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Atmospheric Turbulence
Encountered by Hermes
Aircraft on Routes to
Africa and the Far East

by

Judy E. Aplin

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May 1964

ATMOSPHERIC TURBULENCE ENCOUNTERED BY HERMES AIRCRAFT
ON ROUTES TO AFRICA AND THE FAR EAST

by

Judy E. Aplin

SUMMARY

Counting accelerometer records were obtained of the turbulence encountered by Hermes 4 and Hermes 4A aircraft flying mainly on routes from the U.K.-Europe and Africa, representing some 427,000 and 495,000 miles respectively.

Comparison has been made of these results from aircraft operated by two airlines and, although the overall variations in gust frequency were found to be the usual ones with gust magnitude and altitude, there were differences between the gust spectra of the two aircraft due to their different modes of operation.

The reduction in turbulence encountered by the Hermes 4 during cruise was largely due to its having cruised at 12-13,000 feet whilst the Hermes 4A cruised at 9-10,000 feet, but the relatively gradual climb and descent of the Hermes 4A enabled its pilots to avoid more gusts during the rest of the flights.

Geographical comparisons of the records indicated that small magnitude gusts occurred less frequently in Europe than in East Africa, and higher magnitude gusts occurred rather more frequently in the Far East.

CONTENTS

	<u>Page</u>
1 INTRODUCTION	4
2 EQUIPMENT AND TYPE OF FLYING	4
2.1 Equipment	4
2.2 Type of flying	4
3 DATA	4
4 VARIATION OF GUST FREQUENCY WITH GUST SPEED	5
5 VARIATION OF GUST FREQUENCY WITH ALTITUDE	6
6 VARIATION OF GUST FREQUENCY WITH GEOGRAPHICAL LOCATION	7
7 CONCLUSIONS	7
REFERENCES	8
TABLES 1 to 17	9-23
ILLUSTRATIONS - Figs. 1-11	
DETACHABLE ABSTRACT CARDS	

TABLES

Table

1 - Estimated time in minutes spent at each speed and altitude during climb by Hermes 4 aircraft	9
2 - Estimated time in minutes spent at each speed and altitude during cruise by Hermes 4 aircraft	10
3 - Estimated time in minutes spent at each speed and altitude during descent by Hermes 4 aircraft	11
4 - Estimated time in minutes spent at each speed and altitude during climb by Hermes 4A aircraft	12
5 - Estimated time in minutes spent at each speed and altitude during cruise by Hermes 4A aircraft	13
6 - Estimated time in minutes spent at each speed and altitude during descent by Hermes 4A aircraft	14
7 - Summary of acceleration data from counting accelerometers Mk.2 in Hermes 4 aircraft	15

TABLES (Contd)

<u>Table</u>		<u>Page</u>
8	- Summary of acceleration data from counting accelerometers Mk.2 in Hermes 4A aircraft	16
9	- Aircraft characteristics assumed	17
10	- Representative values of acceleration/gust speed conversion factors	17
11	- Gusts encountered on all routes by Hermes 4 aircraft	18
12	- Gusts encountered on all routes by Hermes 4A aircraft	19
13	- Altitude bands used in analysis	20
14	- Acceleration data recorded in each geographical region during cruise by Hermes 4 aircraft	21
15	- Acceleration data recorded in each geographical region during cruise by Hermes 4A aircraft	21
16	- Gusts encountered in each geographical region during cruise by Hermes 4 aircraft	22
17	- Gusts encountered in each geographical region during cruise by Hermes 4A aircraft	23

ILLUSTRATIONS

	<u>Fig.</u>
Map of the routes flown by Hermes 4 aircraft	1
Map of the routes flown by Hermes 4A aircraft	2
Variation of gust frequency with gust speed during climb and descent for Hermes 4 aircraft	3
Variation of gust frequency with gust speed during climb and descent for Hermes 4A aircraft	4
Variation of gust frequency with gust speed during cruise for Hermes 4 aircraft	5
Variation of gust frequency with gust speed during cruise for Hermes 4A aircraft	6
Overall variation of gust frequency with gust speed for Hermes 4 and Hermes 4A aircraft	7
Variation of gust frequency with altitude for Hermes 4 aircraft	8
Variation of gust frequency with altitude for Hermes 4A aircraft	9
Variation of gust frequency with gust speed in each geographical region for Hermes 4 aircraft	10
Variation of gust frequency with gust speed in each geographical region for Hermes 4A aircraft	11

1 INTRODUCTION

Counting accelerometers were installed on Hermes 4 and Hermes 4A aircraft of B.O.A.C. and Airwork, respectively, to measure the loads imposed on the aircraft by atmospheric gusts encountered during flight. Although published previously in Ref.1 the B.O.A.C. Hermes 4 data have been re-analysed in the currently standard altitude bands and flight conditions, and are summarised accordingly.

This paper gives the recorded acceleration data and the gust speeds estimated from them, and discusses the variation of the frequency of occurrence of gusts with altitude and with geographical region. It is one of a series of papers giving similar information from counting accelerometers in other types of aircraft and, as is usual in these papers, no general description is given of the data processing or methods of analysis used, since these are published in Refs.2 and 3 where it is assumed that the aircraft is rigid and does not pitch, and that a gust has a ramp-shaped profile whose gradient distance is 100 feet.

2 EQUIPMENT AND TYPE OF FLYING

2.1 Equipment

R.A.E. Compound Counting Accelerometers, which are described fully in an Instruction Leaflet⁴ were installed as near as possible to the centre of gravity of the aircraft.

These accelerometers responded to the aircraft normal accelerations, registering by means of counters the number of times that each of a given series of upward and downward accelerations, in 0.1g steps, was exceeded. At intervals of approximately 10 minutes the acceleration counters were photographed together with the airspeed indicator, altimeter and clock. The electrical supply to the instrument was controlled by a Master switch in the cockpit.

2.2 Type of flying

Between April 1952 and October 1953 various aircraft of the B.O.A.C. Hermes 4 fleet carried counting accelerometers on normal passenger services between London and Africa. These routes are shown in Fig.1. A counting accelerometer was installed alternately in the two Hermes 4A aircraft of Airwork which were carrying passengers from Blackbushe to Africa and the Far East. Fig.2 illustrates the routes flown by these aircraft during the recording period February 1954 - March 1956.

3 DATA

Flight details such as the date, duration and route of each flight, together with the time and the weight of the aircraft at take-off, are supplied by the operators to supplement the film record of the acceleration data referred to in para.2.1. All these data are coded, transferred to punched cards and processed using methods explained by Heath-Smith².

Throughout this paper reference will be made to the various flight conditions into which counting accelerometer data are generally divided, these are defined as follows:-

- (a) Initial climb. The first interval of each flight.
- (b) Final descent. The last interval of each flight.
- (c) Climb. Any interval during which the aircraft increased altitude by 2000 ft or more.
- (d) Descent. Any interval during which the aircraft decreased altitude by 2000 ft or more.
- (e) Cruise. The remaining intervals.

The initial climb and final descent records were not used in the analysis of either the Hermes 4 or the Hermes 4A data, since they included some ground bumps.

The mean speed and altitude of each interval have been taken as representative of conditions throughout the climb, cruise and descent intervals and the weight of the aircraft has been reduced progressively throughout each flight according to the fuel consumed.

The time spent at different speeds and altitudes is given for the climb in Table 1, the cruise in Table 2, and the descent in Table 3 for the Hermes 4 aircraft and similarly in Tables 4, 5 and 6 for the Hermes 4A aircraft. From these tables it is apparent that the Hermes 4 cruised at 12-13,000 feet whereas the Hermes 4A cruised at 9-10,000 feet.

The summarised acceleration data are given in Tables 7 and 8 for Hermes 4 and Hermes 4A aircraft, respectively, the records having been divided into climb and descent combined, and cruise. The tables show the number of times each given acceleration increment was exceeded in an altitude band together with the recorded time and estimated distance flown in that band.

The acceleration counts were converted to gust counts by the same method as Heath-Smith¹ used in the previous analysis, i.e. using the discrete gust concept with gust alleviation factors according to Zbrozek³, and Tables 11 and 12 give the results of this conversion for Hermes 4 and Hermes 4A in the same divisions as the acceleration data.

Table 9 gives the aircraft characteristics assumed in the calculations and Table 10 some values of acceleration/gust speed conversion factors at representative conditions. Table 13 is the key to the altitude bands used in the counting accelerometer analysis.

4 VARIATION OF GUST FREQUENCY WITH GUST SPEED

In Figs.3 and 4 the mile/gust value is plotted against each gust speed to illustrate the variation of gust frequency with gust magnitude in each altitude

band of the climb and descent combined data, for the Hermes 4 and Hermes 4A aircraft. Similarly Figs.5 and 6 show this variation during cruise conditions.

From these four figures it is apparent that, in general, the frequency of occurrence of gusts decreases with their magnitude and with altitude. If the upgust and downgust curves are compared on each figure it is found that the ratio of upgusts to downgusts remains fairly constant in each altitude band, with the exception that in the lowest two bands of the climb and descent records from the Hermes 4 aircraft a marked decrease in the occurrence of downgusts relative to the upgusts is indicated. The reason for this is not clear.

To investigate the overall slope of these curves, the data from all altitudes were combined to give one up and one down curve for climb plus descent, and a similar pair for cruise, for each aircraft as shown in Fig.7.

At the low speed end of the cruise curves, the statistically more significant end, the slopes are very similar indicating that the relative frequency of gusts of different magnitudes was the same for both aircraft, although fewer gusts of all but the highest magnitudes were encountered by the Hermes 4 as the position of its cruise curves show. The Hermes 4 was operated at a higher cruising altitude than the Hermes 4A which no doubt accounts for this effect.

Since it encountered fewer gusts of larger magnitude relative to the number of small gusts, the Hermes 4A shows slightly steeper climb and descent curves than the Hermes 4.

5 VARIATION OF GUST FREQUENCY WITH ALTITUDE

To study the effect of altitude on the frequency of occurrence of gusts, the up and down gusts of magnitude equal to, or greater than, 10 ft/sec were combined, divided into the mileage flown in each altitude band and plotted against the mean altitude of the band for both types of aircraft (Figs.8 and 9). The curves were drawn with due regard to 95% confidence limits calculated by Bullen's method⁵, and the choice of gust speed for this investigation was governed by considerations which are defined in another paper of this series⁶.

The climb and descent records were amalgamated but kept separate from those of the cruise. Low altitude cruise data were felt to be mainly stand-off and landing approaches rather than true cruise, and, as such, were omitted from the graphs.

Both sets of curves show the usual decrease in gust frequency with altitude, the turbulence during cruise being markedly less than that during climb and descent in each case since the pilots were able to exercise more discretion in the avoidance of turbulence during the cruise.

The pronounced difference in slope of the two climb and descent curves can probably be attributed to the operational differences between the two airlines. The Hermes 4A aircraft flying Far Eastern routes, where more severe turbulence occurs⁷, show fewer miles/gust at the low altitudes than the Hermes 4. However this effect has been masked at the higher altitudes by the fact that the

Hermes 4A were able to avoid more turbulence during a relatively leisurely climb than the Hermes 4 which were climbing faster to attain their cruising heights.

6 VARIATION OF GUST FREQUENCY WITH GEOGRAPHICAL LOCATION

The cruise records from the main altitude bands were divided according to the geographical area over which flying had taken place and coded according to the regions shown on the maps, Figs.1 and 2.

Tables 14 - 17 give the accelerations recorded by Hermes 4 and Hermes 4A aircraft in each region and the corresponding estimated gust speeds.

Figs.10 and 11 show the mile/gust value plotted against gust speed for the two types of aircraft. These figures do not indicate any very clear trends. On Fig.10, for instance, the curves for regions 3 and 4 are derived from relatively small samples of data and therefore cannot be considered very significant, but the other two pairs of curves, regions 1 and 2, illustrate that gusts of all magnitude occurred more frequently in East Africa than in Europe at the cruising altitude of the Hermes 4 aircraft, i.e. in the region of 13,000 ft. On Fig.11 region 3 again represents small mileage, and may therefore be discounted, and there is little overall difference between the other regions which were flown at about 9000 ft by the Hermes 4A aircraft. Small magnitude gusts occurred less frequently in Europe than in East Africa and higher magnitude gusts occurred rather more frequently in the Far East.

7 CONCLUSIONS

Although no features of special interest have emerged from these data, they do form a significant addition to the statistics already available from other aircraft flying similar routes at these altitudes. They confirm that the gust frequencies follow the usual variation with gust magnitude, altitude and geographical location, and that differences in the operation of aircraft will result in differences in their gust spectra.

By comparing these results from Hermes 4 and Hermes 4A aircraft it has been shown that the reduction in turbulence encountered by the Hermes 4 was largely due to its higher cruising altitude and that the relatively gradual climb and descent of the Hermes 4A enabled its pilots to avoid the more severe gusts.

The effect of geographical location on these results was seen to be that gusts, particularly small magnitude gusts, occurred more frequently in East Africa than in Europe and that large magnitude gusts occurred more frequently in the Far East.

REFERENCES

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6	Aplin, J.E.	Atmospheric turbulence encountered by Comet 2 aircraft carrying cloud collision warning radar. ARC C.P.713. June 1963
7	Heath-Smith, J.R.	Turbulence encountered by Comet 1 aircraft. ARC Current Paper No.248. May 1955

TABLE 1

Estimated time in minutes spent at each speed and altitude
during climb by Hermes 4 aircraft

	Altitude above sea level (I.C.A.N.) × 1000 ft																				
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
120															21						
130										10	21	21				11	10	11			
140				11	115	219	177	312	291	312	343	115	198	52	94	73	94	21	10	10	10
150				32	104	187	104	270	353	260	260	177	104	114	93	31	21	21	31		
160		10		21	32	42	62	73	42	125	188	312	198	125	31	21	83	31	21	10	
170					10		10	10	10	104	115	135	42	42	10	21	10	10	10		
180									10	42		10									
190									10												
TOTALS	-	10	-	64	261	448	353	665	716	853	927	770	542	333	249	157	218	94	72	20	10

Total climb: 6762 minutes

TABLE 2

Estimated time in minutes spent at each speed and altitude during cruise by Hermes 4 aircraft

		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
Indicated airspeed in knots	100	21																						
	110	21																						
	120										10													
	130	41	11	11	10							10			11	32								
	140	41	21						21	21	83	32	94	146	93	104	177	125	146	167	73	11	42	
	150	21	21						10	10	83	84	926	2,662	2,267	1737	655	1456	1081	1935	572	250	21	
	160		32						42	176	198	1248	11,795	21,218	15,986	6313	988	1352	1706	2715	1550	437	146	21
	170								10	42	468	1185	3,588	4,919	3,370	936	104	177	208	271	270	42		
	180								10	21	42	281	312	416	114	73	10	52	21	31				
	190									21	21	52	42	42	10		10	10	21	11				
200									21		10								10					
TOTALS		42	103	85	11	30	72	52	146	498	916	2902	16,767	29,413	21,851	9195	1944	3172	3183	5140	2465	740	167	63

Total cruise: 98,957 minutes

TABLE 3

Estimated time in minutes spent at each speed and altitude
during descent by Hermes 4 aircraft

		Altitude above sea level (I.C.A.N.) in 1000 s of feet																			
		00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
Indicated airspeed in knots	100					10															
	110		10	21	21	32	21	10													
	120	32	42	63	52	84	31	31	31	41	21	32									
	130		21	93	94	63	104	83	21	32	42	21	31	10							
	140		10	31	114	63	32	62	62	42	10		10	11							
	150			42	93	31	52	42	83	125	31	52	21	31	31	10	10	21		10	10
	160		10		32	125	73	145	114	93	84	83	62	83	62	10	52	11		10	
	170			10	83	104	125	188	198	187	219	281	73	166	73	52	84	62	21	10	
	180				21	104	52	136	198	208	364	291	250	125	104	83	31	62	31		10
	190				11	21	21	73	104	83	136	93	83	21	31	31	21	52			
	200				10	10	21	21	42	104	124	11	42	31	10	32	10				
210			11			11	11	10	52	42	31	21	10		10					21	
220								10	10			10									
TOTALS		32	93	271	531	647	543	812	873	967	1093	884	635	478	321	228	208	52	30	41	

Total descent: 894.7 minutes

TABLE 4

Estimated time in minutes spent at each speed and altitude
during climb by Hermes 4A aircraft

		Altitude above sea level (I.C.A.N.) in 1000' s of feet											
		02	03	04	05	06	07	08	09	10	11	12	13
Indicated airspeed in knots	130		40	30		20	20						10
	140		70	292	384	273	353	242	141	40	50		
	150	50	111	323	384	525	545	464	445	141	111		
	160	30	10	30	70	162	364	263	233	111	30	10	
	170	10	10		10	40	131	121	10				
	180						20						
TOTAL		90	241	675	848	1020	1433	1090	829	292	191	10	10

Total climb: 6729 minutes

TABLE 5

Estimated time in minutes spent at each speed and altitude
during cruise by Hermes 4A aircraft

		Altitude above sea level (I.C.A.N.) in 1000's of feet													
		00	01	02	03	04	05	06	07	08	09	10	11	12	13
Indicated airspeed in knots	130	10	30		10			20				20			
	140		20	50				10	61	162	353	404	131	131	50
	150	10	30	40	20		50	50	323	2,818	10,402	13,775	4,080	1182	111
	160		10	10	10	30	111	71	757	12,927	32,025	26,046	5,726	1020	81
	170			10		10	71	30	212	2,858	5,757	3,050	788	71	
	180					10	10	40	30	182	151	50	30		
	190								20	20	20				
	200										10				
TOTAL		20	90	110	40	50	242	221	1403	18,967	48,718	43,345	10,755	2404	242

Total cruise: 126,607 minutes

TABLE 6

Estimated time in minutes spent at each speed and altitude

during descent by Hermes 4A aircraft

		Altitude above sea level (I.C.A.N.) in 1000's of feet											
		01	02	03	04	05	06	07	08	09	10	11	12
Indicated airspeed in knots	110			10			10						
	120	10	20	71	20	10		20					
	130	40	101	101	40	10							
	140	20	142	252	111	40	40	10		10	10		10
	150	10	111	212	263	171	172	141	91	81	20	40	
	160	10	40	161	293	252	404	384	586	464	181	81	10
	170		40	111	202	283	424	455	485	182	20	10	
	180			30	131	161	212	252	131	61	30		
	190				10	10	61	101	30	20			
	200				10	10	40	10	10				
210						10							
TOTAL		100	454	948	1080	947	1373	1373	1333	818	261	131	20

Total descent: 8838 minutes

TABLE 9

Aircraft characteristics assumed

	<u>Hermes 4</u>	<u>Hermes 4A</u>
Wing area:	1408 sq ft	1408 sq ft
Mean chord:	12.44 ft	12.46 ft
Aspect ratio:	9.10	9.07
Slope of the lift curve constant at:	4.53/radian	4.70/radian

TABLE 10

Representative values of acceleration/gust speed conversion factors

Hermes 4

Gust speed/acceleration in ft/sec/g									
Indicated airspeed knots	Sea level			10,000 ft			20,000 ft		
	Aircraft weight (x 1000 lb)								
	50	70	90	50	70	90	50	70	90
100	56.49	72.80	88.82	52.00	69.09	84.57	49.36	65.77	80.66
150	37.66	48.53	59.21	34.67	46.06	56.38	32.91	43.85	53.78
200	28.25	36.40	44.41	26.00	34.55	42.28	24.68	32.88	40.33

Hermes 4A

Gust speed/acceleration in ft/sec/g												
Indicated airspeed knots	Sea level				10,000 ft				20,000 ft			
	Aircraft weight (x 1000 lb)											
	60	70	80	90	60	70	80	90	60	70	80	90
120	51.47	58.47	65.06	71.37	48.79	55.50	61.85	67.91	46.39	52.81	58.96	66.32
160	38.60	43.85	48.80	53.53	36.59	41.63	46.39	50.93	34.79	39.61	44.22	49.74
200	30.88	35.08	39.04	42.82	29.27	33.30	37.11	40.75	27.83	31.69	35.38	39.79

TABLE 12

Gusts encountered on all routes by Hermes 4A aircraft

Flight condition	Altitude band feet	Mean altitude feet	Recorded time min.	Statute miles	Number of times each gust speed was exceeded vertical gust speed in ft/sec E.A.S.																				
					Down								Up												
					40	35	30	25	20	15	10	10	15	20	25	30	35	40	45	50	55				
Climb and descent (excluding initial climb and final descent)	0- 1,500	1,000	100	264					3	18	186	234	32	6	3	2	1	1							
	1500- 3,500	2,690	1,733	5,086				2	17	117	832	1177	184	31	3	1									
	3500- 5,500	4,510	3,550	11,273				1	11	68	452	597	107	24	5	1									
	5500- 9,500 9500-13,500	7,100 10,450	9,269 915	31,639 3,200			2	4	14	55 1	356 33	559 27	100 3	20 1	4 1	1									
TOTAL			15,567	51,462			2	7	45	259	1859	2594	426	82	16	5	2	1							
Cruise	0- 1,500	870	110	306			1	3	24	67	167	434	136	41	14	5	4	4	4	2	1				
	1500- 3,500	2,270	150	445				1	6	46	436	347	62	14	3										
	3500- 5,500	4,830	292	981					2	8	90	123	9	2											
	5500- 9,500	8,680	69,309	241,473		1	2	5	19	84	319	1653	1857	412	106	22	8	3							
	9500-13,500	10,290	56,746	199,937			1	1	7	23	90	300	1172	1154	308	100	24	12	4	3	1				
TOTAL			126,607	443,142		1	3	13	46	206	740	3518	3915	927	263	63	25	11	7	5	2	1			

TABLE 13

Altitude bands used in analysis

00	0 - 1,500
02	1,500 - 3,500
04	3,500 - 5,500
06	5,500 - 9,500
10	9,500 - 13,500
14	13,500 - 17,500
18	17,500 - 21,500
22	21,500 - 25,500
26	25,500 - 29,500
30	29,500 - 33,500
34	33,500 - 37,500
38	37,500 - 41,500
42	41,500 - 45,500

TABLE 14

Acceleration data recorded in each geographical region during cruise by Hermes 4 aircraft

Geographical region	Altitude band feet	Mean altitude feet	Recording time min.	Statute miles	Number of times each acceleration increment was exceeded																								
					Down						Up																		
					1.02g	0.92g	0.82g	0.72g	0.62g	0.52g	0.43g	0.33g	0.23g	0.23g	0.23g	0.33g	0.43g	0.52g	0.62g	0.72g	0.82g								
1. Europe	5,500-9,500 9,500-13,500 13,500-17,500 17,500-21,500	8,600 12,000 14,800 18,600	530 28,946 8,103 6,844	1,959 107,804 31,049 27,688	1	1	1	1	1	1	5	1	3	1	2	18	9	18	46	14	121	20	13	6	2	5	1		
2. East Africa	5,500-9,500 9,500-13,500 13,500-17,500 17,500-21,500	8,400 12,000 15,400 18,400	894 34,739 6,719 956	3,218 128,849 25,372 3,764			1	2	1	4	5	2	19	39	6	35	153	21	4	58	107	44	14	52	14	6	16	1	3
3. West Africa	5,500-9,500 9,500-13,500 13,500-17,500 17,500-21,500	8,100 11,900 15,000 18,100	177 5,325 780 312	645 19,788 3,017 1,216						1	2	2	4		3	28	5	1	8	1	129	24	26	5	4				
4. South Africa	9,500-13,500 13,500-17,500 17,500-21,500	12,500 14,900 18,600	1,872 1,893 395	6,983 7,269 4,612												3			8	1	18	4	4	1	1				
TOTALS			98,485	370,233	1	1	2	5	8	24	69	267	963	1313	366	87	32	11	4	3									

TABLE 15

Acceleration data recorded in each geographical region during cruise by Hermes 4A aircraft

Geographical region	Altitude band feet	Mean altitude feet	Recorded time min.	Statute miles	Number of times each acceleration increment was exceeded																								
					Down						Up																		
					0.82g	0.72g	0.62g	0.52g	0.43g	0.33g	0.23g	0.23g	0.23g	0.33g	0.43g	0.52g	0.62g	0.72g	0.82g	0.92g									
1. Europe	5500-9,500 9500-13,500	8,700 10,300	30,399 27,470	107,200 97,993			7	4	19	14	59	314	335	66	23	3	7	3	2										
2. East Africa	5500-9,500 9500-13,500	8,700 10,300	12,452 13,624	43,381 47,833			1	4	4	15	62	400	480	87	11	2	1	1	1										
3. West Africa	5500-9,500 9500-13,500	8,600 10,000	1,394 818	4,953 2,891				6	1	16	43	155	158	44	5	19	8	6											
5. Far East	5500-9,500 9500-13,500	8,700 10,200	25,066 14,836	85,939 51,220	1	2	4	17	45	132	447	530	530	171	60	14	8	10	3	1									
TOTALS			126,059	441,410	1	3	14	62	181	553	2277	2449	2449	639	212	57	31	8	4	1									

TABLE 16

Gusts encountered in each geographical region during cruise by Hermes 4 aircraft

Geographical region	Altitude band feet	Mean altitude feet	Recorded time min.	Statute miles	Number of times each gust speed was exceeded vertical gust speed in ft/sec E.A.S.														
					Down						Up								
					45	40	35	30	25	20	15	10	10	15	20	25	30	35	40
1. Europe	5,500- 9,500	8,600	530	1,959							2	4	21	2					
	9,500-13,500	12,000	28,946	107,804			1	1	1	4	22	117	154	27	7	4	1		
	13,500-17,500	14,800	8,103	31,049						1	10	83	37	12	3	1			
	17,500-21,500	18,600	6,844	27,688	1	1	1	1	3	7	15	51	54	21	6	1			
2. East Africa	5,500- 9,500	8,400	894	3,218		1	1	1	2	19	30	60	116	41	11	4			
	9,500-13,500	12,000	34,739	128,849			2	3	8	37	169	625	785	218	55	14	6	3	1
	13,500-17,500	15,400	6,719	25,372						4	16	107	110	14	1				
	17,500-21,500	18,400	956	3,764							2	5	11	2					
3. West Africa	5,500- 9,500	8,100	177	645								-	-						
	9,500-13,500	11,900	5,325	19,788					2	2	4	38	140	23	2				
	13,500-17,500	15,000	780	3,017								6	35	3					
	17,500-21,500	18,100	312	1,216								1	5						
5. Far East	9,500-13,500	12,500	1,872	6,983							2	8	18	3	1				
	13,500-17,500	14,900	1,893	7,269								1	4	1					
	17,500-21,500	18,600	395	1,612								-	-						
		TOTALS	98,485	307,233	1	2	5	6	16	74	272	1106	1490	367	86	24	7	3	1

TABLE 17

Gusts encountered in each geographical region during cruise by Hermes 4A aircraft

Geographical region	Altitude band feet	Mean altitude feet	Recorded time min.	Statute miles	Number of times each gust speed was exceeded vertical gust speed in ft/sec E.A.S.														
					Down							Up							
					40	35	30	25	20	15	10	10	15	20	25	30	35	40	45
1. Europe	5500-9,500 9500-13,500	8,700 10,300	30,399 27,470	107,200 97,993				2 5	12 16	60 140	374 476	410 399	73 113	18 43	2 13	6 6	3 3	2 2	1 1
2. East Africa	5500-9,500 9500-13,500	8,700 10,300	12,452 13,624	43,381 47,833				2 2	13 13	62 66	532 266	615 292	95 50	11 15	1 3	1 1	1 1		
3. West Africa	5500-9,500 9,500-13,500	8,600 10,000	1,394 818	4,953 2,891				1 1	9 1	36 8	215 52	182 89	41 12	13 2	6 6				
5. Far East	5500-9,500 9500-13,500	8,700 10,200	25,066 14,836	85,939 51,220	1	2	5	17	47	158	570	671	199	63	13	7	2		
		TOTALS	126,059	441,410	1	3	12	45	169	615	2863	3038	714	205	46	20	7	3	1

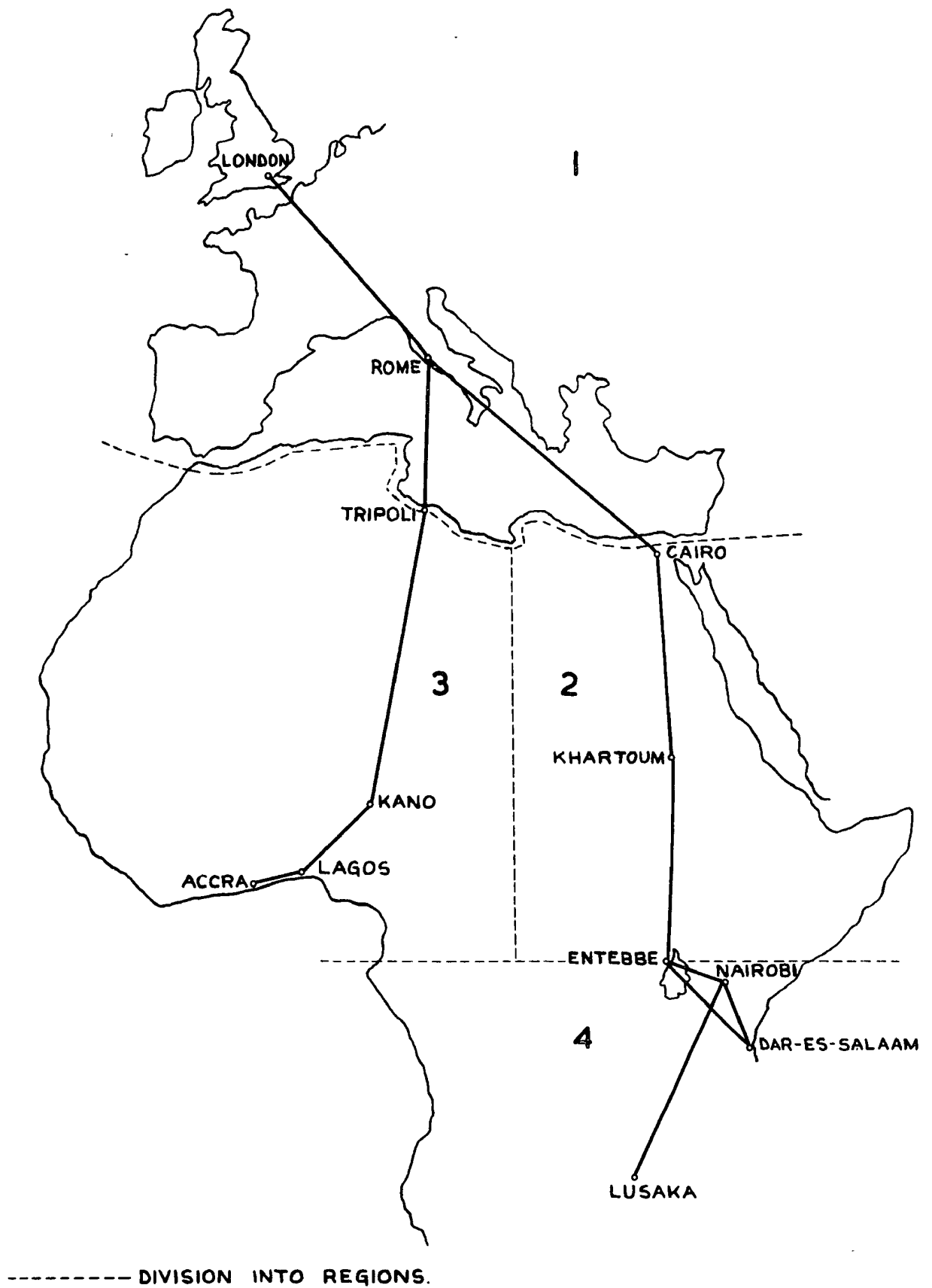


FIG.1. MAP OF THE ROUTES FLOWN BY HERMES 4 AIRCRAFT.

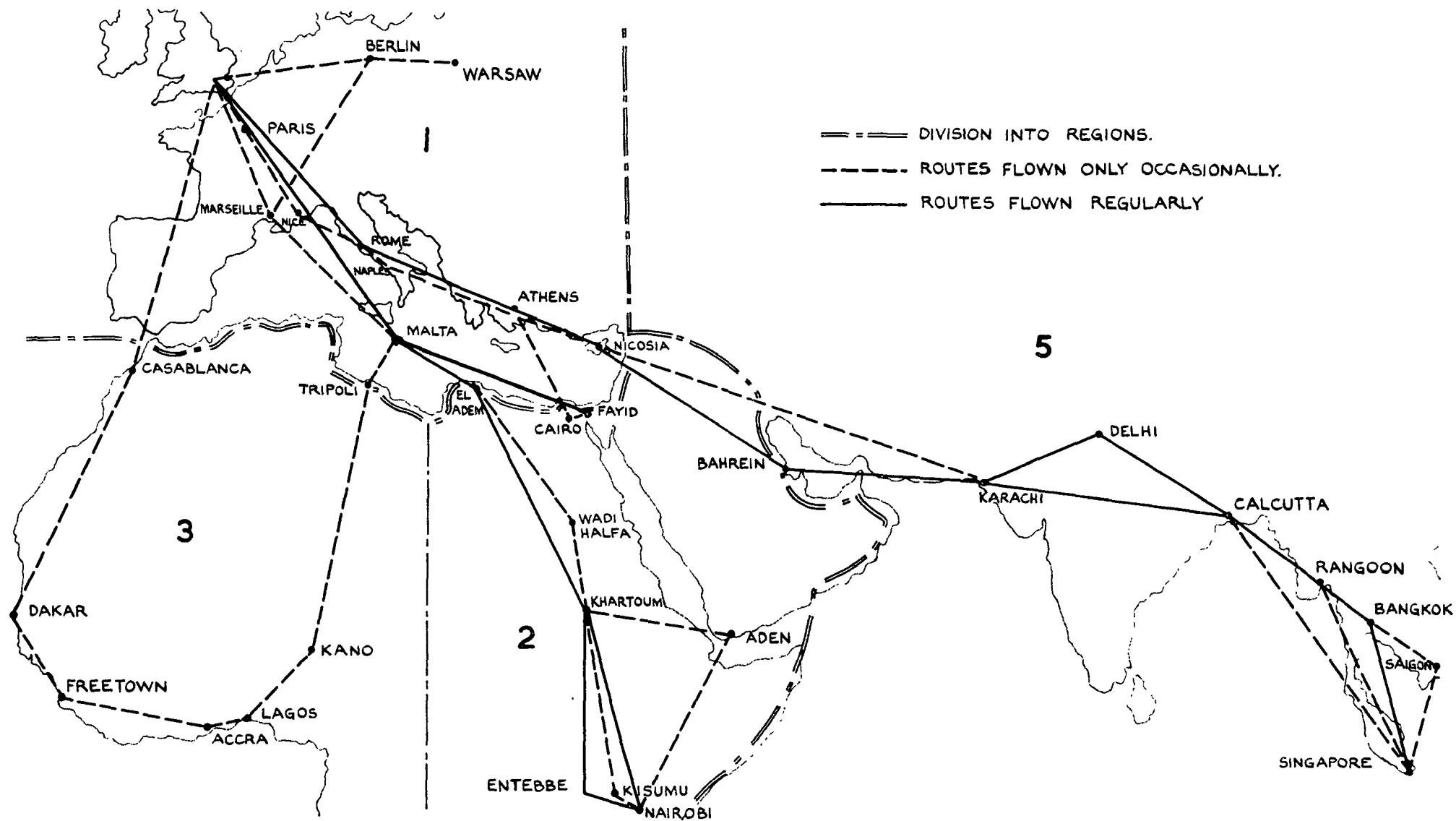


FIG.2. MAP OF THE ROUTES FLOWN BY HERMES 4A AIRCRAFT.

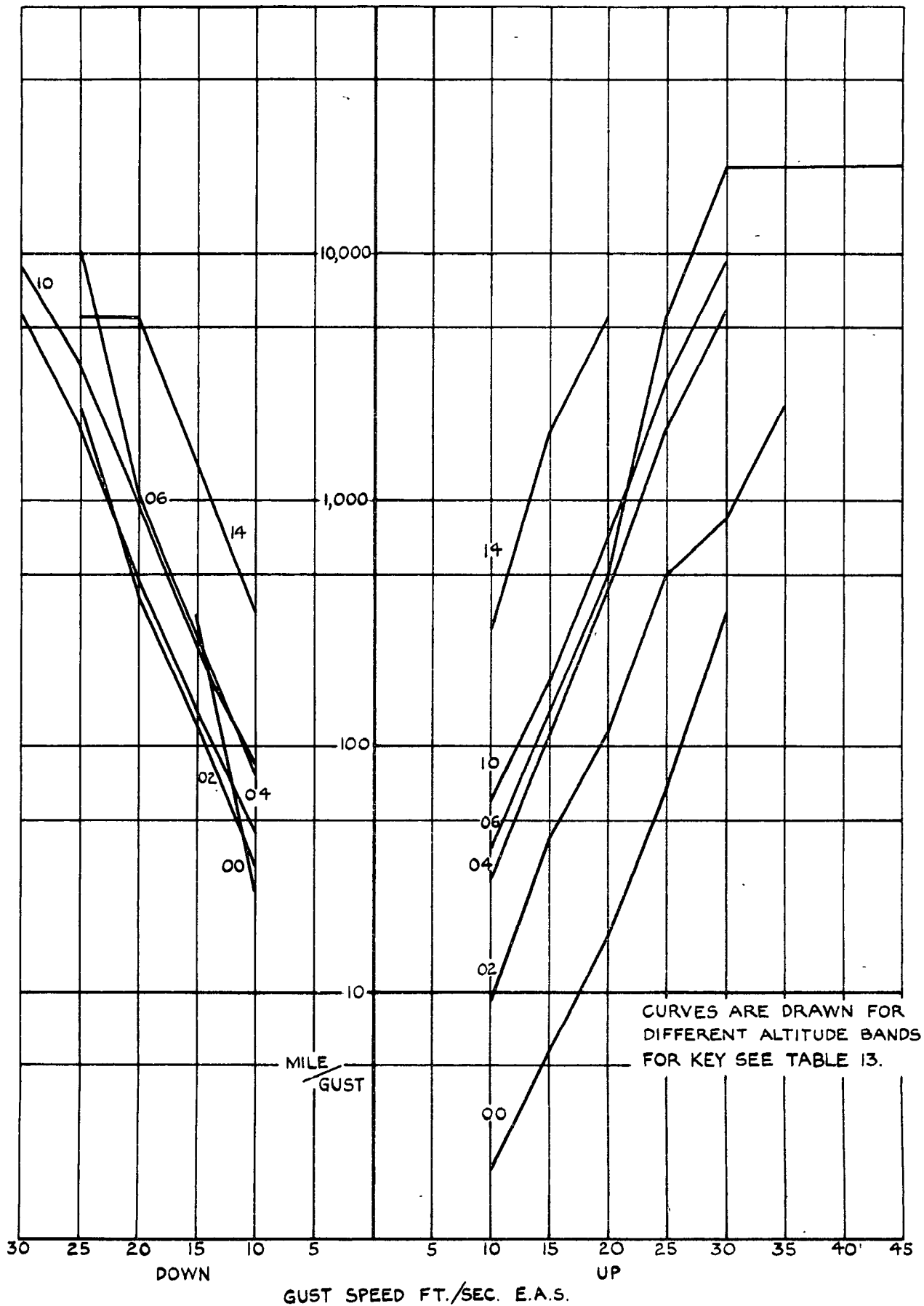


FIG.3. VARIATION OF GUST FREQUENCY WITH GUST SPEED DURING CLIMB AND DESCENT FOR HERMES 4 AIRCRAFT.

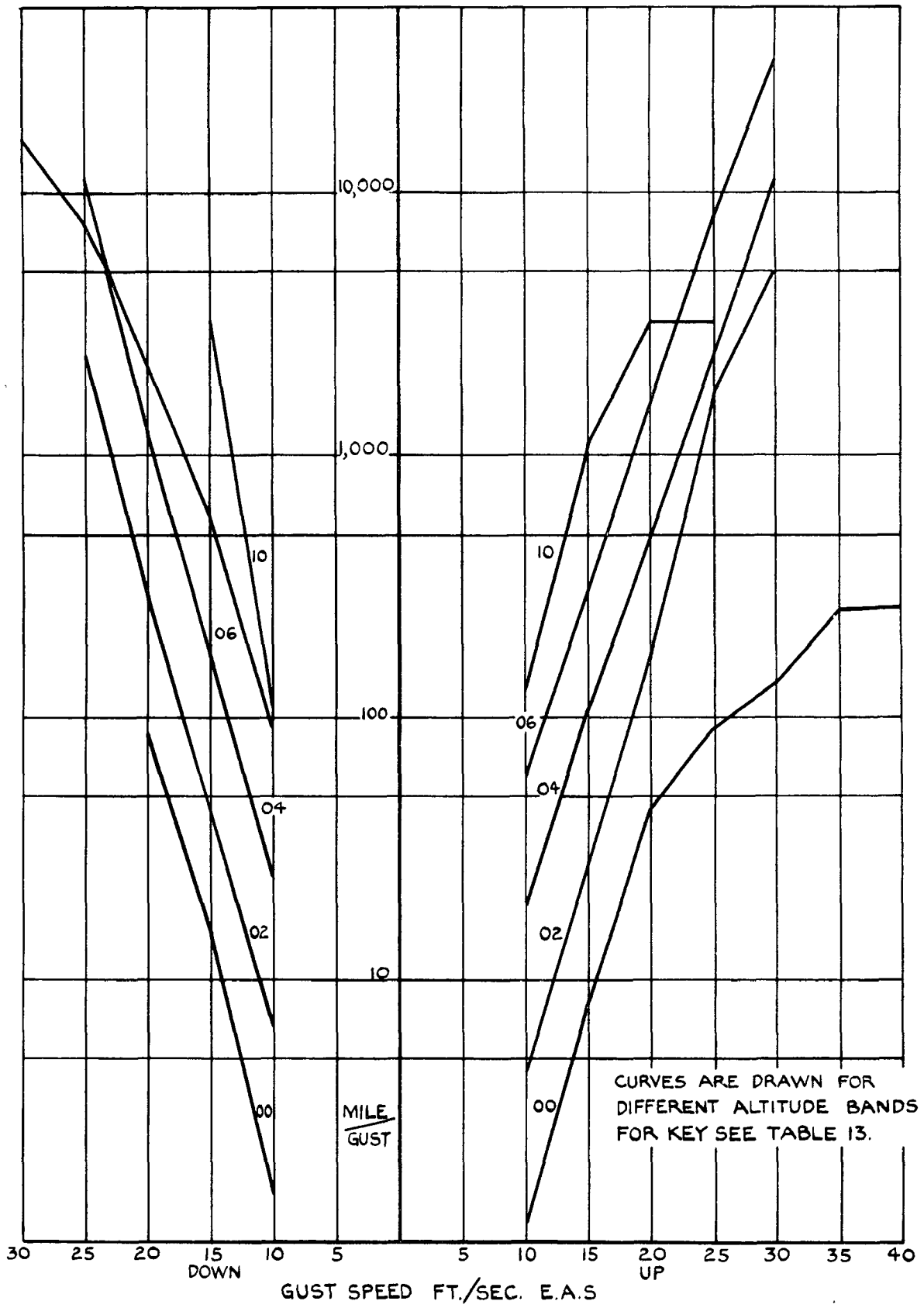


FIG.4. VARIATION OF GUST FREQUENCY WITH GUST SPEED DURING CLIMB AND DESCENT FOR HERMES 4A AIRCRAFT.

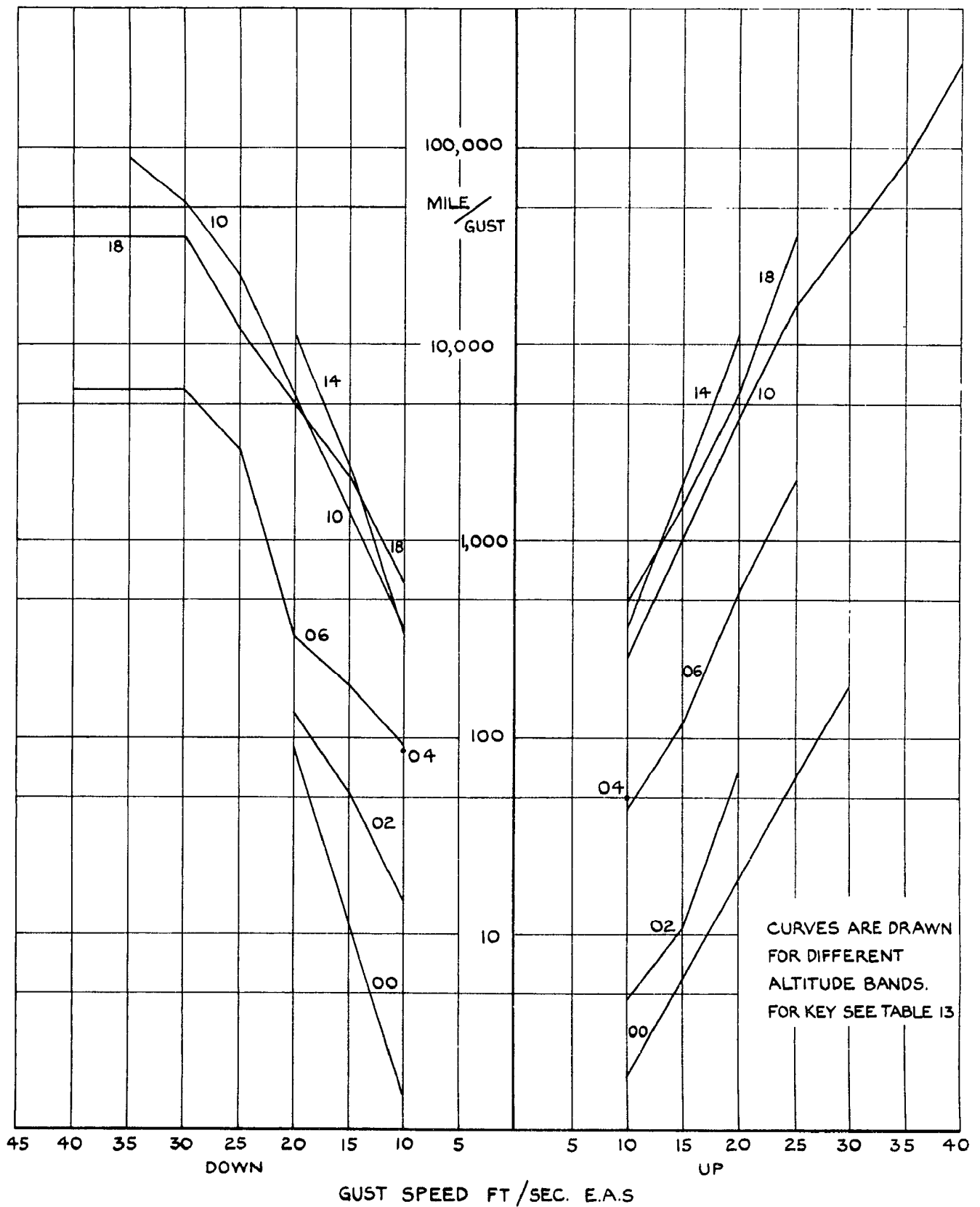


FIG.5. VARIATION OF GUST FREQUENCY WITH GUST SPEED DURING CRUISE FOR HERMES 4 AIRCRAFT.

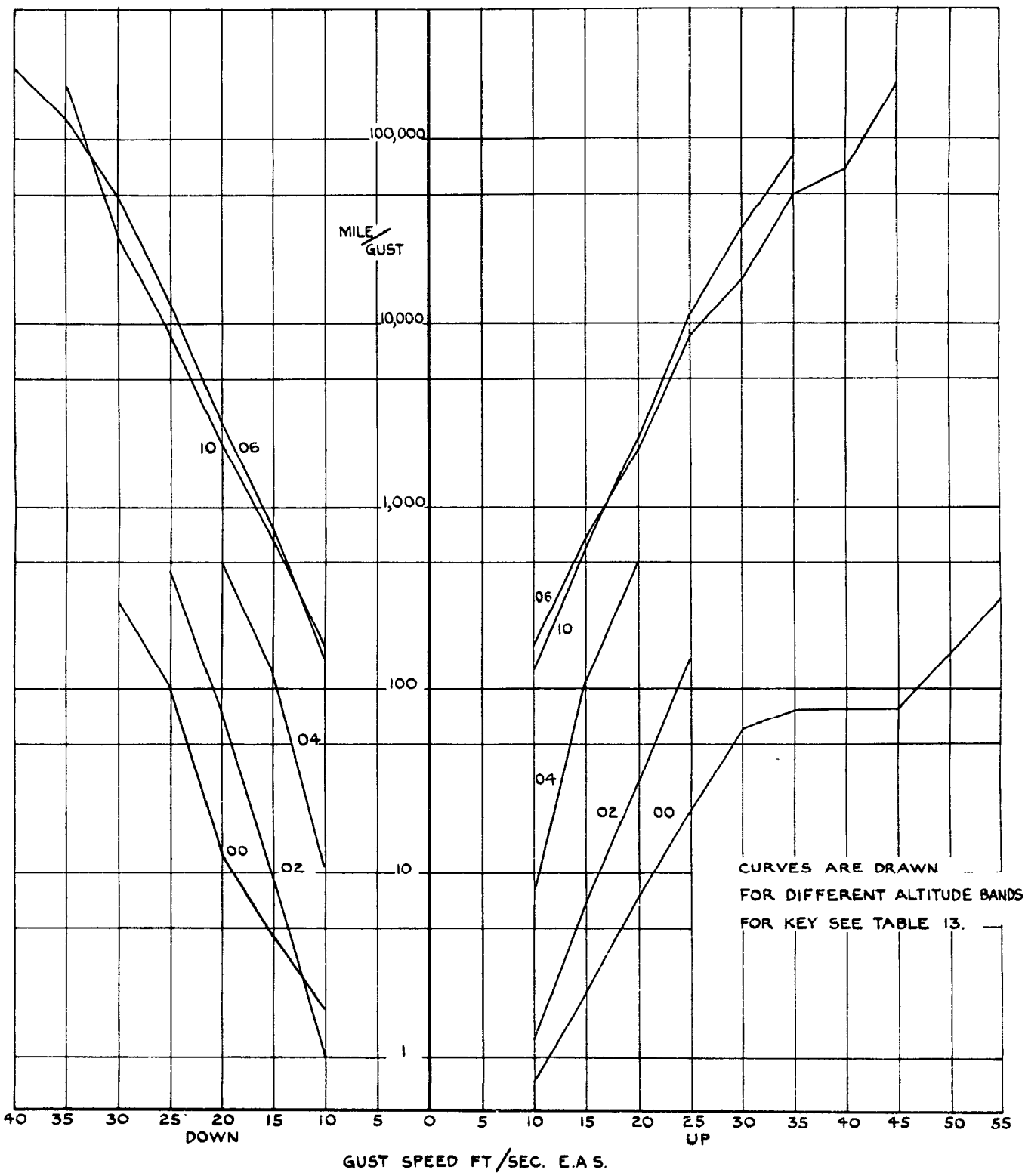


FIG.6. VARIATION OF GUST FREQUENCY WITH GUST SPEED DURING CRUISE FOR HERMES 4A AIRCRAFT.

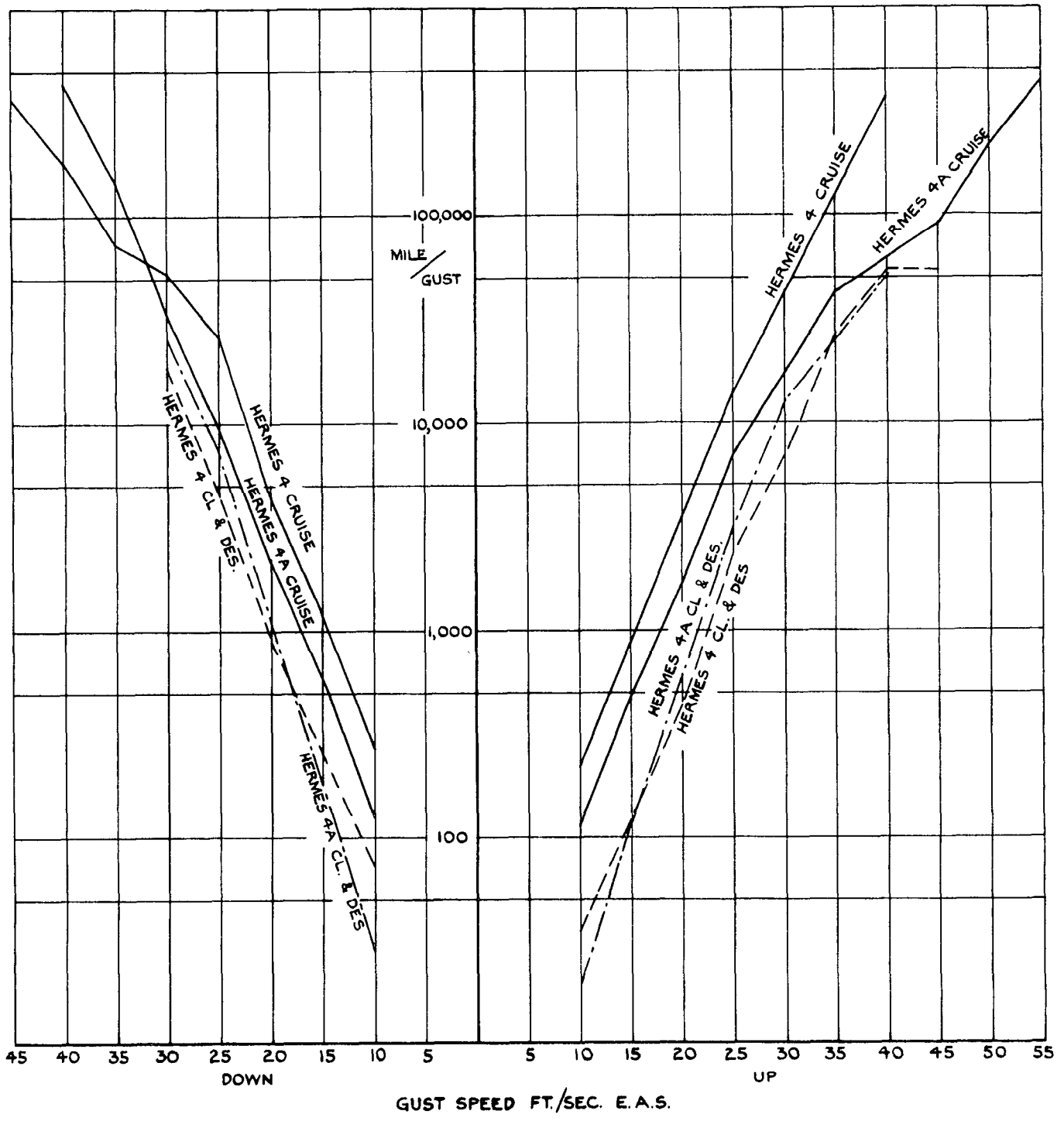


FIG.7. OVERALL VARIATION OF GUST FREQUENCY WITH GUST SPEED FOR HERMES 4 AND HERMES 4A AIRCRAFT.

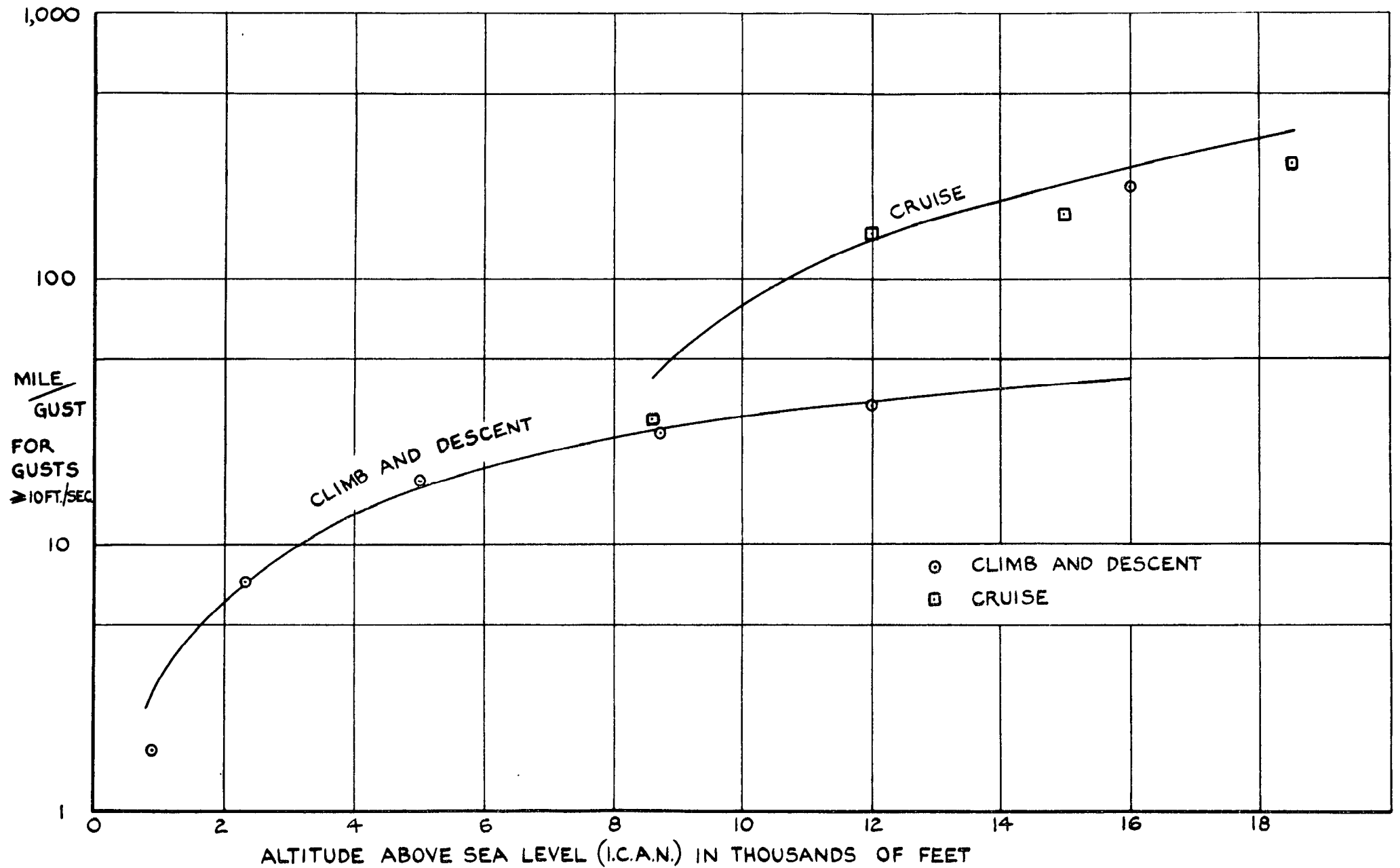


FIG.8. VARIATION OF GUST FREQUENCY WITH ALTITUDE FOR HERMES 4 AIRCRAFT.

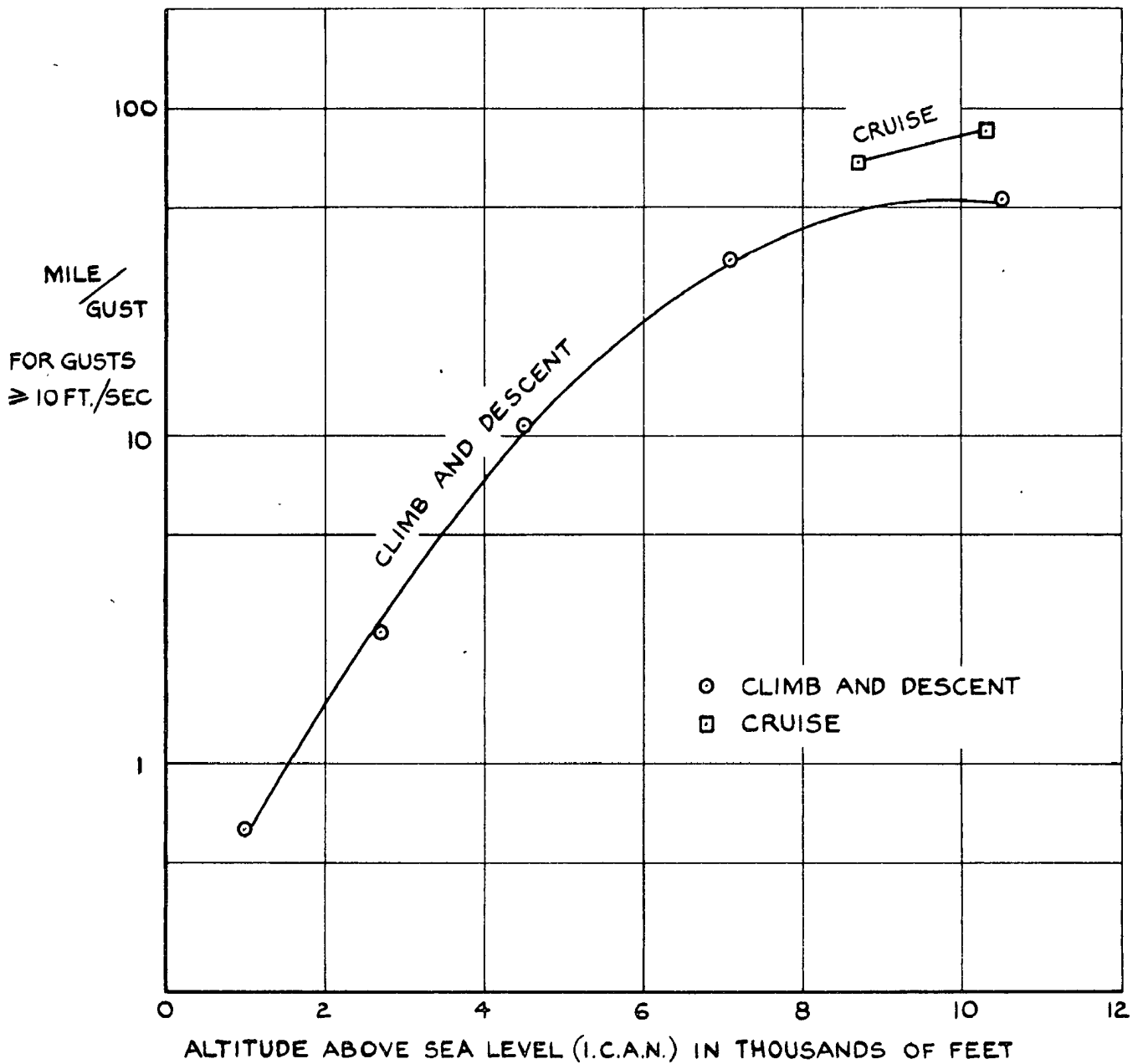


FIG.9. VARIATION OF GUST FREQUENCY WITH ALTITUDE FOR HERMES 4A AIRCRAFT.

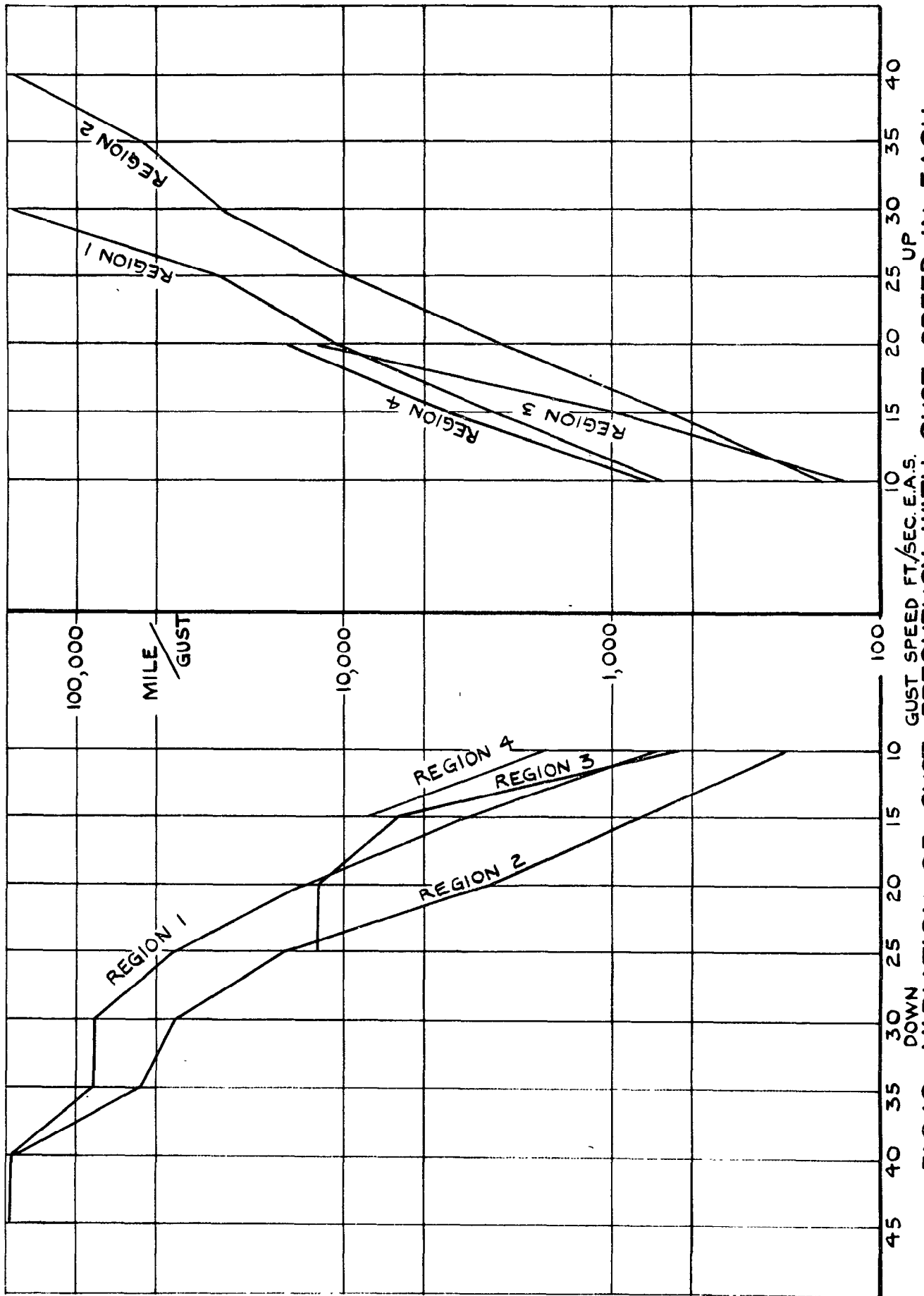


FIG.10. VARIATION OF GUST FREQUENCY WITH GUST SPEED IN EACH GEOGRAPHICAL REGION FOR HERMES 4 AIRCRAFT.

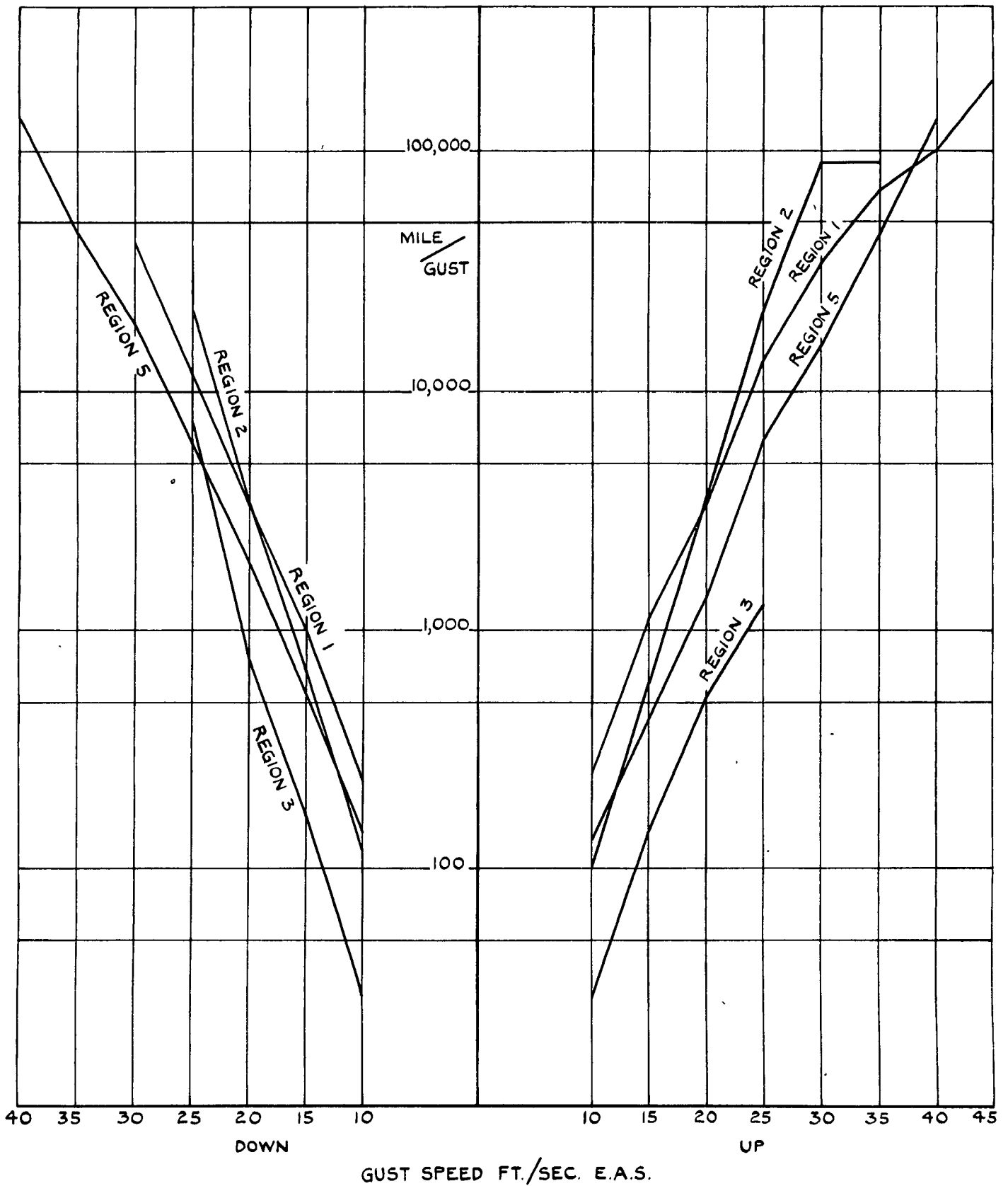


FIG. II. VARIATION OF GUST FREQUENCY WITH GUST SPEED IN EACH GEOGRAPHICAL REGION FOR HERMES 4A AIRCRAFT.

A.R.C. C.P. No.785

551.551 :
533.6.048.5 [A1] (42) Hermes 4

ATMOSPHERIC TURBULENCE ENCOUNTERED BY HERMES AIRCRAFT ON ROUTES TO AFRICA AND THE FAR EAST. Aplin, Judy E. May 1964.

Counting accelerometer records were obtained of the turbulence encountered by Hermes aircraft flying mainly on routes from the U.K. - Europe and Africa. Comparison has been made of results from aircraft operated by two airlines, which represent some 427,000 and 495,000 miles respectively.

Typical variations in gust frequency with gust magnitude, altitude and geographical location were found and the different methods of operating the aircraft also were seen to affect the results.

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