

THE PERFORMANCE OF THE CARDINGTON TURBULENCE INSTRUMENT P.4.

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Introduction

1. This short report is a sequel to TDN No. 4 which described the measurements that were made on the 55 ft platform of the Cardington tower in 1967. From these measurements the eddy fluxes of heat and momentum were calculated and although the heat fluxes appeared to be reasonable, the momentum fluxes seemed highly anomalous. Thus TDN No.4 recommended that the influence of the tower and the method of measuring the total wind be thoroughly investigated. This report outlines the results of the subsequent investigation of the performance of the instrument used in 1967, and described how sensible results were finally obtained.

The experimental check

2. As a thorough check of the recording and computational procedures showed that everything was functioning according to plan, attention was focussed on the actual instrument and its exposure on the tower. However, although further measurements confirmed that the mean wind (and hence probably the momentum flux) was affected by the presence of the tower, it was felt at the time that this in itself would be unlikely to reverse the sign of the momentum flux.

3. The inclination of the wind in the vertical plane was measured by a double hot wire supported on a "horizontal platform" (Readings 1968) and tests in a wind tunnel showed that this platform was aerodynamically unbalanced. This meant that the instrument did not measure the actual inclination of the wind but one modified by the angle the "horizontal platform" made with the true horizon. Furthermore this error varied with both the wind's speed and its inclination.

4. Preliminary calculations revealed that such an effect would affect the values of all the turbulent quantities and that it could easily reverse the sign of the momentum flux. Thus it was decided to do a series of runs with the platform clamped so that it could not rotate.

Note

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As it proved impossible to adjust this platform so that exactly zero inclination was registered on average, the following correction procedure was adopted. Each run was made to last for an hour and the correction angle was then calculated by assuming that the mean vertical wind speed was negligible over this period. This angle was used in calculating all the turbulent quantities.

5. As the presence of the tower could affect the turbulent characteristics of the air flow, it was decided to do most of these runs with the instrument mounted on top of a 28' mast situated some distance from the tower. Furthermore although half the runs were made with the platform clamped as described in paragraph 4, the rest of them were done with the platform free to rotate. Some runs of both types were also made on the tower.

The direction of the momentum flux

6. An examination of the results revealed that positive momentum fluxes were only obtained when the instrument was mounted on the tower and that it did not matter whether the platform was clamped or free to rotate. Furthermore, correcting the individual unclamped runs so that the mean vertical wind speed, \bar{w} , was negligible, did not remove the anomaly entirely, though it did change the sign of the flux in some cases. Thus it is evident that the tower had a serious effect on the nature of the turbulent flow in its vicinity.

The relative magnitudes of σ_w and u_*

7. Fig. 1a is a plot of the derived friction velocity, u_* , against the standard deviation of the vertical wind speed, σ_w (the unclamped runs have not been corrected to make the individual values of \bar{w} zero). It can be seen that the only set of results that appear to be along a line which passes through the origin are those derived from runs made on the mast with the platform clamped.

8. Fig. 2a is also a plot of u_* against σ_w but this time the unclamped runs have been corrected so that the individual values of \bar{w} were zero. From this it is evident that although all the mast runs now produced results that are not inconsistent with a straight line through the origin, the tower runs still do not.

/Thus

Thus it seems reasonable to conclude that the turbulent wind field was distorted by the tower and further that an instrumental uncertainty in the absolute value of the wind inclination may be partially responsible for the peculiar nature of some of the results.

9. Busch and Panofsky (1968) made a survey of experimental results and concluded that the best relation between σ_w and u_* would be of the form " $\sigma_w = a u_*$ " with "a" having a value of 1.3 while the results just discussed would favour a value of about 1.5. However this disagreement is hardly surprising when the nature of the site is considered.

The relative magnitudes of σ_w and σ_u

10. Fig. 1b is a plot of the standard deviation of the horizontal velocity, σ_u , against σ_w with the unclamped runs uncorrected. Similarly Fig 2b is the same plot but this time the individual unclamped runs have been corrected so that the values of \bar{w} are zero.

11. Once again it can be seen that the only set of results that appear to be along a straight line are those derived from clamped runs with the probe mounted on the top of the 28' mast. However this time, correcting the individual unclamped mast runs so that \bar{w} was zero, slightly increased the spread of these results which perhaps means that the lack of aerodynamic balance was also relevant.

12. Incidentally the slope of the straight line plotted in Figs 1b and 2b lies within the range of values quoted by Lumley and Panofsky (1964)

The variation of momentum flux with averaging time

13. Ideally one would expect a plot of momentum flux versus averaging time to give a curve that decreases monotonically to zero as the averaging time increases. However both TDN No.2 and TDN No.4 contain examples of curves that oscillate. This was quite unexpected and could imply that the spectral distributions were of rather peculiar forms - quite different from the curves published by other workers (see Busch and Panofsky (1968) and Panofsky and Mares (1968)).

14. However this type of effect can also be caused by an error in the absolute value of the wind inclination.

/This

This was confirmed by comparing the curves of the variation of momentum flux with averaging time derived from results that had been corrected so that \bar{w} was zero, with the corresponding results where this had not been done. In almost all cases the curves became more regular as is illustrated by Fig 3, which shows the improvement in the third hour of the tower run on the 6th June 1967. However once again it was only the mast runs that normally produced sensible curves with momentum fluxes of the correct sign.

Concluding remarks

15. In the light of the preceding results and discussions it seems reasonable to conclude that the peculiar results reported in TDN No.4 were due to three types of error - namely distortion of the wind flow by the tower, errors in the absolute values of the mean wind inclination and deflections of the inclinometer by the wind flow as a result of lack of aerodynamic balance. However to a certain extent the latter was masked by the other two. This means of course that the results reported in TDN No.2 must also be treated with care as they would be affected by lack of aerodynamic balance and errors in the absolute value of the mean wind inclination - quite apart from possible radio interference in the temperature measuring circuitry.

16. It also seems reasonable to conclude that sensible results may be obtained with this probe by clamping its platform so that it cannot rotate and mounting it on a fixed pole.

REFERENCES

- Busch N. E. and Panofsky H. A. (1968)
"Recent spectra of atmospheric turbulence" Q.J. 94 pp 132-148.
- Lumley J. L. and Panofsky H. A. (1964)
"The structure of atmospheric turbulence" J. Wiley (New York)
- Panofsky H. A. and Mares E. (1968)
"Recent measurements of spectra for heat flux and stress" Q.J. 94
pp 581-585.
- Readings C. J. (1968)
"The Cardington Observational Programme on Turbulent Transfer" MRCP 234

Fig. 1 The self-consistency of the values of σ_w ; σ_u and u_*

(unclamped runs uncorrected)

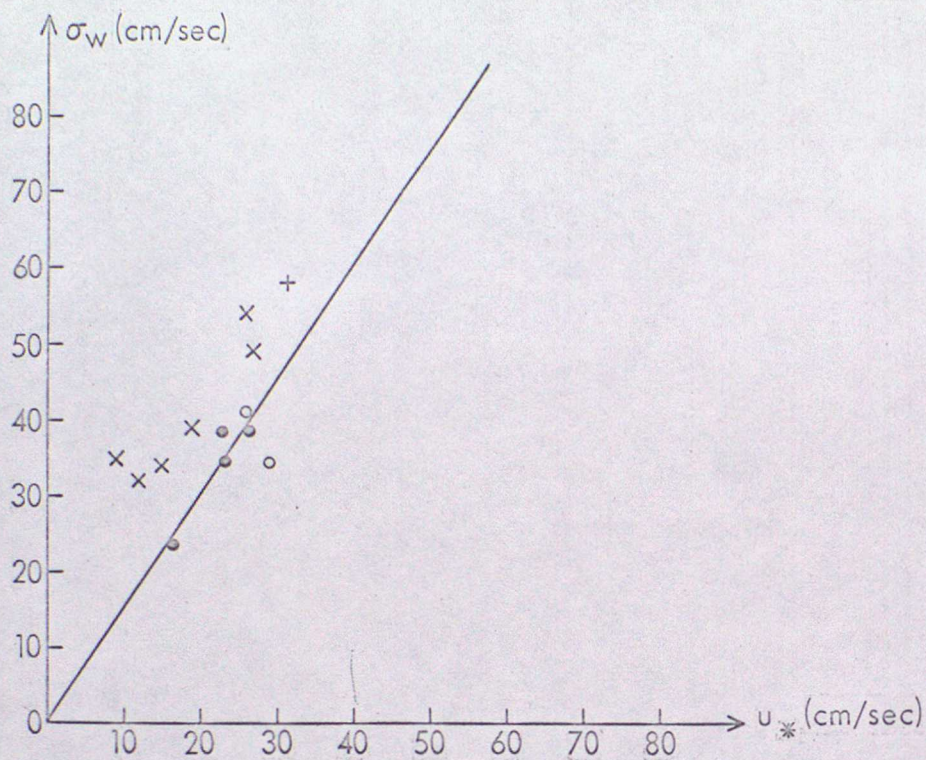


Fig. 1 (a)

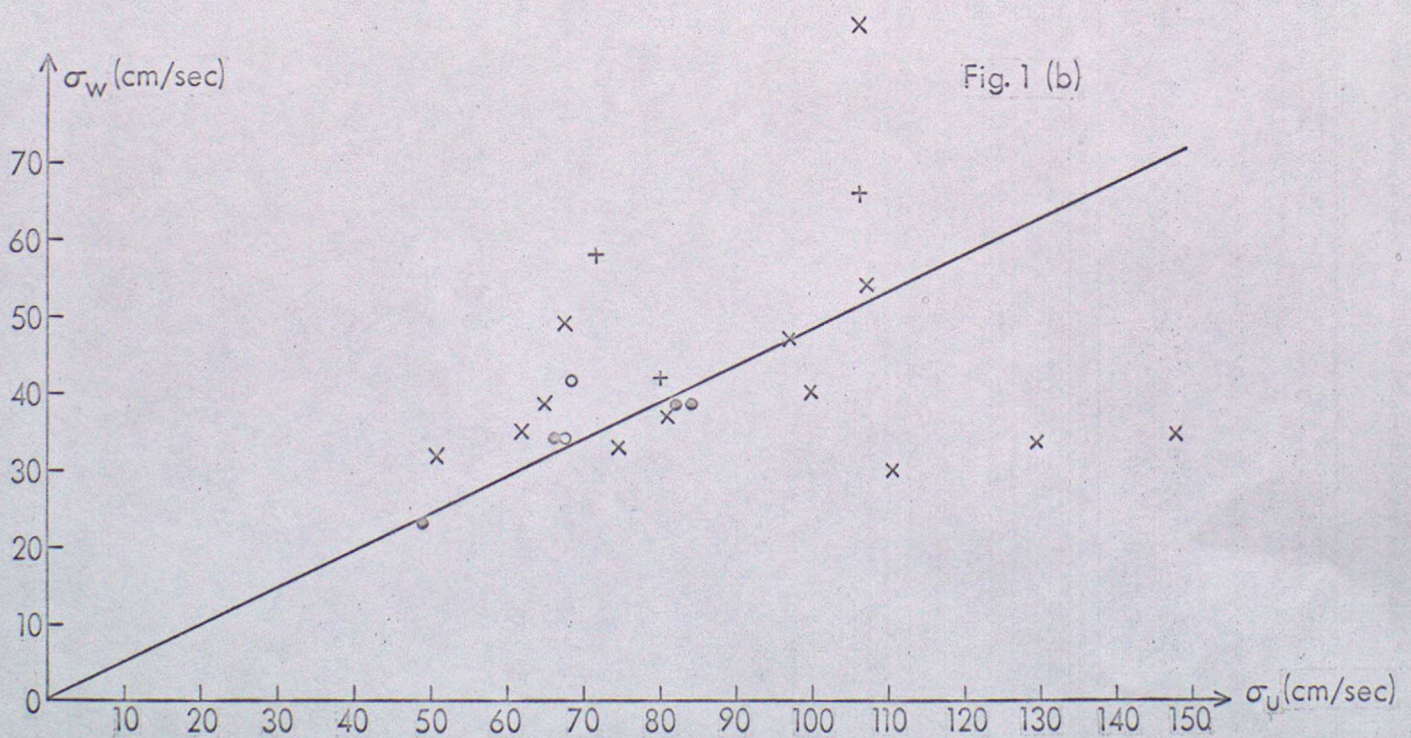


Fig. 1 (b)

- Mast run : unclamped and uncorrected
- Mast run : clamped and corrected
- × Tower run : unclamped and uncorrected
- + Tower run : clamped and corrected

Fig. 2 The self-consistency of the values of: σ_w , σ_u and u_*
(all runs corrected)

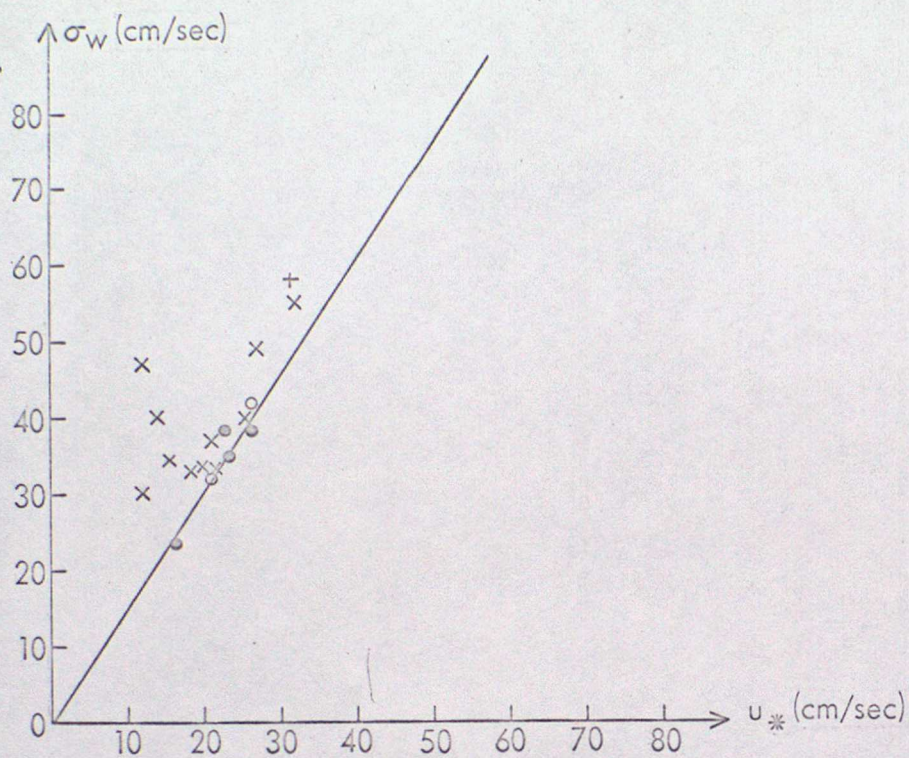


Fig. 2 (a)

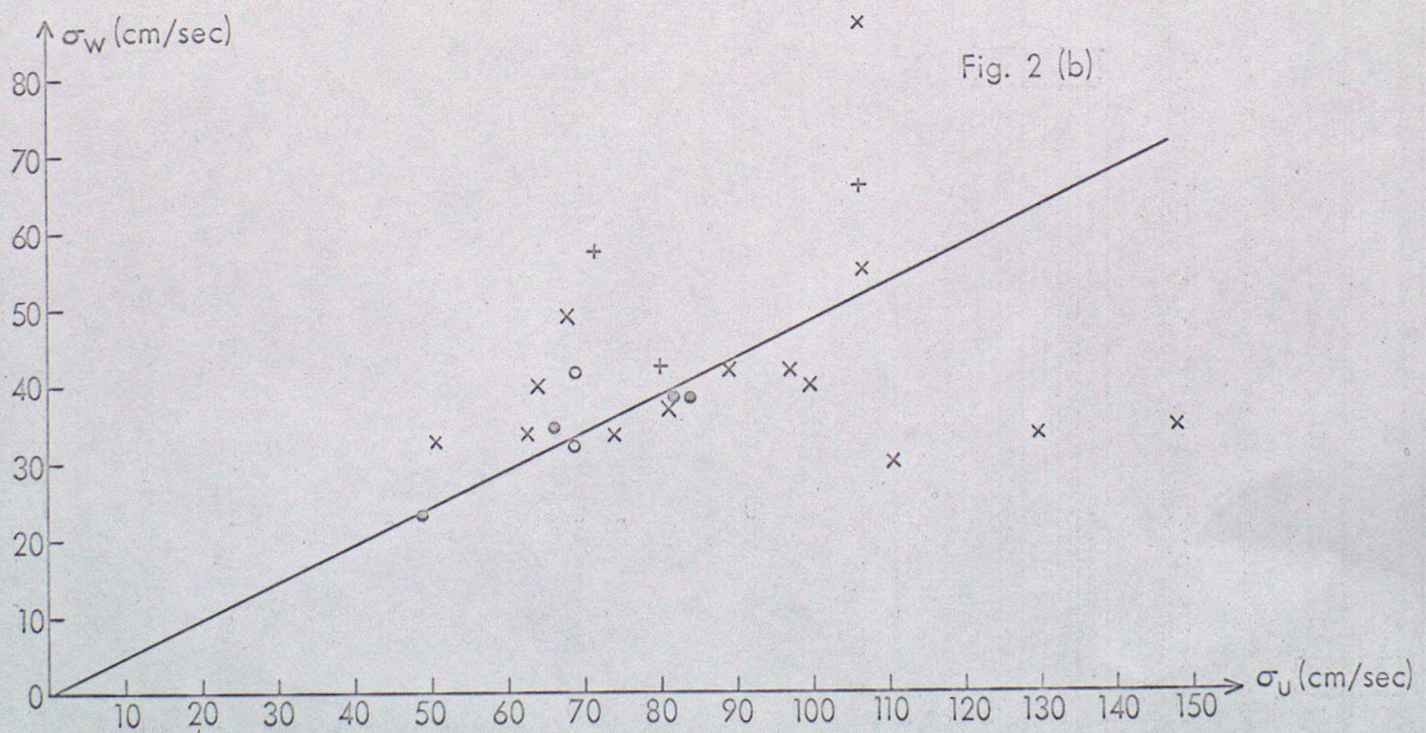


Fig. 2 (b)

- Mast run : unclamped
- Mast run : clamped
- × Tower run : unclamped
- + Tower run : clamped

Fig. 3 Variation of momentum flux with averaging time
(Tower run 6/6/67 : 1520 — 1620 Z)

