C.P. No. 429
(20,645)
A.R.C. Technical Report

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Atmospheric Turbulence Encountered by Bristol Freighter Aircraft in United Kingdom, West Africa and New Zealand

by

J. R. Heath-Smith, B.Sc.(Eng.)

LONDON: HER MAJESTY'S STATIONERY OFFICE

1959

PRICE 3s. 6d. NET

C.P. No. 429

ERRATUM

The pair of lines labelled "1" in Fig.4 are in error and may be replotted by consulting the first item in Table 13.

C.P. No. 429

U.D.C. No. 533.6.048.5(42):533.6.048.5(66):533.6.048.5(931):
551.551 Bristol Freighter

Technical Note Structures 251

October, 1958

ROYAL AIRCRAFT ESTABLISHMENT

ATMOSPHERIC TURBULENCE ENCOUNTERED BY BRISTOL FREIGHTER AIRCRAFT IN UNITED KINGDOM, WEST AFRICA AND NEW ZEALAND

by

J.R. Heath-Smith B.Sc. (Eng)

SUMMARY

Gust accelerations were recorded during 1,500 hours of flying below 10,000 ft by Freighter aircraft in United Kingdom, West Africa and New Zealand.

The gust frequencies in the three regions are compared and the influence of the flight plan on the values recorded is discussed.

The average distance between gusts greater than 10 ft/sec, E.A.S. within 1,000 ft of the ground, varies from two miles in New Zealand to twelve miles in West Africa. Over the sea the distance is greater by a factor of 2 or 3.

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1 INTRODUCTION

As a part of a general gust research programme Counting Accelerometers were installed in Bristol Freighter aircraft based in the United Kingdom, West Africa and New Zealand.

This Note discusses the turbulence recorded in each locality and compares the average turbulence over land and over sea with due allowance for the flight plans adopted by the operators.

2 INSTRUMENTATION

Counting Accelerometers Mks.2, 2E and 4 were used during the tests and were mounted about 10 ft forward of the centre of gravity of the aircraft.

The accelerometer recorded the number of times that each of a series of upward and downward accelerations was exceeded. At intervals of time an automatic observer recorded the counts, airspeed, altitude and time. The time interval of the Mk.2 instrument was 10 minutes and of Mks.2E and 4 was 4 minutes. The instruments differed also in the method employed to confine recording to accelerations occurring in flight. The Mk.2 accelerometer was mechanically locked via an electrical circuit whenever one main wheel oleo was compressed and the Mks.2E and 4 accelerometers were operated electrically by a switch controlled by airspeed which switched on when airspeed exceeded 100 knots I.A.S. during take-off, and off when the speed fell below 85 knots I.A.S. during the final approach.

3 ROUTES

The aircraft were flown on the following routes by Silver City Airways, West African Airways and Straits Air Freight Express:-

(a) Across the English Channel.
(b) Internal Routes in Nigeria and the Gold Coast.
(c) Internal Routes in New Zealand, mainly across Cook Strait.

Maps of the routes are shown in Fig.1.

4 TEST CONDITIONS

Aircraft fitted with accelerometers were flown on normal services.

The distribution of recording time throughout the year is shown for each region in Fig.2. All distributions are uneven owing to variable utilization and periods of instrument unserviceability. They are not dissimilar, however, when considered on a seasonal basis when it is seen that recording is heaviest at about mid-summer.

The flight plans differ considerably and are given as time at each speed and height in Tables 1 to 3.

Table 4 is a comparison, between the regions, of factors which might affect the turbulence recorded.

5 DATA

The total counts of acceleration obtained from each type of instrument in each region are given in Tables 5 to 10. Owing to inadequacy of the switching arrangements the accelerations in the last recording interval of each flight were contaminated with landing accelerations and are not considered in the analysis, although the recording time is included in the flight plans. In the case of West African records the first interval of each flight is also discarded for similar reasons.

6 GUST ANALYSIS

The acceleration data were processed and converted to gust information by the methods described in Ref.1, with the following exception. When processing the first interval of a flight the final airspeed and half the final altitude of the interval were assumed to be representative of the whole interval. The aircraft characteristics assumed are stated in Table 11 and representative acceleration/gust conversion factors are given in Table 12. The estimated gust counts for each region are given in Tables 13 to 15.

The variation with altitude of the turbulence recorded in the three regions is shown in Fig.3 in which the observed values of gust frequency, expressed as the average distance between gusts exceeding 10 ft/sec E.A.S., are plotted on a logarithmic scale and joined by solid lines. Those observations which are considered to contain too few miles or acceleration counts to be representative are not shown.

Fig.4 shows the variation in the frequency of upgusts and downgusts with gust speed in each altitude band. Fig.5 compares the relative frequency variation in the three regions.

As a basis for comparison, Figs.3 and 5 also show the best estimate[2], from data previously obtained between sea level and 30,000 ft, of annual average turbulent conditions on routes in Europe, East and West Africa and the Far East. The quantity of data in the altitude range from sea level to 8,000 ft on which this previous estimate is based is small compared with the present data but is more widespread.

It is assumed here that the expression "annual average turbulent conditions" includes any reduction in the turbulence encountered which is effected by avoidance of turbulence without change of altitude.

7 GUST FREQUENCY V. ALTITUDE

In Fig.3 the records from cruising flight are separated from those taken in climb and descent. It is seen that the turbulence recorded during cruise is generally less than that recorded during climb and descent. It has been suggested[3] that this results when the pilot is able to choose cruising altitude with regard to weather conditions.

English Channel

As most of the flying was in short flights across the sea, the cruising altitude was as low as weather permitted.

Point 1 includes all records immediately following take-off and therefore represents coastal flying at low altitude under all flying weather conditions.

Point 2 represents low altitude cruising over the sea in all but the worst weather and is 3.5 times less severe than point 1. A difference of 8 to 1 has previously been found[4] from Hunter tests over land and sea in the United Kingdom.

Point 3 contains that proportion of the cruise flown at more than 1,500 ft above the sea. It is presumed that these particular flights were made when conditions at lower altitudes were considered too rough.

Records taken lower than 1,500 ft were classified as climb and descent only when the cruising altitude was greater than 1,500 ft, that is, under rough conditions, and point 4 is correspondingly more severe than point 2 and similar to point 3.

West Africa

The route is composed of a mixture of coastal and inland sectors. The cruising altitude is determined broadly by the prevailing winds with the general result that Eastbound aircraft fly below 5,000 ft and Westbound aircraft above 5,000 ft. In addition it is the practice to fly at 6 - 8,000 ft when cumulo-nimbus cloud is present. The records show no correlation between cruising altitude and sector length.

Point 5 contains all low altitude flying with the exception of that in calm weather in coastal sectors. The turbulence is therefore rather greater than the average near the ground and sea.

The altitudes of the airfields vary from sea level to 4,000 ft and therefore point 6 includes turbulence recorded near the ground. The similarity between points 5 and 6 suggests that the intensity of turbulence near the ground is determined by the height above the ground rather than the height above sea level. This is in agreement with unpublished records obtained from Viking aircraft of Central African Airways.

Points 7 and 8 are climb and descent, partly under cumulo-nimbus conditions but mainly to reach Westbound cruising height under all weather conditions. These values are therefore a little more severe than all weather turbulence.

Points 9, 10 and 13 are cruising in good weather and points 11 and 12 are cruising during more than average turbulence.

It is suggested that the broken line represents average atmospheric turbulence during the tests. This is four times less severe than the general estimate on previous evidence, but there is a similar proportionate decrease in the number of gusts with altitude.

New Zealand

Most of the flying was across Cook Strait which is a short sector normally crossed at low altitude. The higher altitudes in the flight plan generally represent inland sectors.

Point 14 is comparable with point 1 of the English Channel and represents all weather over the land near the coast.

Point 15 is the cruise below 1,500 ft which was generally over the sea in all but the worst weather conditions. It is three times less severe than point 14.

Point 16 represents cruising over the sea on those occasions when weather conditions below 1,500 ft were considered too rough. Similarly, point 17 contains the worst weather over the sea but in addition some inland cruising in good weather.

Point 18 contains most weather conditions on the longer inland sectors and is the average value of overland turbulence at about 7,000 ft.

The climb and descent points 19, 20 and 21, contain flying corresponding to inland cruising at the higher altitudes under all weather conditions. In addition points 19 and 20 contain a considerable amount of flying corresponding to bad weather over the sea.

It is concluded that average atmospheric turbulence over the land during the tests can be represented by the broken line passing through points 14 and 18, and that over the sea turbulence was about two times less severe, up to at least 2,000 ft. This line represents a much greater decrease in turbulence

with altitude than the general estimate from previous data but agrees well with the estimate from Viking aircraft over Europe[3]. It is perhaps relevant that the slope of the general estimate is governed to a large extent by the records from Comet aircraft during climb and descent. In this flight condition sideways avoidance is less practicable with the Comet than with the Freighter or Viking. It follows, therefore, that the rapid decrease in turbulence with altitude recorded by the Freighter in New Zealand may be due, at least in part, to sideways avoidance of turbulence which becomes progressively more effective with altitude as the concentrations of turbulence become fewer.

8 GUST FREQUENCY V. GUST SPEED

At all altitudes in all regions upgusts and downgusts were recorded in substantially equal numbers. The inequalities present are probably due partly to zero error in the instrument. Variations between instruments can be detected in the acceleration summaries.

Fig.4 shows that the relative frequency of different gust speeds is in all cases essentially exponential and similar for up and downgusts. However, it varies appreciably with flight condition, altitude and region as shown by the various slopes. There is in fact good correlation between these slopes and the condition under which the turbulence was recorded. In particular, referring to Fig.3, the observations made under the calmest weather conditions in each region (points 2, 10, 15) correspond with the greatest slopes of those regions and observations under the roughest weather conditions (points 4, 11, 12, 19, 20, 21) have the least slopes. It is concluded that with increasing severity of turbulence large gusts become relatively more numerous in relation to small gusts.

It has been shown[5] that turbulence is encountered by an aircraft in short bursts which if plotted in Fig.4 would show one of two slopes. It is assumed that the various slopes of the present data represent combinations of these two forms of turbulence.

In Fig.5 the extremes of the relative gust frequencies of each region are compared with the best estimate from previous data. All regions have relatively fewer large gusts than this estimate. The turbulence recorded in New Zealand is generally more intense than in West Africa or the English Channel. This cannot be attributed with any certainty to differences in the monthly distribution and may be a true representation of the differences in weather conditions in the regions.

9 CONCLUSIONS

Within 1,000 ft of the ground, and as measured on Bristol Freighter aircraft, the approximate average distance between gusts greater than 10 f.p.s. E.A.S. is $5\frac{1}{2}$ miles in the United Kingdom, 12 miles in West Africa and 2 miles in New Zealand. For comparison a previous estimate from general gust data was 3 miles. At this height over the sea the turbulence is less severe by a factor of 3 in the English Channel and 2 in New Zealand.

Decrease in turbulence with altitude in West Africa agrees with previous evidence but in New Zealand the gust frequency decreases at more than twice this rate up to 8,000 ft.

By comparison with general data from higher altitudes the turbulence in all regions contains fewer large gusts in relation to the number of small gusts. Large gusts are relatively most numerous in New Zealand. There is general evidence that with increasing severity of turbulence large gusts become relatively more numerous in relation to small gusts.

ACKNOWLEDGEMENTS

Thanks are due to Silver City Airways, West African Airways, Straits Air Freight Express and the Director of Civil Aviation, Air Department, New Zealand, for their assistance.

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3	Heath-Smith, J.	Turbulence encountered by Viking aircraft over Europe. Current Paper No.311. 1957.
4	Heath-Smith, J.	Atmospheric turbulence encountered by a Hunter aircraft at low altitude. R.A.E. Technical Note No. Structures 245. July, 1958. A.R.C.20, 627.
5	Bullen, N.I.	Aircraft loads in continuous turbulence. A.G.A.R.D. Report No.116. April, 1957.

TABLE 1

Recording time in minutes at each speed and altitude over English Channel

I.A.S. knots	Altitude above sea level I.C.A.N. (1000 ft units)													I.A.S. knots
	Climb and descent						Cruise							
	00	01	02	03	04	05	00	01	02	03	04	05	06	
90	341	62	5	-	-	-	-	-	-	-	-	-	-	90
100	617	22	-	-	-	-	124	139	4	-	-	-	-	100
110	920	144	6	4	-	-	259	205	30	5	-	-	-	110
120	1317	365	45	4	-	5	698	670	84	38	51	5	22	120
130	2317	547	42	9	18	4	2396	4130	1118	170	207	34	82	130
140	1796	545	82	19	9	9	1085	4100	1533	218	233	62	15	140
150	617	149	59	4	-	-	221	1103	355	85	23	9		150
160	58	8	8	-	-	-	12	59	33	10	-	4		160
Totals	7983	1842	247	40	27	18	4795	10406	3157	526	514	114	119	

Grand Total 29788 minutes.

TABLE 2

Recording time in minutes at each speed and altitude in West Africa

I.A.S. knots	Altitude above sea level I.C.A.N. (1000 ft units)																						I.A.S. knots
	Climb and Descent										Cruise												
	00	01	02	03	04	05	06	07	08	09	00	01	02	03	04	05	06	07	08	09	10	11	
90	54	32	117	21	9	13	30	-	-	-	-	6	-	-	-	-	-	-	-	-	-	6	90
100	161	88	194	38	32	104	73	6	12	19	-	52	-	18	-	48	58	178	198	56	34	6	100
110	187	243	366	199	93	187	109	55	6	6	10	157	86	189	155	595	880	885	863	216	222	25	110
120	151	298	294	296	217	292	232	129	12	26	23	326	664	676	288	803	822	887	1528	413	309	6	120
130	95	243	219	239	118	128	118	89	6	20	-	471	609	868	336	669	1321	815	1219	238	6		130
140	50	120	105	156	171	182	100	53	6	-	-	195	408	608	203	169	214	95	25	6	-		140
150	3	31	9	7	14	31	6	11		-	-	6	45	66	19	5	13	-	-	-	-		150
160	-	3	-	6	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-		160
Totals	701	1058	1304	962	654	937	668	343	42	71	33	1213	1812	2425	1001	2289	3308	2860	3833	929	571	43	

Grand Total 27057 minutes

TABLE 3

Recording time in minutes at each speed and altitude in New Zealand

I.A.S. knots	Altitude above sea level I.C.A.N. (1000 ft units)																							I.A.S. knots
	Climb and Descent											Cruise												
	00	01	02	03	04	05	06	07	08	09	10	00	01	02	03	04	05	06	07	08	09	10	11	
90	41	9	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90
100	178	68	10	-	-	-	5	4	6	-	-	15	16	4	2	-	-	-	-	6	-	-	-	100
110	239	231	49	42	14	18	8	-	-	4	-	8	54	7	30	37	26	12	-	42	10	8	4	110
120	750	536	190	104	53	40	13	20	18	-	5	9	699	112	383	439	142	174	222	250	-	17	8	120
130	812	662	242	113	104	51	42	60	18	4	-	88	4503	1524	1287	1433	394	608	450	282	10	-	30	130
140	1870	822	380	154	103	65	-	4	-	-	-	501	6080	2260	1396	945	403	292	62	41	-	-	-	140
150	414	397	146	89	63	52	-	4	-	-	-	67	1019	650	297	184	54	27	16	-	-	-	-	150
160	91	168	112	47	26	-	-	-	-	-	-	4	86	24	55	29	-	-	8	-	-	-	-	160
170	5	20	8	9	5	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	170
Totals	4400	2913	1140	558	368	226	68	92	42	8	5	692	12467	4581	3450	3067	1019	1113	758	621	20	25	42	

Grand Total 37675 minutes

TABLE 4

Comparison of factors influencing the turbulence recorded in the three regions

Region	Geographical position		Terrain	Bias in monthly distribution of recording	Altitude above S.L. × 1000 ft			Average duration of flight
	°N	°E			Max.	Popular	Most recording	min
English Channel	50	0	Coast to coast across sea	Above average March - August	6	1	1-2	23
West Africa	5	5	Partly coastal and partly inland, occasionally above 3000 ft	Above average February and May - August	11	8	3-8	71
New Zealand	40	175	Mainly coast to coast across sea. Some inland	Above average September, December and January	11	1	1-4	41

TABLE 5

Gust accelerations recorded mainly across English Channel with Counting Accelerometer Mk.2

Flight condition	Altitude range ft	Recording time min	Statute miles	Number of times each acceleration increment was exceeded (+Up -Down)													
				-0.62g	-0.52g	-0.43g	-0.33g	-0.23g	0.23g	0.33g	0.43g	0.52g	0.62g	0.72g	0.82g	0.92g	1.02g
Initial climb	0-3500	1690	4383	1	11	54	184	1073	3288	649	213	54	21	7	2		
Climb and Descent	0-1500	665	1534	1	4	6	19	173	404	74	29	8	3				
	1500-3500	182	506			2	8	49	163	17	4						
	3500-5500	18	51				2	4	17	4	1						
Cruise	0-1500	7292	19279	6	15	64	234	1788	5206	834	249	50	15	2	1	1	1
	1500-3500	2762	7563	9	15	55	207	1213	2911	538	185	39	13	1	1		
	3500-5500	365	1036			1	1	14	47	4	2						
	5500-9500	88	242				1	6	32	6	1	1					
	Totals	13062	34594														

TABLE 6

Gust accelerations recorded mainly across English Channel with Counting Accelerometer Mk.2E

Flight condition	Altitude range ft	Recording time min	Statute miles	Number of times each acceleration increment was exceeded (+Up -Down)										
				-0.80g	-0.60g	-0.40g	-0.30g	-0.20g	0.20g	0.30g	0.40g	0.60g	0.80g	1.00g
Initial climb	0-3500	1319	3230		1	19	91	521	997	188	32	3		
Climb and Descent	0-1500	1591	3728	2	4	8	57	334	655	95	15			
	1500-3500	77	190				1	17	22	4				
	3500-5500	27	72				1	4	6	1				
Cruise	0-1500	7909	19997	1	2	55	328	1251	1779	277	54	6	1	1
	1500-3500	921	2428			1	11	75	130	18	1			
	3500-5500	263	696					6	12	1				
	5500-9500	31	81					1	0					
	Totals	12138	30422											

TABLE 7

Gust accelerations recorded in West Africa with Counting Accelerometer Mk.2

Flight condition	Altitude range ft	Recording time min	Statute miles	Number of times each acceleration increment was exceeded (+Up −Down)											
				−0.72g	−0.62g	−0.52g	−0.43g	−0.33g	−0.23g	0.23g	0.33g	0.43g	0.52g	0.62g	0.72g
Climb and Descent	0–1500	49	115						0	3					
	1500–3500	483	1207				2	37	132	156	37	4	2	1	
	3500–5500	473	1231					14	91	102	20	2			
	5500–9500	335	885					8	28	57	8	2			
Cruise	0–1500	522	1284				1	9	51	76	20	1	1		
	1500–3500	1557	4028					13	118	135	26	4			
	3500–5500	1035	2709		2	3	4	30	117	151	39	6	3	2	
	5500–7500	1390	3667				2	7	69	58	12	2			
	7500–9500	1548	4055					8	51	45	6				
	9500–11500	315	813						0	0					
	Totals	7707	19994												

TABLE 8

Gust accelerations recorded in West Africa with Counting Accelerometer Mk.4

Flight condition	Altitude range ft	Recording time min	Statute miles	Number of times each acceleration increment was exceeded (+Up −Down)										
				−0.80g	−0.60g	−0.40g	−0.30g	−0.20g	0.20g	0.30g	0.40g	0.60g	0.80g	1.00g
Climb and Descent	0–1500	207	461			5	23	145	60	5	1			
	1500–3500	966	2305		1	13	75	471	248	40	7			
	3500–5500	1065	2670			16	65	332	119	27	8	2		
	5500–9500	788	1994			7	33	186	59	8	3			
Cruise	0–1500	723	1741		1	8	72	412	147	22	5			
	1500–3500	2679	6813		1	19	144	977	395	61	10			
	3500–5500	2254	5615		4	40	170	636	265	58	21	6	1	
	5500–7500	4778	12099		2	64	213	944	444	102	22	2		
	7500–9500	3214	8338		2	17	58	253	124	33	13	1		
	9500–11500	298	758				2	8	4					
	Totals	16972	42794											

TABLE 9

Gust accelerations recorded in New Zealand with Counting Accelerometer Mk.2

Flight condition	Altitude range ft	Recording time min	Statute miles	Number of times each acceleration increment was exceeded (+Up -Down)																	
				-0.92 g	-0.82 g	-0.72 g	-0.62 g	-0.52 g	-0.43 g	-0.33 g	-0.23 g	0.23 g	0.33 g	0.43 g	0.52 g	0.62 g	0.72 g	0.82 g	0.92 g	1.02 g	1.12 g	1.32 g
Initial climb	0-3500	1585	4032			4	6	21	73	261	856	2479	737	160	38	22	9	2				
Climb and Descent	0-1500	787	2059			1	1	13	24	201	499	485	169	32	5	3	2	1				
	1500-3500	639	1838				4	15	27	114	339	686	217	85	24	11	6	4	1	1		
	3500-5500	342	973				3	5	18	35	116	223	74	23	6	3						
	5500-10500	150	406					1	2	7	19	8	1									
Cruise	0-1500	4708	12853	1	2	5	6	46	155	564	1753	3767	1113	255	55	31	16	6	1			
	1500-3500	3239	9013			2	4	35	84	296	948	1920	602	96	20	13	4	2	2	1		
	3500-5500	1621	4530		1	1	4	11	51	126	355	658	208	53	17	7	5	2	1	1	1	1
	5500-11500	1377	3787		1	1	2	12	21	76	154	107	44	19	6	2	1					
	Totals	14448	39491																			

TABLE 10

Gust accelerations recorded in New Zealand with Counting Accelerometer Mks.2E and 4

Flight condition	Altitude range ft	Recording time min	Statute miles	Number of times each acceleration increment was exceeded (+Up - Down)													
				-1.00g	-0.80g	-0.60g	-0.40g	-0.30g	-0.20g	0.20g	0.30g	0.40g	0.60g	0.80g	1.00g	1.20g	1.40g
Initial climb	0-3500	1181	2927	2	2	16	107	396	1724	3645	1031	245	23	2			
Climb and Descent	0-1500	1158	2818		2	4	28	95	555	3602	866	167	18	2	1	1	
	1500-3500	585	1508		1	3	29	103	365	1303	343	86	8	3	1		
	3500-5500	252	678				1	9	68	108	12	2					
	5500-10500	78	205						5	7							
Cruise	0-1500	8437	21986		1	16	161	766	3981	11846	2156	460	29	4			
	1500-3500	4792	12790	1	1	11	106	356	1510	4869	1230	316	32	4	1		
	3500-5500	2482	6621			1	44	180	792	1577	386	95	12	4	1		
	5500-11500	1185	3233			2	15	59	241	249	41	27					
	Totals	20150	52766														

TABLE 11

Aircraft characteristics assumed

Wing area 1487 sq ft

Aspect ratio 7.8

Mean chord 13.77 ft

Lift slope 4.4 per radian

The weight of the aircraft was assumed to remain constant during a flight at the mean value for that flight.

TABLE 12

Acceleration/gust conversion factors

Values of the conversion factor in ft/sec/g are given below at some speeds and weights at sea level. The value decreases with increasing altitude and is about 10% smaller at 10,000 ft.

Indicated airspeed knots	Weight of aircraft × 1000 lb			
	20	30	40	50
100	28.66	37.35	45.36	53.51
110	26.06	33.96	41.24	48.65
120	23.88	31.13	37.80	44.60
130	22.05	28.73	34.89	41.16
140	20.47	26.68	32.40	38.23
150	19.11	24.90	30.24	35.68

TABLE 13

Summary of gust counts mainly over English Channel

Flight condition	Altitude band ft	Mean altitude ft	Recording time min	Statute miles	Number of times each gust speed was exceeded Vertical gust speed in ft/sec E.A.S. (+Up, -Down)													
					-35	-30	-25	-20	-15	-10	-7.5	7.5	10	15	20	25	30	35	40
Initial climb	0-3500	400	3009	7613				2	40	359	1295	3654	1033	122	21	3	1		
Climb and Descent	0-1500	600	2256	5262		1	2	3	11	125	431	915	254	29	3				
	1500-3500	2200	259	696						7	39	90	17	1					
	3500-5500	4400	45	123						3	6	16	5						
Cruise	0-1500	800	15201	39276				5	68	644	2264	5283	1391	171	27	6	2		
	1500-3500	2100	3683	9991				3	18	186	725	1907	492	51	3	1			
	3500-5500	4200	628	1732						1	9	31	4						
	5500-9500	6000	119	323						1	3	22	5	1					
		Totals	25200	65016															

TABLE 14

Summary of gust counts in West Africa

Flight condition	Altitude band ft	Mean altitude ft	Recording time min	Statute miles	Number of times each gust speed was exceeded Vertical gust speed in ft/sec E.A.S. (+Up, -Down)												
					-30	-25	-20	-15	-10	-7.5	7.5	10	15	20	25	30	35
Climb and Descent	0-1500	700	256	576				5	43	141	59	12	1				
	1500-3500	2500	1449	3512		1	3	15	190	593	390	124	12	1			
	3500-5500	4600	1538	3901				13	119	399	213	69	7	1			
	5500-9500	6600	1123	2879				4	71	211	119	32	4				
Cruise	0-1500	1000	1245	3025		1	3	14	114	367	205	69	7	1			
	1500-3500	2500	4236	10841			1	11	169	735	387	102	8				
	3500-5500	4700	3289	8324		1	10	39	262	654	379	138	24	9	2	1	
	5500-7500	6500	6168	15766			10	59	315	894	442	157	22	4	1		
	7500-9500	8200	4762	12393		1	3	15	98	299	159	57	13	3			
	9500-11500	10100	613	1571					3	8	4	1					
		Totals	24679	62788													

TABLE 15

Summary of gust counts in New Zealand

Flight condition	Altitude band ft	Mean altitude ft	Recording time min	Statute miles	Number of times each gust speed was exceeded Vertical gust speed in ft/sec E.A.S. (+Up, -Down)																
					-45	-40	-35	-30	-25	-20	-15	-10	-7.5	7.5	10	15	20	25	30	35	40	45
Initial climb	0-3500	800	2766	6959		1	1	2	3	25	128	838	2269	5580	2293	341	60	12	1			
Climb and Descent	0-1500	800	1945	4877		1	1	2	4	15	76	455	1021	4066	1636	237	50	13	5	3	2	1
	1500-3500	2300	1224	3346					1	10	41	258	578	1557	647	104	17	5	2			
	3500-5500	4400	594	1651						4	16	62	147	252	96	15	3					
	5500-10500	7000	228	611						1	3	11	27	18	4							
Cruise	0-1500	1000	13145	34839				2	7	27	172	1505	4328	11238	3560	371	52	9	2			
	1500-3500	2400	8031	21803				1	2	18	121	707	1844	5026	1859	220	43	11	4	2		
	3500-5500	4300	4086	11105						3	45	307	826	1573	553	71	16	5	3	1		
	5500-11500	6900	2579	7066				1	2	9	23	103	265	265	91	30	3					
		Totals	34598	92257																		

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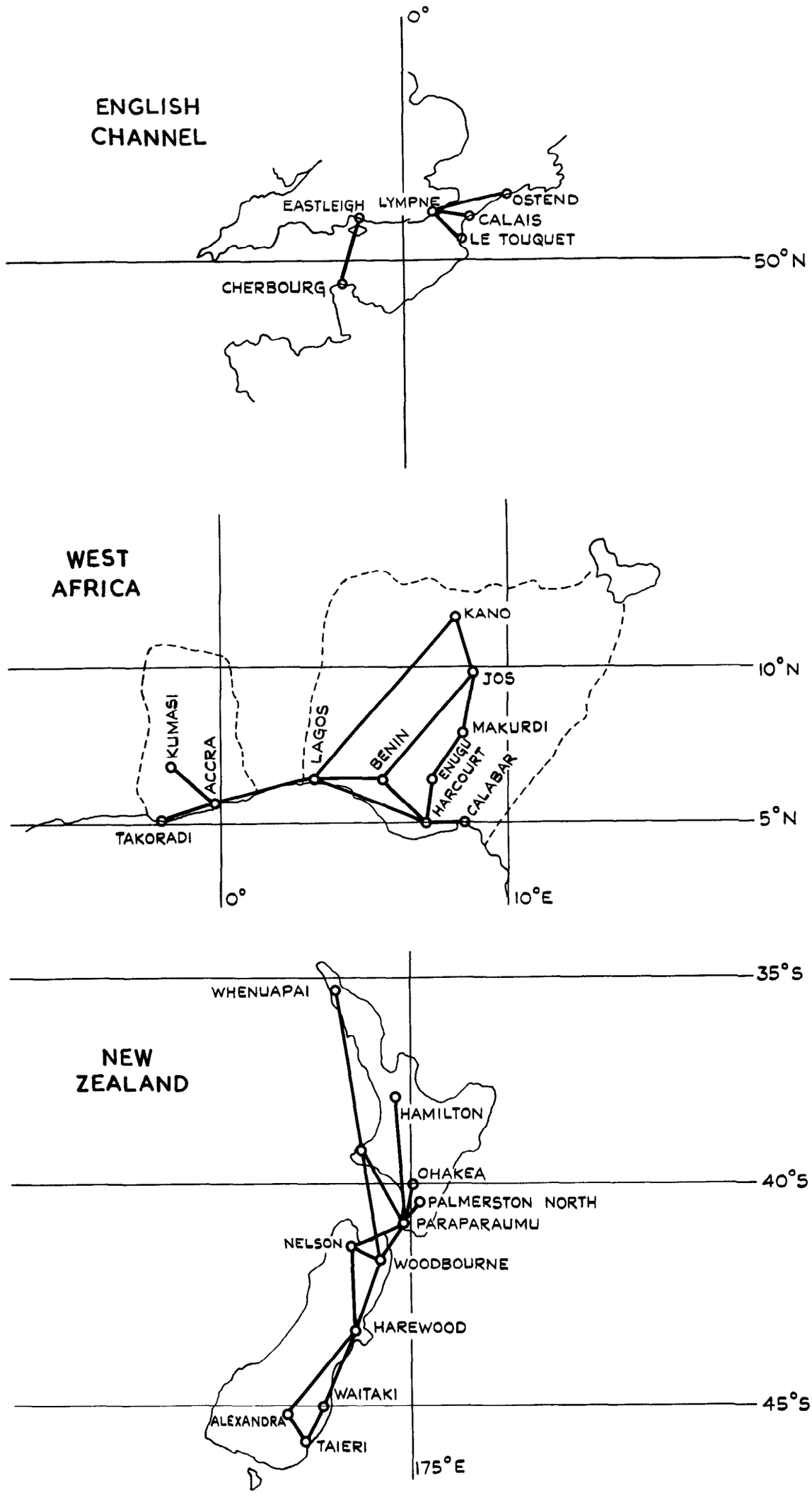
ENGLISH CHANNEL
0°
EASTLEIGH
LYMPNE
OSTEND
CALAIS
LE TOUQUET
50°N
CHERBOURG
WEST AFRICA
KANO
10°N
JOS
KUMASI
ACCRA
LAGOS
BENIN
MAKURDI
ENUGU
HARCOURT
CALABAR
5°N
TAKORADI
0°
10°E
NEW ZEALAND
35°S
WHENUAPAI
HAMILTON
OHAKEA
40°S
PALMERSTON NORTH
PARAPARAUMU
NELSON
WOODBOURNE
HAREWOOD
WAITAKI
45°S
ALEXANDRA
TAIERI
175°E

FIG. 1. ROUTES.

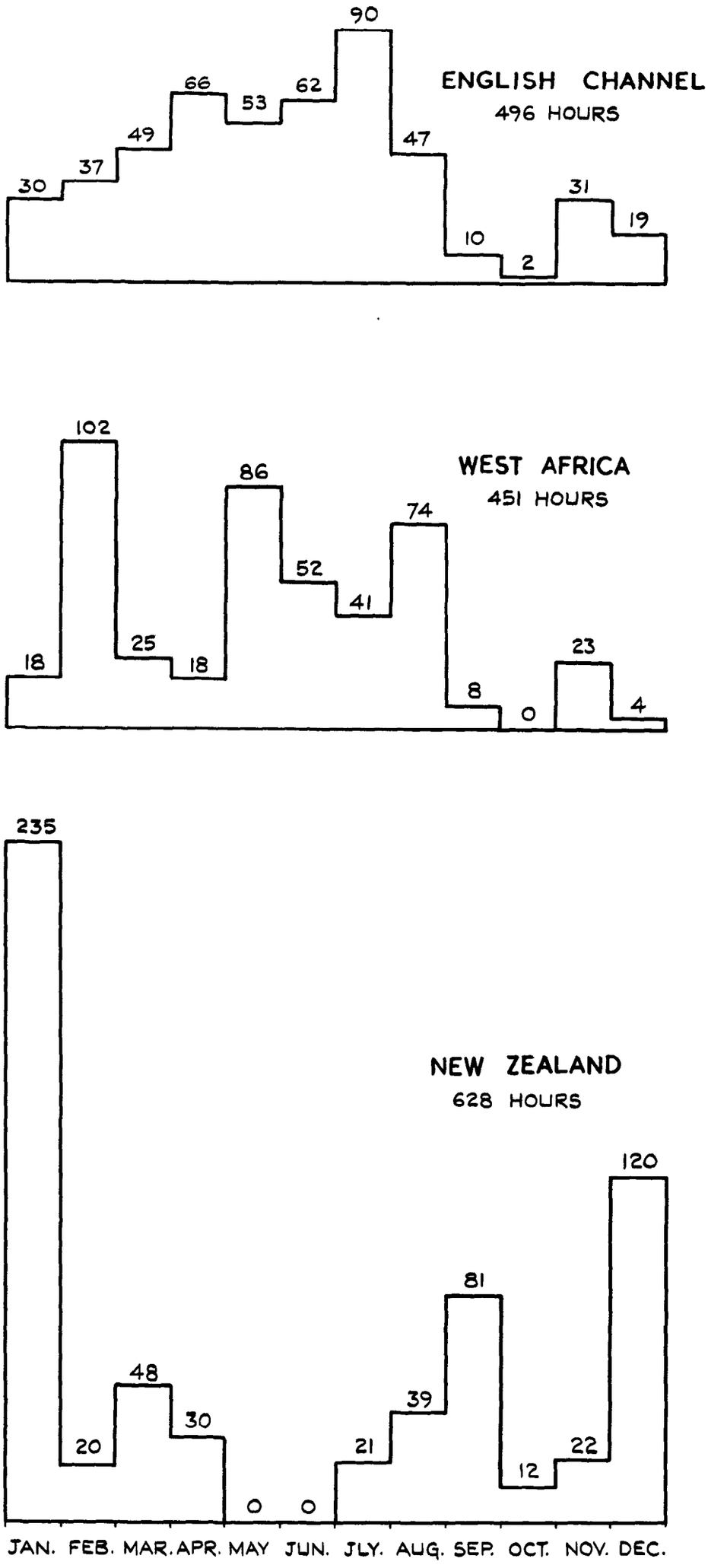

FIG. 2. MONTHLY DISTRIBUTION OF RECORDED FLYING HOURS.

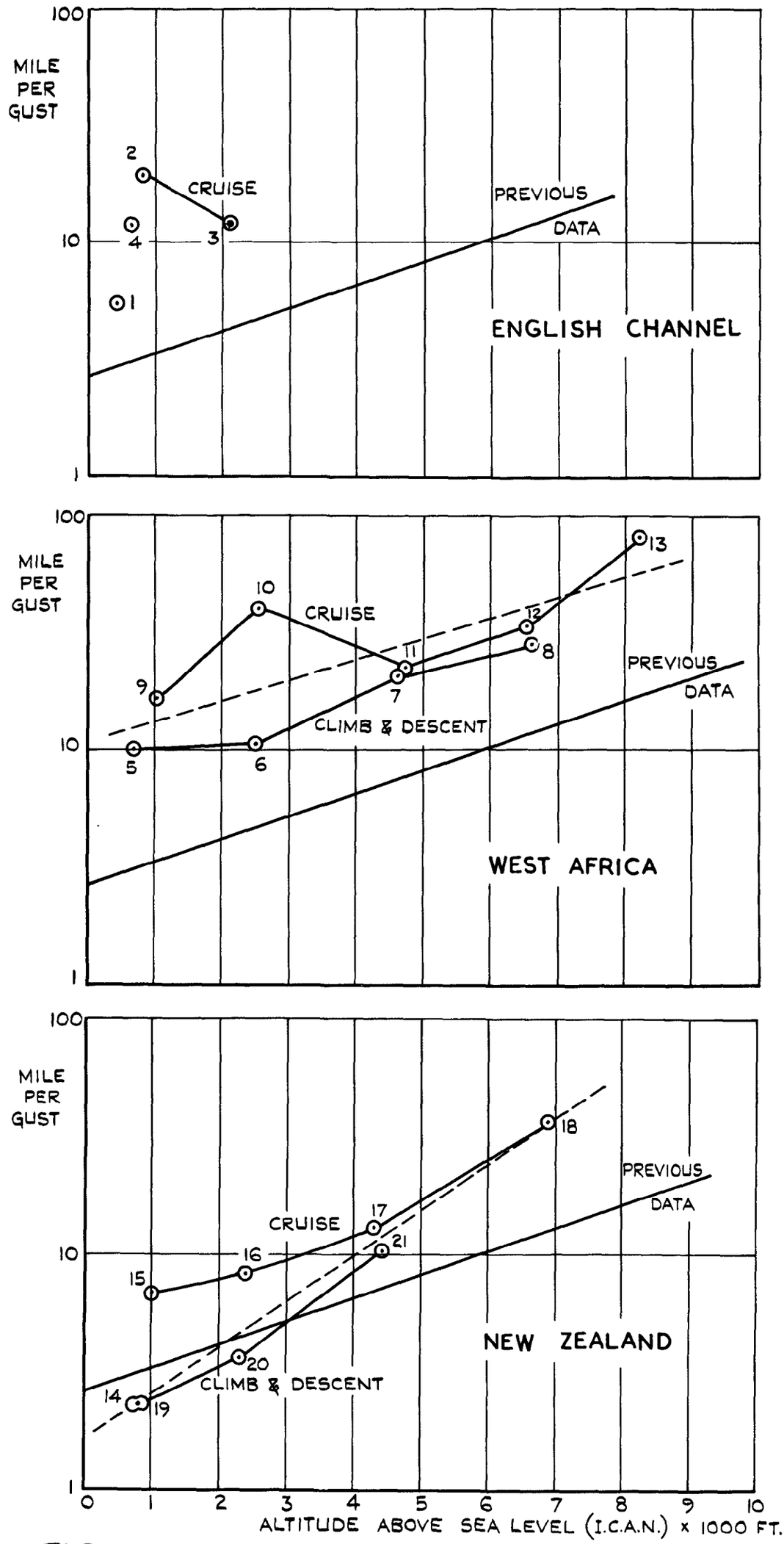

FIG.3. VARIATION OF RECORDED TURBULENCE WITH ALTITUDE.

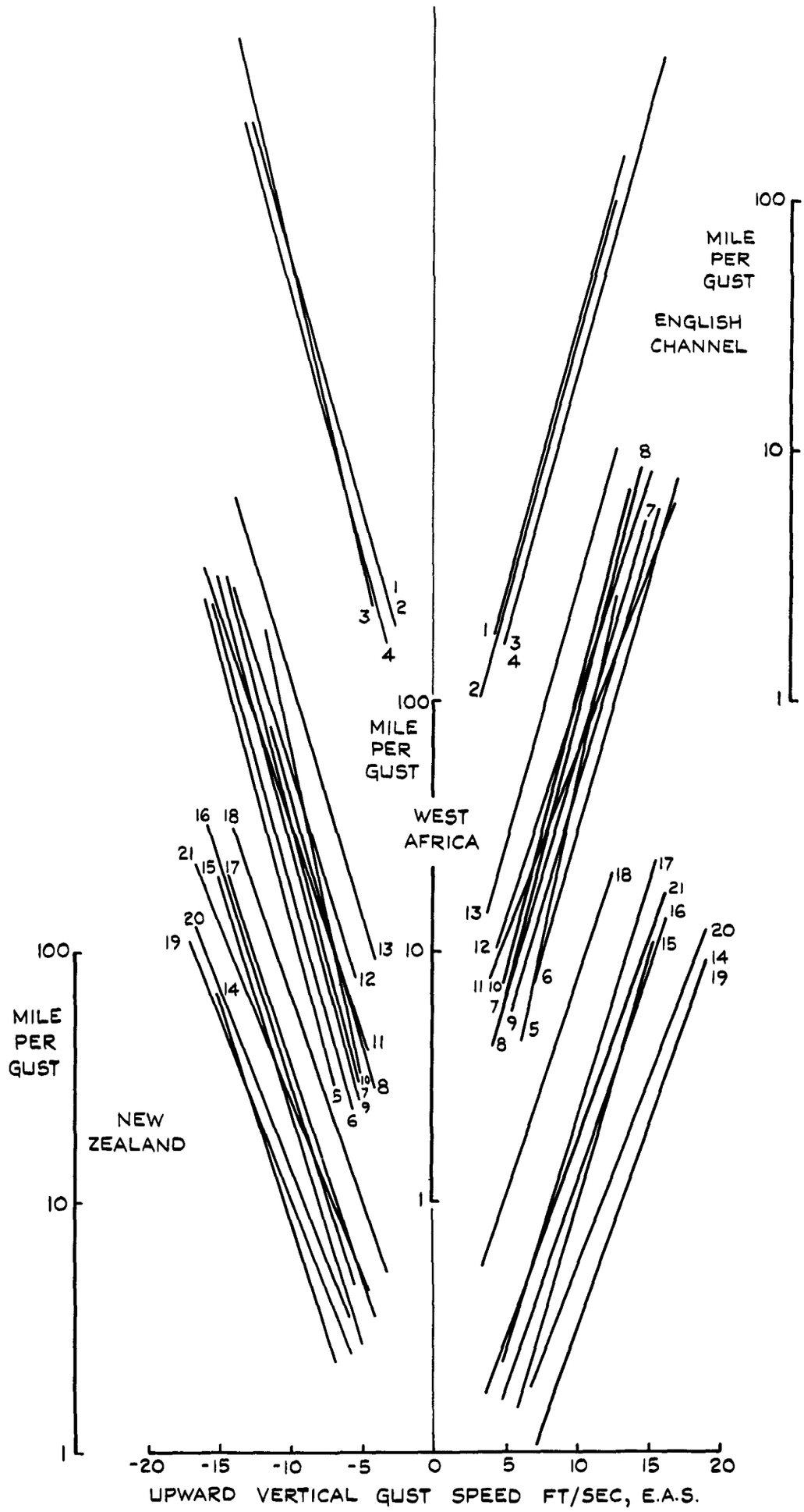

FIG. 4. VARIATION OF GUST FREQUENCY WITH GUST SPEED.

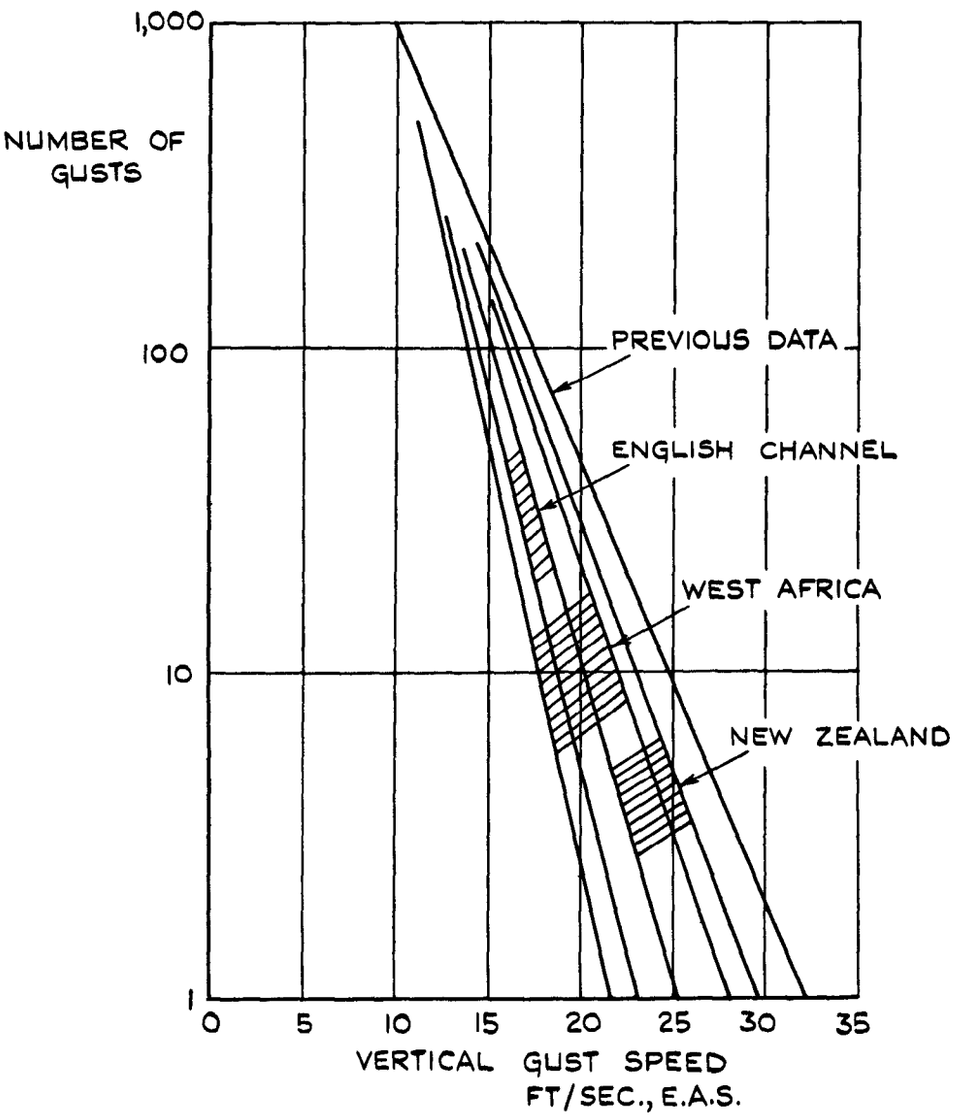

FIG. 5. VARIATION OF RELATIVE GUST FREQUENCY IN EACH REGION BASED ON 1000 GUSTS EXCEEDING 10 FT/SEC, E.A.S.

C.P. No. 429
(20,645)
A.R.C. Technical Report

Published by
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