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RESEARCH NOTES

Instrumentation for Full-scale Wind Load Measurement on Glasshouses

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1. Introduction

Although wind loads are important in glasshouse design, insufficient data exist to allow accurate predictions of these loads to be made. Design wind loads are calculated by applying statistical predictions of maximum wind speed to estimated relationships (pressure coefficients) between the free stream velocity of the wind and the resulting pressures at various points on a building's surface.

To aid efficient structural design, a programme of measurement of actual wind loads on typical glasshouses was undertaken.

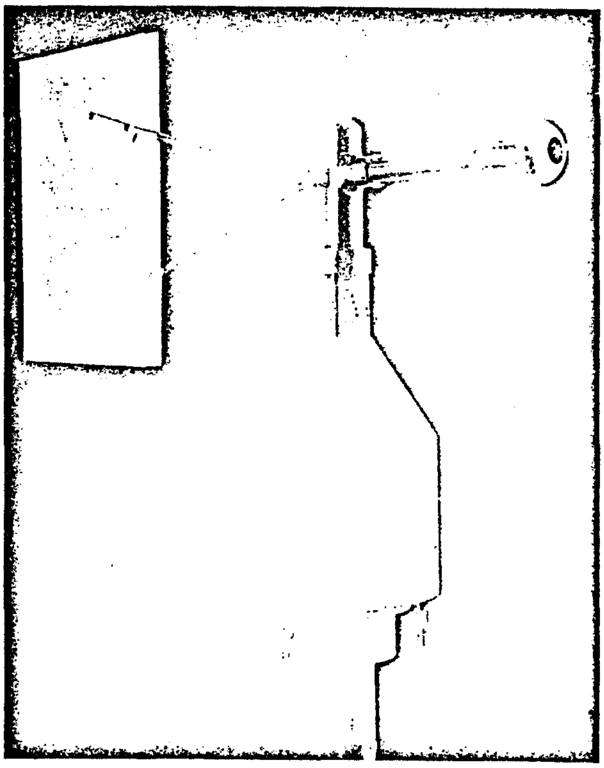

Fig. 1. Dines type anemometer

2. Apparatus

The requirement was for apparatus to record the free stream wind pressure and direction at a standard height of 10 m, together with the resulting pressures at the 40 or 50 points on the glasshouse necessary to determine the pattern of loading. The loads imposed by gusts of short (< 1 s)

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duration were of significance and the Dines[1] type of anemometer (*Fig. 1*) was used for sensing the wind pressure as this has an inherently faster response than the 3-cup type. The Dines instrument has a rotating head with a horizontal tube sensing total pressure, built into a wind vane which holds it into the wind. A modified static (suction) tube is incorporated into a vertical member about which the vane turns. The anemometer was mounted on a 10 m high telescopic mast with the pressure and suction tappings connected by flexible p.v.c. tubing to a Furness electronic micromanometer (type MDC) inside the glasshouse. This instrument gave a millivolt output proportional to wind pressure and had full-scale ranges equivalent to maximum wind speeds of 23–53 m/s.

A small pressure tube anemometer, clamped to the mast of the main instrument, was used to determine the variation of wind velocity with height at each experimental site. This allowed each load to be related to the wind pressure at the same height as the tapping point, to enable pressure coefficients of general application to be derived.

Wind direction was indicated by a continuous rotation potentiometer located in the base of the anemometer housing and operated by movement of the wind vane. The potentiometer had a resistance of 1 kΩ and a resolution of $\frac{1}{2}$° and formed part of a stabilized potential dividing circuit which had a d.c. output of 0–1 V, depending on wind vane position.

The wind load on the glasshouse was sensed by pressure tapping points distributed over the surface. Each tapping point consisted of a 9·5 mm hole at the centre of a braced sheet of transparent acrylic, which was designed to be installed at any position on the glasshouse surface in place of a glass pane (*Fig. 2*). Rainwater entering the hole was drained away by a porous (2/μ) ceramic plug which sealed the lower end of the pressure tapping assembly. Flexible p.v.c. tubing of 6 mm bore in 30 m lengths was used to convey the pressure signals to a central area, where tapping points were connected in sequence to micromanometers of a type similar to that used for the wind pressure measurements. However, since negative as well as positive pressures occur, these micromanometers had a centre point zero and could accommodate signals of ± 1250 N/m^2, which result from winds of 45 m/s (assuming limiting pressure coefficients of $\pm 1{\cdot}0$).

All external and internal house pressures were measured against an ambient reference in the form of a tapping into a 0·05 m^3 galvanized iron tank, sunk flush into level ground remote from the glasshouse. It was established that errors in pressure coefficients of less than 1% would result from differences in pressure between this reference and atmospheric.

A study[2] of the characteristics of the wind pressure and wind load sensing systems has shown that in both cases the overall frequency response was 0–2·5 Hz (3 dB down) for wind speeds in excess of 8·5 m/s.

Data were recorded for 48 tapping points (47 external, 1 internal) to determine the pressure distribution over the surface of each house. Four-minute records from pairs of tappings were taken in sequence, together with continuous records of wind pressure and direction, using analogue signal inputs to a four-channel magnetic tape recorder. Two two-channel chart recorders were operated from the outputs of the tape recorder heads so that during recording a visual check could be maintained on the operation of all components of the system. Examination of the chart records in the laboratory also assisted in the selection of suitable portions of tape record for detailed analysis. The analogue recordings on the magnetic tape were translated into digital form, using a PDP8/E computer, at approximately 0·15 s intervals onto 8-hole paper tape. These were subsequently analyzed on a large computer (ICL 4-70).

To enable corrections to be made during computer analysis, for the effect of any instability of the micromanometer, amplifier and tape recorder zeros, at the beginning of each pressure tapping record a zero pressure signal was generated for a few seconds. This was achieved by commoning the two sides of each micromanometer transducer diaphragm, using solenoid valves energized automatically by a control unit. On the wind direction tape channel a zero signal was generated by closing relay contacts and, additionally, a negative pulse indicated the start and end of each pressure record, in order to control the computerized digitization process.

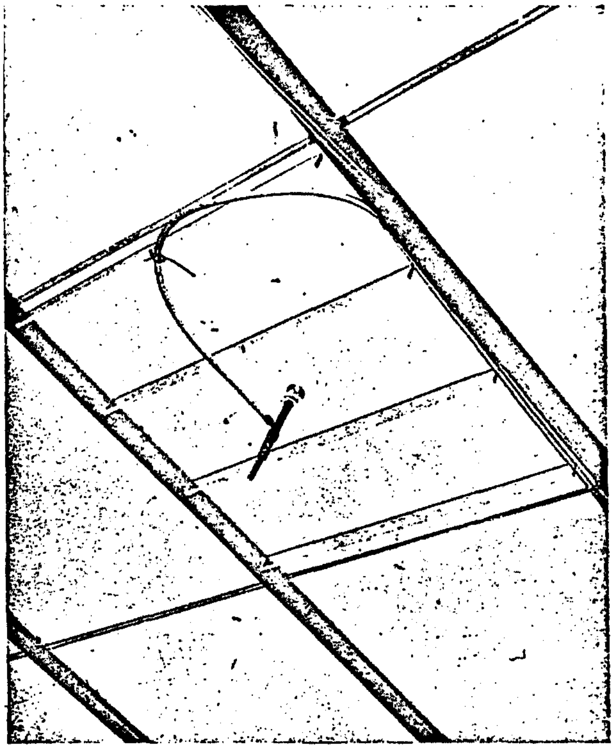

Fig. 2. Pressure tapping in acrylic sheet

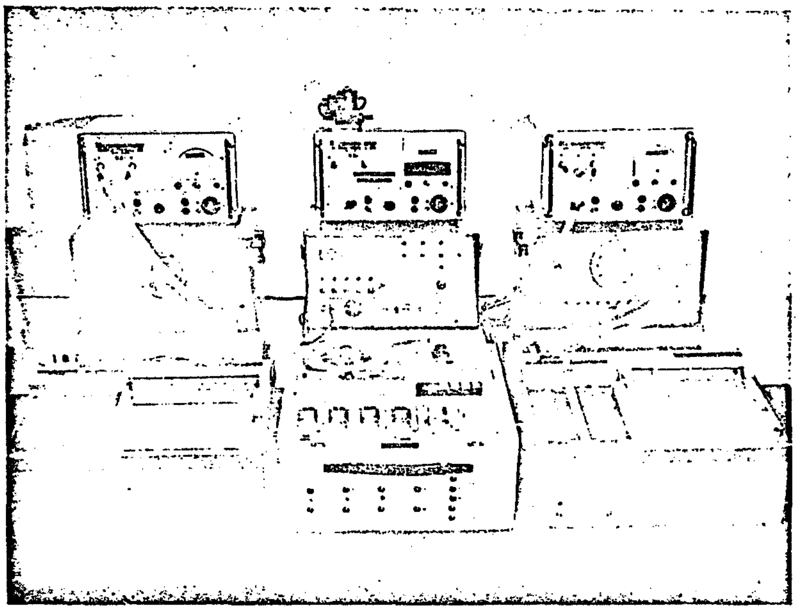

Fig. 3. Sensing and recording apparatus

The apparatus described has been used over a period of two years for wind load measurements on three glasshouses in Lancashire. It has been found to be reliable in operation and much useful information has been acquired. As the tapping points are relatively inexpensive (£3 each), it is economic to equip several houses, which can be served by the portable recording and control apparatus (*Fig. 3*).

REFERENCES

[1] Handbook of Meteorological Instruments Pt. 1. *Instruments for surface observations.* Meteorological Office, H.M.S.O., 1956

[2] Hoxey, R. P. *System response of wind loading instrumentation.* Dept. Note DN/G/307/2301 natn. Inst. agric. Engng, Silsoe, 1973