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Measurements of Velocity Fluctuations in the Working Section of the R.A.E. 4ft. x 3ft. Wind Tunnel with Flow Disturbances in the Second Diffuser

by

J. A. Lawford, B.Sc.

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MEASUREMENTS OF VELOCITY FLUCTUATIONS IN THE WORKING SECTION OF THE R.A.E. 4' × 3' WIND TUNNEL WITH FLOW DISTURBANCES IN THE SECOND DIFFUSER

by

J. A. Lawford, B.Sc.

SUMMARY

An attempt has been made to determine whether a large contraction ratio and wire gauze screens in the maximum section would prevent unsteadiness of flow in the return circuit from affecting the flow in the working section.

Flow disturbances were produced in the second diffuser of the R.A.E. 4' × 3' wind tunnel by means of a large fixed flap or a pair of oscillating flaps. The disturbances obtained by these means were less than had been anticipated, but it was found that a very large flap had no measurable effect on turbulence in the working section. Velocity distributions were not measured in the working section, but since a complete traverse on the vertical centre-line showed no effect on the turbulence, it is felt that the velocity distribution was probably not affected.

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1 INTRODUCTION

High turbulence and fluctuation of the mean flow have occurred in the working sections of some recently constructed wind tunnels, as a result of unsteady flow in the return section caused apparently by a fluctuating separation of flow from the diffuser walls. It has been suggested that a steady flow might be obtained in the working section, in spite of this unsteadiness in the return circuit, by having a large contraction-ratio together with wire-gauze screens in the maximum section.

Since the 4' × 3' tunnel at the R.A.E. has such an arrangement, it was decided to try to cause a fluctuating flow separation in the second diffuser of the tunnel, and then to make hot-wire measurements of the turbulence produced in the tunnel. This work was done at the request of the Wind Tunnel Design Committee of the A.R.C.

2 DETAILS OF TUNNEL AND TESTS

The layout of the 4' × 3' tunnel is shown in Fig.1. The contraction ratio is 31.2:1, and the cone angle of the diffusers is 5°, the last part of the expansion being made rapidly through three spaced wire-gauze screens in order to keep the length of the tunnel reasonable. Three additional wire-gauze screens are fitted in the maximum section, or "bulge". The return circuit is vented to atmosphere between the third and fourth corners, and the working section operates at a pressure below atmospheric pressure in a sealed observation room. Fine speed control is by a by-pass duct which was kept closed during the present tests.

With the return circuit in the "clean" condition, a vertical pitot-static traverse was made 12 feet upstream of the third corner, measured at the tunnel centre line (see Fig.1); the results are plotted in Fig.2. A vertical traverse of the working section was made with a hot-wire normal to the flow, giving root-mean-square values of the longitudinal velocity fluctuations; these are plotted in Fig.3.

A pair of flaps of 9 in. chord and 3 ft span were attached by hinges to the floor and roof of the return section 12 feet downstream of the beginning of the second diffuser (see Fig.1). They were connected at their trailing edges by a rod so that when one flap was closed, the trailing edge of the other was 4 inches from the tunnel wall. The rod passed through the diffuser floor and could be oscillated from outside the tunnel. The pitot-static traverse upstream of the third bend was repeated with the flaps down (i.e. closed on the floor and open at the roof) and with the flaps up. The effect of the flaps is small (see Fig.2), and the effect of moving them from down to up is negligible. A brief traverse with a hot-wire in the working section with the flaps oscillating at a frequency of 1 cycle per second showed no effect on the longitudinal velocity fluctuations compared with the "clean" return circuit.

The 9 in. chord flaps were removed and a single flap of 3 ft span and 3 ft chord was attached to the floor at the same position. Pitot-static traverses upstream of the third bend were made with this flap set to give trailing edge heights from the floor of 14.75 in. and 27 in.; the results are shown in Fig.2. The measurements with a flap trailing edge height of 27 in. show a substantial effect on the velocity distribution. The effect with a trailing edge height of 14.75 in. is still not large. Unfortunately this flap was too large to be oscillated mechanically at these angles with the time and effort available for the present tests.

The traverse with a hot-wire normal to the flow in the working section was repeated with the 3 ft chord flap set at a trailing edge height of 27 in.

Fig.3 shows that the flap had no appreciable effect on longitudinal turbulence. To find whether it had any effect on lateral turbulence, an inclined hot-wire was put in the working section and measurements were made with the flap both closed and set at a trailing edge height of 27 in. The wire was inclined at about 50° to the flow. These measurements were comparative only, no absolute measure of turbulence being obtained. Resistance fluctuation of the wire would be a function of turbulence normal to the wire and lateral turbulence would appear as a component of this. The tests showed no effect of flap position on the root mean square velocity fluctuations normal to the wire. They were made on the vertical traverse of the working section, at the centre line and 6 in. from the roof and floor, with the inclined wire held in both a horizontal and a vertical plane.

Finally, spectra of turbulence normal to the inclined wire were measured 6 in. from the tunnel floor with the wire inclined in a horizontal plane. The spectra were measured with the 3 ft chord flap closed and with its trailing edge 27 in. above the diffuser floor. Fig.4 shows that they are almost identical.

All the tests were made with a working section velocity of 140 ft. per second. The corresponding velocities at the traverse position and flap hinge line in the second diffuser are 17 ft per second and 37 ft per second respectively.

3 DISCUSSION

To make a complete assessment of the effect of a large contraction ratio and screens in the maximum section in preventing unsteadiness of flow in the return section from reaching the working section, it would be necessary to make quantitative measurements of flow fluctuations in the diffuser and working sections of two tunnels with differing contractions, and if possible to compare conditions in the working sections with similar conditions in the diffusers. It is probable that the unsteadiness produced by the 3 ft chord flap was not as severe as that occurring in the diffusers of other wind tunnels where the flow in the working section has been affected, but it is nevertheless true that a very large flap, causing considerable change in velocity distribution in the diffuser, had no measurable effect on turbulence in the working section.

Furthermore, without flaps, the root mean square intensity of all three components of turbulence at the end of the second diffuser is about 12 per cent of local velocity (or 1.4 per cent of working section velocity), but the intensities at the working section centre-line are less than 0.02 per cent, (Ref.1). No measurements were made of the effect of the flaps on the velocity distribution in the working section, but since a traverse along the vertical centre-line showed that the turbulence distribution had not changed (Fig.3), it is felt to be highly probable that the velocity distribution was also unaffected.

4 CONCLUSIONS

A very large flap in the second diffuser caused substantial change of velocity distribution in the diffuser but had no effect on turbulence in the working section. Two smaller oscillating flaps had a much smaller effect on the flow in the diffuser and also had no effect in the working section.

REFERENCE

Ref. No.	Author	Title, etc
1	Schuh, H.	The R.A.E. 4 ft x 3 ft low turbulence wind tunnel. Part IV. Further turbulence measurements. A.R.C. 16363. June, 1953

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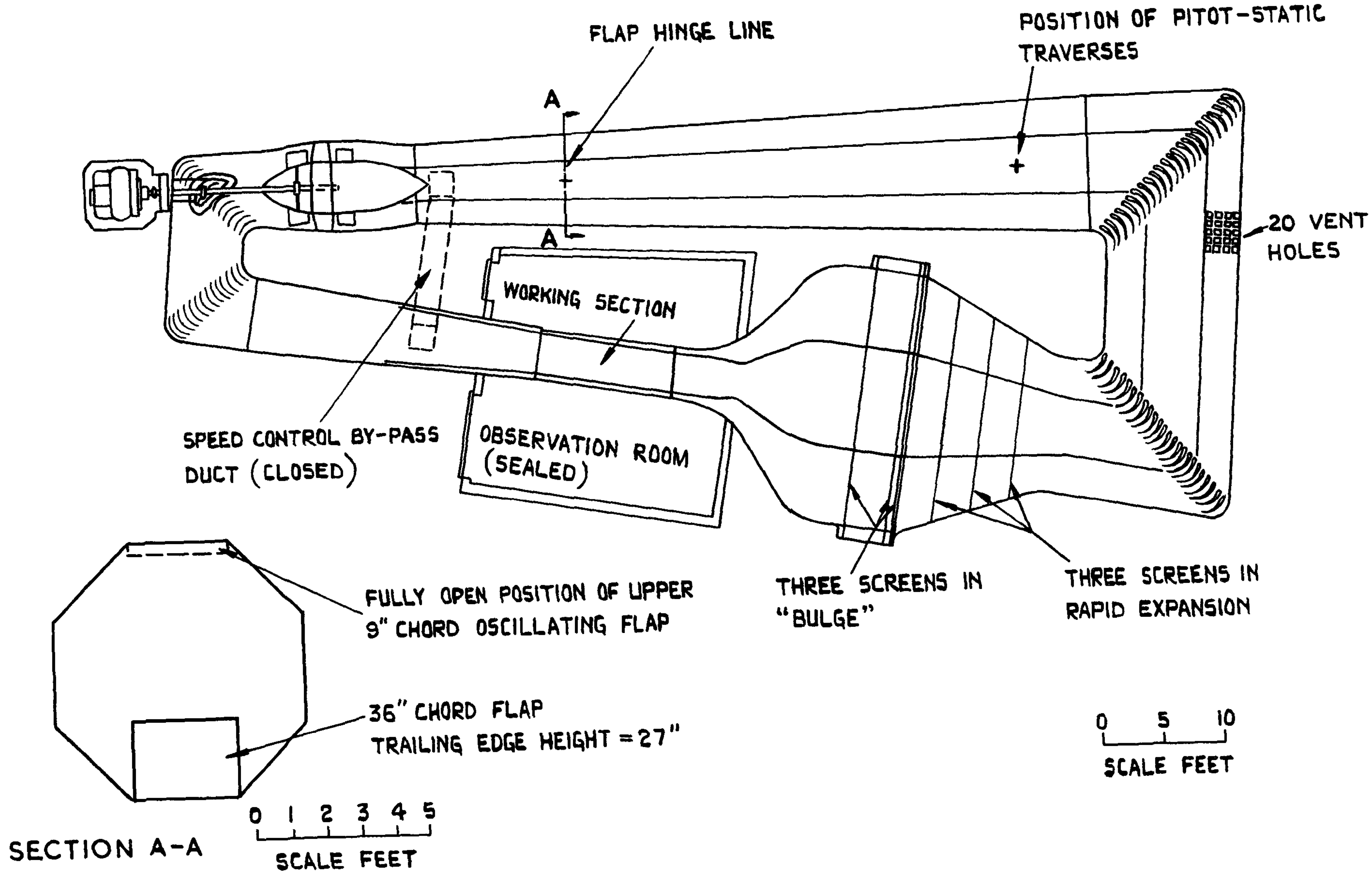
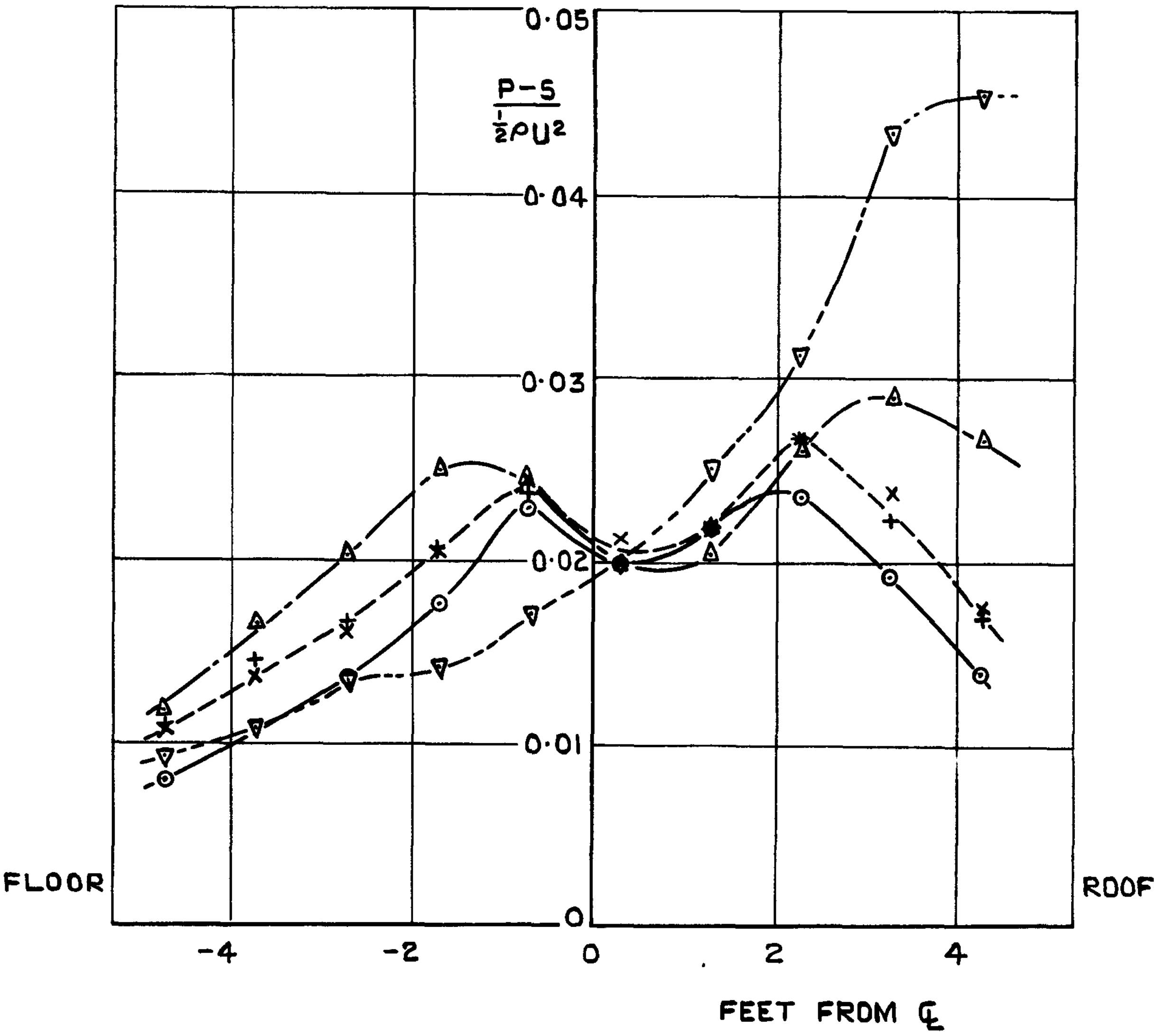


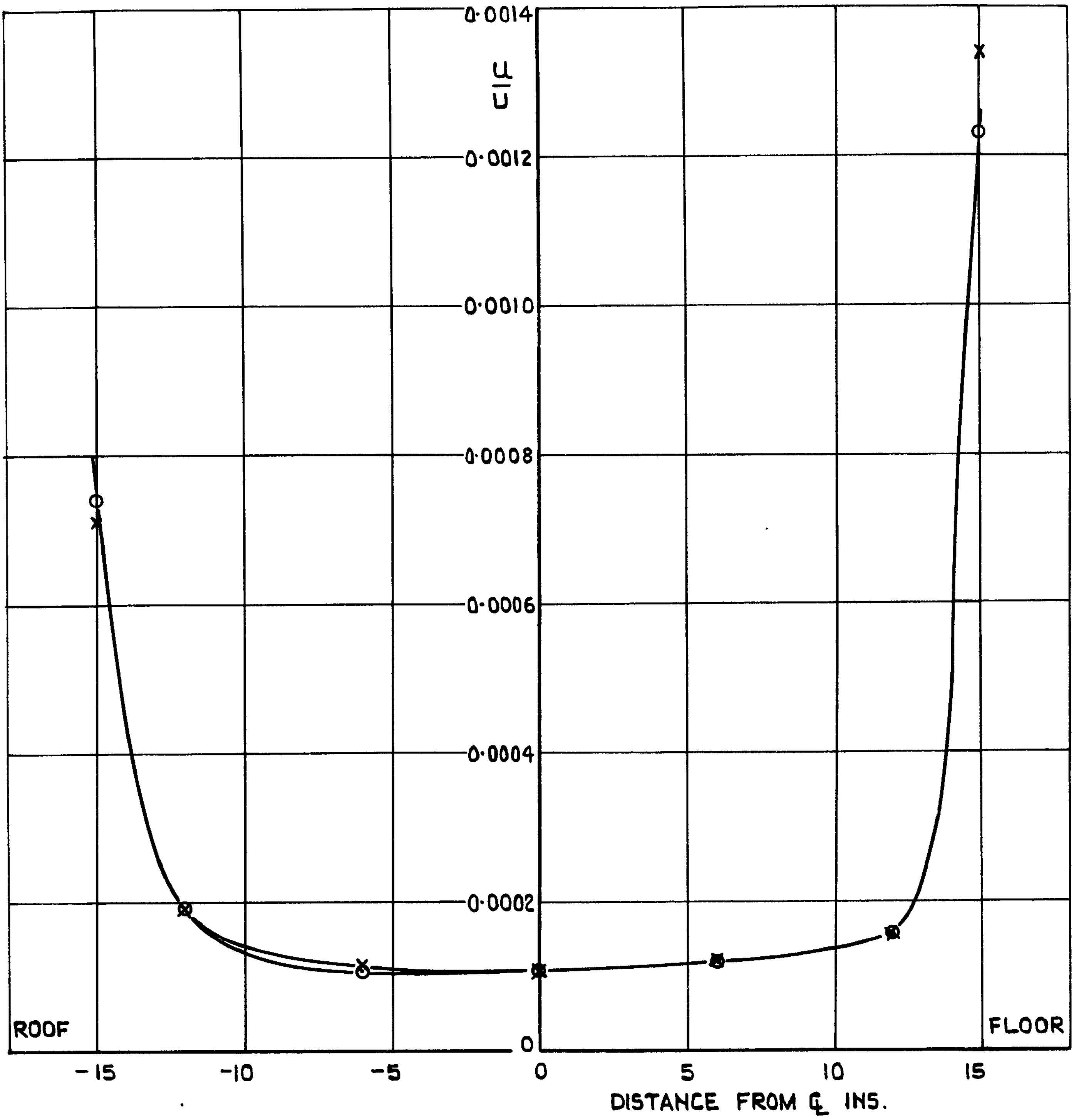
FIG. 1. 4'x3' WIND TUNNEL PLAN VIEW ON CENTRE LINE.



"CLEAN" RETURN CIRCUIT
FLAPS UP } 9 IN CHORD FLAPS ON ROOF AND FLOOR.
FLAPS DOWN } T.E. HEIGHT 4 INS.
3FT. CHORD FLAP ON FLOOR. T.E. HEIGHT = 14·75 IN.
3FT. CHORD FLAP ON FLOOR. T.E. HEIGHT = 27 IN.

U = VELOCITY IN WORKING SECTION (140 FT./SEC.)

FIG. 2 PITOT–STATIC TRAVERSES AT DOWNSTREAM END OF SECOND DIFFUSER.

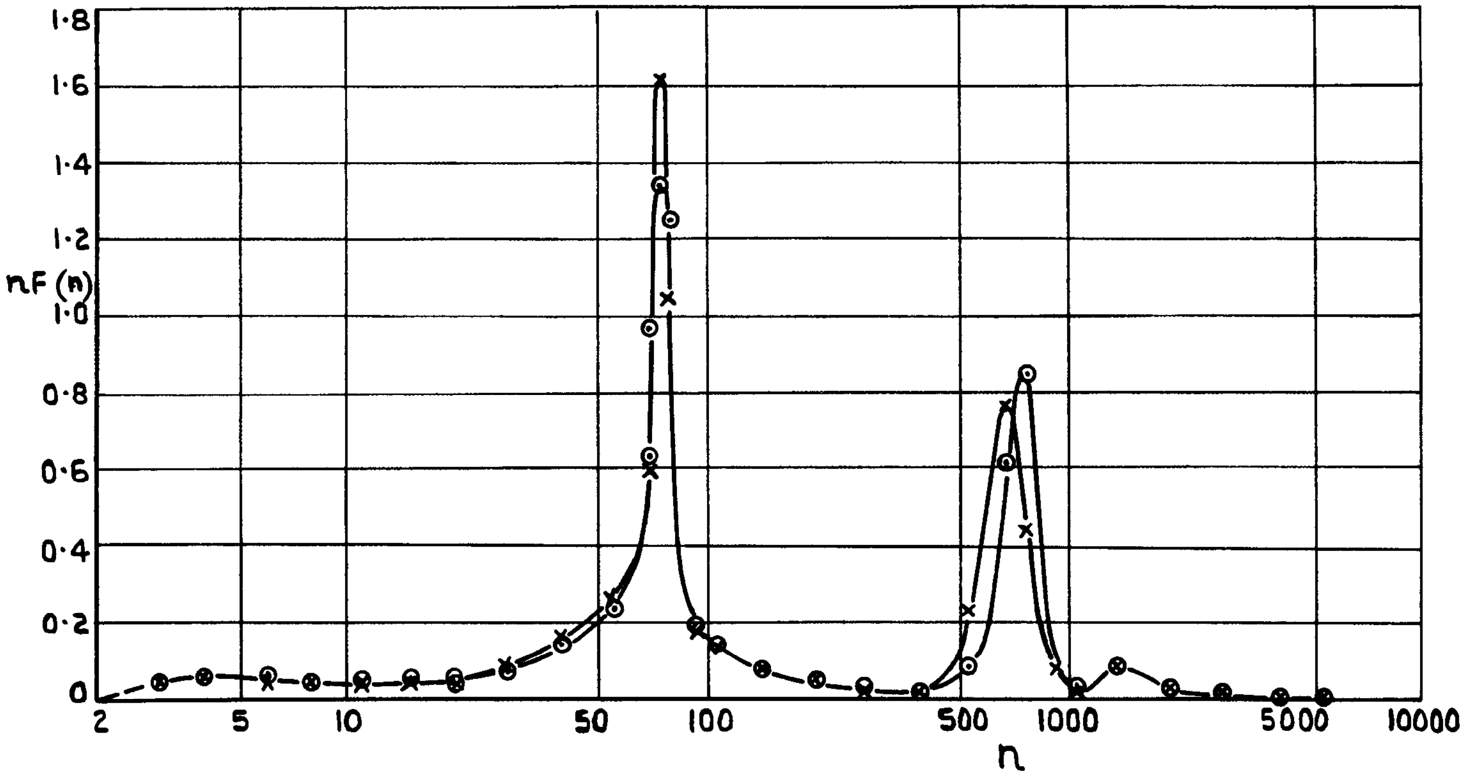


⊙ "CLEAN" RETURN CIRCUIT

× 3FT. CHORD FLAP ON FLOOR OF RETURN CIRCUIT T.E. HEIGHT = 27 INS.

U = 140 FT./SEC.

FIG. 3 LONGITUDINAL VELOCITY FLUCTUATIONS IN WORKING SECTION.



⊙ "CLEAN" RETURN CIRCUIT

X 3FT. CHORD FLAP ON FLOOR OF RETURN CIRCUIT T.E. HEIGHT = 27 INS.

n ANALYSER TUNED FREQUENCY

nF(n) VALUES ARE "NORMALISED" BETWEEN n = 2 AND n = 5000

$$\left(\text{i.e.} \int_{n=2}^{n=5000} nF(n)\, d \log n = 1\right)$$

FIG. 4 SPECTRA OF VELOCITY FLUCTUATIONS NORMAL TO AN INCLINED HOT WIRE IN THE WORKING SECTION.

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