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TESTS ON TWO METHODS OF ESTIMATING DESIGN GUST SPEED FROM SHORT PERIODS OF ANEMOGRAPH RECORD

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1. INTRODUCTION

The basic wind speed used in the design of buildings is the maximum gust speed likely to be exceeded on average only once in 50 years. This "1 in 50 year" gust speed is normally estimated from a statistical analysis of annual maximum gusts from one site, at least 10 years of continuous record are required to form a reasonable estimate.

In this paper two methods of estimating the 1 in 50 year gust value using less than 10 years of record are compared. The methods are tested by using short periods of data from stations having long records and comparing the results with those obtained from an extreme value analysis of the whole period of data. The methods were also used to provide estimates of the 1 in 50 year gust value for a station having only 4 years of record.

2. DETAILS OF THE METHODS

The two methods are:-

(1) That described by Sachs in his book "Wind Forces in Engineering" (Reference 1).

(2) A method suggested by Shellard (Ref 2) and used in climatological Memorandum 50 A(CM 50A). (Ref 3).

With Sachs' method one year of anemograph data is required from the new site, these data are compared with data for the same period from a nearby long term station. Sachs' states that this method is suitable for any two stations with similar wind conditions, whatever their topography.

The procedure is:-

(a) The daily maximum gusts for each month are plotted on extreme value probability paper.

(b) The line of least squares is calculated and drawn on the plot.

(c) The theoretical extreme gust for the month is read off at the point of intersection of the line of least squares and the probability level appropriate to the month concerned (Probability level = .968 for 31 day month; .967 for 30 day; .964 for 28 day month).

[The theoretical extreme can be calculated directly from the data without using probability paper from the equation:-

$$V_X = U + \frac{1}{a} y$$

Where V_X is the theoretical extreme; U is the mode; $\frac{1}{a}$ is $\frac{\sigma}{\sigma_N}$ (ie standard deviation adjusted for sample size); and y = -loge [-loge $(1-\frac{1}{N})$] where N= days in month. (y=3.42 for N=31; 3.38 for N=30 and 3.31 for N=28). This is much quicker than the graphical method and was used in all the following tests].

The theoretical extreme at the new site is expressed as a ratio of the theoretical extreme at the long term station for each month. The highest of the twelve monthly ratios is applied to the 1 in 50 year gust value for the long term station to give an estimate of the 1 in 50 year value at the new site.

With Shellard's method it is considered that at least four years of data are required for both the new site and the long term station. The sum of the annual extreme gusts in the four years at the new site is expressed as a ratio of the sum of the annual extreme gusts in the same four years at the long term station. The ratio, sum at new site ÷ sum at long term station, is applied to the 1 in 50 year gust value for the long term station to give an estimate of the 1 in 50 year value at the new site.

3. THE TESTS

The methods were tested using data from two groups of stations (Table 1). The three stations in Group 'A' all have 1 in 50 year values published in CM 50 A. Several periods of data were used to produce a series of estimates of the 1 in 50 year value of Great Dun Fell based on each of the low level stations and for each low level station based on the other low level station. The estimates were then compared with the value given in CM 50 A.

With stations in Group 'B' each of the long term stations was used to provide estimates of the 1 in 50 year gust at Middle Wallop, a new station having only four years of record. Using Sachs'method 4 estimates were made but with Shellard's method only one estimate from each reference station was possible.

Further periods of data were used to obtain a series of estimates of each long term station based on the other using Shellard's method.

STATION DETAILS TABLE 1

		ANEMOMETER HEIGHT		
	NAT GRID REF	AMSL	EFFECTIVE	1 in 50 year GUST CM 50A
GROUP 'A'				
Great Dun Fell	NY 710322	857m	10m	72 m/sec*
Sellafield	NY 027032	25m	11m	42 m/sec
Carlisle	NY 384603	41m	9m	48 m/sec*
GROUP 'B' ≠				
Boscombe Down	SU 172403	130m	16m	39 m/sec
Porton	SU 210366	120m	10m	36 m/sec
Middle Wallop	SU 298387	94m	10m	-

* CM 50A value for Great Dun Fell was based on only 10 years of data; using 15 years gives value of 73 m/sec.

* CM 50A value for Carlisle was based on only 11 years of data; using 15 years gives a value of 46 m/sec.

This later value was used for all estimates based on Carlisle.

≠ Use of Larkhill data produced anomalous estimates. An investigation has shown that structures erected in the vicinity of the anemometer in recent years have affected the exposure in a manner which makes the records unsuitable for the analysis of extreme gust values.

4. ESTIMATES USING STATIONS IN GROUP 'A'

(1) Sachs' method was used to obtain estimates using data for each of the years 1975, 1976 and 1977. To make the method clear the recorded maximum gust, the theoretical extreme gust and the ratio Great Dun Fell: Sellafield for each month of 1975 are given in TABLE 2.

TABLE 2

	ACTUAL MAXIMUM GUSTS			THEORETICAL GUSTS		
	GREAT DUN FELL	SELLAFIELD	RATIO	GREAT DUN FELL	SELLAFIELD	RATIO
JAN	42.2 m/s	27.3 m/s	1.55	48.3 m/s	27.8 m/s	1.74
FEB	32.4	19.1	1.70	32.0	19.4	1.65
MAR	29.4	18.0	1.63	33.3	18.7	1.78
APR	31.4	18.0	1.74	37.9	20.0	1.90
MAY	32.4	16.5	1.97	33.8	16.3	2.08
JUN	28.3	20.6	1.38	31.7	17.8	1.78
JUL	-*	-	-	-	-	-
AUG	24.7	21.1	1.17	26.0	18.7	1.39
SEP	39.7	17.5	2.26	40.9	22.4	1.83
OCT	29.4	17.5	1.68	35.9	20.5	1.75
NOV	34.5	19.6	1.76	38.1	21.2	1.80
DEC	35.0	17.5	2.00	40.0	20.1	1.98

* Missing data

The highest ratio of the theoretical extreme gusts is 2.08. Applying this factor to the 1 in 50 year gust value for Sellafield gives 2.08 x 42 = 87.4 m/s as the estimate of the 1 in 50 year value for Great Dun Fell. Estimates for each of the stations in Group 'A' are given in Table 3 together with the percentage error of the estimate when compared with CM 50A (46 m/sec for Carlisle).

TABLE 3 ESTIMATES USING SACHS METHOD

	USING DATA FOR THE YEAR 1975	1976	1977
Great Dun Fell based on Sellafield	87.4 m/s (+21%)	94.7 (+32%)	81.1 (+13%)
Great Dun Fell based on Carlisle	75.7 (+ 5%)	85.4 (+19%)	87.1 (+21%)
Carlisle based on Sellafield	56.7 (+24%)	61.7 (+35%)	58.7 (+29%)
Sellafield based on Carlisle	46.3 (+10%)	45.7 (+ 9%)	45.3 (+ 8%)

(2) To obtain a series of estimates based on Shellard's method the fifteen years of data 1963-77 were divided into three five year periods, 1963-67, 68-72, and 73-77. The sum of the maximum annual gusts at a station was compared with the sum for the same period at the other stations, the derived estimates of the 1 in 50 year gust values are given in Table 4 together with the percentage error.

NB Shellard does not recommend this method for use in estimating extreme values for high level stations, it is used here to estimate values for Great Dun Fell solely for comparison with Sachs and with the results using stations in Group 'B'.

Shellards method for estimating extreme speeds on exposed hills using the power law is given in CM 50A.

TABLE 4 ESTIMATES USING SHELLARDS METHOD

	USING DATA FOR THE PERIOD		
	1963-67	1968-72	1973-77
Great Dun Fell based on Sellafield	-	71.1 m/s (-1%)	72.9 m/s (+1%)
Great Dun Fell based on Carlisle	-	69.8 (-3%)	72.2 (00%)
Carlisle based on Sellafield	46.2 (+1%)	46.5 (+2%)	46.1 (+1%)
Sellafield based on Carlisle	41.5 (-1%)	42.0 (00%)	41.5 (-1%)

5. ESTIMATES USING STATIONS IN GROUP 'B'

(1) Table 5 gives estimates of the 1 in 50 year gust values using Sachs' method. As Middle Wallop has only four years of record it could not be used as a reference station to provide estimates for the other stations.

TABLE 5 ESTIMATES USING SACHS' METHOD

	USING DATA FOR THE PERIOD			
	1974	1975	1976	1977
Middle Wallop based on Boscombe Down	45.9 m/s	41.8	45.9	46.9
Middle Wallop based on Porton	38.1	39.2	40.2	40.2
Porton based on Boscombe Down	46.1 (+28%)	43.6 (+21%)	50.0(+39%)	46.1 (+28%)
Boscombe Down based on Porton	38.4 (-2%)	36.7 (- 6%)	37.4(- 4%)	33.9(-13%)

[Boscombe Down data were reduced to 10m effective height, using the power law]

(2) Using Shellard's method only one estimate for Middle Wallop could be obtained from each reference station. These two estimates are given in Table 6 together with estimates for each of the long term stations obtained from longer periods of record.

TABLE 6 ESTIMATES USING SHELLARD'S METHOD

	USING DATA FOR THE PERIOD				
	1955-9	1960-64	1965-69	1970-74	1974-77
Middle Wallop based on Boscombe Down	-	-	-	-	38.8
Middle Wallop based on Porton	-	-	-	-	35.7
Porton based on Boscombe Down	47.3(+31%)	42.3(+17%)	43.4(+21%)	41.9(+16%)	41.1(+14%)
Boscombe Down based on Porton	29.7(-24%)	33.1(-15%)	32.4(-17%)	33.5(-14%)	34.3(-12%)

[Boscombe Down data adjusted to 10m effective height before use].

6. SUMMARY OF THE RESULTS

(i) Stations in Group 'A'

(a) Estimates using Sachs' method - Table 3 - all exceed the expected value, the overestimate being from +5% to +35%. The amount of error is dependent both upon the period of data and upon the reference station used.

(b) Estimates using Shellard's method - Table 4 - are very close to the expected values the errors ranging from -3% to +2%, well within the confidence limits of the long term estimates.

(ii) Station in Group 'B'

The results of both methods - table 5 and 6 - have the following in common:-

(a) estimates for Middle Wallop based on Boscombe Down are higher than those based on Porton; (b) estimates for Porton based on Boscombe Down all exceed the CM 50A value for Porton; (c) estimates for Boscombe Down based on Porton are all less than the CM 50A value for Boscombe Down (these are the only under-estimates using Sach's method).

7. DISCUSSION AND SUBSEQUENT ANALYSIS

As Boscombe Down and Porton are situated in similar terrain and are only about 5 miles apart it was thought that very good estimates would be obtained for one station based on the other and that the variability due to the use of different periods of data would be highlighted. The very large errors which were found - especially when Shellard's method was used - are most surprising and warrant further attention.

An extreme value analysis for both stations using all data to 1977 confirmed the CM 50A values. The lines of expected extreme gusts are shown in figure I. For either Shellard's or Sachs' method to produce accurate results the ratio between the speeds at the two stations must remain constant for all levels of return period. For a pair of lines to maintain a constant ratio in the 'X' direction they must intercect the 'Y' axis at the same point. [The point of intersection between the extrapolated line of expected extremes and the 'Y' axis on extreme value probability paper has no meaning in terms of wind speed or return period.] In Figure 1 it is obvious that the ratio between the speeds for Boscombe Down and Porton is not constant and that the intercepts on the 'Y' axis will be markedly different.

The lines of expected extreme gusts for the stations in Group 'A' together with those for Boscombe Down and Porton are shown in Figure 2, where the 'Y' axis has been extended to include the intercept values. The 'Y' intercepts for stations in Group 'A' are not widely separated (-5.4 to -8.3), but the intercept for Porton (-15.5) is very different from that for Boscombe Down (-9.4). This wide difference between intercept values is the reason for the large errors found when Boscombe Down and Porton were used.

The intercepts for all UK stations having at least 10 years of record have been calculated. The values range from -3.9 to -15.5 (Porton), the mean is -9.23 and the standard deviation is 2.28. The percentage frequency distribution for the 86 UK stations is shown in Figure 3. So far it has not been possible to identify physical causes (e.g. topography) to explain the variations in intercept. However, it is intended to explore this further when a re-analysis of extreme winds (incorporating more recent data and new techniques) is completed.

While no other pair of neighbouring stations has such a large difference between intercept values as that between Boscombe Down and Porton, differences large enough to invalidate the use of either Sachs' or Shellard's methods were found and a new station might well prove to be incompatible with its neighbours. Additionally the Sachs' method (by virtue of selecting the highest of the monthly ratios) is biased towards an overestimate.

8. CONCLUSIONS

For either Sachs' or Shellard's method to produce reasonably accurate estimates the ratio between the speeds at the two stations must be almost constant for all return periods; i.e. the lines of expected extremes must have similar 'Y' intercepts. As this intercept cannot be estimated for a new station and as neighbouring stations can have quite different intercepts neither method can be recommended. For sites in the UK the maps of basic design wind speed in CM 50A should be used as described in that publication.

REFERENCES

1. Sachs, P. - Wind forces in engineering. International series of monographs in Civil Engineering, Volume 3 - Pergamore Press, pp 45-47.
2. Shellard, H.C. - Wind Records and their application to Structural Design, Met Mag, London Vol, 91 (1962) pp 39-47.
3. CLIMATOLOGICAL MEMORANDUM 50A - Extreme Wind Speeds over the United Kingdom for periods ending 1971 - Hardman C.E., Helliwell N.C. and Hopkins J.S.

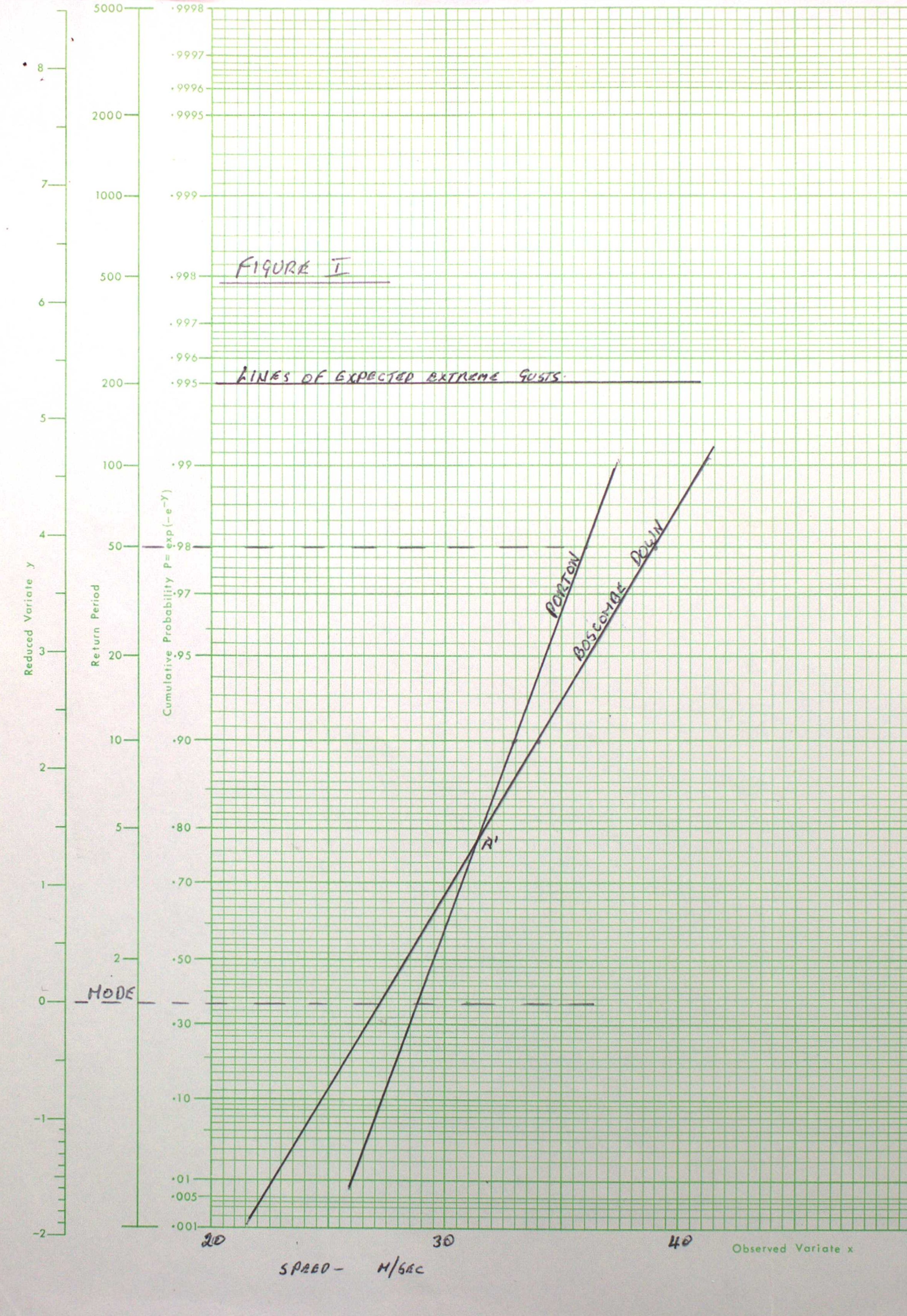

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FIGURE 2.

LINES OF EXPECTED EXTREME GUSTS

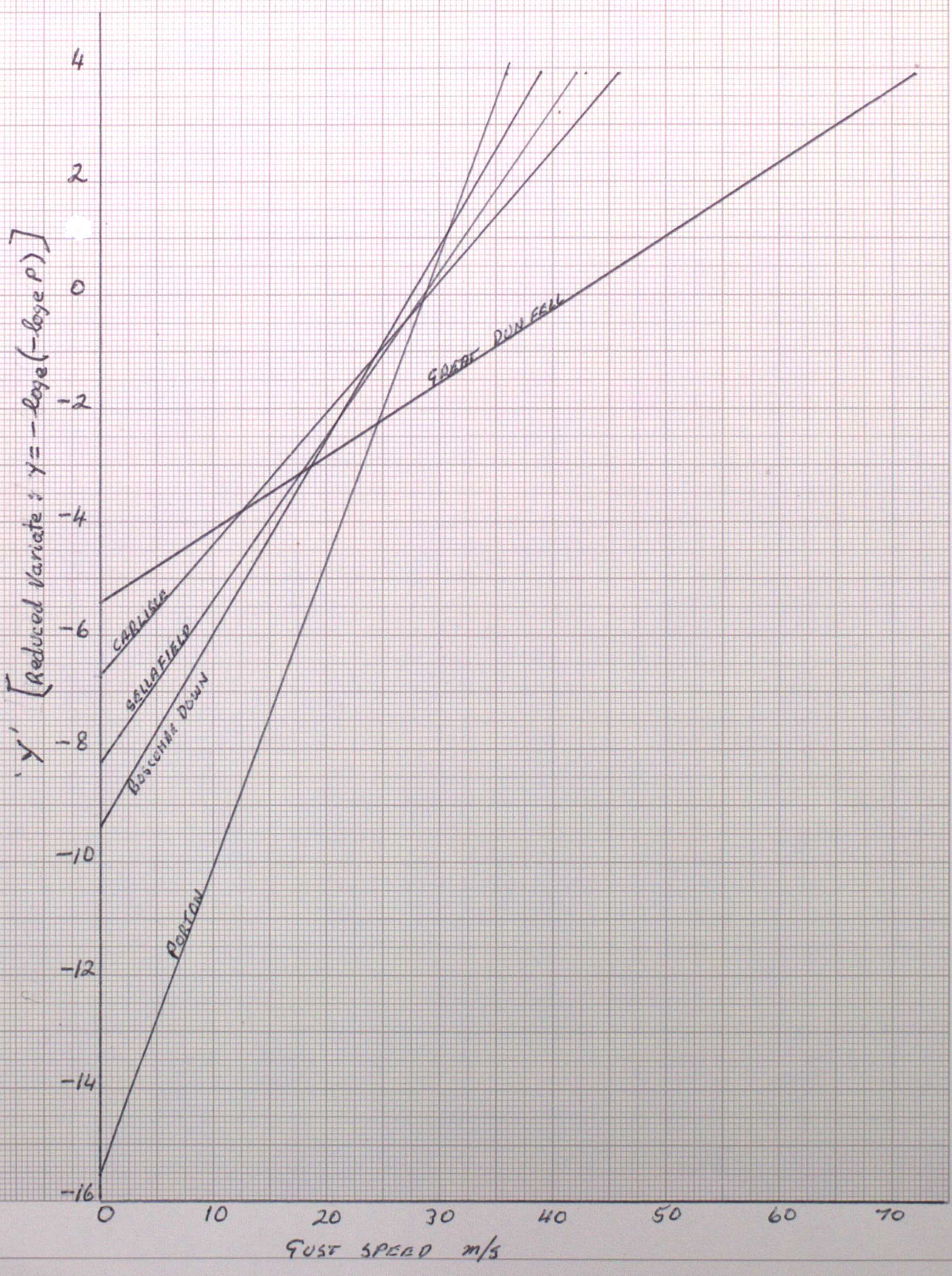

Figure 3.

Percentage Frequency Distribution of 'Y' intercept values of Lines of Extreme Gust

For 86 U.K. Anemograph stations.