C.P. No. 463
(21,317)
A.R.C. Technical Report

C.P. No. 463
(21,317)
A.R.C. Technical Report

MINISTRY OF AVIATION

AERONAUTICAL RESEARCH COUNCIL

CURRENT PAPERS

Atmospheric Turbulence Encountered by Viscount Aircraft over Europe

by

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

LONDON: HER MAJESTY'S STATIONERY OFFICE

1960

FOUR SHILLINGS NET

U.D.C. No. 533.6.048.5:551.551.Viscount

Technical Note No. Structures 267

July, 1959

ROYAL AIRCRAFT ESTABLISHMENT

ATMOSPHERIC TURBULENCE ENCOUNTERED BY VISCOUNT AIRCRAFT OVER EUROPE

by

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

SUMMARY

Counting Accelerometer records were obtained from Viscount aircraft during 600,000 miles flying on European routes.

It is shown that the gust frequencies observed are in fair agreement with previous experience on more widespread routes.

The variation of turbulence below 10,000 ft during the year proved to be irregular and the maximum variation between monthly averages was about 3 to 1. At about 20,000 ft there was a single annual fluctuation with a maximum variation of the order of 25 to 1 and maximum intensity during the Summer months.

LIST OF CONTENTS

		Page
1	INTRODUCTION	4
2	INSTRUMENTATION	4
3	TEST CONDITIONS	4
4	DATA	4
5	GUST ANALYSIS	4
6	VARIATION OF GUST FREQUENCY WITH ALTITUDE	5
7	VARIATION OF GUST FREQUENCY WITH GUST SPEED	6
8	SEASONAL VARIATION OF GUST FREQUENCY	6
9	CONCLUSIONS	7
LIST OF REFERENCES		7
TABLES 1-13		9-19
ILLUSTRATIONS - Figs.1-6		

LIST OF TABLES

Table		
1	Recording time at each speed and height during climb and descent - BEA Viscount	9
2	Recording time at each speed and height during cruise - BEA Viscount	10
3	Recording time at each speed and height during climb and descent - Aer Lingus Viscount	11
4	Recording time at each speed and height during cruise - Aer Lingus Viscount	12
5	Accelerations recorded on BEA Viscount with Mk.2 Counting Accelerometer	13
6	Accelerations recorded on BEA Viscount with Mk.4 Counting Accelerometer	14
7	Accelerations recorded on Aer Lingus Viscount with Mk.4 Counting Accelerometer	15
8	Aircraft characteristics assumed	16
9	Representative values of acceleration/gust speed conversion factors	16

LIST OF TABLES (Contd.)

Table		Page
10	Gusts encountered by BEA Viscount	17
11	Gusts encountered by Aer Lingus Viscount	18
12	Frequency of gusts exceeding 10 ft/sec in each month during climb and descent (0-9,500 ft)	19
13	Frequency of gusts exceeding 10 ft/sec in each month during cruise (17,500-25,500 ft)	19

LIST OF ILLUSTRATIONS

	Fig.
Monthly distribution of recording time	1
Variation of 10 ft/sec gust frequency with altitude - BEA Viscount	2
Variation of 10 ft/sec gust frequency with altitude - Aer Lingus Viscount	3
Variation of gust frequency with gust speed - BEA Viscount	4
Variation of gust frequency with gust speed - Aer Lingus Viscount	5
Monthly variation of 10 ft/sec gust frequency - BEA Viscount	6

1 INTRODUCTION

To obtain information about the atmospheric gusts encountered on European airline routes, Counting Accelerometers were carried by Viscount aircraft operated by British European Airways and Aer Lingus. The records obtained represent 600,000 miles during the period October 1953 to February 1958.

This Note discusses the variation of gust frequency with altitude and season in relation to previous results.

2 INSTRUMENTATION

At different times during the recording period Counting Accelerometers Mks.2 and 4 were installed in the aircraft near the centre of gravity. The accelerometer records the number of times 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 about 10 mins. and of the Mk.4 instrument was 4 minutes below 12,500 ft and 12 minutes above this altitude. The instruments differed also in the method of recording during take-off and landing. The Mk.2 instrument recorded continuously and therefore the first and last intervals of flight contain acceleration counts from ground loads. To exclude ground accelerations from the Mk.4 records the instrument switched on automatically when the airspeed exceeded 125 knots during take-off and switched off when airspeed was reduced below 110 knots during landing.

3 TEST CONDITIONS

The aircraft carrying the instruments flew normal passenger services on European routes. The distribution of recording time throughout the year is shown in Fig.1. There is some unevenness in the BEA distribution owing to variable utilization of the aircraft and periods of unserviceability of the instrument but every month is substantially recorded. The comparatively small amount of recording on Aer Lingus is all in June and July.

Tables 1 to 4 give details of the time spent at different altitudes and airspeeds during cruise and during climb and descent. It is seen that most of the BEA cruise was between 17,000 ft and 25,000 ft. Aer Lingus cruise tended to be lower.

4 DATA

The total counts of acceleration obtained at each flight condition and in each altitude band are given in Tables 5 to 7. In the case of the Mk.2 instrument the accelerations recorded during the first and last intervals of each flight are not given as they are contaminated with ground accelerations. The recording time is included, however, in the flight plan.

To supplement the acceleration data the date, flight sector, take-off weight and landing weight were recorded for each flight.

5 GUST ANALYSIS

The acceleration data were processed and converted to gust information by a standard method[1]. When interpreting the accelerations recorded during the first interval of a flight the final airspeed and half the final altitude of the interval were assumed to represent the whole interval. Similarly for the last interval of a flight the initial speed and half the initial altitude were assumed.

The aircraft characteristics used in analysis are stated in Table 8 and representative acceleration/gust speed conversion factors are given in Table 9.

The estimated gust counts in each flight condition and altitude band are given in Tables 10 and 11 for BEA aircraft and Aer Lingus aircraft respectively. The counts of gusts exceeding 10 ft/sec during each month of the year are given in Table 12.

6 VARIATION OF GUST FREQUENCY WITH ALTITUDE

Fig.2 shows the observed frequency of gusts greater than 10 ft/sec E.A.S. at different altitudes recorded on BEA aircraft. The vertical line through each observation indicates the 95% confidence limits calculated by the method of Ref.2. The numbers against the points facilitate reference to them in the text. The broken line represents a general estimate of atmospheric turbulence[3] which was based on earlier data from Europe and routes connecting London with South Africa and the Far East. The present observations show a trend similar to the previous estimate, the numbers of gusts decreasing continuously with increasing altitude up to 15,000 ft.

The flight plans show that there was little cruising below 14,000 ft and therefore points 10 to 13 represent virtually all cruising conditions. Cruise observations at lower altitudes probably represent test flying and occasional stand-off conditions during the descent on operational flights. The remaining observations, numbered 1 to 9 were made during climb and descent. These points are of particular importance in determining average atmospheric conditions as it has been seen that cruising was nearly always above 14,000 ft and, therefore, climb and descent was recorded at lower altitudes on every operational flight.

Points 1 and 2 are derived from the first and last recording intervals of each flight respectively and, although they contain therefore practically all flying below 1,000 ft and most of the flying below 4,000 ft, the assumption made in Section 5 about the speed of the aircraft detracts from the value of these observations. The possible error introduced by this assumption is to under estimate the turbulence.

Point 3 represents that part of the climb and descent below about 3,500 ft which was not included in the first or last recording interval of a flight. Very little mileage was recorded under these conditions which represent an abnormally low rate of climb and descent and this point is therefore of little value in determining average conditions.

Point 9 represents climb and descent within the cruising range on those occasions when the aircraft cruised above 18,000 ft. As a result some weather conditions may be excluded and the observation is not definitely the result of average conditions.

The curve of average conditions is determined therefore by points 4 to 8 and is shown in Fig.2 as a straight line above 5,000 ft and curved at lower altitudes. This line is in fairly good agreement with the previous estimate but generally represents slightly less turbulence than was previously recorded. Some difference is to be expected as the previous estimate is a general one based on data from various routes which include the tropics.

Points 10-13 indicate that average turbulence during cruise was virtually the same at all cruising heights. As there is considerable evidence that on average, turbulence lessens with increasing altitude up to at least 30,000 ft it follows that the choice of cruising altitude within the band 14,000-29,000 ft was influenced by weather conditions, the highest altitudes corresponding with the most turbulent weather.

If the climb and descent line is extended linearly it intersects the cruise curve at about 18,000 ft. As the great majority of the cruise was flown above this altitude there is some reason to suppose that nearly all cruise was under conditions of more than average turbulence.

From these two inferences, i.e. that cruising altitude depended to some extent on weather conditions and that turbulence was greater than average during most of the cruise it could be concluded that choice of cruising altitude was determined mainly by considerations which resulted in an increase in the turbulence encountered. There are two possible explanations; that favourable tailwinds were sought after or that the aircraft was habitually positioned in a certain relation to cloud formation e.g. just above the cloud tops. This argument depends, however, on the uncertain extension of the climb and descent curve. It should be noted that the turbulence in the cruise is much less than that met by aircraft cruising at an altitude of say 8,000 ft, which may mean there is less tendency for the pilot to take avoiding action.

The recording on the Aer Lingus Viscount represents a comparatively low mileage and only the climb and descent observations up to 10,000 ft are shown in Fig.3. Again the points numbered 1 and 2 contain all intervals immediately after take-off and immediately before landing respectively. Although the confidence limits are rather wide the observations indicate an exponential decrease of turbulence with altitude at a higher rate than that measured with the BEA aircraft. There is little to be gained from the comparison as the Aer Lingus recording is entirely in June and July and the routes are rather different, being confined more to the U.K.

7 VARIATION OF GUST FREQUENCY WITH GUST SPEED

Fig.4 shows the variation of gust frequency with gust speed measured on BEA Viscounts at various altitudes and flight conditions. Fig.5 shows similar information from the Aer Lingus aircraft. Only climb and descent observations are shown in those cases where there are at least 5 counts exceeding 15 ft/sec. Generally the slope has been extended linearly for gusts greater than about 15 ft/sec as the number of larger gusts is too small to be significant. The broken line represents a previous estimate of average conditions.

The variation of gust frequency is similar for upgusts and downgusts, the distributions being approximately symmetrical about the zero gust speed datum. The results from both types of instrument show a tendency for a gust speed of 10 ft/sec to be exceeded more often upwards than downwards but a firm estimate of the relative proportion is not possible as the effect is comparable with normal instrument calibration errors. The slopes are generally steeper than the previous estimate which indicates fewer large gusts in relation to small gusts, with the sole exception of the observation made during the cruise of the BEA aircraft in the altitude band 17,500 to 21,000 ft.

8 SEASONAL VARIATION OF GUST FREQUENCY

For investigation of seasonal variation the records are examined in two groups; those obtained during climb and descent below 9,500 ft and those during cruise between 17,500 and 25,500 ft. Tables 12 and 13 give for each group the number of gusts exceeding 10 ft/sec E.A.S. and the corresponding mileage during each month of the year. The variations are shown graphically in Fig.6, the 95% confidence limits being indicated for each observation.

The variation at low altitude is seen to be irregular with a maximum difference between months of about 3 to 1. This is a reliable result as the confidence limits are uniformly small and the climb and descent records represent average weather conditions.

The result at higher altitudes is a less reliable estimate of average atmospheric conditions as the confidence limits are wide and, as it has been shown, during cruise the altitude is determined to some degree by weather conditions. Nevertheless, the variation appears as approximately a single fluctuation during the year of a sinusoidal nature with a maximum difference between months of about 25 to 1 and with maximum turbulence during the Summer months.

A similar variation has been found previously in data from below 10,000 ft over Europe[4] and from the range 9,500-17,500 ft in the tropics[5] but in neither case was so pronounced as the variation in the present data which are from higher altitudes (17,500-25,500 ft) and it seems likely that this seasonal effect is due to variation in the number of cumulo-nimbus formations as these are the predominant source of turbulence at the higher altitudes. This idea is strengthened by the coincidence of the most turbulent period and the season of thunderstorms.

9 CONCLUSIONS

Gust records obtained from Viscount aircraft during 600,000 miles flying on European routes confirm previous evidence of a progressive reduction in the number of gusts with increasing altitude. The variation with altitude is approximately exponential but is more rapid than this below 5,000 ft.

There are slightly more upgusts than downgusts with speeds in excess of 10 ft/sec.

The number of gusts greater than 10 ft/sec is a little lower than the previous general estimate and the number of large gusts is smaller in relation to the number of small gusts.

Below 10,000 ft the maximum variation in average monthly gust frequency during the year is about 3 to 1 and the pattern of variation is irregular. At about 20,000 ft there is a single annual fluctuation with a maximum variation of the order of 25 to 1 and maximum intensity during the Summer months.

ACKNOWLEDGMENTS

Thanks are due to British European Airways, Aer Lingus and Vickers Armstrong Ltd. for their assistance.

LIST OF REFERENCES

No.	Author	Title, etc.
1	Heath-Smith, J.R.	The estimation of atmospheric gust frequencies from counting accelerometer records using the DEUCE computer. A.R.C. 20,921. October 1958.
2	Bullen, N.I.	The sampling errors of turbulence measurements. R & M 3063. May, 1956.
3	Bullen, N.I.	The variation of gust frequency with gust velocity and altitude. ARC Current Paper No.324.

LIST OF REFERENCES (Contd.)

No.	Author	Title, etc.
4	Heath-Smith, J.R.	Turbulence encountered by Viking aircraft over Europe. ARC Current Paper No.311, 1957.
5	Heath-Smith, J.R.	Atmospheric turbulence encountered by Super Constellation aircraft. C.P. 432. January 1959.

TABLE 1

Recording time in minutes at each speed and altitude during climb and descent - BEA Viscount

I.A.S. knots	Altitude above sea level I.C.A.N. (x 1000 ft)																												
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
100	29			4		5																							
110	38	25	4					6		2																			
120	280	134	91	13	4	8			9	3		6	7	6															
130	381	327	225	105	31	45	20	22	15	16		11	18	21	20	11	19	21		11	11								
140	189	343	258	242	128	81	76	76	91	71	39	86	64	144	147	257	256	296	69	63	63		21	11					
150	117	342	673	416	326	315	293	411	332	355	374	484	596	1009	936	898	874	939	226	315	74	63	11	42	21	11		11	11
160	85	400	760	584	529	513	699	725	605	614	528	535	570	489	545	369	306	346	173	189	95	74	42	32	21	11			
170	51	317	825	563	412	551	510	554	499	344	282	228	305	271	259	357	284	437	252	168	179	32	42	32					
180	16	261	423	234	319	373	383	280	353	202	287	275	318	364	354	442	546	613	343	147	84	84	11	32	21				
190	23	147	233	107	183	242	223	266	274	248	270	219	266	536	562	798	699	839	325	168	126	63	74	11	11	11			
200	17	205	126	76	123	104	124	170	294	145	133	186	248	248	396	476	540	395	223	116	42	53	32						
210	5	79	97	52	46	72	63	93	97	62	99	86	116	110	117	62	124	59	48	21	11	21							
220	5	62	32	16	16	47	3	4	36	35	29	25	18	41	11	7	11	25											
230	5	16	5	20	5	20	11			4		26	7	11			23												
240	5	5	11	11		11											11												
250		5	10						5																				
260					5																								
Total	1246	2668	3773	2443	2127	2367	2405	2607	2510	2101	2041	2167	2533	3260	3347	3677	3693	3970	1659	1198	685	390	233	160	74	33	0	11	11

Total time:- 53,389 minutes

TABLE 2

Recording time in minutes at each speed and height during cruise - BEA Viscount

I.A.S. knots	Altitude above sea level I.C.A.N. (x 1000 ft)																													
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
100							4																							
110	15	11		6			4																							
120	9	29	17					4														21								
130	15	84	44	4		5				4			11				11				11	12	11							
140	21	107	56	24	49	19				11	11		11				11		11	11	21		21	11	21	35		15	12	
150		104	81	30	63	7	17			25	43	15	11	12	25		36	11	84	84	107	45	98	113	80	77	108	50	40	
160	4	37	53	51	37	24	11	16	15	15	4	24	21	11	21	10	83	133	215	331	337	424	509	384	468	173	175	199	185	
170		29	37	39	65	19	13	7	5		31	91	11	57	65	55	144	189	276	657	755	992	1180	1319	1154	613	641	461	67	11
180	5	17	6	61	38	27	25	4	11	38	40	140	168	31	42	77	54	424	794	2461	2444	3077	3453	3841	3221	1093	854	279	14	
190			20	35	33	11	21	19	18	47	24	142	105	64	86	134	406	701	1831	2801	3951	5020	4783	3430	1865	929	158			
200			13	17	51	9	28	14	70	77	41	81	88	32	108	245	347	685	1116	1620	2975	2437	2179	1137	468		11			
210		3	4		9	5	4	24	21	76	127	127	90	48	65	129	150	259	203	331	160	258	53		13					
220					8	9	20	4	8	18	60	49	64		41	20	32	11	32	42										
230						5			21		11	14			11	11														
240		11				5																								
250						4			11																					
Total	69	432	331	267	353	149	147	92	180	311	392	683	580	255	464	681	1274	2413	4562	8338	10761	12286	12287	10235	7290	2920	1947	1004	318	11

Total time:- 81,034 minutes

TABLE 3

Recording time in minutes at each speed and height during climb and descent - Aer Lingus Viscount

I.A.S. knots	Altitude above sea level I.C.A.N. (x 1000 ft)																				
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
100																					
110																					
120	5			2																	
130	17	15	5	4																	
140	30	50	47			5	8					5			11		5				
150	21	38	63	41	33	33	34	27	23	17	26	24	31	34	24	27		10	9		11
160	8	33	97	51	10	38	92	62	14	56	27	42	54	69	36	14		8		8	
170	7	33	39	37	17	37	20	40	28	13	10	26		26	29	16	13			10	
180	3	33		6	8	24	23	17	17	34	21	20	48	49	18	19	18	10			
190	3	14	4	5	5		4	10	4	18	7	32	72	34	50	8			9		
200		4		5				4	8	8	5	18	32	96	22	15	19	9			
210				4											19						
220		7										7									
Total	94	227	255	155	73	137	181	160	94	146	96	174	237	308	209	99	55	37	18	18	11

Total time:- 2,784 minutes

TABLE 4

Recording time in minutes at each speed and height during cruise - Aer Lingus Viscount

I.A.S. knots	Altitude above sea level I.C.A.N. (x 1000 ft)																								
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
100																										
110																										
120	4																									
130	4	4	4																							
140	15	8	8	19																						
150				13	4	5	4																			
160		8	11	13														10			9	11				
170			10	15					4					4	9	20	30	5	13	11	9				11	
180		12	31	3				4						10	29	61	46				36					66
190							5				5	9		9	5	96	75	43		27	109	50			12	21
200											11		18	23	198	295	507	111	29		50	12				
210											4	15	6	36	73	116	181	19								
220													11	28		11	4									
230												12				11										
240																11										
Total	23	32	64	63	4	5	9	4	4	0	20	36	35	110	314	621	843	188	42	38	213	73	0	0	23	87

Total time:- 2,851 minutes

TABLE 5

Accelerations recorded on B.E.A. Viscount with Mk.2 Counting Accelerometer

Flight condition	Altitude range ft	Recording time mins	Statute miles	Number of times each acceleration increment was exceeded (+up -down)																	
				-1.02	-0.92	-0.82	-0.72	-0.62	-0.52	-0.43	-0.33	-0.23	0.23	0.33	0.43	0.52	0.62	0.72	0.82	0.92	1.02	1.12
Climb and descent (excluding first and last recording intervals of each flight)	0-1,500	63	178									11	38	1								
	1,500-3,500	630	1,977						3	10	47	400	571	116	42	7	6					
	3,500-5,500	1,149	3,990					3	6	17	63	614	687	123	34	3						
	5,500-9,500	4,037	14,897					3	17	59	131	872	1109	216	56	9	3					
	9,500-13,500	4,683	18,317						2	16	50	395	430	90	34	8	3	1				
	13,500-17,500	5,322	22,579					2	4	7	16	188	213	46	13	5	3					
	17,500-21,500	3,346	14,812							10	37	201	122	21	5	2	2	1	1			
	21,500-25,500	500	2,315								6	44	38	5								
	25,500-29,500	22	98						2	9	24	91	77	26	7	1	1	1				
Cruise	0-1,500	204	574							4	14	183	269	41	20	1						
	1,500-3,500	95	302						2	4	12	98	126	45	9	2	2	1	1			
	3,500-5,500	63	225								2	32	73	20	8	1	1	1	1			
	5,500-9,500	212	913									0	0									
	9,500-13,500	1,184	5,056						2	4	14	120	154	38	16							
	13,500-17,500	2,904	13,491								3	43	30	3								
	17,500-21,500	17,846	86,775		3	7	11	23	48	64	132	467	349	121	76	30	17	8	5	4	4	
	21,500-25,500	7,406	37,596							11	42	251	214	41	8	1	1					
	25,500-29,500	315	1,612					1	1	1	1	1	5	1								

Total 225,707 miles

TABLE 6

Accelerations recorded on B.E.A. Viscount with Mk.4 Counting Accelerometer

Flight condition	Altitude range ft	Recording time mins	Statute miles	Number of times each acceleration increment was exceeded (+up -down)										
				-0.80	-0.60	-0.40	-0.30	-0.20	0.20	0.30	0.40	0.60	0.80	1.00
Initial climb	-	2,834	9,466		1	31	242	1616	1884	311	45	1		
Final descent	-	1,349	3,880			6	58	602	969	161	23	2	1	
Climb and descent (excluding initial climb and final descent)	0-1,500	192	514			4	11	94	125	16	2			
	1,500-3,500	1,336	4,082			20	73	529	810	143	15			
	3,500-5,500	2,123	7,352			12	71	404	647	110	19			
	5,500-9,500	5,177	18,764		2	13	68	504	708	135	31	1		
	9,500-13,500	5,318	20,560			5	35	266	271	43	8	1		
	13,500-17,500	9,365	39,101		1	22	51	311	52	9	2	1		
	17,500-21,500	586	2,728				1	5	6					
Cruise	0-1,500	297	829			3	15	124	192	31	11			
	1,500-3,500	503	1,593			1	19	166	249	62	16			
	3,500-5,500	442	1,555			3	7	57	114	15	2	1		
	5,500-9,500	517	2,091		1	2	10	34	74	17	3	1		
	9,500-13,500	726	3,231			2	7	72	30	9	4			
	13,500-17,500	1,928	9,188				3	56	67	8	1	1		
	17,500-21,500	18,101	89,845			4	21	202	159	19	1			
	21,500-25,500	25,326	128,275		5	27	119	596	637	133	42	5	2	
	25,500-29,500	2,965	14,926			6	15	65	76	4	1			

Total 357,980 miles

TABLE 7

Accelerations recorded on Aer Lingus Viscount with Mk.4 Counting Accelerometer

Flight condition	Altitude range ft	Recording time mins	Statute miles	Number of times each acceleration increment was exceeded (+up -down)										
				-0.80	-0.60	-0.40	-0.30	-0.20	0.20	0.30	0.40	0.60	0.80	1.00
Initial climb	-	274	894			4	36	265	514	93	14			
Final descent	-	129	368				6	68	145	23	3			
Climb and descent (excluding initial climb and final descent)	0-1,500	90	252			1	6	56	111	28	6			
	1,500-3,500	238	748		1	2	21	86	139	26	6	1		
	3,500-5,500	210	702			2	4	25	66	11	3			
	5,500-9,500	581	2,068			1	5	29	48	11	1			
	9,500-13,500	815	3,301					9	17					
	13,500-17,500	400	1,694					2	4					
	17,500-21,500	47	198					0	0					
Cruise	0-1,500	55	158				3	24	50	6	1			
	1,500-3,500	127	407				2	18	43	7				
	3,500-5,500	9	28					0	2					
	5,500-9,500	17	63			1	2	9	4					
	9,500-13,500	201	957					11	10					
	13,500-17,500	1,966	9,527		1	9	34	95	104	34	15	2	1	
	17,500-21,500	366	1,805					1	1					
	21,500-25,500	110	572					0	2					

Total 23,742 miles

TABLE 8

Aircraft characteristics assumed

Wing area	963 ft^2
Mean chord	10.22 ft
Aspect ratio	9.2

Slope of the lift curve constant at 4.60/radian

TABLE 9

Representative values of acceleration/gust speed conversion factors (ft/sec/g)

Indicated airspeed knots	Altitude (feet)															
	Sea level				10,000				20,000				30,000			
	Aircraft weight (1,000 lb)															
	40	45	50	55	40	45	50	55	40	45	50	55	40	45	50	55
100	59.7	65.6	71.0	78.2	56.8	62.4	67.6	74.4	54.1	59.4	66.1	71.0	51.6	58.1	63.1	69.4
120	49.9	54.7	59.2	65.1	47.4	52.0	56.4	62.0	45.1	49.5	55.1	59.2	43.0	48.4	52.6	57.8
140	42.8	46.9	50.8	55.8	40.6	44.5	48.3	53.2	38.6	42.4	47.2	50.7	36.9	41.5	45.1	49.6
160	37.4	41.0	44.4	48.9	35.5	39.0	42.3	46.5	33.8	37.1	41.3	44.4	32.3	36.3	39.4	43.4
180	33.3	36.5	39.5	43.4	31.6	34.6	37.6	41.3	30.1	33.0	36.7	39.4	28.7	32.3	35.1	38.6
200	29.9	32.8	35.5	39.1	28.4	31.2	33.8	37.2	27.1	29.7	33.0	35.5	25.8	29.0	31.5	34.7
220	27.2	29.8	32.3	35.5	25.8	28.3	30.7	33.8	24.6	27.0	30.0	32.3	23.5	26.4	28.7	31.5
240	24.9	27.3	29.6	32.6	23.7	26.0	28.2	31.0	22.5	24.8	27.5	29.6	21.5	24.1	26.3	28.9
260	23.0	25.2	27.3	30.1	21.9	24.0	26.0	28.6	20.8	22.9	25.4	27.3	19.8	22.3	24.3	26.7

TABLE 10

Gusts encountered by BEA Viscount

Flight condition	Altitude range ft	Mean altitude ft	Recording time mins	Statute miles	Number of times each gust speed was exceeded vertical gust speed in ft/sec E.A.S. (+up - down)														
					-40	-35	-30	-25	-20	-15	-10	10	15	20	25	30	35	40	45
Initial climb	-	2,000	2,834	9,466				1	12	82	773	946	113	16					
Final descent (Mk.4 instrument only)	-	1,200	1,349	3,880					2	43	415	705	96	19	6	1	1	1	
Climb and descent (excluding initial climb and final descent from both instruments)	0-1,500	1,000	255	692				2	5	14	106	174	21	5	1				
	1,500-3,500	2,600	1,966	6,059				3	18	77	585	962	133	21	6	3	1		
	3,500-5,500	4,600	3,272	11,342			1	2	8	43	527	726	91	10					
	5,500-9,500	7,500	9,214	33,661			3	17	42	111	721	1001	160	26	3	2			
	9,500-13,500	11,700	10,001	38,877					3	30	264	301	54	6					
	13,500-17,500	15,600	14,687	61,680					9	26	175	188	28	5	4				
	17,500-21,500	19,000	3,932	17,540						6	92	61	9	2	2	1			
	21,500-25,500	22,800	500	2,315							26	21							
	25,500-29,500	27,500	22	98					1	12	56	52	10	1	1				
Cruise	0-1,500	900	501	1,403				1	5	35	359	560	85	25	2				
	1,500-3,500	2,400	598	1,895					3	9	133	236	47	9	2	1	1		
	3,500-5,500	4,300	505	1,780						2	25	73	9	2	1	1			
	5,500-9,500	7,500	729	3,004					1	2	13	19	3	1					
	9,500-13,500	11,400	1,910	8,287						7	62	108	24	3					
	13,500-17,500	16,200	4,832	22,679						1	32	20	3	1	1				
	17,500-21,500	19,900	35,947	176,620		4	8	19	48	91	298	242	92	36	14	7	4	2	
	21,500-25,500	23,000	32,732	165,871			1	3	10	46	270	276	54	15	6	3	1		
	25,500-29,500	26,500	3,280	16,538			1	1	2	7	23	16	1						

Total 583,687 miles

TABLE 11

Gusts encountered by Aer Lingus Viscount

Flight condition	Altitude range ft	Mean altitude ft	Recording time mins	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	10	15	20	25	30
Initial climb	-	1,700	274	894			1	10	113	248	28	4		
Final descent	-	500	129	368				2	43	105	14	2		
Climb and descent	0-1,500	1,000	90	252				4	42	102	21	4		
	1,500-3,500	2,600	238	748		1	1	7	51	74	11	3	1	
	3,500-5,500	4,700	210	702			1	2	13	33	5	1		
	5,500-9,500	7,400	581	2,068				1	11	21	2			
	9,500-13,500	11,900	815	3,301					0	0				
	13,500-17,500	14,800	400	1,694					0	0				
	17,500-21,500	18,900	47	198					0	0				
	21,500-25,500	-	5	25					0	0				
	25,500-29,500	-	6	30					0	0				
Cruise	0-1,500	700	55	158				3	22	43	6	1		
	1,500-3,500	2,500	127	407					8	20	1			
	3,500-5,500	4,500	9	28					0	1				
	5,500-9,500	6,800	17	63				1	3	0				
	9,500-13,500	12,200	201	957			1	5	32	32	9	2	1	
	13,500-17,500	15,500	1,966	9,527					0	0				
	17,500-21,500	19,900	366	1,805					0	0				
	21,500-25,500	24,800	110	572					0	0				

Total 23,742 miles

TABLE 12

Frequency of gusts exceeding 10 ft/sec in each month during climb and descent
(0-9,500 ft)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Number of 10 ft/sec gusts	554	173	228	277	358	208	444	527	299	660	436	607
Recorded mileage	7547	1062	2180	3754	3412	3664	4837	5898	3498	5581	6291	4030
Average miles per gust count	13.6	6.1	9.6	13.6	9.5	17.6	10.9	11.2	11.7	8.5	14.4	6.6

TABLE 13

Frequency of gusts exceeding 10 ft/sec in each month during cruise
(17,500-25,500 ft)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Number of 10 ft/sec gusts	35	2	6	26	70	45	365	282	4	92	114	57
Recorded mileage	47089	4592	14881	23129	23110	24308	31968	42944	22594	30652	52167	25060
Average miles per gust count	1346	2296	2480	890	330	540	88	153	5648	333	457	440

RT.2078.C.P.463.K3 - Printed in England

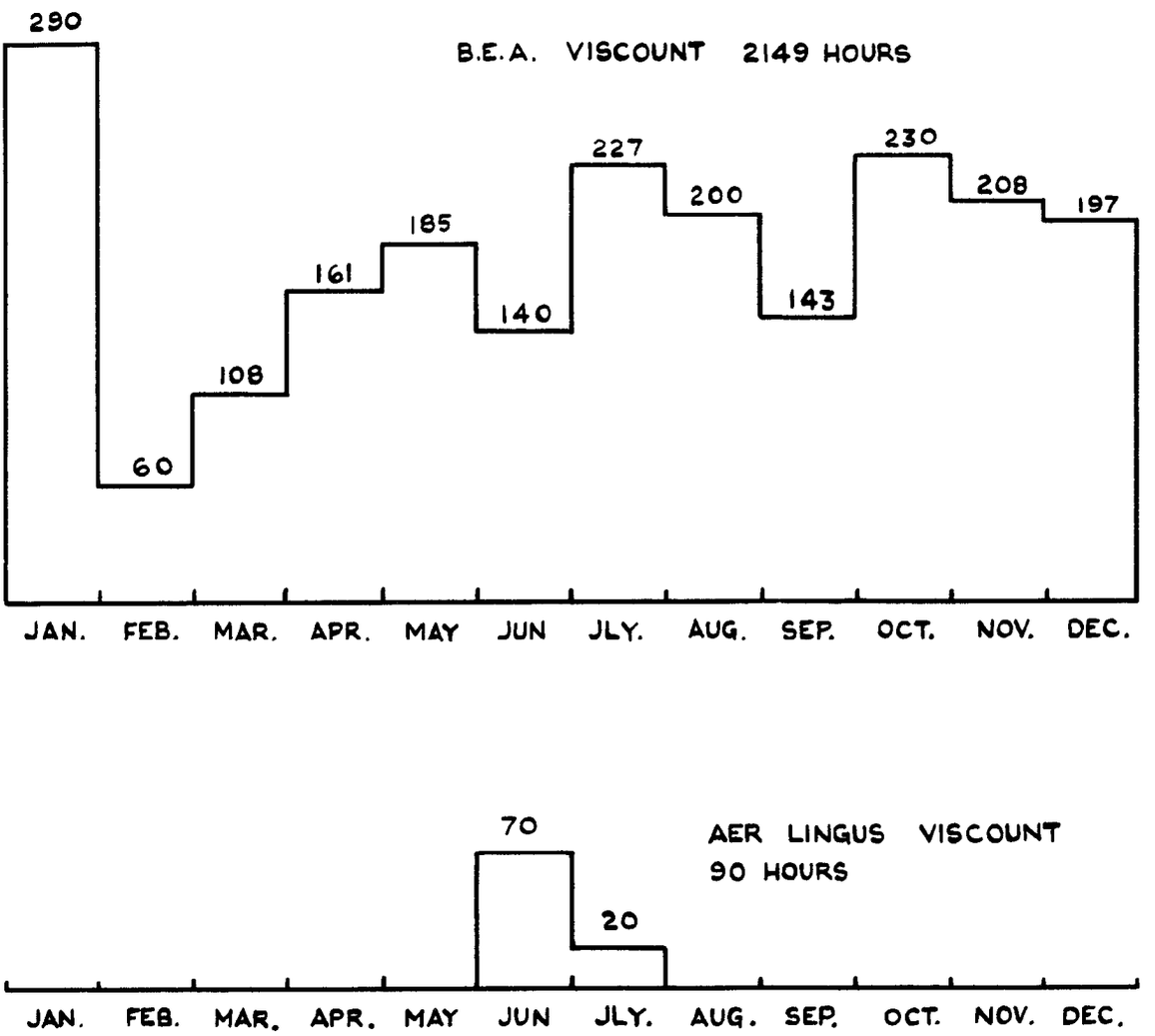

FIG. I. MONTHLY DISTRIBUTION OF RECORDING TIME.

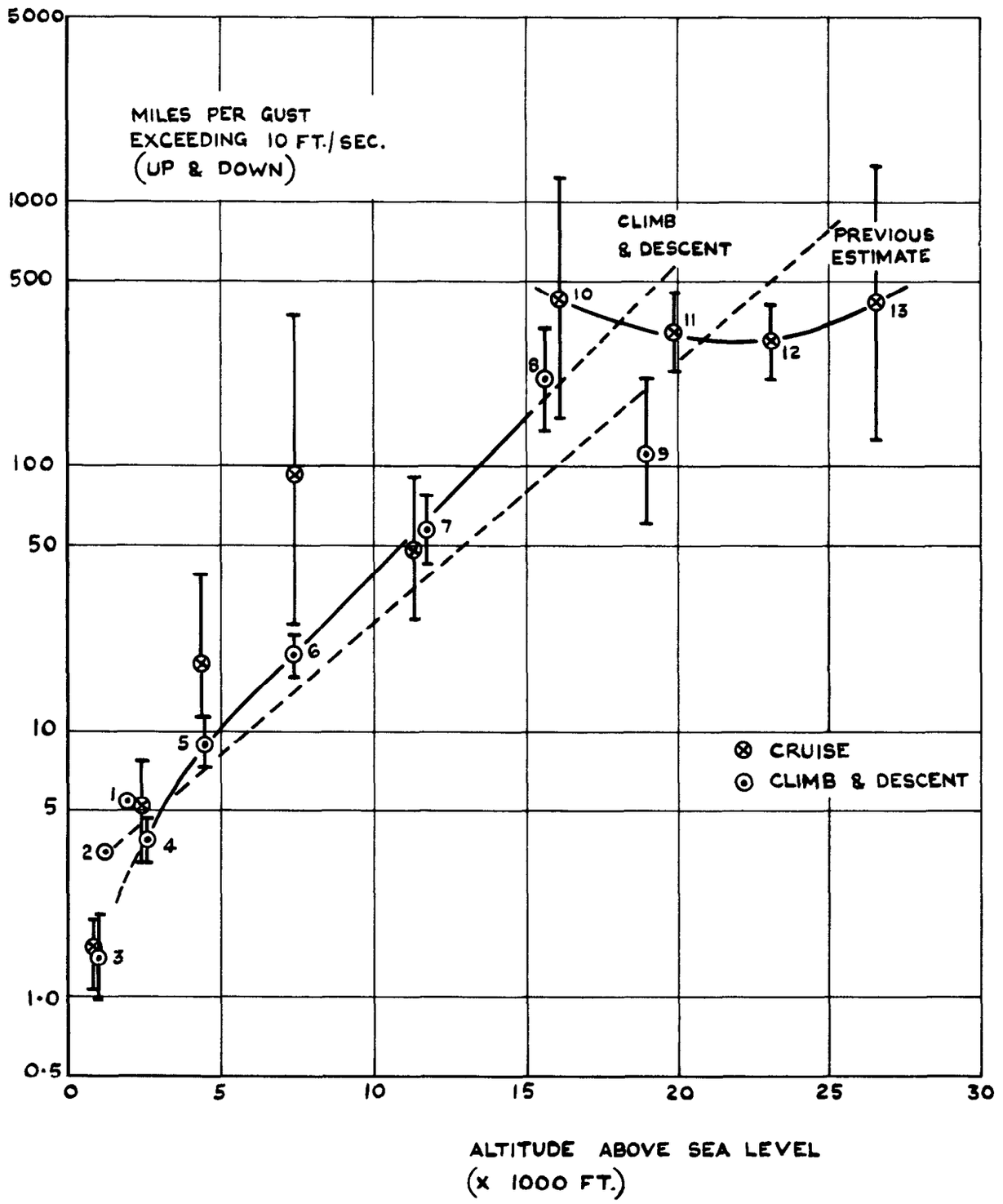

FIG. 2 VARIATION OF 10 FT/SEC. GUST FREQUENCY WITH ALTITUDE - B.E.A. VISCOUNT.

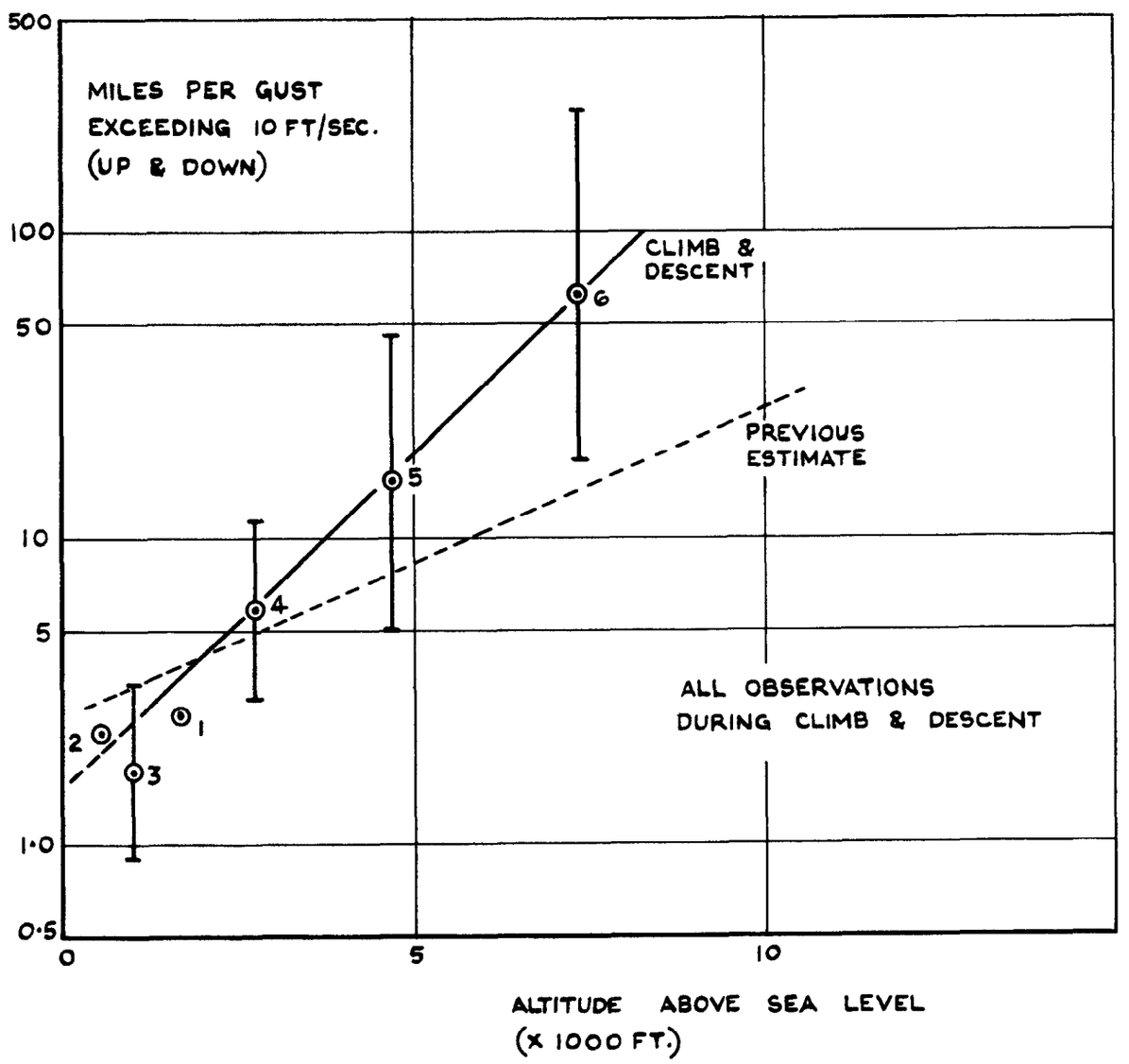

FIG. 3 VARIATION OF 10FT/SEC. GUST FREQUENCY WITH ALTITUDE-AER LINGUS VISCOUNT.

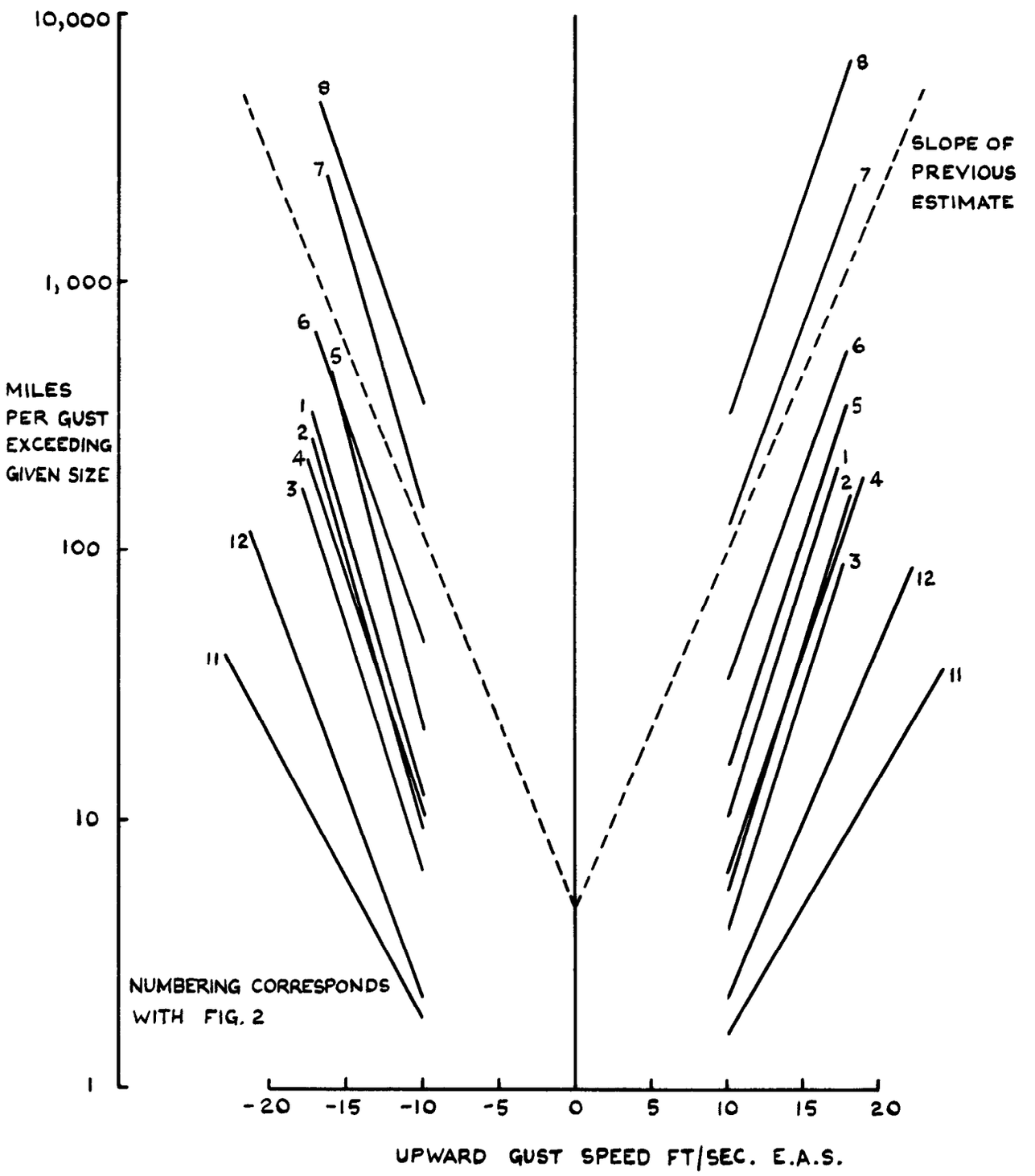

FIG. 4 VARIATION OF GUST FREQUENCY WITH GUST SPEED - B.E.A. VISCOUNT.

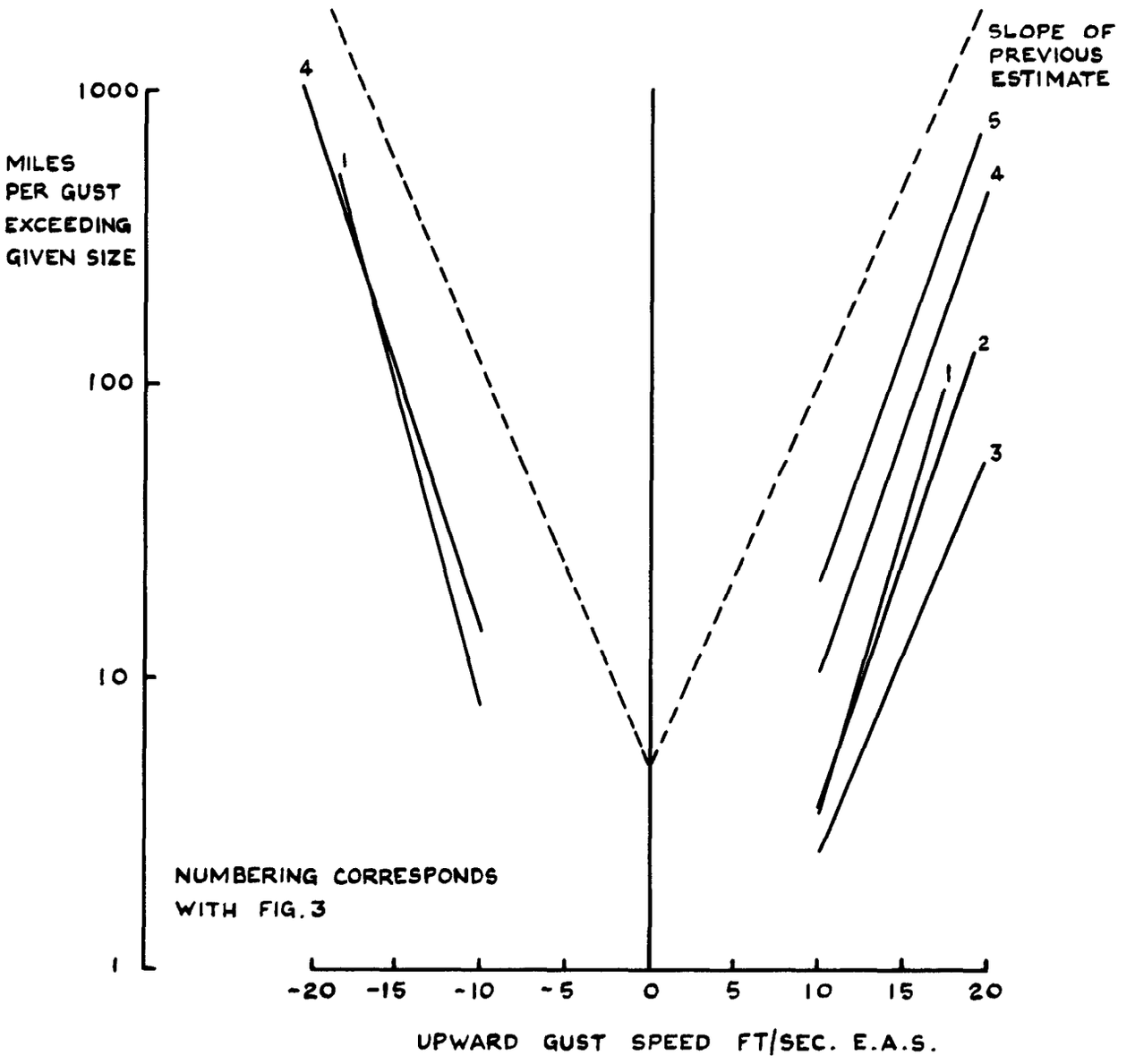

FIG. 5 VARIATION OF GUST FREQUENCY WITH GUST SPEED - AER LINGUS VISCOUNT.

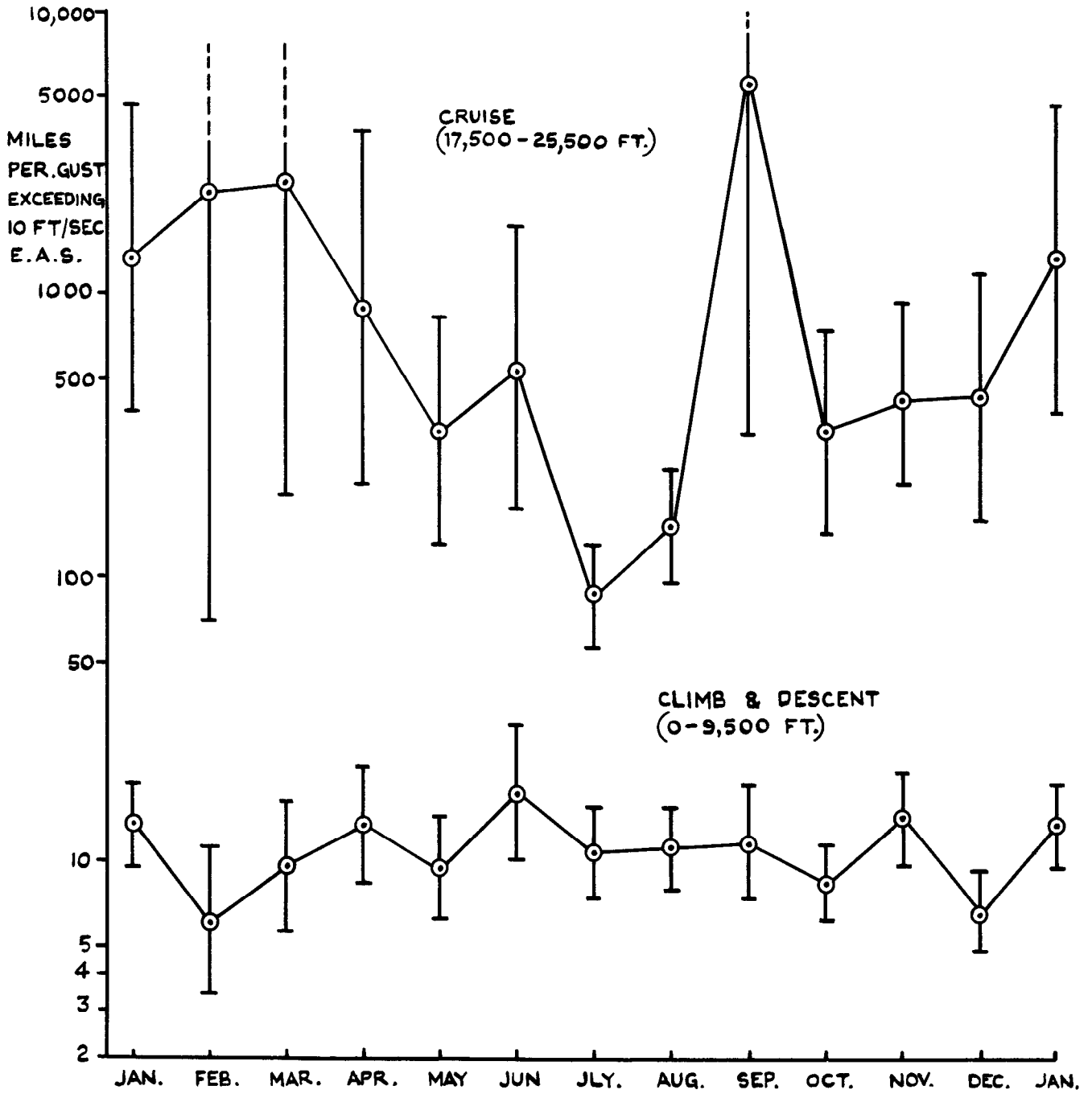

FIG. 6 MONTHLY VARIATION OF 10 FT/SEC. GUST FREQUENCY - B.E.A. VISCOUNT.

C.P. No. 463
(21,317)
A.R.C. Technical Report

Published by
HER MAJESTY'S STATIONERY OFFICE

To be purchased from
York House, Kingsway, London w.c.2
423 Oxford Street, London w.1
13A Castle Street, Edinburgh 2
109 St. Mary Street, Cardiff
39 King Street, Manchester 2
Tower Lane, Bristol 1
2 Edmund Street, Birmingham 3
80 Chichester Street, Belfast
or through any bookseller

Printed in England

S.O. Code No. 23-9011-63

C.P. No. 463