Evaporation Memorandum No. 40.

ESTIMATION OF MONTHLY AVERAGE SURFACE (2-METRE) WIND SPEEDS FROM MONTHLY AVERAGE MEAN SEA LEVEL PRESSURE MAPS.

B G Wales-Smith

Summary.

Lack of monthly averages of wind speeds at meteorological stations in Great Britain for the 1880s led to an investigation into the relationship between monthly average surface (2m) wind speed and adjusted geostrophic wind scale measurements made from monthly average mean sea level pressure charts. Some simple theoretical aspects of the relationship are discussed and empirical results obtained from a pilot study are analysed. It is shown the application of a simple multiplying function of adjusted geostrophic wind scale speed to such scale speeds gives a surprisingly accurate estimate of measured wind speeds. Seasonal and spatial variations in the multiplying function are discussed but it is shown that the advantages from such refinements are likely to be small and that their usefulness could be tested only by the analysis of much larger quantities of data than used in the pilot study.

1. Introduction.

This investigation arose from a need to assemble fairly rapidly and with a strictly limited investment of labour, a data-set of monthly averages of the meteorological variables required to estimate potential evaporation, following Penman (1948), for meteorological stations in Great Britain, from 1881 onwards. The variables are air temperature, vapour pressure, duration of bright sunshine and the wind speed at 2 metres above the ground. The first three are conveniently tabulated in the Monthly Weather Report but the fourth variable, wind speed, is represented only by highly simplified wind-roses. Monthly average mean sea level pressure charts are available.

2. Theoretical aspects of the relationship between averages of measured wind speeds and geostrophic wind scale measurements made from mean isobars for the averaging period.

2.1 A very simple extreme case is that of a large stationary depression or anticyclone maintaining one pressure pattern over Great Britain for a whole month. Assuming neutral stability in the lowest Km of the troposphere and no ageostrophic motion, a good estimate of the monthly average wind speed at any level <1 Km above a chosen point could be obtained by the use of a geostrophic wind scale and suitable adjustments for the effects of cyclonic or anticyclonic curvature of the isobars and for the chosen level.

2.2 An extreme case in which the geostrophic wind speed would be meaningless would be one in which, with straight isobars, a given pressure gradient prevailed over the country for half the month and an equal and opposite pressure gradient prevailed for the other half.

2.3 From 2.1 and 2.2 it is reasonable to propose that the representativeness of the average pressure gradient (in terms of average wind speed) would be expected to be high when the average pressure gradient is strong and could be low when the average pressure gradient is weak.

2.4 It is further proposed that curvature corrections should not be made to geostrophic wind scale measurements from time-averaged pressure patterns. It is suggested however, that if the average pressure pattern is highly representative of daily patterns some degree of isobar curvature could appear in the monthly average patterns and that this could result in geostrophic scale measurements being over or under-estimates of gradient wind speeds depending on the sense of the curvature.

3. Data-processing and analyses.

Monthly values of mean hourly wind speed were extracted from the Monthly Weather Report for 1968, 1969 and 1970 for Leuchars, Leeming and Mildenhall (Honington for 1970). These average speeds were adjusted to give V_2, estimates of 2-metre wind speeds, using the table on p.75 of the Meteorological Observer's Handbook (Meteorological Office, 1969).

A geostrophic wind scale was constructed for 1mb intervals for the scale of the map used in the MWR, for 55° latitude, and the scale values were multiplied by 0.4 (see insert to Figure 1) to give estimates of surface ($\approx$ 2-metre) wind speeds following Findlater et al (1966); these values will be referred to as V_{2g}. Bearing in mind 2.2 and 2.3 an arbitrary lower limit of 3.5 Kt was imposed on V_{2g}. The 108 station-month values of V_2 and V_{2g} are plotted in Figure 1. The speeds were rounded to the nearest knot so groups of points coincide. The monthly station values of V_2/V_{2g} were calculated and are variously averaged in Table 1. These averages show some suggestions of systematic spatial and seasonal variation but not enough to justify the adoption of averages as monthly factors to adjust V_{2g} to estimate V_2. If the 9 station-year average factor 1.46 is used to adjust V_{2g} to estimate V_2 the results are as shown in Figure 2. 85% of the points lie within ± 2 Kt of the 1:1 line but there appears to be a tendency to increase higher values of V_{2g} too much and not to increase lower values sufficiently.

Table 2 shows the distribution of $V2/V_{2g}$ for V_2=3,4,----, 10 Knots. Although the numbers of cases decrease with increasing V_{2g} there is an obvious pattern suggesting that V_2/V_{2g} decreases with increasing V_{2g} reaching unity at $V_{2g} \approx 9$ Kt. It is probably worth mentioning that the 26 cases for V_{2g}=5 Kt are more closely packed than the 17 for V_{2g}=4 Kt and the 11 cases for V_{2g}=7 Kt are also more closely packed than the 11 for V_{2g}=6 Kt. This evidence supports the apparent pattern despite the reduction of number of cases with increasing V_{2g}.

Average values of V_2/V_{2g} at 1 Knot intervals are plotted in Figure 3 and a smooth curve has been fitted intuitively by eye. An approximate conversion of V_{2g} to $V^1{}_{2g}$ (where the latter is adjusted V_{2g}) is given along the horizontal axis.

These rough values of the function were used to adjust V_{2g} from the 108 station-month data-set. V_2 is plotted against $V^1{}_{2g}$ in Figure 4 where the 1:1 line and ± 2 Knot lines have been inserted. It can be seen by comparing Figures 2 and 4 that $V^1{}_{2g}$ is a better approximation to V_2 than is 1.46 V_{2g}. The points lying beyond the ± 2 Knot lines in Figure 4 have been labelled to indicate month of occurrence.

The adjusting factors were next applied to V_{2g} values for 5 stations in 1972 and 1973. $V^1{}_{2g}$ values are given to the nearest 0.5 Kt and are plotted against V_2 in Figures 5 and 6. It is seen that most $V^1{}_{2g}$ are correct to ± 1 Kt and that nearly all are correct to ± 2Kt. As in Figure 4 the worst estimates are labelled with abbreviated month names; in figures 5 and 6 the month names are given for errors of $\geqslant$ 1Kt.

A glance at this aspect of Figures 4 to 6 shows that there was a tendency for a a few warmer month winds to be under-estimated and for a few colder month winds to be over-estimated by the processes described.

5. Conclusions and further work.

Until there is time to carry out an analysis of a very much larger quantity of data it is suggested that the adjustments derived in Figure 3 must suffice since they produce surprisingly accurate results.

The process outlined in this memorandum might well find application in the 2-metre wind model which forms part of the system described by Wales-Smith, Prior and Arnott (1977).

REFERENCES.

Penman, H. L. (1948) Natural evaporation from open water, bare soil and grass. Proc.Roy.Soc.,Ser.A.,193,120-145.

Meteorological Office (1969) Meteorological Observer's Handbook,HMSO Lond.

Findlater, J. et al (1966) Surface and 900 mb wind relationships. Scientific Paper No 23 Meteorological Office.

Wales Smith, B. G., Prior, J. M. and Arnott, J. A. (1976) A meteorological system for estimating evaporation, soil moisture deficit and hydrologically effective rainfall. Unpublished material. Meteorological Office Library.

Fig. 1. Comparison between V_2 and V_{2g} at Leuchars, Leeming and Mildenhall/Honington 1968–1970 (wind speeds rounded to nearest Knot.)

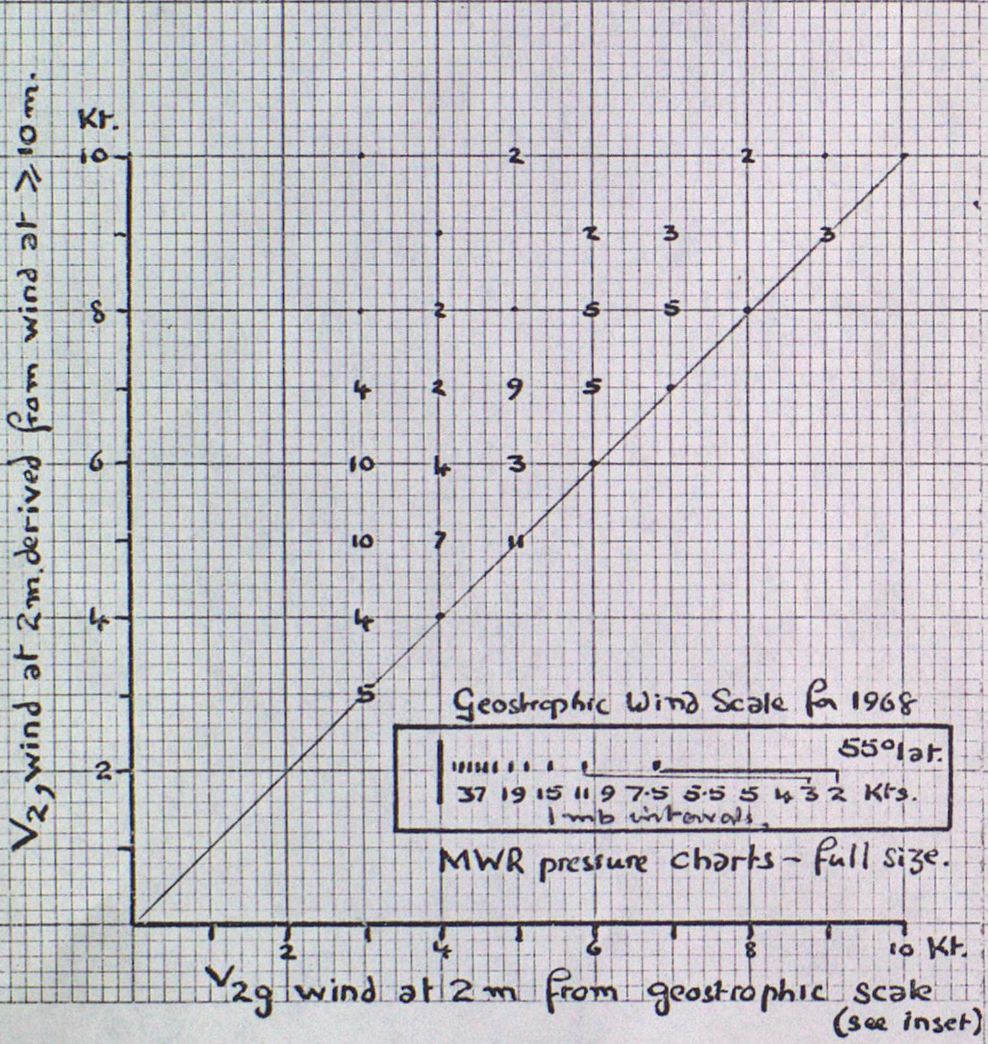

Fig. 2 Comparison of V_2 and $1{\cdot}46\ V_{2g}$ (to nearest Knot) using the same data as Fig. 1.

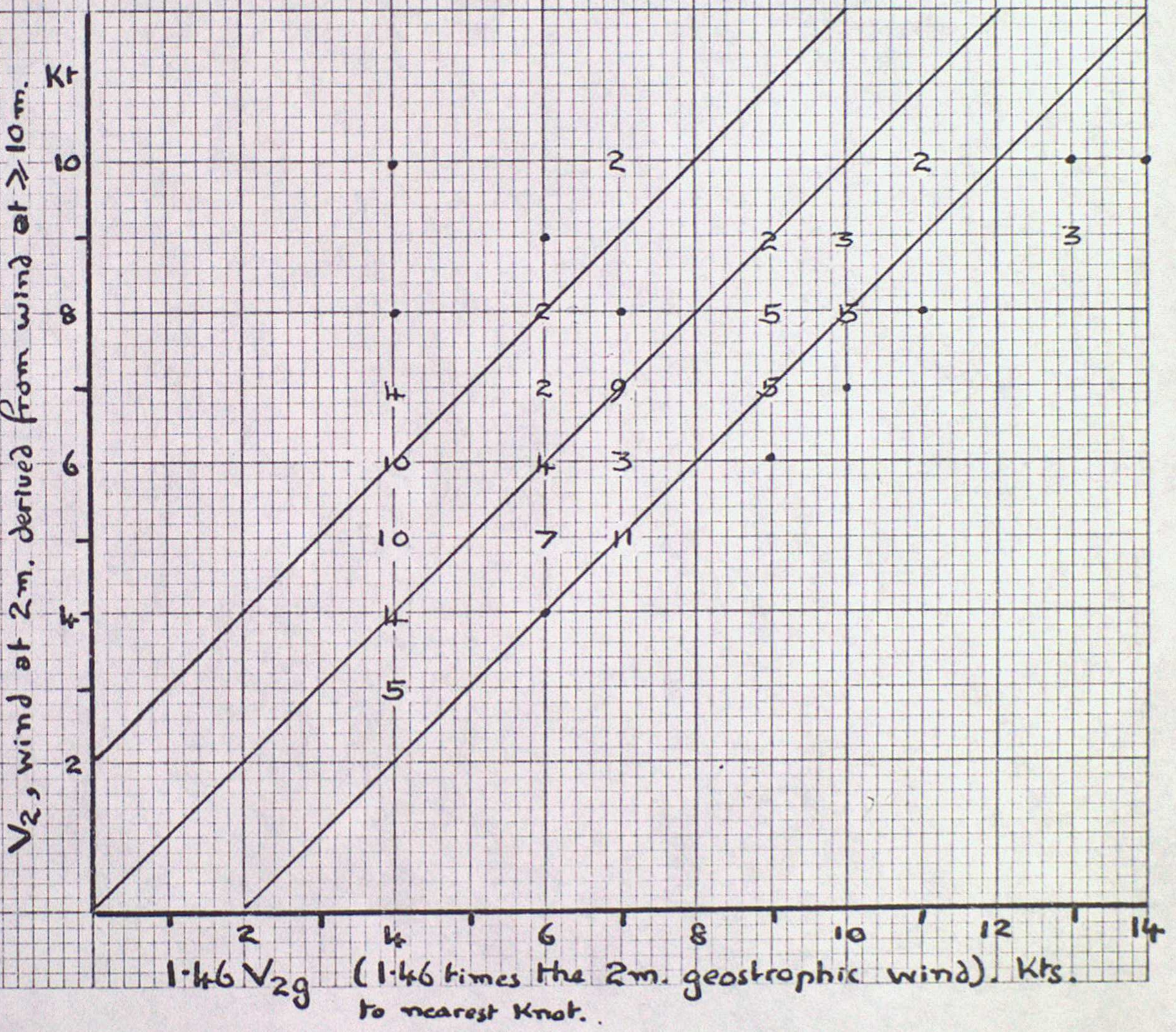

Fig. 3 Average V_2/V_{2g} for $V_{2g} = 3, 4, \ldots, 10$.
108 station-months (as in Fig. 1.)

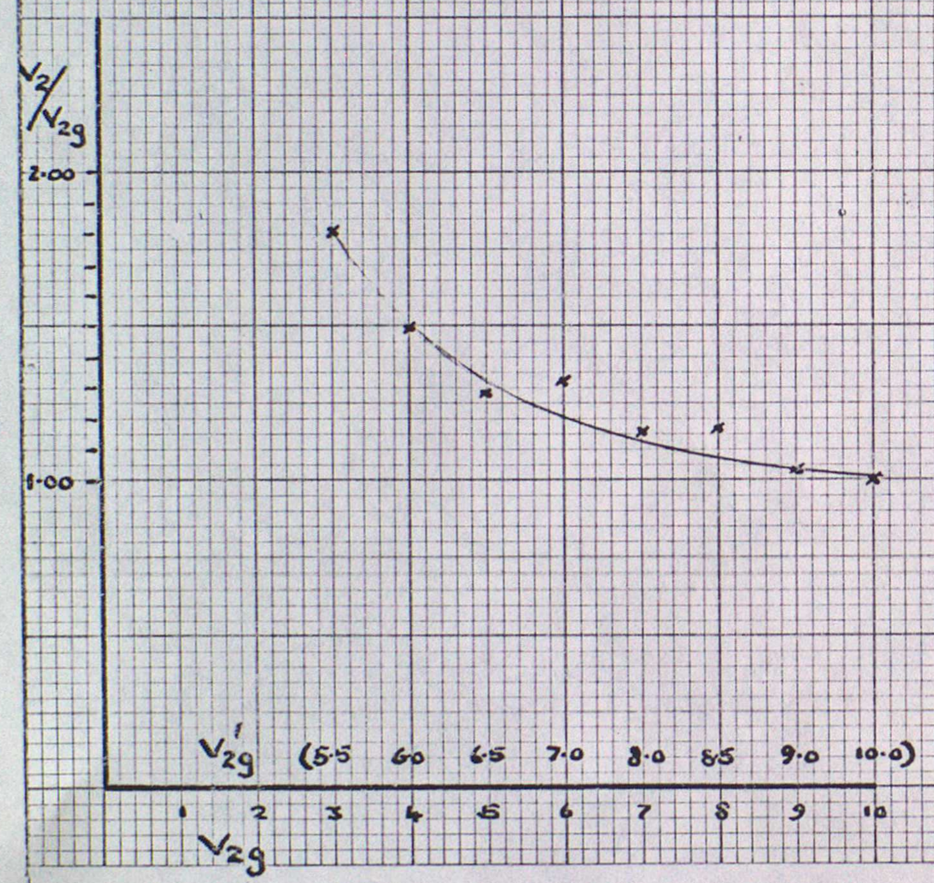

Fig 4 Comparison of V_2 and V'_{2g} (to nearest Kt.)
using the same data as Fig. 1.

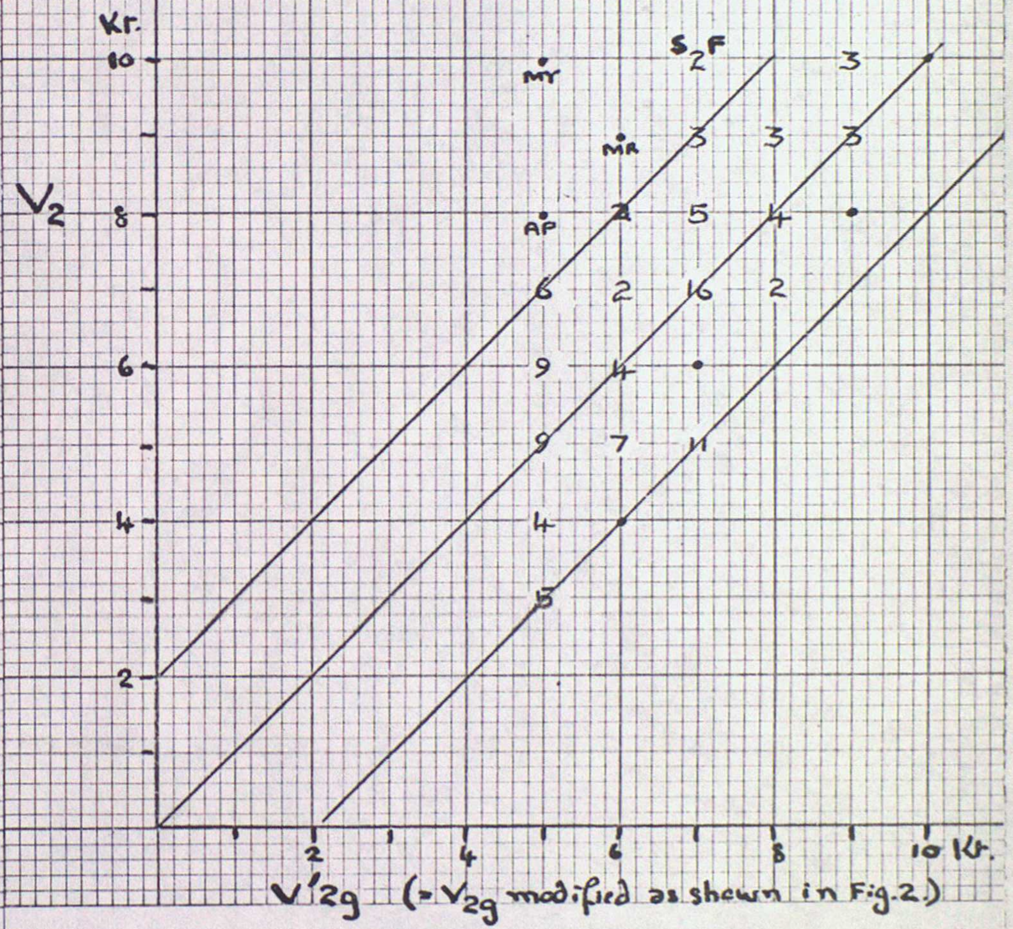

Fig. 5. V_2 vs. V'_{2g} (V'_{2g} to nearest 0.5 Kt) for 1972 Kinloss, Leuchars, Leeming, Honington and Heathrow.

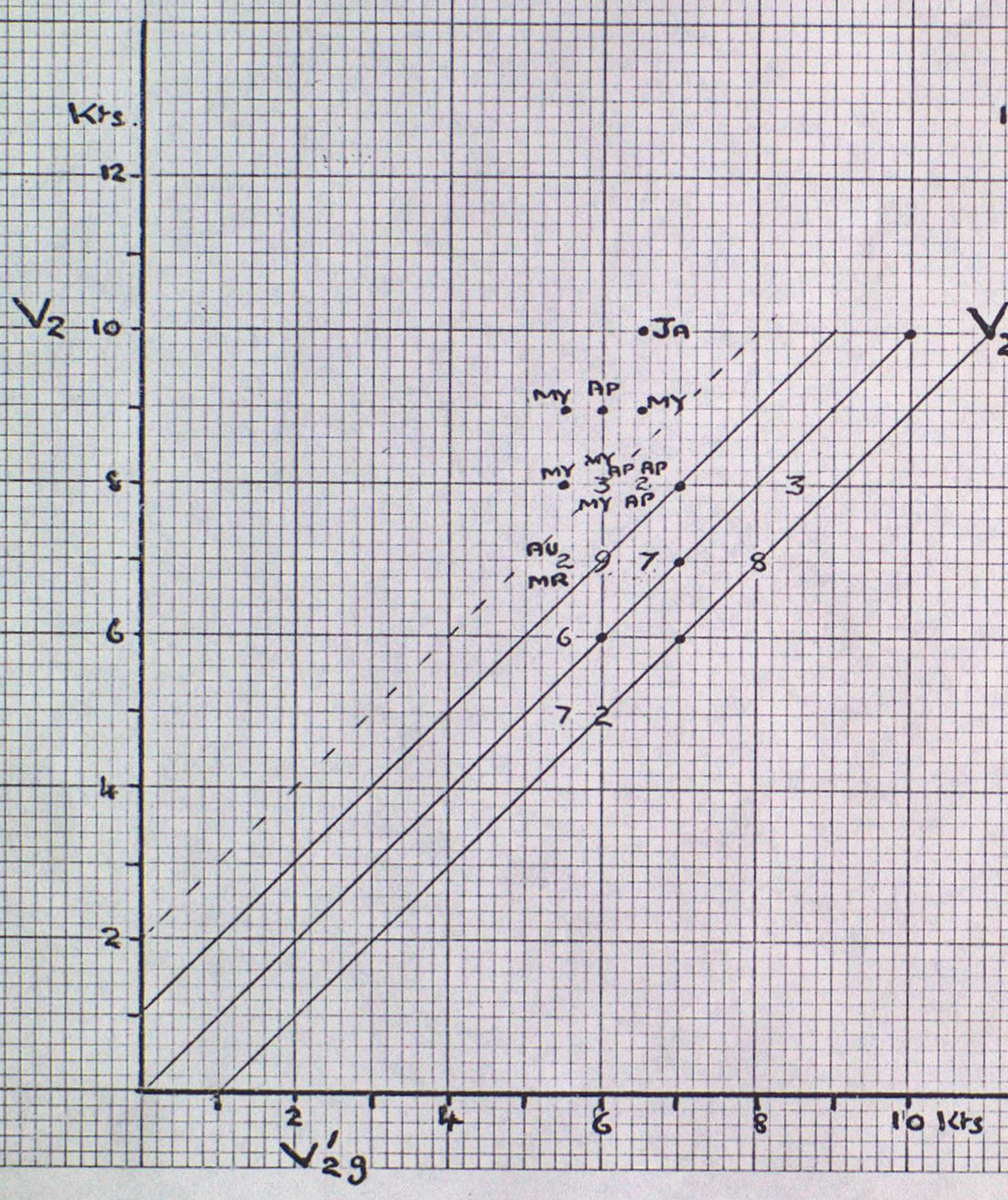

Fig. 6. V_2 vs V'_{2g} (V'_{2g} to nearest 0.5 Kt) for 1973 (Stations as Fig. 5)

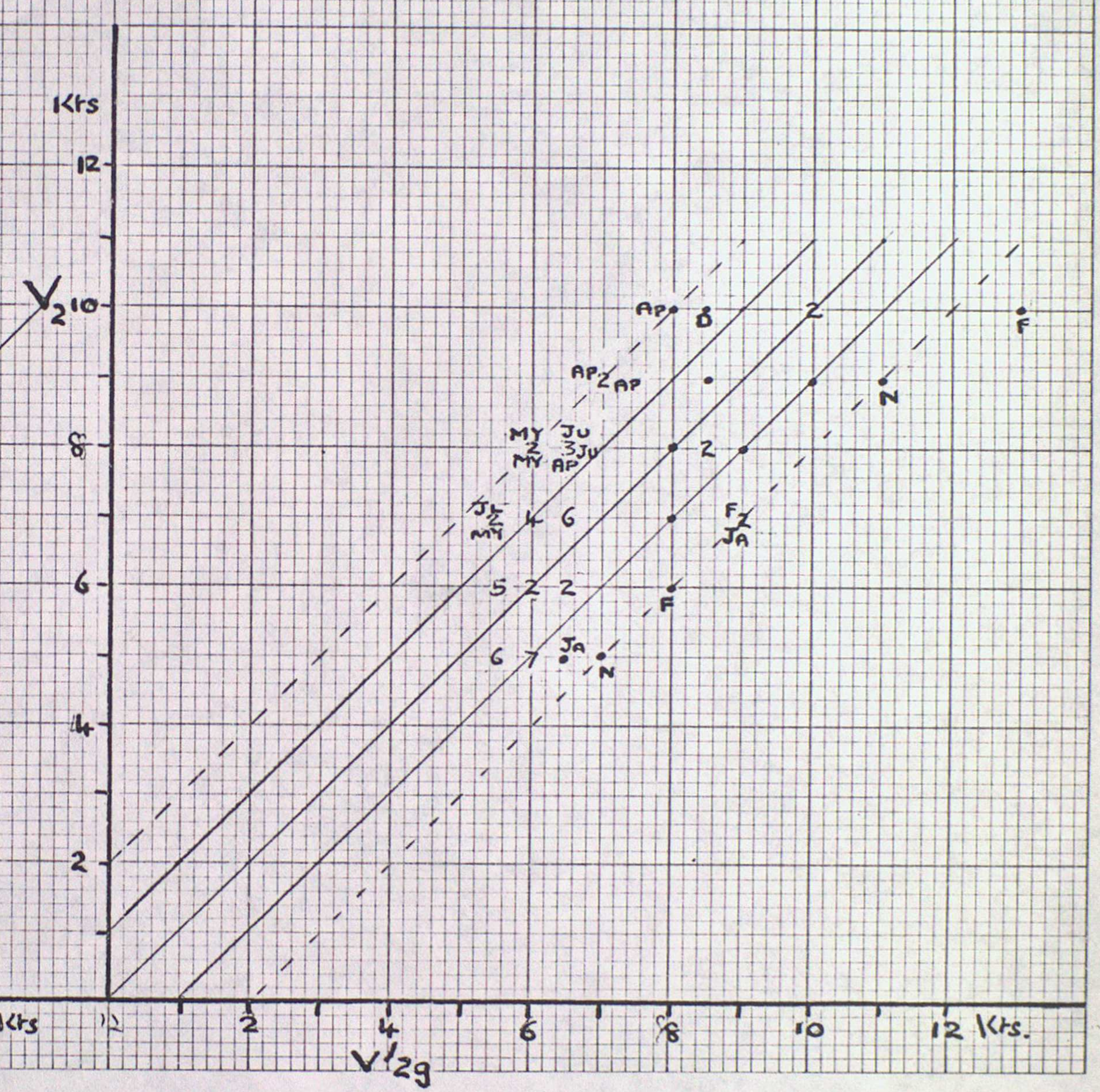

Table 1. V_2/V_{2g}

Stn.	Leuchars 3yrs	Leeming 3 yrs	Mildenhall -Honington 3 yrs	3 stns 3 yrs	3stns 1968	3stns 1969	3stns 1970
JAN	1·27	1·10	1·19	1·19	1·15	1·13	1·27
FEB	1·50	1·19	1·33	1·34	1·25	1·61	1·17
MAR	1·45	1·19	1·18	1·27	1·13	1·42	1·28
APR	1·86	1·60	1·36	1·61	1·69	1·71	1·42
MAY	2·16	1·64	1·66	1·82	1·58	1·33	2·55
JUN	1·83	1·78	1·44	1·68	1·78	1·47	1·80
JUL	1·61	1·33	1·06	1·33	1·56	1·11	1·28
AUG	2·22	2·00	1·31	1·84	1·86	1·67	2·00
SEP	1·47	1·14	1·22	1·28	1·30	1·33	1·19
OCT	1·20	1·10	1·06	1·12	1·06	1·05	1·25
NOV	1·46	1·38	1·38	1·41	1·89	1·13	1·20
DEC	1·63	1·44	1·89	1·65	1·50	1·55	1·91
Av							
1968	1·59	1·59	1·26		1·47		
1969	1·74	1·20	1·19			1·37	
1970	1·58	1·44	1·56				1·53
3yr	1·64	1·41	1·34	1·46			

Table 2. Distribution of V_2/V_{2g} for $V_{2g} = 3, 4, ----, 10$ (108 cases)

V_{2g} kt.	1·00 1·19	1·20 1·39	1·40 1·59	1·60 1·79	1·80 1·99	2·00 2·19	2·20 2·39	2·40 2·59	2·60 2·79	2·80 2·99	3·00 3·19	3·20 3·39	Av	
3	5	4		9		9	6		1			1	1·81	35
4	1	8	3	2		2	1						1·49	17
5	11	1	11	1		2							1·28	26
6	4	4	3										1·32	11
7	8	3											1·16	11
8	1	2											1·17	3
9	4												1·03	4
10	1												1·00	1