HEADQUARTERS QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
QUARTERMASTER RESEARCH & ENGINEERING CENTER
NATICK, MASSACHUSETTS

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

RESEARCH STUDY REPORT

RER-32

TEMPERATURE AND DENSITY ALTITUDE CONSIDERATIONS FOR DESIGN OF ARMY HELICOPTERS

ARTHUR V. DODD

METEOROLOGIST

REGIONAL ENVIRONMENTS RESEARCH BRANCH

PROJECT No. 7-83-01-006

MARCH 1960

(PREPARED AS A LETTER REPORT IN MARCH 1956)

17

TEMPERATURE AND DENSITY ALTITUDE CONSIDERATIONS FOR DESIGN OF ARMY HELICOPTERS

1. Background

The basic design criteria for the development of Army helicopters require that aircraft be capable of hovering out of ground effect at an altitude of 6,000 feet when the temperature is 95°F. This requirement, commonly referred to as the Army Hot Day requirement, is more severe than the criteria in use for Air Force and Navy aircraft, and has been questioned by authorities familiar with helicopter operations. The 6,000 foot design temperature of the Air Force and Navy is 81°F, requiring an air frame weight approximately one-half that necessary to meet the Army standard.

The frequency of occurrence of high temperatures at elevations up to 6,500 feet in the warmer latitudes is presented in this study in order that the current Army hovering ceiling requirement can be evaluated.

2. Presentation of Data

a. Altitude Delimitation

Before the current Army Hot Day requirement was adopted, apparently an altitude requirement of 6,000 feet was established for helicopters hovering out of ground effect. With this ceiling limit in mind Figure 1 was prepared to show the global distribution of highlands in two classes. The "moderately high" areas in black (between 1,000 and 2,000 meters or 3,280 and 6,560 feet) are of prime interest since they are the areas of highest altitudes at which helicopters currently are expected to operate under all temperature conditions. Since high temperatures are not as frequent at high latitudes, the study was limited to an analysis of temperatures regimes between latitudes 45°N and 45°S at "moderately high" altitudes. From the map it can be seen that "moderately high" areas are most extensive in southern Asia, southern Africa, and western United States and Mexico. They are not extensive in Australia and South America or in Europe south of 45°N.

b. Temperature Regimes During Warmest Month

Temperature measurements throughout the world are generally made under "standard" conditions in instrument shelters at heights ranging from about four to eight feet. During the warmer period of the day temperature differences between the "standard" level and the height of ground effect on hovering helicopters (about 10 to 20 feet with current rotor lengths) are small. It is therefore possible to apply "standard" measurements to the helicopter design requirement problem.

THE PERCENTAGE OF TIME DURING THE WARMEST MONTH THAT "STANDARD" TEMPERATURES WERE ABOVE 80°, 85°, 90°, 95°, 100°, AND 105°F WAS DETERMINED FOR A NUMBER OF STATIONS IN THE "MODERATELY HIGH" AREAS OF THE WORLD. AT THE MAJORITY OF STATIONS THESE PERCENTAGE FREQUENCIES WERE ESTIMATED FROM CONSIDERATION OF THE AVERAGE TEMPERATURE AND THE AVERAGE DAILY RANGE OF TEMPERATURE DURING THE WARMEST MONTH USING A TECHNIQUE DEVELOPED BY SPREEN.* ACTUAL PERCENTAGE FREQUENCIES WERE AVAILABLE FOR UNITED STATES STATIONS AND A FEW STATIONS THROUGHOUT THE WORLD. ALL FREQUENCY DATA ARE PRESENTED IN TABLE 1 ALONG WITH MEAN DAILY MAXIMUM AND ABSOLUTE MAXIMUM TEMPERATURES OF THE WARMEST MONTH.

TIME DID NOT ALLOW FOR ESTIMATION OF FREQUENCY OF HIGH TEMPERATURES FOR ALL MONTHS. THE ANNUAL FREQUENCY OF OCCURRENCE OF TEMPERATURES ABOVE THE GIVEN LEVELS, HOWEVER, CAN BE ROUGHLY ESTIMATED BY MULTIPLYING THE PERCENTAGE FREQUENCIES IN TABLE 1 BY THE FOLLOWING FACTORS:

STATION LATITUDE	0° - 20°				20° - 45°				
	PERCENTAGE OF TIME EXCEEDED				PERCENTAGE OF TIME EXCEEDED				
TEMPERATURE (°F)	80	85	90	95	80	85	90	95	100
FACTOR	.55	.50	.38	.25	.35	.31	.28	.21	.15

THESE FACTORS WERE DETERMINED EMPIRICALLY FROM ANALYSIS OF TEMPERATURE FREQUENCIES AT TEN STATIONS DURING ALL MONTHS. A FACTOR AS LOW AS .08 WOULD INDICATE THAT TEMPERATURES ABOVE THE GIVEN VALUE USUALLY OCCUR DURING THE WARMEST MONTH WHILE A FACTOR OF 1.0 WOULD INDICATE THAT TEMPERATURES ABOVE THE GIVEN VALUE PROBABLY OCCUR IN EVERY MONTH. IT CAN BE SEEN THAT HIGH TEMPERATURES ARE NOT RESTRICTED TO ONE MONTH. AT LOW LATITUDE STATIONS TEMPERATURES ABOVE 80°F MAY OCCUR EQUALLY AS OFTEN IN AS MANY AS SIX MONTHS. IN THE HIGHER LATITUDES, HOWEVER, TEMPERATURES ABOVE 95°F OR 100°F NORMALLY OCCUR ONLY IN THE TWO OR THREE WARMEST MONTHS.

c. Density Altitude

THE DENSITY ALTITUDES THAT WERE EXCEEDED FIVE PERCENT OF THE TIME IN THE WARMEST MONTH, IS PRESENTED IN THE FINAL COLUMN OF TABLE 1. THESE FIGURES WERE ALSO USED IN THE PREPARATION OF FIGURE 2 WHICH IS A SCATTER DIAGRAM OF DENSITY ALTITUDE VERSUS STATION ALTITUDE.

DENSITY ALTITUDE REFERS TO A THEORETICAL DENSITY WHICH WOULD EXIST IN A STANDARD ATMOSPHERE AT A GIVEN HEIGHT. THIS STANDARD ATMOSPHERE HAS

*SPREEN, WILLIAM C. EMPIRICALLY DETERMINED DISTRIBUTIONS OF HOURLY TEMPERATURES JOURNAL OF METEOROLOGY, VOLUME 13, AUGUST 1956, WASHINGTON, D.C.

A PRESSURE OF 29.92" OF HG AND A TEMPERATURE OF 59°F AT SEA LEVEL. THE ASSUMED TEMPERATURE LAPSE RATE IS 3.56°F PER THOUSAND FEET; THUS IN THIS STANDARD ATMOSPHERE, AT AN ELEVATION OF 2,000 FEET, THE TEMPERATURE WOULD BE ABOUT 7°F LOWER THAN THE SEA LEVEL TEMPERATURE. WHEN TEMPERATURES ARE HIGHER THAN THE "STANDARD" TEMPERATURE THE DENSITY OF THE AIR WILL BE LESS AND WILL BE EQUAL TO THE AIR DENSITY AT SOME HIGHER ALTITUDE WHERE THE "STANDARD" TEMPERATURE PREVAILS. THIS THEORETICAL HIGHER ALTITUDE IS CALLED THE DENSITY ALTITUDE.

THE DENSITY ALTITUDE AT EACH STATION WAS COMPUTED BY FIRST ESTIMATING THE TEMPERATURE WHICH IS EXCEEDED FIVE PERCENT OF THE TIME IN THE WARMEST MONTH (FROM TABLE 1) AND THEN COMPUTING THE DENSITY ALTITUDE FROM A CHART WHICH PRESENTS DENSITY ALTITUDE AS A FUNCTION OF TEMPERATURE AND ALTITUDE (FIGURE 3 - THE CHART WAS ENLARGED FROM TM 1-260, PRINCIPLES OF ROTARY WING FLIGHT, SEPTEMBER 1957). THE DENSITY ALTITUDES SO DERIVED ARE ONLY APPROXIMATIONS BECAUSE HUMIDITY AND PRESSURE VARIATIONS FROM NORMAL WERE NOT CONSIDERED AND BECAUSE THE "FIVE PERCENT" TEMPERATURES WERE ESTIMATES. WIND ALSO WAS NOT CONSIDERED ALTHOUGH IT HAS A DEFINITE EFFECT ON HOVERING CEILINGS. WHEN TEMPERATURES ARE HIGH THERE IS USUALLY SOME AIR MOVEMENT AND THE HOVERING CEILING IS RAISED.

3. DISCUSSION OF DATA

FROM FIGURE 1 IT CAN BE SEEN THAT A SUBSTANTIAL PERCENTAGE OF THE LAND BETWEEN 45°N AND 45°S CAN BE CLASSED AS HIGHLANDS AND IS POTENTIALLY A CHALLENGE TO HELICOPTER OPERATIONS. OF COURSE NOT ONLY THE AMOUNT OF SUCH LANDS BUT ITS DISTRIBUTION IN STRATEGIC AREAS OF THE WORLD IS SIGNIFICANT.

HIGH TEMPERATURES AT MODERATE ELEVATIONS OCCUR MOST FREQUENTLY IN THE SOUTHERN PORTIONS OF ASIA AND NORTH AMERICA. KERMAN, IRAN, ALTITUDE 6,100 FEET, HAS TEMPERATURES ABOVE 95°F 18 PERCENT OF THE TIME IN JULY AND THE AVERAGE DAILY MAXIMUM DURING THAT MONTH IS 101°F; KABUL, THE CAPITAL OF AFGHANISTAN, AT 5,895 FEET, HAS A MEAN DAILY MAXIMUM IN JULY OF 92°F AND TEMPERATURES ARE ABOVE 95°F SIX PERCENT OF THE TIME. THE TEMPERATURE REGIMES AT THESE STATIONS ARE EXTREME BUT ARE INDICATIVE OF THE OCCURRENCE OF APPRECIABLE AREAS OF HIGH HOT LANDS IN SOUTHWEST ASIA. IF MORE CLIMATIC DATA WERE AVAILABLE FROM THIS REGION THERE WOULD UNDOUBTEDLY BE MANY MORE REPORTS OF SIMILAR HOT CONDITIONS AT MODERATE ELEVATION.

IN NORTH AMERICA TEMPERATURES AT MODERATE ELEVATIONS ARE MOST EXTREME IN CENTRAL MEXICO WHERE CAMARGO, 5,423 FEET, HAS A JUNE MEAN DAILY MAXIMUM OF 108°F AND TEMPERATURES CAN BE EXPECTED TO BE ABOVE 95°F NEARLY A QUARTER OF THE MONTH. IN THE SAME AREA, LAGOS, 6,138 FEET, HAS TEMPERATURES ABOVE 95°F ELEVEN PERCENT OF THE TIME IN AN AVERAGE JUNE. TEMPERATURES ARE GENERALLY NOT AS HIGH AT THESE ELEVATIONS IN THE UNITED

STATES; NEVERTHELESS, MEAN DAILY MAXIMUM TEMPERATURES ABOVE 80°F OCCUR AT ALTITUDES UP TO 6,500 FEET AND TEMPERATURES ABOVE 95°F OCCUR AT ALL STATIONS IN TABLE 1 EXCEPT ELY, NEVADA. MORE DETAILED INFORMATION ON THE OCCURRENCE OF HIGH TEMPERATURES AT HIGH ALTITUDES IN THE UNITED STATES IS PRESENTED IN RESEARCH REPORT EA-9 "HIGH TEMPERATURES AT HIGH ELEVATIONS", QUARTERMASTER RESEARCH & ENGINEERING COMMAND, NATICK, MASSACHUSETTS, JANUARY 1958.

IN FIGURE 2 IT CAN BE SEEN THAT AT ANY GIVEN ALTITUDE IN TROPICAL AND TEMPERATE LOCATIONS THE DENSITY ALTITUDE DURING THE WARMEST MONTH VARIES BY ABOUT 2,000 FEET FROM THE COOLEST TO THE WARMEST STATIONS, AND THE DENSITY ALTITUDE IS MORE A FUNCTION OF ALTITUDE THAN IT IS OF TEMPERATURE. TEMPERATURES ARE AN IMPORTANT DETERMINANT OF DENSITY ALTITUDE, BUT THE DETERMINATION OF THE ALTITUDE CEILING AT WHICH HELICOPTERS SHOULD BE EXPECTED TO HOVER IS THE MOST IMPORTANT ASPECT OF THE HELICOPTER DESIGN REQUIREMENT PROBLEM.

THE BLUE LINE IN FIGURE 2 IS THE DENSITY ALTITUDE OF THE "ARMY HOT DAY REQUIREMENT". THE RED LINE IN THE FIGURE IS THE DENSITY ALTITUDE OF THE AIR FORCE-NAVY "HOT ATMOSPHERE". THE RELATIVE MERITS OF THE TWO STANDARDS CAN ONLY BE DETERMINED WHEN THE REQUIRED CEILING HEIGHT AND THE AMOUNT OF RISK TO BE ALLOWED ARE DETERMINED. THE GEOGRAPHICAL DATA IN THIS REPORT WILL ASSIST IN THE DETERMINATION OF THE RELATIVE MERITS OF THE TWO STANDARDS.

TABLE 1: FREQUENCY OF OCCURRENCE OF HIGH TEMPERATURES DURING WARMEST MONTH AT STATIONS AT MODERATE ELEVATIONS

STATION	LATITUDE	LONGITUDE	ALTITUDE	TEMPERATURE DURING WARMEST MONTH (°F)								DENSITY ALTITUDE EXCEEDED 5% OF TIME
				MEAN DAILY MAX	ABSOLUTE MAX	% OF TIME EXCEEDED						
						80	85	90	95	100	105	
NORTH AMERICA												
MEXICO												
COAHUILA	25°47'N	103°07'W	3,625	96	108	42	27	12	5	1	*	6,200 FEET
VILLA GONZALES	30 38	106 31	3,953	97	109	50	31	18	9	3	*	7,550
NAZAS	25 13	104 07	4,183	99	111	52	43	26	14	7	2	8,000
SALTILLO	25 26	101 00	5,279	82	100	15	5	2	1	*		8,550
CAMARGO	27 42	105 10	5,423	108	120	66	50	33	23	16	6	9,750
LAGOS	21 21	101 55	6,138	97	109	41	29	19	11	7	1	10,250
AGUASCALIENTES	21 53	102 18	6,224	82	99	27	15	6	1			9,700
BUSTILLOS	28 28	106 39	6,526	90	99	29	19	10	1			10,200
UNITED STATES												
AMARILLO	35 14	101 42	3,604	92	106	40	26	14	4			6,800
EL PASO	31 48	106 24	3,916	94	105	60	44	26	11	3	*	7,600
SALT LAKE CITY	40 46	111 58	4,240	91	101	38	24	12	3	*		7,500
RENO	39 30	119 47	4,400	92	104	32	20	8	1	*		7,600
POCATELLO	42 55	112 32	4,466	90	101	30	17	7	1	*		7,650
GRAND JUNCTION	39 06	108 32	4,839	92	100	39	25	13	2	*		8,200
WINSLOW	35 01	110 44	4,883	93	104	39	26	14	4	*		8,250
MILFORD	38 25	113 01	5,033	92	103	40	28	13	3	*		8,500
ELKO	40 50	115 47	5,079	80	104	32	21	8	1	*		8,400
CASPER	42 55	106 20	5,290	86	103	25	14	5	1	*		8,400
ALBUQUERQUE	35 03	106 37	5,314	92	101	38	24	11	2	*		8,700
DENVER	39 46	104 53	5,332	87	103	26	14	5	1	*		8,550
ELY	39 17	114 51	6,557	86	92	23	12	1				9,750

TABLE 1 (CONT.)

STATION	LATITUDE	LONGITUDE	ALTITUDE	TEMPERATURES DURING WARMEST MONTH (°F)								DENSITY ALTITUDE
				MEAN DAILY MAX	ABSOLUTE MAX	% OF TIME EXCEEDED						EXCEEDED 5% OF TIME
						80	85	90	95	100	105	
EUROPE												
SPAIN												
GRANADA	37°11'N	3°47'W	2,198	90	104	31	17	6	1	*		5,100
SORIA	41 30	2 00	3,471	80	106	13	5	2	1	*		6,000
AVILA.	40 30	4 35	3,694	80	100	13	4	1	*			6,300
PORTUGAL												
MONTALEGRE	41 50	7 50	3,369	74	96	5	2	1	*			5,500
SERRA DA ESTRALLA	40 05	7 50	4,547	70	90	2	1	*				6,700
AUSTRALIA												
ALICE SPRINGS	23°37'S	133°55'W	1,926	95	116	54	32	24	7	3	1	4,800
KIANDRA	35 33	148 31	4,640	69	91	3	1					6,950
AFRICA												
SOUTH AFRICA												
QUEENSTOWN	31°54'S	26°52'E	3,533	86	105	23	12	5	1	*	-	6,550
KIMBERLY	28 56	24 46	3,935	91	107	36	20	7	3	1	*	7,000
CARNARVON	30 58	22 08	4,112	90	101	31	20	10	2	*	-	7,400
FRASERBURG	31 55	21 31	4,150	87	104	24	15	6	1	*	-	7,250
SUTHERLAND	32 25	20 42	4,776	84	96	20	11	5	*	-	-	7,800
LINDLEY	27 53	27 55	5,000	85	99	23	11	4	1	-	-	8,050
JOHANNESBURG	26 11	28 03	5,750	80	92	12	3	*	-	-	-	8,550
HARRISMITH	28 16	29 10	5,900	76	95	8	2	*	-	-	-	8,600
QACHASNEK	30 07	28 42	6,469	77	95	9	4	*	*	-	-	9,300

TABLE I (CONT.)

STATION	LATITUDE	LONGITUDE	ALTITUDE	TEMPERATURES DURING WARMEST MONTH (°F)								DENSITY ALTITUDE EXCEEDED 5% OF TIME
				MEAN DAILY MAX	ABSOLUTE MAX	% OF TIME EXCEEDED						
						80	85	90	95	100	105	
AFRICA (CONT.)												
SOUTHWEST AFRICA AND BACHUANALAND												
BETHANIEN	26°30'S	17°10'E	3,085	103	115	58	44	30	20	7	4	6,900
KHOMO	21 00	24 30	3,501	95	107	48	30	15	6	1	*	6,800
GANZI	21 30	21 45	3,710	92	100	44	27	9	2	*	-	6,750
GUIBES	26 44	16 54	4,291	91	101	36	22	10	3	*	-	7,500
WINDHOEK	22 34	17 06	5,666	86	95	24	10	1	*	-	-	8,700
THE RHODESIAS AND MOMAMBIQUE												
VICTORIA FALLS	17 56	25 50	3,034	96	106	51	33	18	9	3	*	6,550
LIVINGSTONE	17 50	25 49	3,090	96	109	53	33	19	8	2	*	6,600
SPUNGABERA	20 28	32 46	3,445	81	102	17	5	2	*	*	-	6,000
MUNGU	15 17	23 05	3,488	99	109	58	40	23	13	6	1	7,150
CHIPINGA	20 12	32 38	3,694	80	98	12	4	1	*	-	-	6,200
FORT ROSEBERY	11 11	28 53	3,830	94	104	42	27	16	7	*	-	7,150
MVINILUNGA	11 43	24 26	4,450	89	96	28	14	5	*	-	-	7,600
MPIKA	11 51	31 27	4,647	85	93	22	9	2	-	-	-	7,400
SALISBURY	17 50	31 01	4,831	85	99	23	14	6	1	-	-	7,950
MELSETTER	19 47	32 51	[illegible]	80	96	12	6	1	*	-	-	7,700
ABERCORN	08 49	31 23	5,407	85	97	13	4	1	*	-	-	8,150
INYANGA	18 13	32 44	5,514	77	91	9	3	*	-	-	-	8,300
MOUNT NUZA	18 43	32 49	6,668	68	82	*	-	-	-	-	-	9,100

TABLE I (CONT.)

STATION	LATITUDE	LONGITUDE	ALTITUDE	TEMPERATURES DURING WARMEST MONTH (°F)								DENSITY ALTITUDE EXCEEDED 5% OF TIME
				MEAN DAILY MAX	ABSOLUTE MAX	% OF TIME EXCEEDED						
						80	85	90	95	100	105	
AFRICA (CONT.)												
TANGANYIKA, UGANDA, KENYA, SUDAN												
DODOMO	06°15'S	35°44'E	3,707	88	93	31	15	5	*	-	-	6,700
ENTEBBE	00 04 N	32 29	3,878	80	88	13	3	*	-	-	-	6,400
ARUA	03 01	30 55	4,200	88	98	34	16	6	*	-	-	7,300
LERUA	04 00	32 35	4,265	95	103	50	40	19	7	1	-	7,750
ARUSHA	03 21 S	36 42	4,630	85	99	23	12	4	1	-	-	7,750
MBARARA	00 37	30 39	4,734	83	93	17	6	*	-	-	-	7,600
MUBENDI	00 35 N	31 22	5,128	81	94	16	4	*	-	-	-	7,800
NAIROBI	01 16 S	36 50	5,495	81	91	14	6	*	-	-	-	8,400
MBEYA	08 52	33 27	6,000	79	87	7	*	-	-	-	-	8,700
BR. SOMALILAND, ETHIOPIA, ERITREA												
UPPER SHEIKH	09 56 N	45 12	5,212	88	92	23	12	*	-	-	-	8,200
CHENAFENA	14 18	39 01	5,351	91	95	31	18	7	*	-	-	8,550
BONGA	07 13	36 17	5,658	85	88	20	3	*	-	-	-	8,450
HARAR	09 19	42 09	6,071	80	90	10	1	*	-	-	-	9,000
ADI UGRI	14 53	38 49	6,627	85	-	18	4	1	-	-	-	9,600
ALGERIA, MOROCCO												
EL HAJEB	33 41	05 22 W	3,445	94	111	43	26	15	7	4	1	7,000
DJANET	24 35	09 25 E	3,609	100	111	88	67	33	18	5	1	8,300
IDELES	23 48	05 53	4,593	99	-	65	47	25	15	6	1	8,350
AXILAL	31 58	06 34 W	4,688	93	106	47	25	13	5	1	*	8,100
BEKRIT	32 10	04 50	6,266	87	100	26	15	7	2	*	-	9,800

TABLE I (CONT.)

STATION	LATITUDE	LONGITUDE	ALTITUDE	TEMPERATURES DURING WARMEST MONTH (°F)								DENSITY ALTITUDE EXCEEDED 5% OF TIME
				MEAN DAILY MAX	ABSOLUTE MAX	% OF TIME EXCEEDED						
						80	85	90	95	100	105	
AFRICA (CONT.)												
FRENCH EQUITORIAL AFRICA, FRENCH WEST AFRICA, ANGOLA												
N'GAOUNDERE	07°18'N	13°32'E	3,671	85	-	23	10	1	-	-	-	6,400
MALANJE	09 30 S	16 10	3,773	86	101	25	12	3	1	*	-	6,650
MALI	12 09 N	12 17 W	4,820	86	99	22	10	1	*	-	-	7,800
NUMBA FARM	11 50 S	15 00 E	5,413	77	82	2	-	-	-	-	-	7,800
SOUTH AMERICA												
ARGENTINA												
ZAPALA	38 55	70 04 W	3,330	82	100	17	7	3	*	*	-	5,900
ANDALGALA	27 36	66 20	3,504	92	110	46	24	10	3	1	*	6,900
SALTA	24 47	65 25	3,878	83	101	16	6	1	*	*	-	6,600
MALARGUE	35 33	69 35	4,652	85	95	22	13	7	*	-	-	7,800
PERU												
MOQUEQUA	17 11	70 56	4,485	82	89	18	5	*	-	-	-	7,250
LA JOYA	16 44	71 51	5,351	79	88	5	1	-	-	-	-	7,800
EQUADOR												
SHELL MERA	01 30	78 03	3,421	80	87	3	*	-	-	-	-	5,550
BANOS	01 24	78 23	6,002	73	8:	2	-	-	-	-	-	8,400

TABLE I. (CONT.)

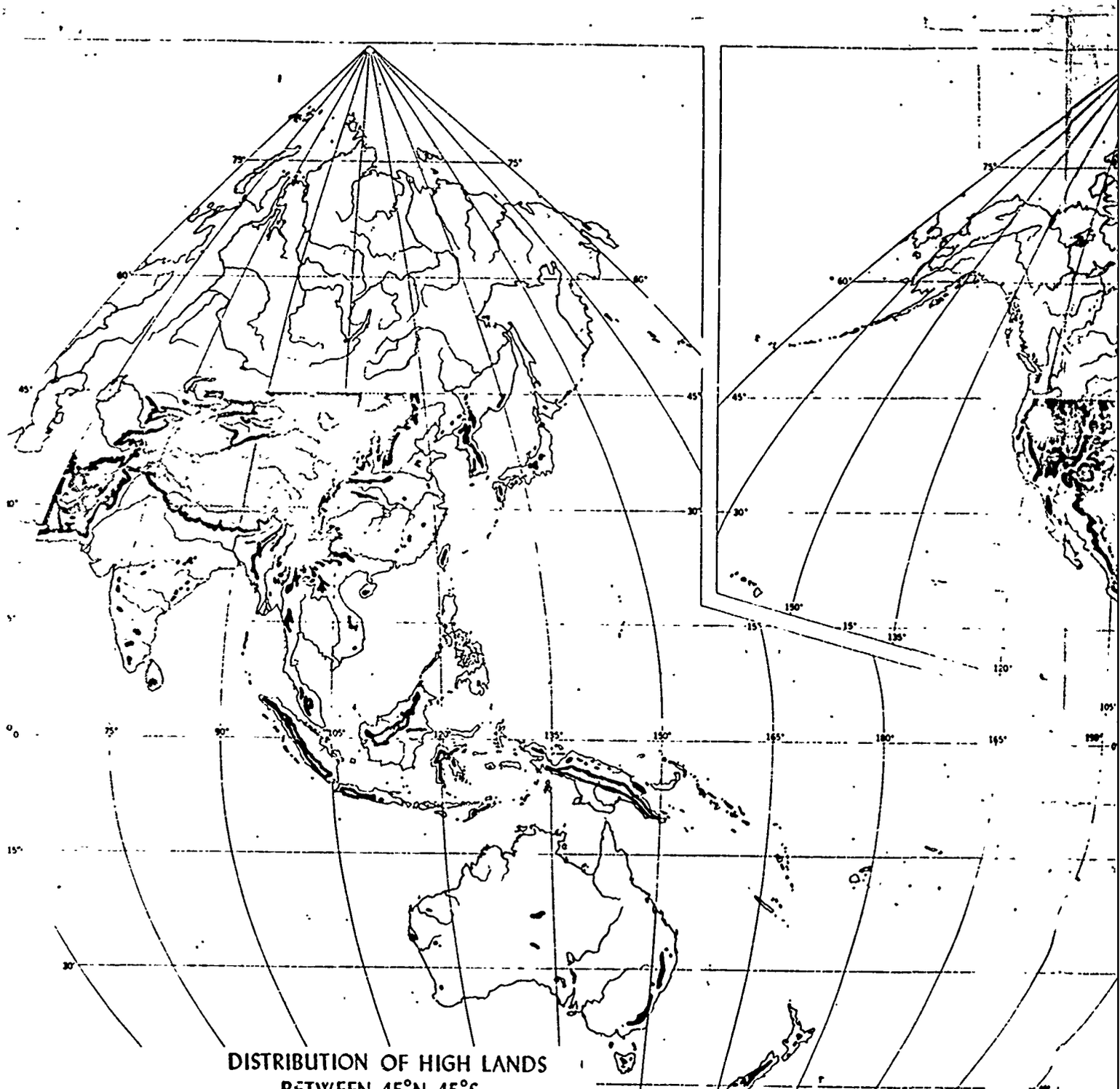
STATION	LATITUDE	LONGITUDE	ALTITUDE	TEMPERATURES DURING WARMEST MONTH (°F)								DENSITY ALTITUDE EXCEEDED 5% OF TIME
				MEAN DAILY MAX	ABSOLUTE MAX	% OF TIME EXCEEDED						
						80	85	90	95	100	105	
SOUTH AMERICA (CONT.)												
BRAZIL												
CURITYBA	25°25'S	49°17'W	3,113	81	-	*	-	-	-	-	-	5,500
ASIA												
TURKEY												
AFYON	38 45 N	35 18 E	3,300	85	99	25	14	6	2	-	-	6,250
ELAZIG	38 42	39 15	3,345	92	98	25	13	5	-	-	-	6,300
SIVAS	39 45	37 00	4,167	86	104	27	17	8	3	*	-	7,400
YOZGAT	39 50	34 48	4,345	77	89	8	3	*	-	-	-	6,900
KARS	40 36	43 06	5,740	80	91	15	7	*	-	-	-	8,650
KARS	40 36	43 06	6,155	78	92	14	6	*	-	-	-	9,250
ERZURUM	39 54	41 16	6,401	81	93	15	7	1	-	-	-	9,500
SYRIA AND LEBANON												
EL KAREYA	33 49	35 40	3,281	81	-	9	3	-	-	-	-	5,700
AL SUWAYDAH	32 50	36 35	3,609	87	103	27	13	5	*	-	-	6,650
LES CEDRES	34 16	36 02	6,332	72	79	-	-	-	-	-	-	8,700
IRAN												
TEHERAN	35 43	51 23	4,396	99	109	79	50	29	15	6	1	8,300
DOROUD	33 28	49 03	4,621	-	107	66	56	44	28	10	*	8,500
KERMANSHAH	34 19	47 04	4,860	97	106	50	32	20	10	4	*	8,700
HAMADAN	34 48	48 30	5,690	99	104	52	38	27	18	7	0	9,650
SULTANABAD	34 05	49 39	5,767	-	104	64	51	29	14	2	0	9,500
KERMAN	30 21	47 05	6,100	101	112	58	48	28	18	10	6	10,450

TABLE I (CONT.)

STATION	LATITUDE	LONGITUDE	ALTITUDE	TEMPERATURES DURING WARMEST MONTH (°F)								DENSITY ALTITUDE EXCEEDED 5% OF TIME
				MEAN DAILY MAX	ABSOLUTE MAX	% OF TIME EXCEEDED						
						80	85	90	95	100	105	
ASIA (CONT.)												
AFGHANISTAN												
HERAT	34°20'N	62°10'E	3,042	97	110	60	30	20	10	4	1	6,550
KANDAHAR	31 36	65 41	3,424	105	108	70	55	40	25	10	5	7,400
CHAMAN	30 55	66 28	4,311	101	111	80	55	32	20	9	2	8,300
FT. SANDAMAN	31 21	69 27	4,614	100	111	75	57	32	16	6	1	8,500
KABUL	34 30	69 18	5,895	92	112	41	23	11	6	3	1	9,800
PAKISTAN, INDIA, KASHMIR, NEPAL, USSR												
CHERRAPUNJI	25 15	91 44	4,309	74	82	*	-	-	-	-	-	6,400
KATMANDU	27 42	85 12	4,388	85	97	22	18	1	*	-	-	7,050
DROSH	35 34	71 47	4,723	97	110	71	50	24	11	3	*	8,350
GILGIT	35 55	74 23	4,890	97	113	71	50	26	13	4	1	8,500
SRINAGAR	34 05	74 50	5,205	86	99	25	12	3	*	-	-	8,200
QUETTA	30 10	67 01	5,490	93	104	47	27	12	4	*	-	8,900
PARACHINAR	33 52	70 04	5,673	88	101	24	12	3	*	*	-	8,800
NARYN	41 26	76 00	6,611	74	94	6	2	*				9,450
CEYLON												
DIYATALANA	06 49	80 58	4,101	78	87	5	.5	-	-	-	-	6,500
NUWARA-ELIYA	06 58	80 46	6,168	72	80	*	-	-	-	-	-	8,600
MALAYA												
MAXWELL'S HILL	04 52	100 48	3,400	77	83	1	*	-	-	-	-	5,450
CAMERON HIGHLANDS	04 28	101 23	5,120	73	78	-	-	-	-	-	-	7,200

TABLE I (CONT.)

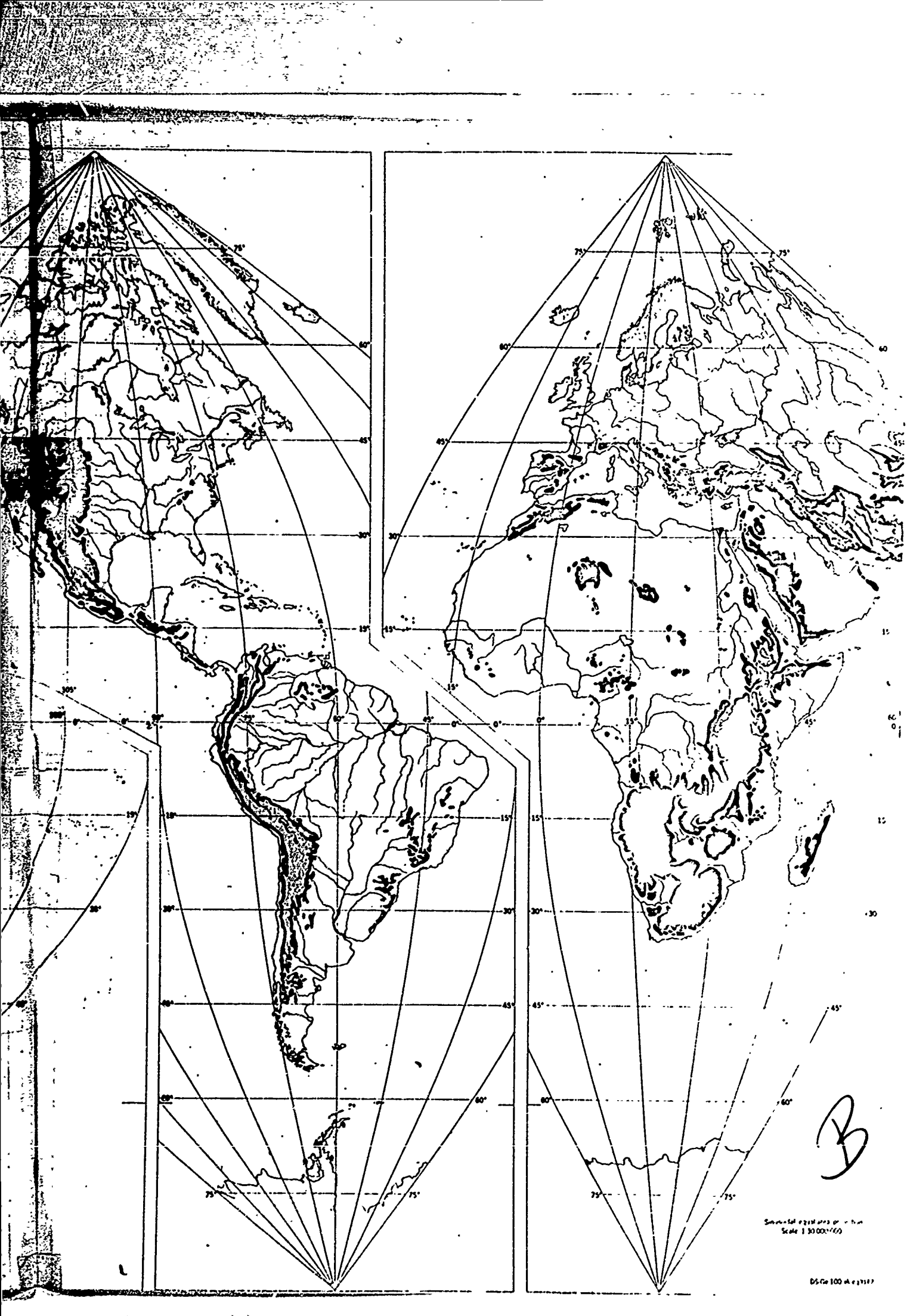
STATION	LATITUDE	LONGITUDE	ALTITUDE	TEMPERATURES DURING WARMEST MONTH (°F)							DENSITY ALTITUDE EXCEEDED 5% OF TIME
				MEAN DAILY MAX	ABSOLUTE MAX	% OF TIME EXCEEDED					
						80	85	90	95	100	105	
ASIA (CONT.)												
INDO-CHINA												
XIENG KHODANG	19°20'N	103°22'E	3,770	80	90	20	5	*	-	-	-	6,300
BOLOVEN	15 16	106 08	3,937	80	90	6	2	*	-	-	-	6,300
DALAT	11 57	108 26	4,921	80	88	12	6	-	-	-	-	7,700
CHA PA	22 22	103 52	5,381	74	84	2	-	-	-	-	-	7,600
CHINA AND KOREA												
KUEI-YANG	26 30	106 38	3,528	86	92	28	11	2	-	-	-	6,350
PUNGSAN	40 49	128 10	3,773	76	94	6	1	*	-	-	-	6,150
MENG-TZU	23 21	103 23	4,281	84	94	15	3	1	*	-	-	6,800
TENG CHUNG	25 02	98 28	5,360	75	83	2	-	-	-	-	-	7,650
PAO SHAN	25 05	99 10	5,491	-	87	4	.2	-	-	-	-	7,900
KUN-MING	25 04	102 40	6,213	78	90	9	1	-	-	-	-	9,000
HSIANG-YUN	25 28	100 34	6,371	79	90	8	2	-	-	-	-	9,150
JAPAN AND PHILLIPINES												
HAKONE-YAMA	35 11	139 01	3,077	73	85	1	*	-	-	-	-	5,050
OCHIAI	35 48	138 49	3,687	78	88	5	1	*	-	-	-	5,900
ASO-ZAN	32 54	131 04	3,749	74	85	1	*	-	-	-	-	5,800
IBUKI-YAMA	35 25	136 24	4,514	69	82	*	-	-	-	-	-	6,600
BAGUIO	16 25	120 35	4,962	77	84	2	-	-	-	-	-	7,250
IWATE-YAMA	39 51	141 01	5,810	62	75	-	-	-	-	-	-	7,600

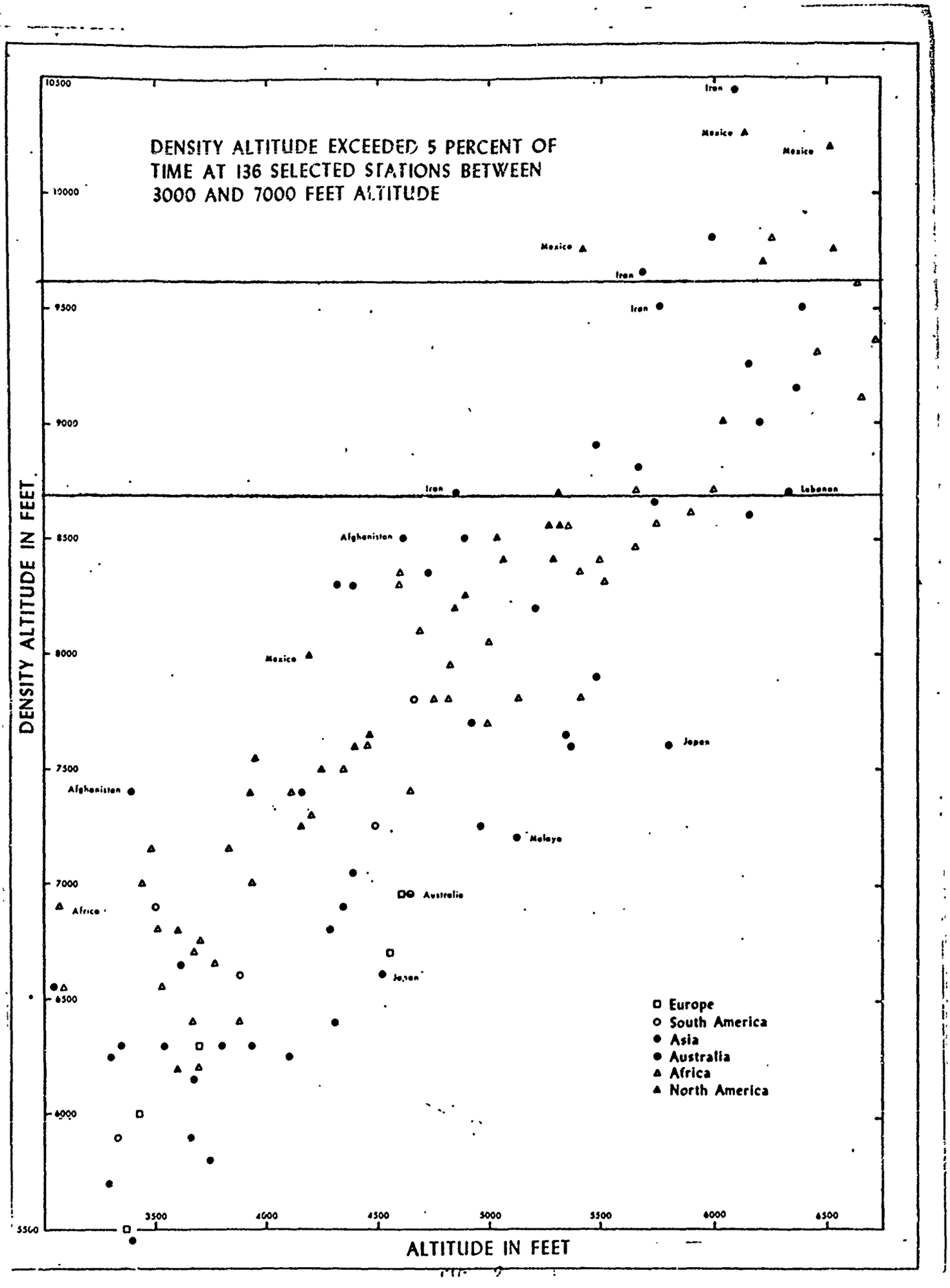


DISTRIBUTION OF HIGH LANDS
BETWEEN 45°N 45°S

High		Elevations above 2000 meters
Moderately High		Elevations between 1000 and 2000 meters
Low		Elevations below 1000 meters

Moderately high lands in areas of the world between 45°N and 45°S are considered for determining helicopter design criteria. Areas of greater elevation are too high for consideration and areas of lower elevation do not present as severe design problems.




DENSITY ALTITUDE EXCEEDED 5 PERCENT OF TIME AT 136 SELECTED STATIONS BETWEEN 3000 AND 7000 FEET ALTITUDE
DENSITY ALTITUDE IN FEET
ALTITUDE IN FEET
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
3500
4000
4500
5000
5500
6000
6500
Iran
Mexico
Mexico
Mexico
Iran
Iran
Iran
Lebanon
Afghanistan
Mexico
Japan
Afghanistan
Malaya
Australia
Africa
Japan
Europe
South America
Asia
Australia
Africa
North America

SET ALTIMETER TO 29.92 IN. HG.
WHEN READING PRESSURE ALTITUDE

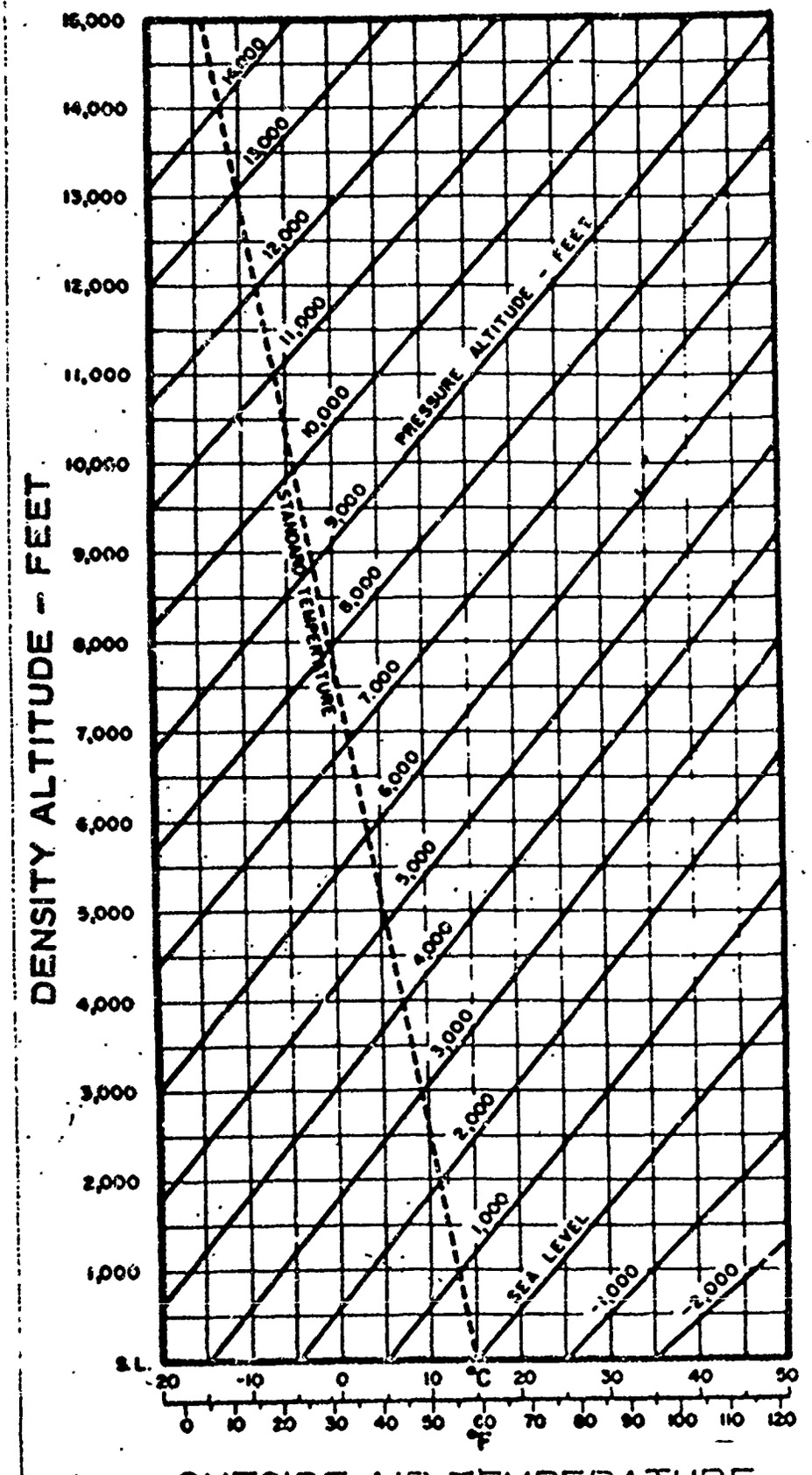


FIG 3