DECIMAL INDEX
551.553.6: 551.553.8

METEOROLOGICAL OFFICE
CLIMATOLOGICAL SERVICES (Met O 3)

Climatological Memorandum No. 50

Corrigendum

It has been found, as a result of a comparison of overlapping records from the pressure-tube anemograph with effective height 23 feet and the new electrical anemograph with effective height 34 feet at Blackford Hill, that the maximum speeds quoted for Edinburgh should be corrected to read as follows:-

Table II	57	60	63	67	61	50.5
Table III	99	104	109	114	101	87.8

The following consequential changes should also be made:-

Table IV	Edinburgh	1.73
Table VI	Edinburgh	91 mph.

Fig 2	Speed of	62	at	Edinburgh	to	read		63
Fig 3	"	"	97	"	"	"	"	109
Fig 4	"	"	84	"	"	"	"	91

N.B. The isopleths of Figs 2, 3 and 4 are not changed because the Blackford Hill speeds represent an exposed shoulder of a hill at 450 feet above sea level and are higher than would be expected on open and more level sites in Edinburgh.

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DECIMAL INDEX
551.553.6 : 551.553.8

METEOROLOGICAL OFFICE

CLIMATOLOGICAL SERVICES (Met O 3)

CLIMATOLOGICAL MEMORANDUM No.50

Extreme wind speeds over the United Kingdom for periods ending 1963

By H. C. Shellard, B.Sc.

1. Introduction

This memorandum replaces Climatological Memorandum No. 6 and also incorporates most of the contents of the author's 1962 paper on extreme winds speeds.(1) At the same time the data published in the latter paper have been brought up to date, taking account of additional records for the four years ending December 31, 1963. The number of stations for which data are now presented is 100. Of these 66 have records ranging from 10 years to 50 years in length, the remaining 34 are stations with records from 4 to 9 years only.

For stations with 10 years or more of record the data have been analysed using the statistical theory of extreme values. The highest recorded speeds in each year have been made homogeneous by reducing them to the standard height of 10m (33 ft) above the ground by means of the formulae

$$V_{10} = V_h \left(\frac{10}{h}\right)^{0.17}$$ for speeds meaned over one hour(2)

$$V_{10} = V_h \left(\frac{10}{h}\right)^{0.085}$$ for gust speeds(3)

Each series has then been fitted by a Type I extreme value distribution, following the method of Gumbel.(4) Hence estimates have been obtained of the maximum mean hourly and maximum gust speeds likely to be exceeded on the average only once in 10, 20, 50 and 100 years at each station.

For the 34 stations whose records ranged from 4 to 9 years estimates were obtained by comparing their annual extreme speeds with those recorded over the same period at the nearest long-period station and applying the mean ratios so obtained to the once in 10, 20, 50 and 100 year estimates previously computed for the latter. Naturally these estimates are less reliable than those obtained by statistical analysis of ten years or more of recorded annual extremes, and can be considered as only a rough guide, to be superseded as soon as sufficient data become available for independent analysis. The highest speeds on record up to the end of 1964 are also given for each station.

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In addition to these data concerning maximum mean hourly speeds and maximum gusts, some estimates of maximum speeds averaged over 15 seconds are included. Such estimates were first made in 1964 in connection with revision of the British Standard Code of Practice on Loading (C.P.3, Chapter V)[5] by a B.S.I. Committee on which the author has represented the Meteorological Office. It may be noted too that an averaging period of 10-15 seconds has been suggested as being significant for the design of buildings by Scruton and Newberry[6].

2. Application of statistical theory of extreme values to maximum annual wind speeds

Table I lists the highest gust speeds in miles per hour recorded at Cardington in each of the years 1932 to 1954 inclusive, arranged in order of size from smallest to largest. The fourth column contains the corresponding values of $p = \frac{m}{n+1}$ where m is the rank and n the number of observations, in this case 23; they provide plotting positions for use on extreme probability graph paper and represent the probabilities that the corresponding values of x (highest gust) be not exceeded. Extreme probability graph paper has a linear scale along one axis, usually the vertical, and this is used for the observed values. The horizontal axis is the probability scale and is marked according to the formula $y = -\log_e(-\log_e p)$. The limiting values $p = 0$ and $p = 1$ are never reached but values of y range from -1.933 for $p = .001$ to 6.907 for $p = .999$. If a set of extreme annual wind speeds is fitted by the distribution then they will lie along a straight line when arranged in order of rank and plotted against $p = \frac{m}{n+1}$ on this special paper. If extreme value probability paper is not available then values of $y = -\log_e(\log_e p)$ can either be computed or taken from published tables[7]. The extremes can then be plotted against y on ordinary graph paper. Values of y for the set of highest gust data from Cardington are given in the last column of Table I and Fig. 1 shows the plotted data for both the highest gusts and the highest mean hourly speeds recorded at the station during the years 1932-1954 inclusive. Both the p and y scales are shown and also that of T, the return period in years, which is equal to $\frac{1}{1-p}$. This is the average time interval between recurrences of an event and is useful because it allows the annual maximum value which may be expected to be exceeded on the average only once in any desired number of years to be read off directly from the graph.

It can be seen from Fig. 1 that these Cardington wind data fit the theory quite well and the best straight lines have been computed and drawn in. The lines on either side are control curves which indicate the limits between which each extreme value should lie with a probability of .68, the theory being accepted if all the observations lie between them. By extrapolating the fitted straight line it is possible to predict the return period corresponding to any desired speed or the speed which has any desired return period. With only 20 to 30 years of record available it would

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probably be unwise to carry the extrapolation very far, certainly not beyond 100 years. Thus from Fig. 1 it may be inferred that the speeds which are likely to be exceeded only once in 50 years are 103 m.p.h. in a gust and 66 m.p.h. averaged over one hour. These speeds relate to the effective height of the Cardington anemograph, i.e. 135 feet above the ground. Whether the speeds are reduced to the standard height of 33 ft. before or after the computions are made, using the formulae given in Section 1, is of course immaterial. It is important, however, that any necessary reductions be made beforehand in cases where the effective height of the anemometer has changed during the period of the record.

3. Results

The wind data from 66 anemograph stations have been analysed in this way and the results are set out in Table II(a), which refers to mean hourly speeds, and in Table III(a), which refers to gust speeds. All values refer to a height of 10 metre (33 ft.) above the ground and have been reduced to that level using the formulae of Section 1. The mean annual maximum and highest speeds actually recorded up to December 1963, both reduced to 33 feet, together with details of the years of record used, are also indicated. In Tables II(b) and III(b) are given corresponding mean hourly and gust speed data for 34 additional stations whose records ranged in length from 4 to 9 years, the values having been obtained as follows. The sum of the available annual extremes, corrected to standard height, was expressed as a fraction of the sum of the extremes for the same years at the nearest of the long-period stations listed in part (a) of the table. The once in 10, 20, 50 and 100 years speeds for the long period station were then multiplied by this fraction to give the estimated values for entry in the corresponding columns in part (b) of the table for the station concerned. For example, the sums of the annual maximum gusts at Benbecula and Stornoway, corrected to 33 feet, were 654 and 685 respectively; hence the estimated once in 50 years maximum gust at Benbecula is approximately $\frac{654}{685} \times 125 = 119$ mph. Comparison with Tiree instead of Stornoway gave $\frac{654}{659} \times 120 = 119$ mph, the same result.

The highest mean hourly speeds at 33 feet above the ground likely to be exceeded on the average only once in 50 years are plotted in Fig.2 on a map of the United Kingdom on which tentative isopleths are drawn at intervals of 10 mph. Fig.3 similarly shows the general distribution of gust speeds likely to be exceeded on the average only once in 50 years. It must be emphasised, however, that extreme wind speeds are appreciably influenced by local topography and that these maps give only a broad picture based on wind records from, generally speaking, open and level sites. Interpolation with the aid of such maps should therefore be carried out with considerable caution. Values so obtained may need appreciable adjustment according to special conditions affecting the site concerned, e.g. topographical features, general exposure and possible effects of local obstructions.

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4. Estimation of maximum speeds averaged over short periods of time

The current British Code of Practice concerned with the calculation of wind loading on buildings[5] requires the basic design wind speed to be the highest expected wind speed averaged over one minute and it is likely that the revised Code will specify the use of an average over a shorter period, probably 15 seconds, as a basic speed for the design of whole structures, with an even shorter period, probably 3 seconds, for the design of certain unclad structures or of individual members of buildings. The records from standard anemographs have too close a time scale for mean speeds to be measured over periods of one minute or less, however, and the readily available statistics are limited to means over one hour and details of the highest gusts. The highest speeds averaged over periods of 1 minute and 15 seconds will clearly lie somewhere between the highest mean hourly speed and the highest gust, while the highest 3-second mean will approximate to the highest gust speed, since the gusts that are fully recorded by an anemograph have durations of 3 seconds or more. A possible solution is to multiply the maximum mean hourly speed by factors, derived from experimental open-scale recordings of wind data, relating the one minute and 15-second maxima to the hourly maximum. Durst[8] has analysed some open-scale records from Cardington and obtained the following factors:-

Ratio of probable maximum speed averaged over time 't' to that averaged over one hour

t	1 hr.	10 min.	1 min.	30 sec.	20 sec.	10 sec.	5 sec.
Ratio	1.00	1.06	1.24	1.33	1.36	1.43	1.47

Durst emphasised that these factors refer only to sites where the wind is unobstructed and the topography flat.

Table IV, based on the data in Tables II(a) and III(a) gives the ratio of the once in 50 years maximum gust to the once in 50 years mean hourly speed at each station. It will be noted that these range from 1.46 to 2.32 with an average value of 1.72 and a median value of 1.68. In general the lowest factors relate to very open sites on flat land, usually near the coast, and the highest relate to built-up areas or sites that are obstructed by trees or buildings. This was to be expected because this ratio is one measure of the gustiness or scale of turbulence and this depends on the roughness of the terrain, increasing as the roughness increases. Hence it may be deduced that Durst's factors will be too low for urban and city exposures and too high for flat coastal exposures. In 1963 the author[9] very tentatively suggested, until further data became available, the following factors for estimating maximum speeds over one minute, 30 seconds and 10 seconds respectively:-

	1 min.	30 sec.	10 sec.
(a) Open rural exposures	1.25	1.33	1.45
(b) Urban and city exposures	1.45	1.60	1.80

/However,

References

(1) Shellard, H. C. Extreme wind speeds over the United Kingdom for periods ending 1959. Met. Mag. 1962, 91, p.39.

(2) Carruthers, N. Variation in wind velocity near the ground. Q.J.R. Met. Soc., 1943, 69, p.293.

(3) Deacon, E. L. Gust variation with height up to 150m. Q.J.R. Met. Soc., 1955, 81, p.562.

(4) Gumbel, E. J. Statistical theory of extreme values and some practical applications. Appl. Maths. Ser., Nat. Bur. Stand., 1954, No. 33.

(5) London, British Standards Institution; British Standard Code of Practice. CP3-ChV, Loading, 1952.

(6) Scruton C. and Newberry C.W. On the estimation of wind loads for building and structural design. Proc. Instn. Civ. Engrs., 25, June 1963, p.97.

(7) Washington, D.C., Nat. Bur. Stand; Probability tables for the analysis of extreme value data. Appl. Maths. Ser., Nat. Bur. Stand., 1953, No. 22.

(8) Durst, C. S. Wind speeds over short periods of time. Met. Mag. 1960, 89, p.181.

(9) Shellard, H. C. The estimation of design wind speeds. N.P.L. Symposium No. 16, Wind Effects on Buildings and Structures, Vol. 1, p.29, London, 1965.

(10) Faber, S. E. and Bell, G. J. Typhoons in Hong Kong and building design. Proc. Eng. Soc. Hong Kong, 1963.

However, a paper by Faber and Bell[10] has provided some factors for the city of Hong Kong which suggest that the above ratios for urban exposures may be too high. Their values were 1.28, 1.42 and 1.64 for the three averaging periods respectively, with a ratio of maximum gust to maximum hourly speed of 2.05.

It is now suggested that the factors used for estimating maximum speeds over periods between one hour and a few seconds should be related to the roughness of the terrain, as indicated by the ratio of maximum gust to maximum hourly speed. Suggested factors are given in Table V, it being assumed that the maximum gust has a duration of about 3 seconds.

Table V. Factors for estimating maximum speeds over short period 't' from maximum hourly speeds

Ratio of max. gust to max. hourly speed	t = 10 min.	1 min.	30 sec.	15 secs.	10 secs.	3 sec.
1.4	1.05	1.17	1.22	1.27	1.30	1.40
1.5	1.05	1.20	1.26	1.33	1.37	1.50
1.6	1.06	1.23	1.30	1.38	1.43	1.60
1.7	1.06	1.25	1.34	1.44	1.50	1.70
1.8	1.06	1.27	1.37	1.48	1.55	1.80
1.9	1.06	1.28	1.39	1.52	1.60	1.90
2.0	1.06	1.29	1.42	1.56	1.66	2.00
2.1	1.06	1.30	1.44	1.60	1.71	2.10

These values are of course subject to further revision as more open-scale recordings in strong winds become available, in particular those which it is planned to obtain in central London.

Using the factors of Table V in conjunction with the once in 50 years extremes of Tables II and III, estimates have been made of the once in 50 years maximum speeds, averaged over 15 seconds at 33 feet, and these are given in Table VI. Fig. 4, on which tentative isopleths are drawn at intervals of 10 mph, shows the distribution of the maximum 15-second winds over the United Kingdom.

/References

Table I

ANNUAL MAXIMUM WIND SPEEDS (GUSTS) AT CARDINGTON, 1932–54				
RANK m	HIGHEST GUST m.p.h.	YEAR	PLOTTING POSITION $p = \frac{m}{N+1}$	REDUCED VARIATE $y = -\log_e(-\log_e p)$
1	55	1953	0·042	−1·16
2	59	1950	0·083	−0·91
3	60	1941	0·125	−0·73
4	61	1951	0·167	−0·58
5	62	1952	0·208	−0·45
6	63	1937	0·250	−0·33
7	63	1939	0·292	−0·21
8	64	1942	0·333	−0·09
9	65	1933	0·375	0·02
10	67	1949	0·417	0·13
11	68	1948	0·458	0·25
12	69	1945	0·500	0·37
13	71	1940	0·542	0·49
14	72	1934	0·583	0·62
15	72	1944	0·625	0·75
16	76	1954	0·667	0·90
17	78	1943	0·708	1·06
18	78	1946	0·750	1·25
19	81	1932	0·792	1·46
20	82	1936	0·833	1·70
21	86	1938	0·875	2·01
22	88	1935	0·917	2·44
23	93	1947	0·958	3·15

Table II. Maximum mean hourly wind speeds (mph) at 33ft above the ground

Station	No. of yrs. record	Period of record used	Speeds likely to be exceeded only once in stated no. of years				Highest on record	Mean annual maximum
(a)			10	20	50	100		
Lerwick	33	1931-63	68	72	77	81	73	58.1
Kirkwall	14	1930-43	58	61	65	69	59	50.1
Stornoway	27	1937-63	70	75	81	85	73	59.5
Aberdeen	15	1933-47	44	47	52	55	44	35.5
Dyce	12	1952-63	56	61	68	73	61	43.2
Balmakewan	21	1915-35	45	48	53	56	51	36.8
Bell Rock	33	1930-55, 57-63	56	59	63	66	60	48.8
Leuchars	15	1949-63	49	52	56	59	51	41.9
Edinburgh	46	1915-33, 36-62	56	58	62	65	59	48.8
Tiree	37	1927-63	65	70	76	81	71	53.3
Millport	14	1950-63	59	63	69	73	57	47.8
Paisley	50	1914-63	42	44	47	49	46	36.2
Renfrew	18	1946-63	50	53	58	61	51	41.8
Prestwick	20	1944-63	51	54	58	61	51	43.7
Eskdalemuir	40	1914-45, 56-63	53	57	61	64	56	46.1
Point of Ayre	28	1936-63	57	61	65	68	63	49.4
Durham	26	1938-63	48	51	55	58	50	41.3
South Shields	30	1934-63	53	57	62	66	61	43.6
Catterick	10	1933-42	51	56	62	67	49	38.8
Spurn Head	32	1922-46, 48-50, 54, 56-58	56	58	62	64	59	49.9
Cranwell	33	1928-44, 47-48, 50-63	46	49	53	57	49	38.6
Gorleston	41	1913-31, 34-39, 41-48 1951-57, 63	50	53	56	59	55	43.9
Mildenhall	26	1938-63	46	49	54	57	56	37.1
Felixstowe	22	1931-35, 37-38, 44-52 1954-59	45	48	51	53	45	39.0
Dunstable	14	1944-48, 51-59	46	49	54	57	48	37.4
Cardington	32	1932-63	46	49	53	57	50	37.2
Rothamsted	10	1955-64	30	32	34	35	30	26.7
Stevenage	10	1950-59	40	43	46	50	39	34.0
Shoeburyness	38	1926-63	48	51	55	58	53	40.7
Leicester	10	1938-40, 43-45, 47-50	45	50	56	61	42	33.0
Birmingham	40	1924-63	37	39	42	45	38	31.8
Keele	11	1953-63	37	38	41	42	38	32.2
Avonmouth	11	1953-63	52	54	57	60	52	45.6
Kingsway	14	1944-54, 61-63	36	38	42	44	35	29.7
Hampton	14	1950-63	34	36	39	41	34	28.7
Croydon	27	1928-39, 44-58	41	43	46	49	45	34.7
Southgate	22	1939-41, 45-63	32	34	37	38	32	27.3
Kew	33	1931-63	33	35	37	39	37	29.3
Dover	30	1924-39, 48-50, 53-63	43	45	47	49	46	39.5
Lympne	27	1923-29, 31-43, 45-51	48	50	54	56	52	42.0
Manston	12	1943-54	46	48	51	54	45	39.6
Thorney Is.	21	1943-63	42	45	48	51	45	35.7
Calshot I	24	1920, 22-41, 50-52	51	54	58	61	50	43.0
S. Farnborough	19	1945-63	45	49	53	57	49	35.8
Abingdon	17	1944-45, 49-63	39	41	44	46	40	33.2
Larkhill	33	1931-63	45	47	50	52	46	40.1
Boscombe Down	31	1933-63	47	50	54	57	49	39.7
Porton	10	1954-63	43	44	46	47	42	39.6
Sellafield	14	1950-63	51	53	57	60	50	43.2
Fleetwood	36	1924-43, 46-57, 60-63	61	64	69	72	62	52.1
Southport	49	1913-54, 57-63	59	62	67	70	65	50.8
Speke	15	1948-50, 52-63	50	52	55	58	51	43.8
Bidston	35	1929-63	55	59	64	67	62	46.8
Ringway	19	1942-50, 54-63	51	54	59	62	54	43.1
Sealand	19	1928-41, 43-47	49	52	56	59	53	41.4

/Holyhead

Holyhead	19	1933-51	61	64	69	73	64	51.7
Valley	12	1952-63	60	64	69	72	58	50.7
Aberporth	19	1945-63	55	59	63	67	55	47.0
Port Talbot	12	1952-63	54	58	63	67	53	44.8
St. Ann's Head*	14	1935-46, 48-49	57	62	69	74	58	45.6
Milford Haven	12	1951-62	50	53	57	59	51	43.7
Plymouth	39	1921-43, 47-48, 50-63	53	57	61	64	58	45.7
Lizard	26	1935-42, 45-47, 49-63	61	64	68	71	67	54.5
Pendennis*	20	1929-38, 41-50	48	50	53	55	49	42.6
Scilly	37	1927-63	62	65	70	73	63	52.7
Aldergrove	34	1928-46, 49-63	48	51	55	58	52	40.6
(b)								Comparison station used
Grimsetter	8	1957-64	63	67	71	75	68	Lerwick
Dounreay	6	1959-64	64	67	72	76	61	Lerwick
Halkirk	4	1959-62	54	58	62	65	56	Lerwick
Butt of Lewis	6	1930-35	71	74	79	84	63	Kirkwall
Benbecula	8	1957-64	66	71	77	82	66	Tiree
Lossiemouth	5	1960-64	55	59	62	66	66	Dounreay
Auchterhouse	4	1960-63	45	48	51	54	46	Leuchars
Rannoch	6	1959-64	56	60	65	69	63	Tiree
Lowther Hill	4	1961-64	95	101	109	114	99	Prestwick
Duirinish	5	1960-64	61	66	71	76	57	Tiree
West Freugh	4	1961-64	59	63	68	71	63	Point of Ayre
Ronaldsway	4	1961-64	67	72	77	80	63	Point of Ayre
Stanstead Abbotts	4	1958-61	34	36	38	40	30	Kew
Coryton	6	1959-64	35	37	40	42	32	Shoeburyness
Sheffield+	6	1959-64	37	39	42	46	46	Cranwell
Elmdon	4	1961-64	53	56	60	64	47	Birmingham
Amersham	4	1961-64	29	31	33	35	32	Kew
London Airport	6	1959-64	42	45	47	50	41	Kew
Gatwick	5	1960-64	43	46	49	51	43	Kew
S. Kensington	9	1930-38	30	32	34	36	33	Kew
Isle of Grain	9	1956-64	42	45	48	51	45	Shoeburyness
Rye	8	1945-52	49	51	55	57	51	Lympne
Calshot II	6	1959-64	50	53	57	60	44	Thorney Is.
Hurn	5	1960-64	46	50	53	56	42	Thorney Is.
Winfrith	4	1960-63	52	55	59	63	43	Thorney Is.
Carlisle	4	1961-64	44	46	49	52	43	Sellafield
Spadeadam	5	1960-64	55	59	63	66	51	Eskdalemuir
Moor House	9	1956-64	55	59	63	67	54	Durham
Manchester (Barton)	8	1934-41	47	50	54	56	48	Southport
Kete	7	1952-58	61	66	70	75	63	Aberporth
Rhoose	6	1959-64	55	60	65	69	50	Port Talbot
Ballykelly	7	1958-64	55	58	63	66	60	Aldergrove
Nutts Corner	4	1959-62	47	49	53	56	52	Aldergrove
Jersey Airport	7	1958-64	62	65	69	72	73	Lizard

*Effective heights of 212 and 256 feet (i.e. the heights of the vanes above msl) have been adopted for St. Ann's Head and Pendennis, respectively, as being more realistic than those assigned hitherto.

+Omitting the exceptional speeds recorded in the lee-wave gales of February 1962, the values in columns 4 to 7 become 34, 36, 39 and 42 mph, respectively.

Table III. Maximum gust speeds (mph) at 33 ft above the ground

Station	No. of yrs. record	Period of record used	Speeds likely to be exceeded only once in stated no. of years				Highest on record	Mean annual maximum
(a)			10	20	50	100		
Lerwick	33	1931-63	101	106	113	118	108	88.5
Kirkwall	14	1930-43	92	97	102	106	100	82.3
Stornoway	27	1937-63	108	115	126	132	112	89.5
Aberdeen	15	1933-47	78	83	89	93	83	67.8
Dyce	12	1952-63	92	100	112	121	99	69.8
Balmakewan	21	1915-35	76	82	89	94	87	62.8
Bell Rock	33	1930-55, 57-63	88	92	99	104	91	75.8
Leuchars	15	1949-63	83	88	96	100	84	68.9
Edinburgh	46	1915-33, 36-62	86	91	97	100	89	77.0
Tiree	37	1927-63	101	109	120	128	113	83.1
Millport	14	1950-63	98	106	116	123	108	79.5
Paisley	50	1914-63	88	93	101	106	105	75.2
Renfrew	18	1946-63	93	100	108	115	96	76.0
Prestwick	20	1944-63	84	89	94	99	87	73.6
Eskdalemuir	40	1914-45, 56-63	86	91	98	103	90	74.3
Point of Ayre	28	1936-63	86	92	96	100	89	75.5
Durham	26	1938-63	89	94	100	105	95	76.7
South Shields	30	1934-63	83	88	96	101	86	68.9
Catterick	10	1933-42	86	92	99	105	88	71.1
Spurn Head	32	1922-46, 48-50, 54 56-58	85	90	96	101	91	73.1
Cranwell	33	1928-44, 47-48, 50-63	83	90	99	106	107	67.2
Gorleston	41	1913-31, 34-39, 41-48 1951-57, 63	76	81	86	90	82	66.5
Mildenhall	26	1938-63	85	91	99	105	94	69.9
Felixstowe	22	1931-35, 37-38, 44-52 54-59	80	86	93	98	85	66.5
Dunstable	14	1944-48, 51-59	79	86	95	102	82	62.1
Cardington	32	1932-63	77	82	89	94	83	64.0
Rothamsted	10	1955-64	70	74	79	83	73	60.7
Stevenage	10	1950-59	75	80	87	91	73	63.2
Shoeburyness	38	1926-63	76	80	86	91	79	64.4
Leicester	10	1938-40, 43-45, 47-50	83	91	101	108	84	65.2
Birmingham	40	1924-63	74	79	85	90	79	62.4
Keele	11	1953-63	81	86	93	99	85	67.0
Avonmouth	11	1953-63	84	90	97	103	84	70.0
Kingsway	14	1944-54, 61-63	78	84	93	99	78	62.5
Hampton	14	1950-63	70	74	80	84	69	59.5
Croydon	27	1928-39, 44-58	74	78	84	88	77	64.0
Southgate	22	1939-41, 45-63	61	64	68	70	62	54.1
Kew	33	1931-63	69	73	77	80	70	61.3
Dover	30	1924-39, 48-50, 53-63	80	85	92	97	88	66.8
Lympne	27	1923-29, 31-43, 45-51	80	84	89	93	84	69.8
Manston	12	1943-54	78	82	87	91	80	68.1
Thorney Is.	21	1943-63	77	81	86	90	80	67.0
Calshot I	24	1920, 22-41, 50-52	80	85	92	98	86	67.2
S. Farnborough	19	1945-63	75	79	84	87	79	65.7
Abingdon	17	1944-45, 49-63	73	78	85	90	77	60.0
Larkhill	33	1931-63	78	82	86	89	79	70.5
Boscombe Down	31	1933-63	78	83	90	95	86	65.9
Porton	10	1954-63	73	76	81	84	71	64.5
Sellafield	14	1950-63	82	87	93	97	87	71.3
Fleetwood	36	1924-43, 46-57, 60-63	89	94	101	106	92	76.9
Southport	49	1913-54, 57-63	88	93	100	105	92	76.0
Speke	15	1948-50, 52-63	87	93	100	106	86	74.1
Bidston	35	1929-63	94	99	106	111	100	81.3
Ringway	19	1942-50, 54-63	84	89	95	100	90	72.7
Sealand	19	1928-41, 43-47	82	87	93	97	86	70.7

/Holyhead

Holyhead	19	1933-51	94	100	107	113	107	79.1
Valley	12	1952-63	92	97	105	110	89	78.8
Aberporth	19	1945-63	89	94	101	106	92	76.2
Port Talbot	12	1952-63	83	87	92	95	82	74.1
St. Ann's Head*	14	1935-46, 48-49	96	103	112	117	98	80.8
Milford Haven	12	1951-62	87	92	99	104	96	74.1
Plymouth	39	1921-43, 47-48, 50-63	79	84	90	95	90	67.0
Lizard	26	1935-42, 45-47, 49.63	92	96	101	105	93	83.3
Pendennis*	20	1929-38, 41-50	86	91	98	103	87	73.0
Scilly	37	1927-63	95	101	108	113	106	82.6
Aldergrove	34	1928-46, 49-63	83	88	94	99	87	72.5
(b)								Comparison station used
Grimsetter	8	1957-64	102	107	114	119	109	Lerwick
Dounreay	6	1959-64	101	106	113	118	100	Lerwick
Halkirk	4	1959-62	84	88	94	98	90	Lerwick
Butt of Lewis	6	1930-35	100	106	111	116	99	Kirkwall
Benbecula	8	1957-64	100	108	119	127	108	Tiree
Lossiemouth	5	1960-64	89	93	99	104	100	Dounreay
Auchterhouse	4	1960-63	75	80	87	91	72	Leuchars
Rannoch	6	1959-64	91	98	108	115	101	Tiree
Lowther Hill	4	1961-64	132	140	148	155	122	Prestwick
Duirinish	5	1960-64	96	103	114	122	95	Tiree
West Freugh	4	1961-64	90	97	101	105	94	Point of Ayre
Ronaldsway	4	1961-64	94	101	105	110	88	Point of Ayre
Stanstead Abbotts	4	1958-61	68	72	76	79	62	Kew
Coryton	6	1959-64	68	72	77	82	65	Shoeburyness
Sheffield+	6	1959-64	92	100	109	117	96	Cranwell
Elmdon	4	1961-64	86	92	99	104	76	Birmingham
Amersham	4	1961-64	65	69	72	75	68	Kew
London Airport	6	1959-64	75	79	83	86	69	Kew
Gatwick	5	1960-64	81	85	90	94	81	Kew
S. Kensington	9	1930-38	71	75	79	82	72	Kew
Isle of Grain	9	1956-64	70	74	79	84	71	Shoeburyness
Rye	8	1945-52	72	75	80	83	71	Lympne
Calshot II	6	1959-64	76	80	85	89	66	Thorney Is.
Hurn	5	1960-64	80	85	90	94	69	Thorney Is.
Winfrith	4	1960-63	81	86	91	95	70	Thorney Is
Carlisle	4	1961-64	80	84	90	94	72	Sellafield
Spadeadam	5	1960-64	84	89	96	101	79	Eskdalemuir
Moor House	9	1956-64	91	96	102	107	85	Durham
Manchester (Barton)	8	1934-41	84	88	95	100	85	Southport
Kete	7	1952-58	97	103	110	116	108	Aberporth
Rhoose	6	1959-64	82	86	90	93	84	Port Talbot
Balleykelly	7	1958-64	93	99	105	111	105	Aldergrove
Nutts Corner	4	1959-62	85	90	96	101	92	Aldergrove
Jersey Airport	7	1958-64	93	97	102	106	104	Lizard

*Effective heights of 212 and 256 ft. (i.e. the heights of the vanes above msl) have been adopted for St. Ann's Head and Pendennis, respectively, as being more realistic than those assigned hitherto.

+Omitting the exceptional speeds recorded in the lee-wave gales of February, 1962, the values in columns 4 to 7 become 87, 95, 104 and 111 respectively.

Table IV. Ratio of maximum gust speed (g) to maximum mean hourly speed (v), on once in 50 year basis, at 33 feet above the ground

Station	$g/_v$	Station	$g/_v$	Station	$g/_v$
Lerwick	1.47	Mildenhall	1.83	Abingdon	1.93
Kirkwall	1.57	Felixstowe	1.82	Larkhill	1.72
Stornoway	1.56	Dunstable	1.76	Boscombe Down	1.67
Aberdeen	1.71	Cardington	1.68	Porton	1.76
Dyce	1.65	Rothamsted	2.32	Sellafield	1.63
Balmakewan	1.68	Stevenage	1.89	Fleetwood	1.46
Bell Rock	1.57	Shoeburyness	1.56	Southport	1.49
Leuchars	1.71	Leicester	1.80	Speke	1.82
Edinbrugh	1.57	Birmingham	2.02	Bidston	1.66
Tiree	1.58	Keele	2.27	Ringway	1.61
Millport	1.68	Avonmouth	1.70	Sealand	1.66
Paisley	2.15	Kingsway	2.21	Holyhead	1.55
Renfrew	1.86	Hampton	2.05	Valley	1.52
Prestwick	1.62	Croydon	1.83	Aberporth	1.60
Eskdalemuir	1.61	Southgate	1.84	Port Talbot	1.46
Point of Ayre	1.48	Kew	2.08	St. Ann's Head	1.62
Durham	1.82	Dover	1.96	Milford Haven	1.74
South Shields	1.55	Lympne	1.65	Plymouth	1.48
Catterick	1.60	Manston	1.71	Lizard	1.49
Spurn Head	1.55	Thorney Is.	1.79	Pendennis	1.85
Cranwell	1.87	Calshot I	1.59	Scilly	1.54
Gorleston	1.54	S. Farnborough	1.58	Aldergrove	1.71

Table VI. Estimated maximum speeds averaged over 15 seconds, on a once in 50 years basis at 33 feet above the ground

Station	15-sec. max. mph	Station	15-sec. max. mph	Station	15 sec. max. mph	Station	15 sec. max. mph
Lerwick	101	Cardington	75	Southport	88	Duirinish	99
Kirkwall	88	Rothamsted	57	Speke	82	West Freugh	90
Stornoway	110	Stevenage	70	Bidston	90	Ronaldsway	96
Aberdeen	75	Shoeburyness	75	Ringway	82	Stanstead Abbotts	59
Dyce	96	Leicester	83	Sealand	79	Coryton	61
Balmakewan	75	Birmingham	66	Holyhead	93	Sheffield	75*
Bell Rock	86	Keele	68	Valley	92	Elmdon	85
Leuchars	81	Avonmouth	82	Aberporth	87	Amersham	54
Edinburgh	84	Kingsway	69	Port Talbot	82	London Airport	69
Tiree	104	Hampton	62	St. Ann's Head	96	Gatwick	73
Millport	98	Croydon	69	Milford Haven	83	S. Kensington	57
Paisley	76	Southgate	56	Plymouth	81	Isle of Grain	68
Renfrew	87	Kew	59	Lizard	90	Rye	72
Prestwick	81	Dover	72	Pendennis	79	Calshot II	75
Eskdalemuir	85	Lympne	76	Scilly	95	Hurn	76
Point of Ayre	86	Manston	73	Aldergrove	79	Winfrith	80
Durham	82	Thorney Is.	71	Grimsetter	99	Carlisle	74
South Shields	84	Calshot I	80	Dounreay	98	Spadeadam	84
Catterick	86	S. Farnborough	73	Halkirk	83	Moor House	88
Spurn Head	84	Abingdon	67	Butt of Lewis	101	Barton	79
Cranwell	80	Larkhill	72	Benbecula	104	Kete	95
Gorleston	76	Boscombe Down	77	Lossiemouth	86	Rhoose	82
Mildenhall	80	Porton	67	Auchterhouse	74	Ballykelly	89
Felixstowe	76	Sellafield	80	Rannoch	92	Nutts Corner	78
Dunstable	79	Fleetwood	90	Lowther Hill	136	Jersey Airport	91

*71 mph, omitting exceptional lee-wave gales of February 1962

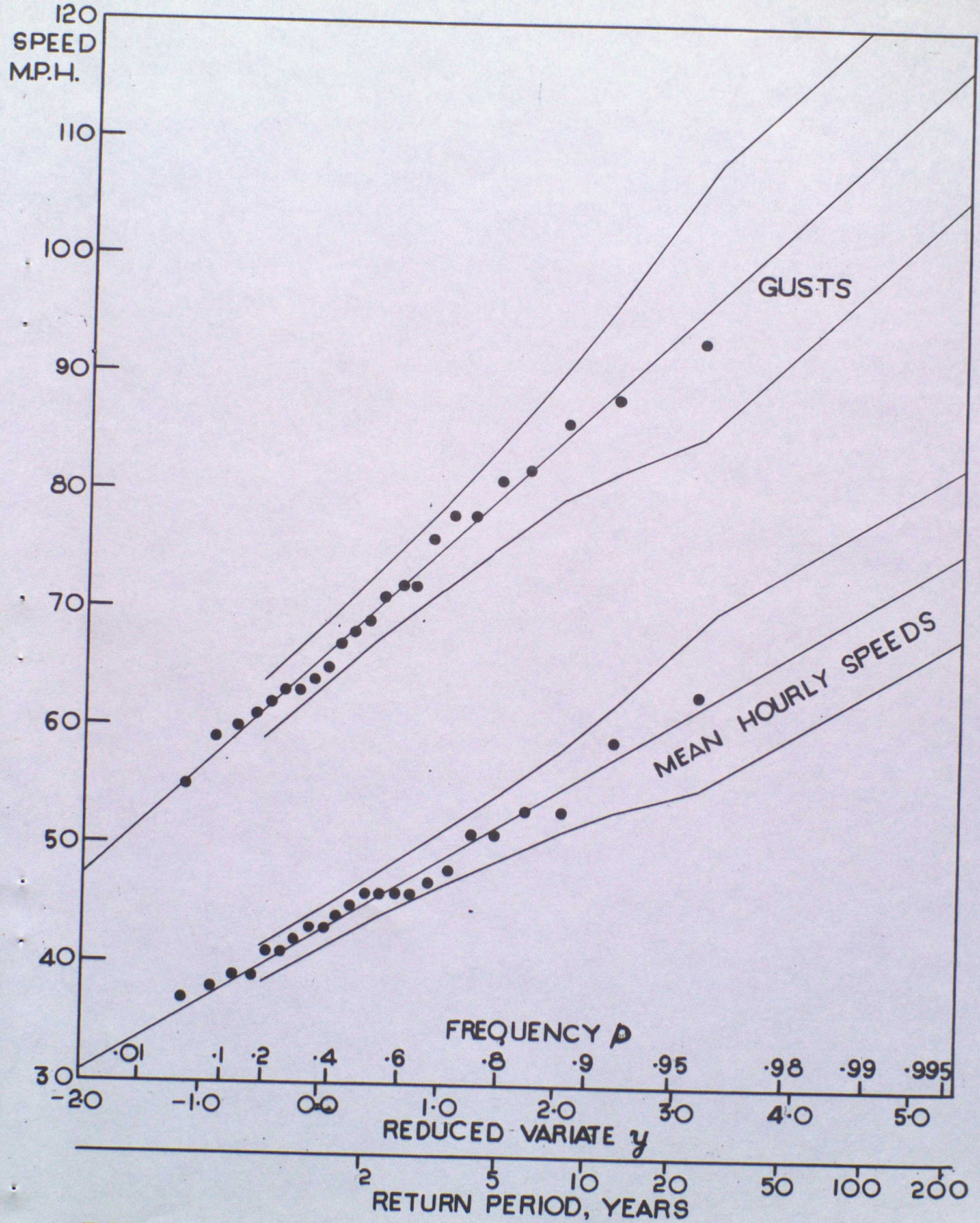


FIG I. ANNUAL MAXIMUM WIND SPEEDS, CARDINGTON 1932-54

Fig 2. Highest mean hourly speed (mph) at 33 ft likely to be exceeded only once in 50 years
(Values based on less than 15 years of record are underlined)

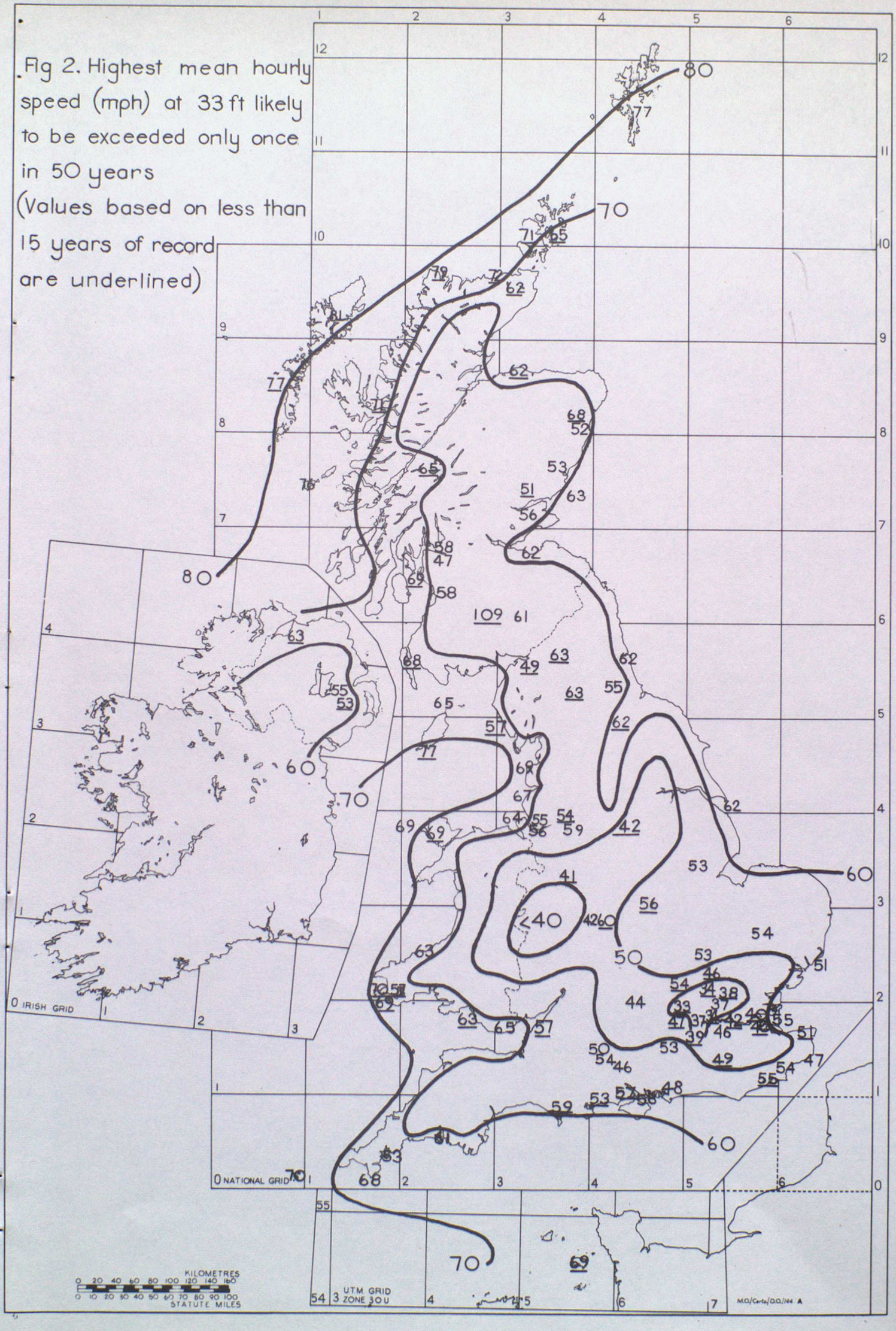
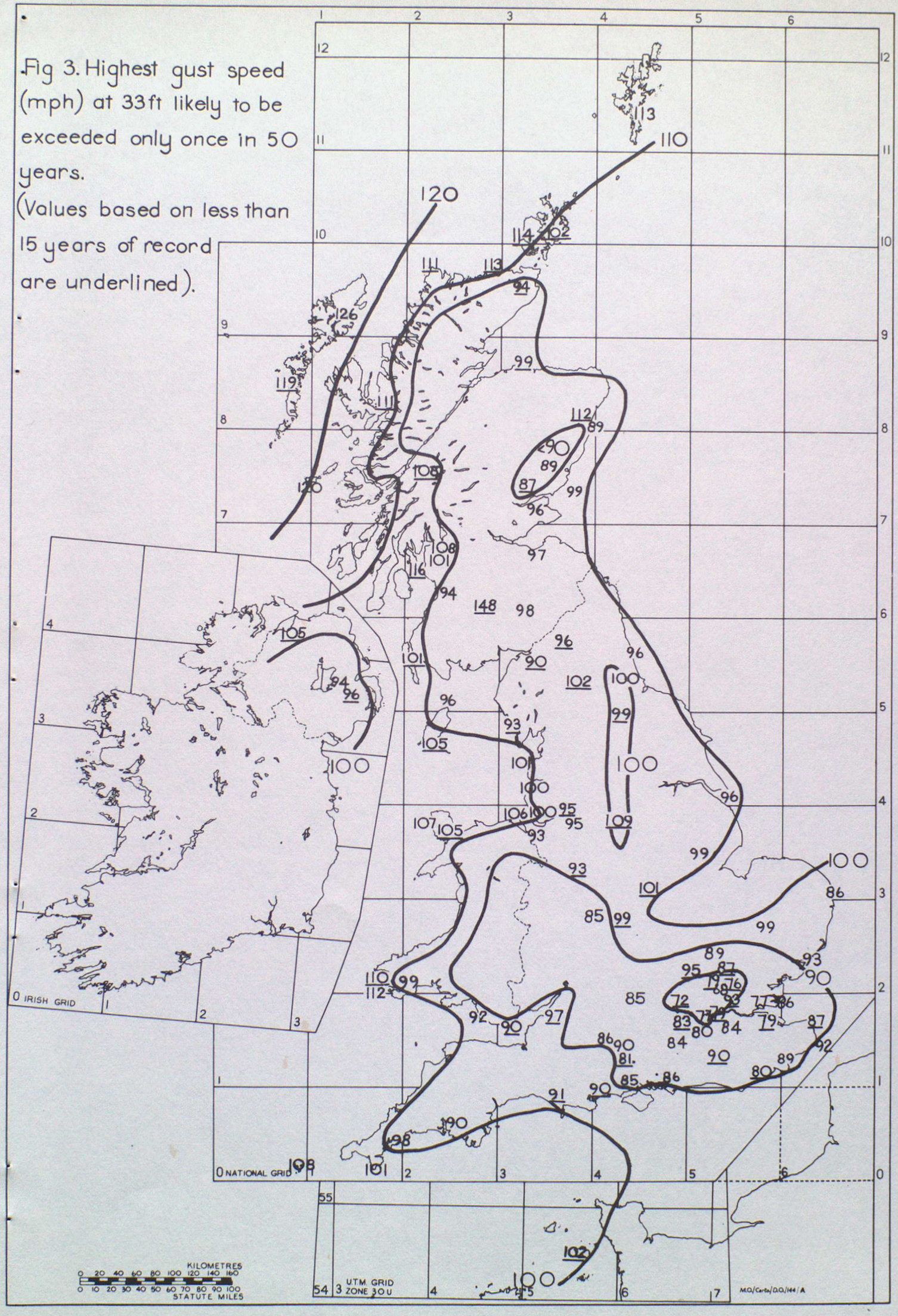


Fig 3. Highest gust speed (mph) at 33ft likely to be exceeded only once in 50 years.
(Values based on less than 15 years of record are underlined).



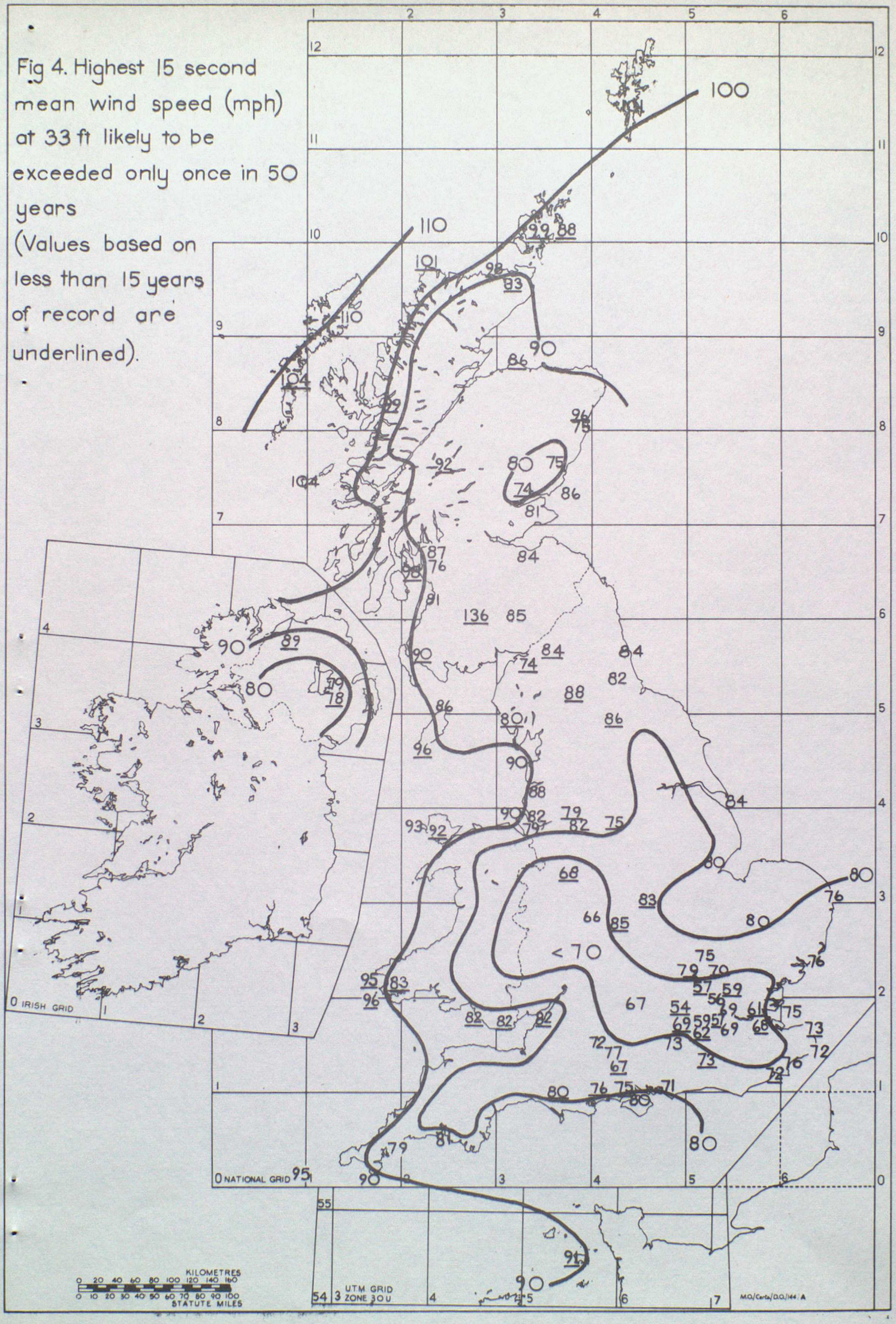


Fig 4. Highest 15 second mean wind speed (mph) at 33 ft likely to be exceeded only once in 50 years (Values based on less than 15 years of record are underlined).