A wind-pressure transducer

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A WIND-PRESSURE TRANSDUCER

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A pressure transducer is described which was specially developed to measure wind pressures exerted on buildings. The instrument, which gives an electrical output, is suitable for measuring pressure in the range $\pm$ 1200 Nm^{-2} ($\pm$ 25 lb ft^{-2}). The frequency response is such that pressure fluctuations lasting only 0.1 s can be recorded.

The transducer was designed and developed with the collaboration of Mr C W Newberry and Mr R S Jerrett.

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1 Introduction

The transducer described in this note was developed specifically for a programme of wind pressure measurement on tall buildings in London. No suitable transducer existed for this purpose. The programme required simultaneous continuous records of pressure at a large number of points widely dispersed on the surfaces of the buildings. Pressures were expected to be in the range ± 1200 N m^{-2} (± 25 lb ft^{-2}), and it was aimed to achieve an accuracy to ± 10 N m^{-2} ($\pm 0{\cdot}25$ lb ft^{-2}); it was necessary to measure pressure transients of the order of 0·1 s. Furthermore, in order that the recorded pressures were representative of pressures averaged over cladding panels, the active area of the gauge needed to be as large as possible, compatible with easy installation in typical buildings. All these requirements were met in practice. Figure 1 shows the transducer. It is essentially a shallow cylindrical box, 140 mm (5·5 in) in overall diameter and approximately 30 mm (1·1 in) deep, one face of which comprises a pressure plate. The instrument is designed to be fitted into curtain walling components so that the pressure plate is flush with the surface of the building.

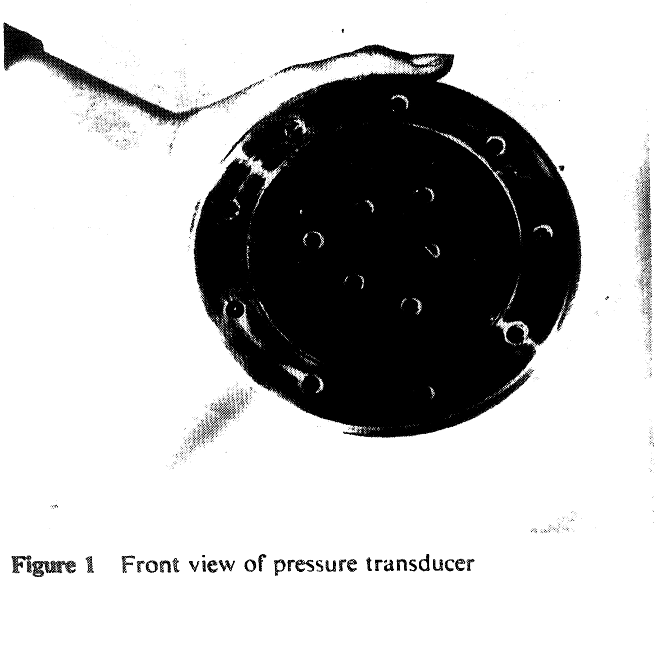

Figure 1 Front view of pressure transducer

2 Description of the transducer

Figure 2 is a diagram of the transducer. The rigid circular pressure plate D is mounted from the body B on three cantilever bars C spaced symmetrically in a plane. The narrow annular gap between the pressure plate and the body is sealed by a thin flexible membrane M which accommodates the movement of the pressure plate and also isolates the interior of the transducer from the external pressure. This allows the interior to be vented to a reference pressure via the nozzle N provided on the back of the body. The difference between the external pressure and the reference pressure exerts a load on the pressure plate which is transferred to the three cantilevers. The strain thus produced is measured by foil resistance strain gauges fixed to the cantilevers.

The pressure plate comprises two disks each about 100 mm (4 in) in diameter, which are screwed together, trapping the sealing membrane between them. The sensitivity of the transducer to acceleration is minimized by making the pressure plate as light as possible compatible with strength and rigidity. This is achieved by making the pressure plate hollow and by using light alloy. The plate is screwed to a boss E, also of light alloy, which serves as a central anchorage for the three cantilevers. The boss is dimensioned so that the back of the transducer body acts as a stop which limits the

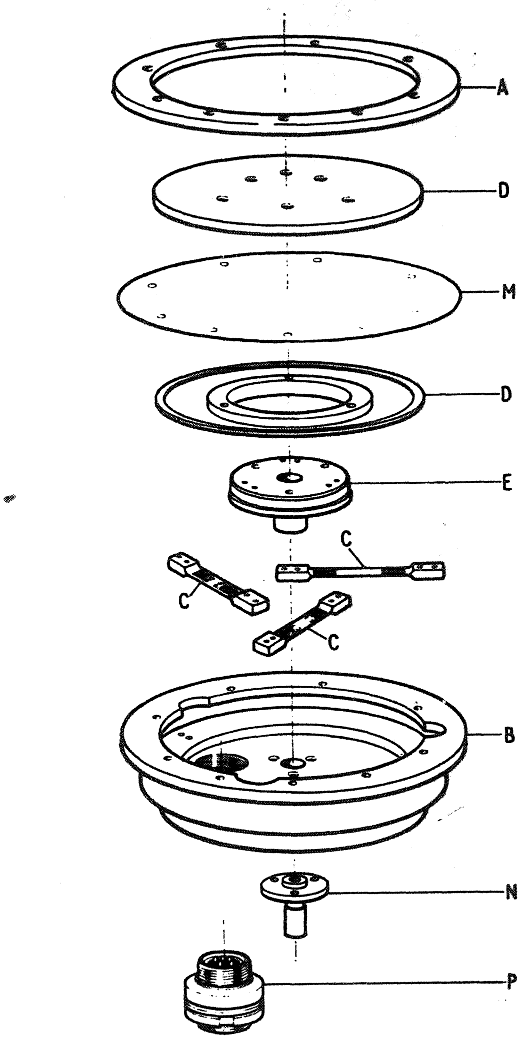

Figure 2 Exploded view of pressure transducer
A, membrane clamping ring; B, transducer body; C, Cantilever; D, part of pressure plate; E, boss; M, sealing membrane; N, venting nozzle; P, plug

deflection of the pressure plate. This prevents the cantilevers becoming overstrained. The composite unit comprising the two parts of the pressure plate and the boss has a total mass of 100 g. The mass of the whole transducer is 650 g.

Melinex sheet 0·012 mm (0·0005 in) thick is used for the sealing membrane. It produces negligible restraint on the movement of the pressure plate in the normal working range of the instrument, which is up to a deflection of 0·10 mm (0·004 in). In this respect it is superior to all the other materials tried.

The cantilever bars are made of cast iron, which has a lower Young's modulus than steel, giving the instrument increased sensitivity. The bars are 62 mm (2·437 in) overall length and 6 mm × 5 mm (0·250 in × 0·203 in) in section. The central 34 mm (1·312 in) is thinned by surface grinding to 6 mm × 0·75 mm (0·250 in × 0·032 in) in section. Each end is secured by two screws constraining the cantilevers to bend in reflex curvature. Four foil resistance strain gauges, 6 mm (0·25 in) long, are attached to each bar as near as possible to the positions of maximum bending moment (see figure 3). These are wired to form a Wheatstone bridge, each arm consisting of three gauges in series from the corresponding position on each cantilever. By this means the deflection of the cantilevers is averaged, and since every strain gauge is active the maximum possible sensitivity is obtained. Connection is made to the bridge circuit through a four-way plug P mounted on the back of the transducer. The bridge may be energized with alternating or direct current up to a maximum of 5 V.

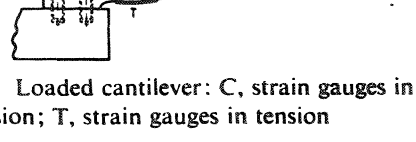

Figure 3 Loaded cantilever: C, strain gauges in compression; T, strain gauges in tension

3 Design and manufacture

Since transducers which have been installed in a building are generally inaccessible for frequent checks, the only practical way of measuring the zero position is by recording during calm periods, which may be quite infrequent. The long-term zero stability is therefore crucial to the satisfactory performance of the transducer. The need to respond to short duration pressure changes combined with the requirement of a relatively large active area, led to a design where the movement of the pressure plate was very small, thereby minimizing the momentum of the moving parts and of the air movement in the venting system. However, this small movement increases the problem of obtaining satisfactory zero stability.

The two most important factors controlling stability are temperature compensation and freedom from residual stress in the components. The arrangement of the strain gauges ensures complete temperature compensation. The actual performance was checked in the range −10°C to +40°C, and no significant variation of zero was detected. The strain induced in the cantilevers by a load of 10 N m^{-2} (0·25 lb ft^{-2}), which is the level of accuracy aimed at, is only about 4 × 10^{-4}. This clearly shows the need to maintain a very low level of residual stress in the component parts, which was achieved by selecting materials with a low residual stress content, by annealing and by careful machining. The grade of aluminium alloy selected for the pressure plate and body was NE4, specified as having a low stress content. The cast iron used for the cantilevers was Meehanite GD.

An improvement of zero stability was obtained by ageing the completed transducers on a special rig. The interior of each unit was connected to a common system in which the pressure was pulsed every few seconds by a piston. In this way the transducers were subjected to a large number of working cycles before installation. With these precautions, long term zero stabilities equivalent to about ±10 N m^{-2} (±0·25 lb ft^{-2}) were achieved.

4 Calibration

The transducer output is a linear function of pressure, the deviation from linearity being about 1% of full scale. The nominal sensitivity is 0·6 μV V^{-1} N^{-1} m^{2} (30 μV V^{-1} lb^{-1} ft^{2}). That is, if the transducer is energized with 1 V and the pressure plate loaded with 1 N m^{-2}, the output from the bridge will be 0·6 μV. Individual transducers differ from each other in sensitivity owing to slight variations of cantilever thickness, so that each unit requires calibration. Initially calibration was carried out by varying the internal pressure, measuring this with a water manometer and recording the response of the transducer. For comparison, a second calibration was done by loading the pressure plate with dead weight, the body cavity in this case being open to the atmosphere. Subsequently dead-weight calibration only was used because it was more convenient.

5 Frequency response
The frequency response of the transducer was checked up to about 200 Hz. The lowest resonance was found to be about 70 Hz. The return period of the pressure plate to the zero position from full load was also measured and is about 4 ms which corresponds to the 70 Hz resonance. The transducer is quite adequate to measure up to frequencies of 10 Hz or even higher.

6 Performance in service
The transducers have been installed in two buildings in Central London. 48 have been installed at Royex House, Barbican, and 62 on the GPO Tower. They have functioned extremely well. Most units have been *in situ* for three or four years and apart from a small percentage which have developed faults, the calibrations have remained unchanged during this period. The transducer is suitable for use in conjunction with standard commercially available recording equipment, either analogue or digital. In the programme of wind pressure measurement already mentioned analogue recording equipment was used, comprising 3 kHz carrier amplifiers and multichannel ultraviolet galvanometer recorders.

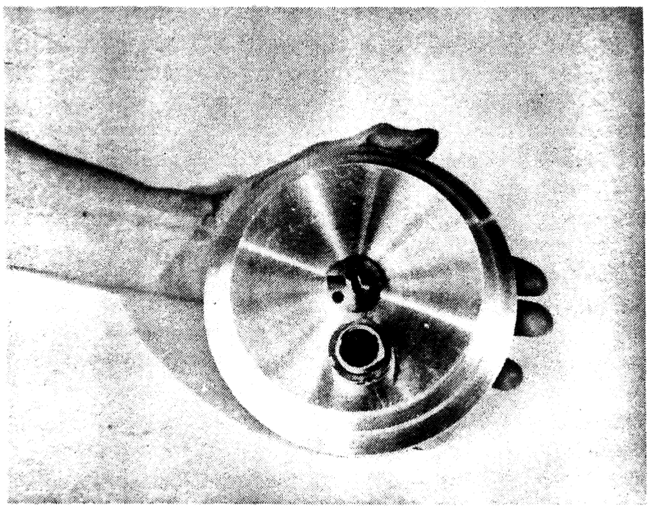

Figure 4 Rear view of pressure transducer

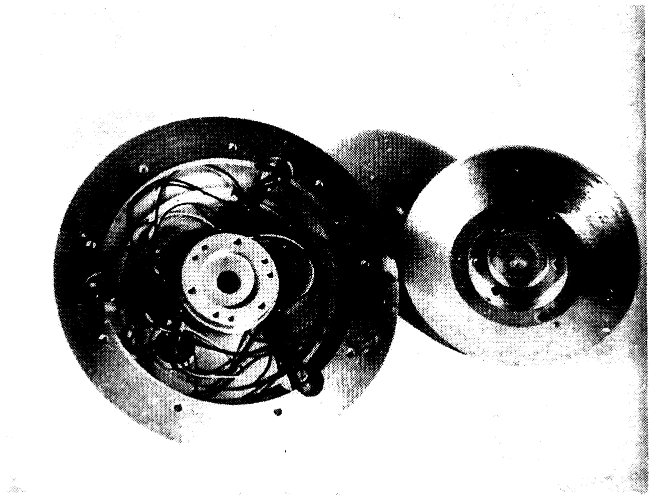

Figure 5 Interior of pressure transducer