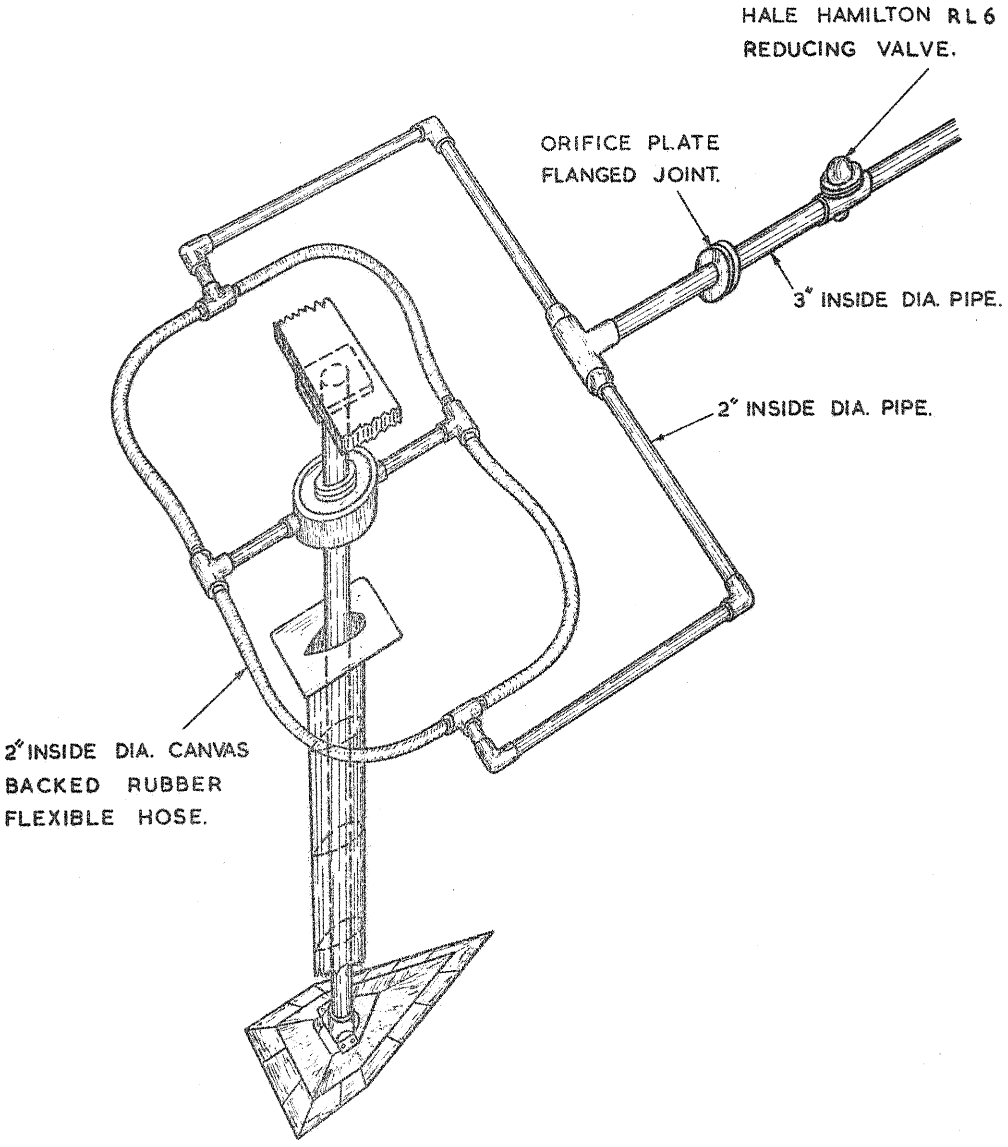

FIG. I. GENERAL ARRANGEMENT OF AIR FEED SYSTEM TO WIND TUNNEL MODEL.

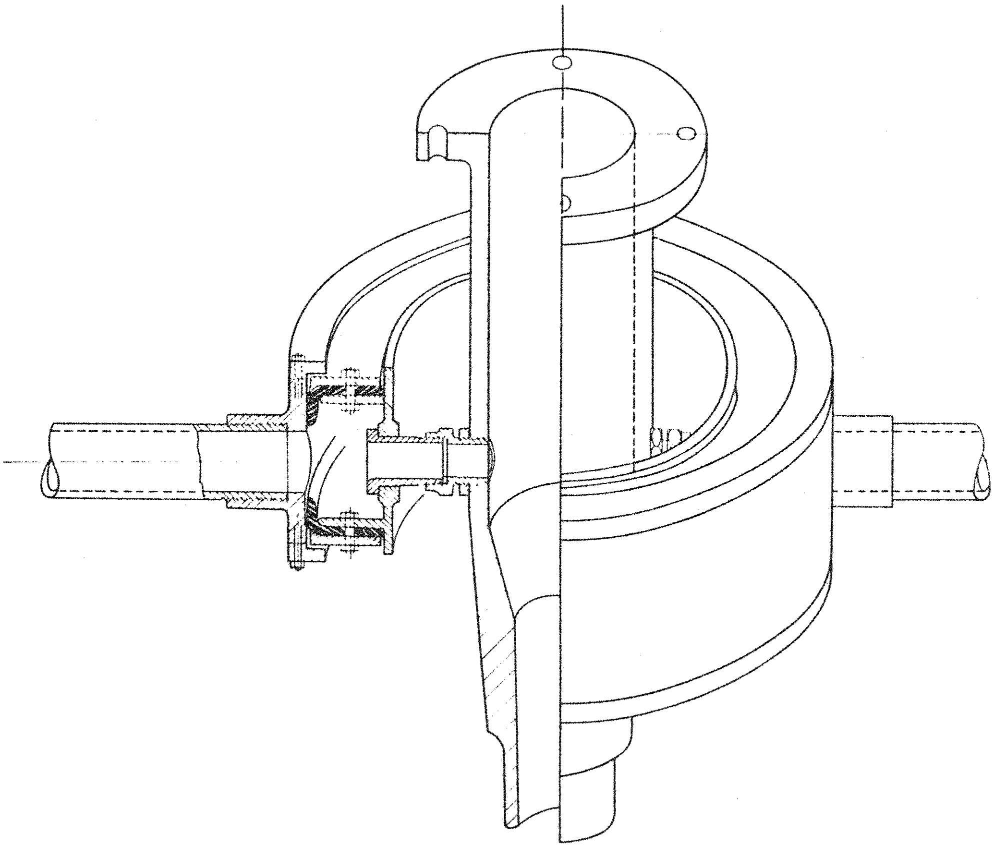

FIG. 2a. ROTATORY ANNULAR JUNCTION BOX FOR MODEL JAW ADJUSTMENT.

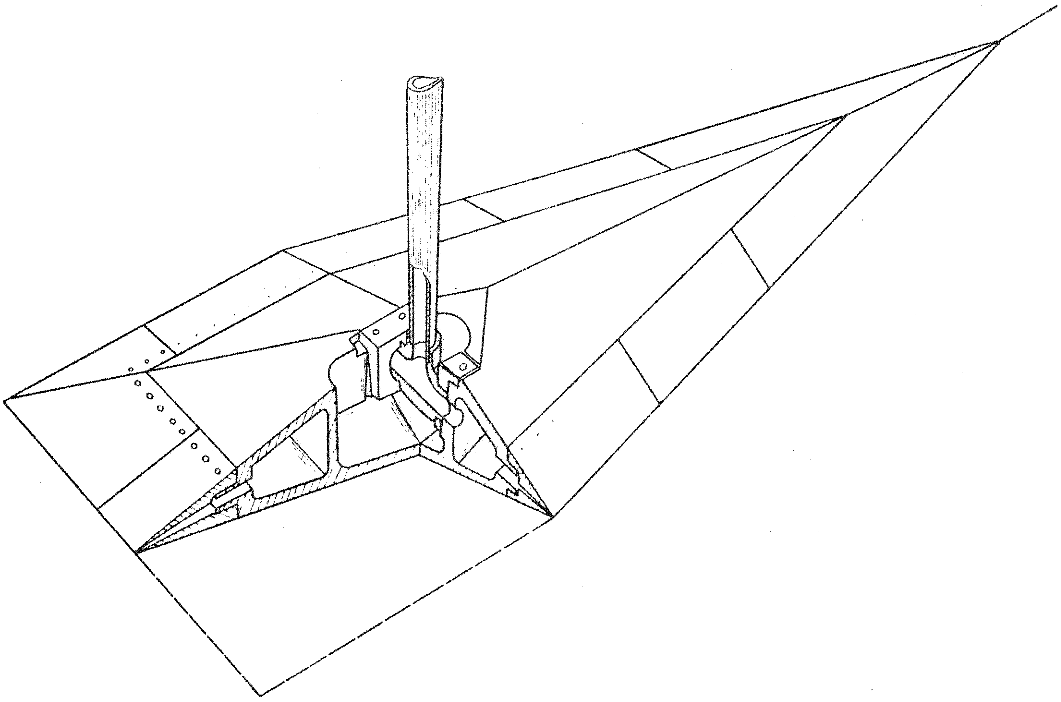

FIG. 2b. MODEL -T- JUNCTION ATTACHMENT FOR INCIDENCE ADJUSTMENT.

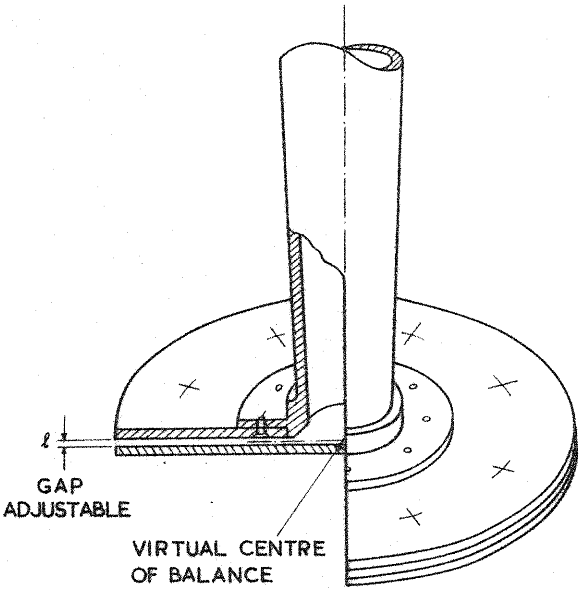

FIG. 3. CALIBRATOR MODEL.

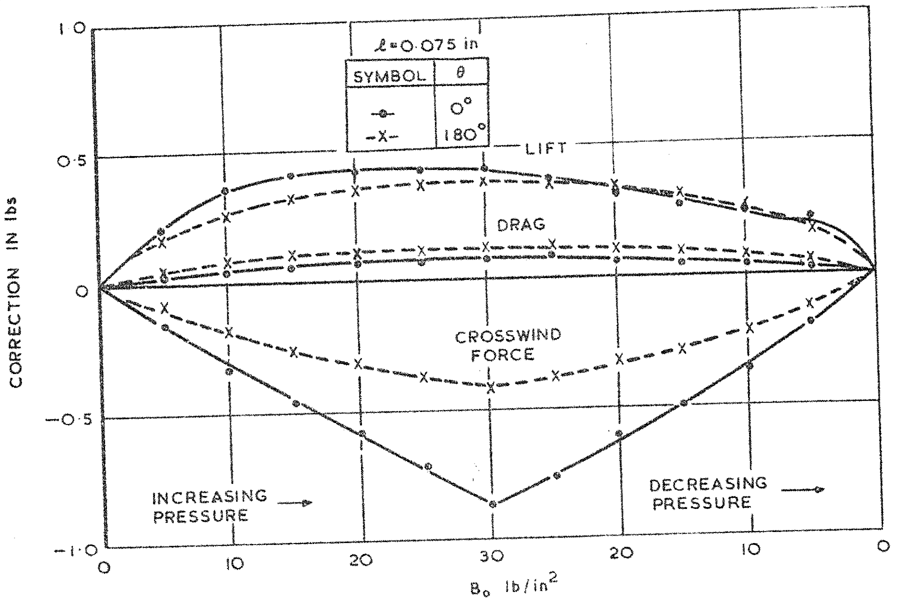

FIG. 4a. EFFECT OF CHANGE OF PRESSURE ON FORCE CONSTRAINT.

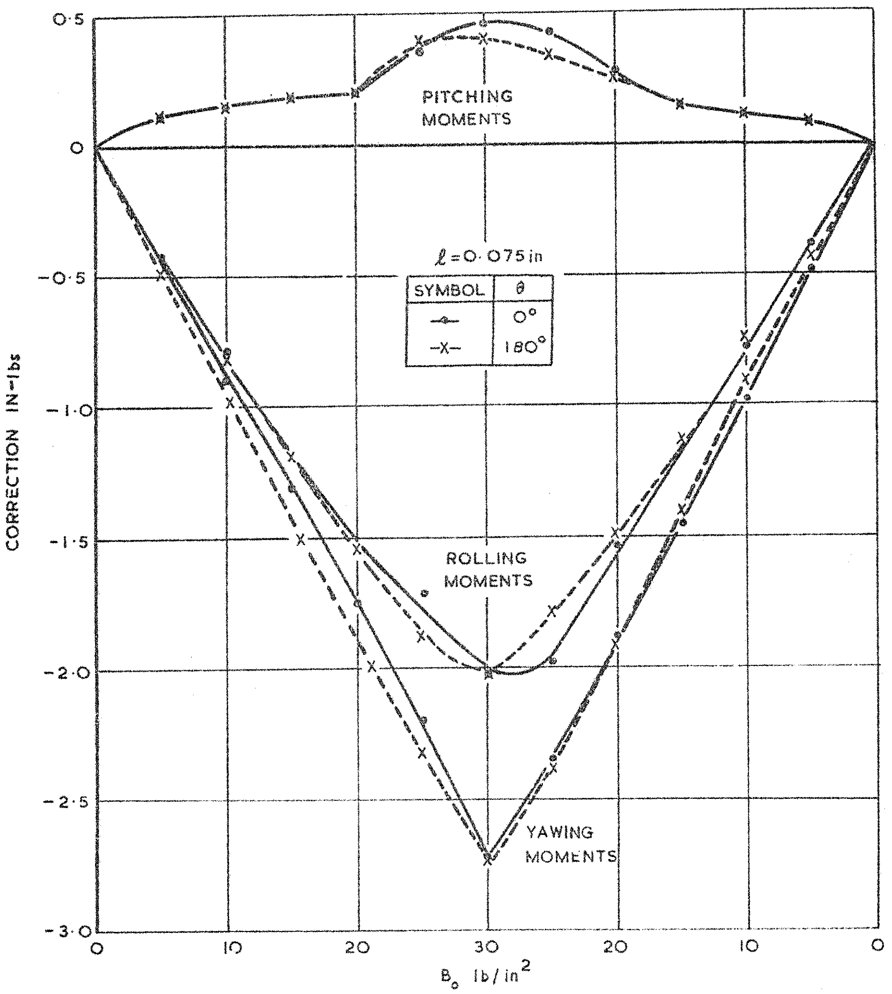

FIG. 4b. EFFECT OF CHANGE OF PRESSURE ON MOMENT CONSTRAINT.