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TECHNICAL REPORT

EP-2

LOW TEMPERATURES AT FORT CHURCHILL



QUARTERMASTER RESEARCH & DEVELOPMENT CENTER
ENVIRONMENTAL PROTECTION DIVISION

JULY 1954

NATICK, MASSACHUSETTS

HEADQUARTERS QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND
Quartermaster Research & Development Center, US Army
Natick, Massachusetts

ENVIRONMENTAL PROTECTION DIVISION

Technical Report
EP-2

FREQUENCY AND DURATION OF LOW TEMPERATURES
AT FORT CHURCHILL, MANITOBA, CANADA

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Foreword

Fort Churchill, Manitoba, Canada, which lies in a transition region between the Subarctic and Arctic, is ideally located for studies requiring low temperatures. Extreme low temperatures, high wind speeds, and long periods of daylight during winter (longer than at arctic stations) provide excellent conditions for conducting studies of the responses of man and equipment to cold-dry environments.

This report concerns an evaluation of the frequencies and duration of low temperatures at Fort Churchill. It was prepared at the request of the Office of the Assistant Chief of Staff, G-4, U.S. Army. It is intended for the use of persons who are responsible for selecting the most appropriate time for conducting low temperature tests and research studies at Fort Churchill, and for others interested in temperature expectancies and duration of sustained periods of low temperatures.

This is the first of a series of reports which deal with the frequency of low temperatures in the Northern Hemisphere. Similar studies are in preparation for Big Delta and Anchorage, Alaska. These detailed studies of low temperatures may be used to supplement the information contained in the Environmental Handbooks for Department of the Army Test Sites, e.g., Fort Churchill, Big Delta and Whittier, Alaska, and Devils Lake, North Dakota.

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Abstract

This report presents in detail the frequency and duration of critical low temperatures at Fort Churchill, Manitoba, Canada. The lowest temperature recorded was only -57°F , but temperatures at or below -25°F may be expected 30 to 40 percent of the time in January and February. Temperatures at or below 0°F may be expected 68 percent of the time in December, nearly 94 percent of the time in January, and 90 and 62 percent of the time in February and March, respectively. Temperatures at or below freezing (32°F) may be anticipated more than 95 percent of the time from November through March.

High wind speeds, combined with low temperatures, cause excessive windchill at Fort Churchill during winter. The average value in January for the seven-year period of record is $1,765 \text{ kg-cal/m}^2/\text{hr}$.

FREQUENCY AND DURATION OF LOW TEMPERATURES
AT FORT CHURCHILL, MANITOBA, CANADA

1. Introduction

Fort Churchill, Canada is located in the Province of Manitoba on the western shore of Hudson Bay at a latitude of $58^{\circ}47'N$. and longitude of $94^{\circ}17'W$. (Figure 1). The military camp, established in 1942, is located just southeast of the town of Churchill. The Canadian Army assumed control of the post in 1946. The post has served in the past as a base for various cold weather exercises but in recent years has been used mainly for winter testing by the Canadian Military Services, the UK Winter Warfare Study Team representing the military services of the United Kingdom and by various technical services of the United States Army.

Climatically, Fort Churchill is well suited for cold weather testing. The climate of the area is similar in many respects to that of cold continental interiors, but because of the proximity of Hudson Bay the absolute extremes of low temperature recorded in such interior regions do not occur.

LOCATION MAP

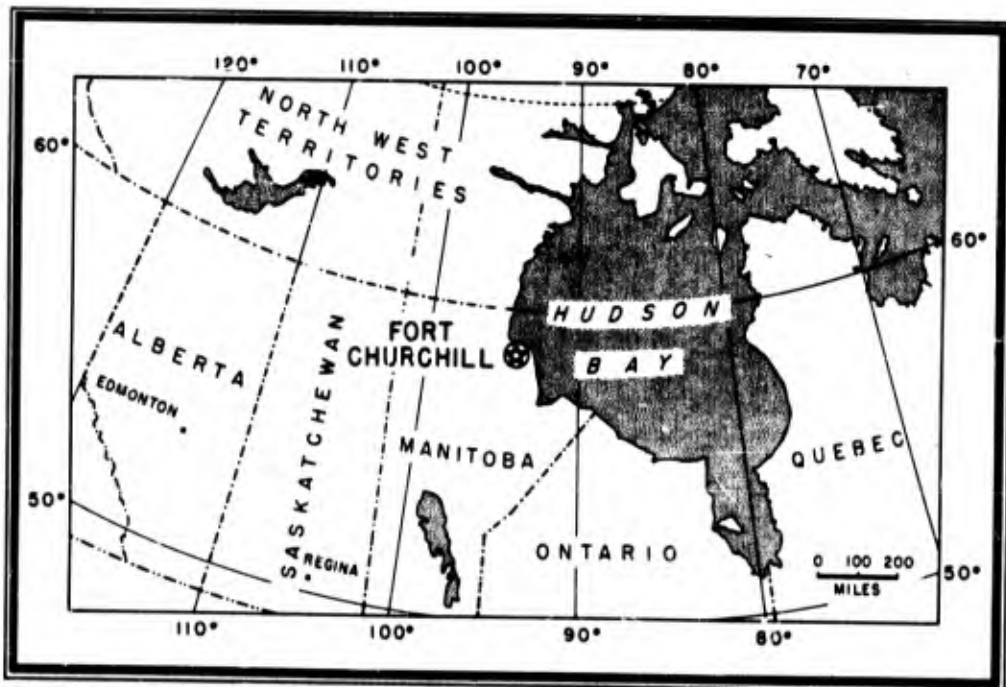


FIGURE 1: LOCATION OF FORT CHURCHILL

Of the elements, both geographic and climatic, which comprise cold environments, one of primary importance, which imposes a great stress on men and equipment, is temperature. It is the purpose of this report to present in graphic and tabular form the actual temperature conditions under which troops and materiel may be required to operate. Of major importance in considering the results of this study is the fact that all data used in the report were obtained from observations taken at approximately "head level." A considerable difference in temperature may occur close to the ground, especially in calm periods when the absence of turbulent mixing of layers of air close to the surface may accentuate this difference. Emphasis is given to frequencies and durations of specified temperatures in order to depart from the use of "mean" or "average" which provide, at best, only an indication of the actual conditions which may exist. The study is not confined to winter; consideration is also given to the occurrence of significant temperatures in other seasons of the year.

2. Data

Data used in the preparation of graphs and tables were obtained from daily weather observations, taken at standard instrument heights, as recorded by the Fort Churchill Meteorological Office. Observations were taken binourly, and hourly values of temperature were determined by interpolation. Data available in this form were for January and February 1946, and for December 1947 through June 1953.

3. Selection of Temperature Values

Temperature values selected for use in this study, with the exception of 0°F, directly influence the issue of clothing and equipment or are specifically mentioned in SR 705-70-5.* These values are also contained in Military Standard 210, 1 June 1953.** These temperature occurrences are classified under the following values: at or below, 50°F, 32°F, 23°F, 14°F, 0°F, -25°F, -40°F, -65°F and -80°F. Temperatures of -65°F and -80°F were not recorded and are therefore not included in tables or graphs of this report. The frequency of occurrence and the duration (in hours and days) of temperatures in these classes are given in tabular and graphic form in order to facilitate their use.

4. Seasonal Occurrence of Low Temperatures

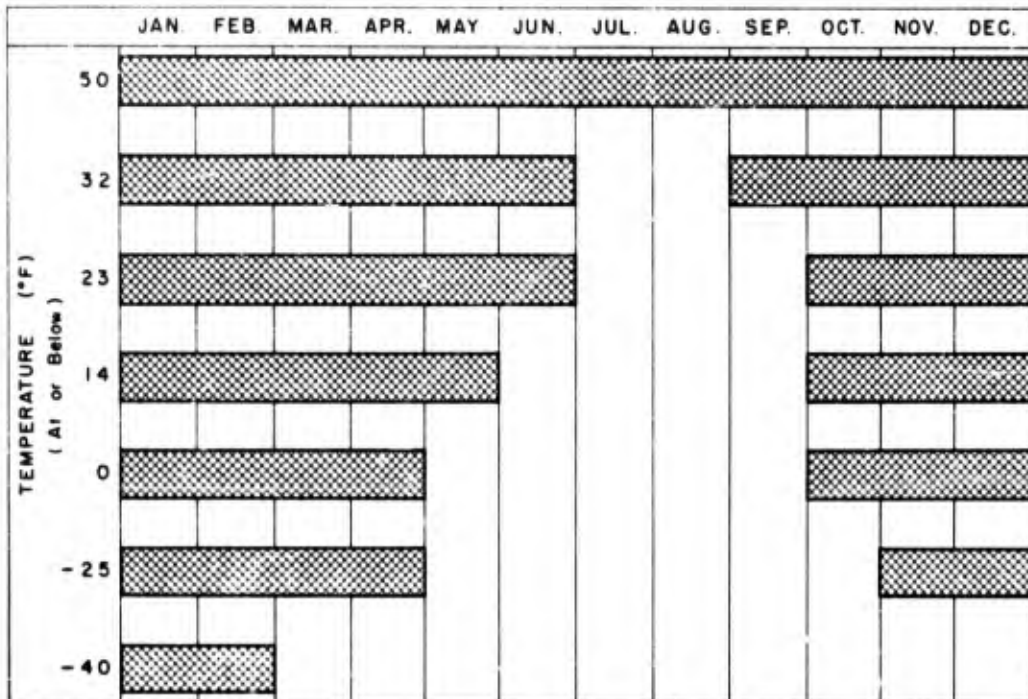
The lowest temperatures recorded at Fort Churchill occur during January and February. In over 35 years of record the lowest temperature ever recorded was -57°F, in January. In the six to seven years of observations used in the preparation of this study the lowest temperature recorded was

*Operation and Protection of Materiel Under Adverse Conditions of Temperature.

**Climatic Extremes for Military Equipment, Military Standard 210.

-44°F in February. Freezing temperatures (at or below 32°F) occur in all months except July and August. Figure 2, below, shows months of the year in which each of the selected temperatures may be expected to occur, and Table I, below, gives the earliest and latest dates of occurrence of each temperature during the period of record.

FIGURE 2
MONTHS DURING WHICH SPECIFIED TEMPERATURES HAVE OCCURRED
AT FORT CHURCHILL, CANADA
Period of Record: 6 to 7 years



C-61 APRIL, 1954 **TABLE I: EARLIEST AND LATEST DATES OF OCCURRENCE OF SPECIFIED TEMPERATURES**
Period of Record: 6 to 7 Years

Temperature (°F) At or Below	Earliest Date	Latest Date
50°	All Year	All Year
32°	9 September	29 June
23°	4 October	3 June
14°	15 October	18 May
0°	28 October	24 April
-25°	21 November	14 April
-40°	3 January	23 February

TABLE II: FREQUENCY OF HOURLY TEMPERATURES AT OR BELOW SPECIFIED VALUES (IN °F)
 Period of Record: 6 to 7 Years

Month	50°			30°			20°			10°		
	Possible Occur.	Actual Occur.	Percent** Max. Mean Min.	Actual Occur.	Percent** Max. Mean Min.	Actual Occur.	Percent** Max. Mean Min.	Actual Occur.	Percent** Max. Mean Min.	Actual Occur.	Percent** Max. Mean Min.	
Jan	5,208	5,208	100.0 100.0 100.0	5,208	100.0 100.0 100.0	5,208	100.0 100.0 100.0	5,208	100.0 100.0 100.0	5,191	99.7 99.2	
Feb	4,656	4,656	100.0 100.0 100.0	4,656	100.0 100.0 100.0	4,656	100.0 100.0 100.0	4,656	100.0 100.0 100.0	4,560	97.9 93.2	
Mar	4,440	4,440	100.0 100.0 100.0	4,440	100.0 100.0 100.0	4,440	100.0 100.0 100.0	4,440	100.0 100.0 100.0	4,133	93.1 85.8	
Apr	4,296	4,292	100.0 100.0 99.4	3,845	89.5 68.2	3,017	83.1 70.2 45.6	3,017	83.1 70.2 45.6	2,109	49.1 26.3	
May	4,368	4,292	100.0 98.3 95.8	3,135	83.9 71.8 55.9	605	36.4 13.4 0.0	605	36.4 13.4 0.0	81	6.1 1.5 0.0	
Jun	4,128	3,360	96.4 81.4 72.7	606	33.5 14.7 5.7	6	0.1 0.1 0.0	6	0.1 0.1 0.0	0	0.0 0.0 0.0	
Jul	4,464	2,392	62.2 53.6 38.2	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Aug	4,464	2,034	64.4 45.8 2.2	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Sep	4,296	3,854	97.4 89.7 70.0	184	9.6 4.3 0.1	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Oct	3,456	3,379	100.0 97.8 91.0	2,178	81.1 63.0 33.3	990	43.8 28.7 7.8	990	43.8 28.7 7.8	287	16.1 8.3 0.0	
Nov	3,600	3,600	100.0 100.0 100.0	3,517	100.0 97.7 89.4	2,901	93.9 80.6 76.0	2,901	93.9 80.6 76.0	2,065	69.4 57.4 34.0	
Dec	4,416	4,416	100.0 100.0 100.0	4,416	100.0 100.0 100.0	4,345	100.0 98.4 92.5	4,345	100.0 98.4 92.5	3,992	98.3 90.4 67.2	
Jan	5,208	4,878	100.0 93.7 85.2	2,107	92.7 40.5 19.9	152	16.1 2.9 0.0	152	16.1 2.9 0.0	0	0.0 0.0 0.0	
Feb	4,656	4,199	100.0 90.2 69.5	1,624	51.5 34.9 8.3	56	5.8 1.2 0.0	56	5.8 1.2 0.0	0	0.0 0.0 0.0	
Mar	4,440	2,748	84.1 61.9 35.0	398	17.7 9.0 1.5	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Apr	4,296	632	36.8 14.7 0.5	3	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
May	4,368	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Jun	4,128	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Jul	4,464	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Aug	4,464	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Sep	4,296	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Oct	3,456	14	1.8 0.4 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Nov	3,600	675	31.7 18.8 2.4	8	1.0 0.2 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	
Dec	4,416	3,002	80.9 66.0 44.6	489	17.6 11.1 4.7	0	0.0 0.0 0.0	0	0.0 0.0 0.0	0	0.0 0.0 0.0	

The actual number of occurrences are given for each value, together with the percentage frequency. Values of 99.95 percent, or greater, are given as 100.0 percent.

5. Frequency of Low Temperatures

The percentage frequency of low temperatures for each month is presented in Table II. The average number of days per month with minimum temperatures at or below the selected values are shown in Table III, below.

TABLE III: AVERAGE NUMBER OF DAYS PER MONTH WITH MINIMUM TEMPERATURES AT OR BELOW SPECIFIED VALUES (IN °F)
Period of Record: 6 to 7 Years

<u>MONTH</u>	<u>50°</u>	<u>32°</u>	<u>23°</u>	<u>14°</u>	<u>0°</u>	<u>-25°</u>	<u>-40°</u>
January	31.0	31.0	31.0	31.0	30.6	18.3	3.1
February	28.3	28.3	28.3	28.3	27.3	16.9	1.4
March	31.0	31.0	30.8	30.5	26.2	5.8	0.0
April	30.0	29.8	26.0	20.3	10.5	0.3	0.0
May	31.0	24.2	11.0	2.2	0.0	0.0	0.0
June	29.3	12.7	0.3	0.0	0.0	0.0	0.0
July	30.5	0.0	0.0	0.0	0.0	0.0	0.0
August	25.5	0.0	0.0	0.0	0.0	0.0	0.0
September	29.5	4.2	0.0	0.0	0.0	0.0	0.0
October	31.0	23.6	11.8	5.6	0.4	0.0	0.0
November	30.0	30.0	27.2	22.2	10.6	0.6	0.0
December	31.0	31.0	31.0	29.2	26.0	6.7	0.0

6. Duration of Low Temperatures

Duration of low temperatures is important for determining proper clothing protection for troops, establishing practical design criteria and for understanding fully the actual extremes of temperature under which men and equipment will be called upon to operate and function. The efficiency of troops or equipment may not be seriously impaired if exposed to extreme low temperatures (-25°F or below) for only a few hours. However, if similar temperatures persist for a day, or days, additional precautions may be required in order to maintain desired efficiency. Troops and equipment may also be subject to greater stress when exposed to temperatures near 0°F for several days than when exposed to lower temperatures, for example -25°F for a much shorter time, perhaps only a few hours. It is of primary importance therefore, to know not only what low temperatures may occur but how long these temperatures may be expected to prevail.

Daily minimum temperatures were analyzed to determine the number of consecutive days per year during which each temperature occurred.

In the graphs and charts showing the duration of low temperatures the beginning of the year was taken as 1 July and the end of the year as 30 June. This allowed continuous tabulation and presentation of data through the winter period when extreme low temperatures occur, without a break for the beginning of a new calendar year. Figure 3 shows the average of the longest period of consecutive days per year with minimum temperatures at or below the selected values. Table IV, below, gives the average of the longest period of consecutive days per month during which daily minimum temperatures may be expected to be at or below the selected limits.

TABLE IV: AVERAGE LONGEST PERIOD OF CONSECUTIVE DAYS PER MONTH* WITH MINIMUM TEMPERATURES AT OR BELOW SPECIFIED VALUES (IN °F)
 Period of Record: 6 to 7 Years

MONTH	50°	32°	23°	14°	0°	-25°	-40°
January	31.0	31.0	31.0	31.0	29.9	11.0	2.0
February	28.3	28.3	28.3	28.3	22.3	10.3	1.0
March	31.0	31.0	30.8	28.0	19.2	3.6	0.0
April	30.0	29.7	19.7	14.2	7.8	0.3	0.0
May	31.0	23.5	7.8	1.2	0.0	0.0	0.0
June	26.8	4.8	0.2	0.0	0.0	0.0	0.0
July	19.5	0.0	0.0	0.0	0.0	0.0	0.0
August	14.2	0.0	0.0	0.0	0.0	0.0	0.0
September	28.8	3.0	0.0	0.0	0.0	0.0	0.0
October	31.0	24.0	7.2	3.0	0.4	0.0	0.0
November	30.0	30.0	21.2	14.2	5.6	0.6	0.0
December	31.0	31.0	31.0	28.2	20.2	4.6	0.0

*Determined by averaging the longest period of consecutive days with each specified temperature for each month. For example, the longest period of consecutive days with minimum temperature at or below -25°F in January for each year is as follows: 1946 - 9 days, 1948 - 4 days, 1949 - 7 days, 1950 - 31 days, 1951 - 8 days, 1952 - 7 days, 1953 - 11 days. These periods were averaged to obtain the value (11 days) shown in the table.

A similar analysis was performed to determine the average longest period of consecutive days per month and per year during which daily temperatures did not exceed the selected values. Results of this analysis are presented in Table V and shown graphically in Figure 4.

TABLE V: AVERAGE LONGEST PERIOD OF CONSECUTIVE DAYS PER MONTH* WITH MAXIMUM TEMPERATURES AT OR BELOW SPECIFIED VALUES (IN °F)
 Period of Record: 6 to 7 Years

MONTH	50°	32°	23°	14°	0°	-25°	-40°
January	31.0	31.0	31.0	29.7	21.0	2.8	0.0
February	28.3	28.3	28.3	21.7	15.3	2.5	0.0
March	31.0	30.8	25.7	14.2	6.5	0.7	0.0
April	29.5	14.0	11.0	4.7	1.0	0.0	0.0
May	21.3	6.0	1.5	0.0	0.0	0.0	0.0
June	5.7	1.0	0.0	0.0	0.0	0.0	0.0
July	1.6	0.0	0.0	0.0	0.0	0.0	0.0
August	2.8	0.0	0.0	0.0	0.0	0.0	0.0
September	12.2	0.0	0.0	0.0	0.0	0.0	0.0
October	16.4	7.0	2.7	0.7	0.0	0.0	0.0
November	30.0	27.6	13.0	7.6	2.6	0.0	0.0
December	31.0	31.0	26.3	22.7	9.8	0.8	0.0

*Determined by averaging the longest period of consecutive days with each specified temperature for each month. For example, the longest period of consecutive days with maximum temperature at or below 0°F in December for each year is as follows: 1947 - 5 days, 1948 - 4 days, 1949 - 13 days, 1950 - 10 days, 1951 - 21 days, 1952 - 6 days. These periods were averaged to obtain the value (9.8 days) shown in the table.

Tables VI and VII show the maximum greatest and the minimum greatest number of consecutive days and the longest duration (in hours) of temperatures at or below the selected values.

TABLE VI: LONGEST PERIODS OF CONSECUTIVE DAYS WITH MAXIMUM AND MINIMUM AT OR BELOW SPECIFIED TEMPERATURES (IN °F)
 Period of Record: 6 to 7 Years

Minimum Temperature	Longest Periods (Days Per Year)		Maximum Temperature	Longest Periods (Days Per Year)	
	Shortest	Longest		Shortest	Longest
50	281	313	50	201	263
32	202	239	32	143	175
23	140	183	23	81	119
14	104	145	14	34	85
0	50	94	0	14	45
-25	7	38	-25	2	8
-40	0	7	-40	0	0

FIGURE 3
 AVERAGE OF THE LONGEST PERIOD OF CONSECUTIVE DAYS PER YEAR
 WITH MINIMUM TEMPERATURES AT OR BELOW
 SPECIFIED VALUES AT FORT CHURCHILL, CANADA
 Period of Record: 6 to 7 years

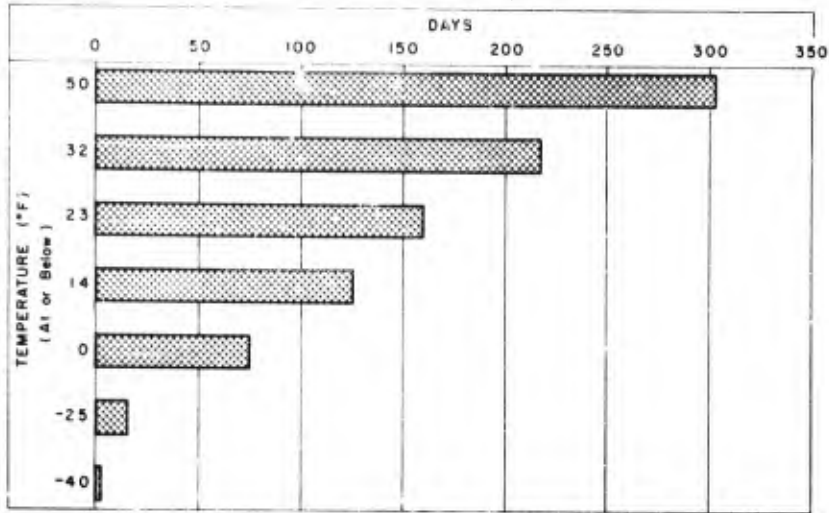


FIGURE 4
 AVERAGE OF THE LONGEST PERIOD OF CONSECUTIVE DAYS PER YEAR
 WITH MAXIMUM TEMPERATURES AT OR BELOW
 SPECIFIED VALUES AT FORT CHURCHILL, CANADA
 Period of Record: 6 to 7 years

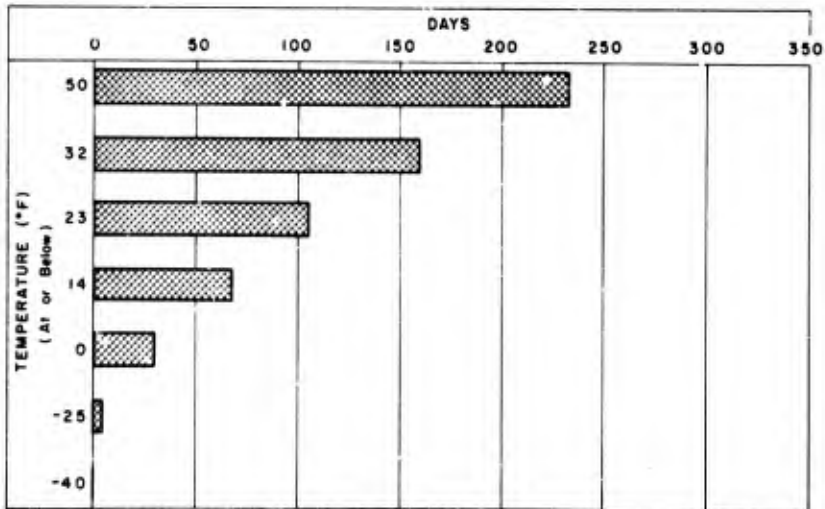


TABLE VII: LONGEST DURATION IN HOURS AT OR BELOW SPECIFIED TEMPERATURES (IN °F)
 Period of Record: 6 to 7 Years

<u>Temperature</u>	<u>Longest Duration (Hrs)</u>
50	6,282
32	4,215
23	2,874
14	2,077
0	1,080
-25	170
-40	16

Since temperatures at the lower limits do not occur over a large number of consecutive days a tabulation of consecutive hours of temperatures at or below -25°F and -40°F is given in Table VIII, below.

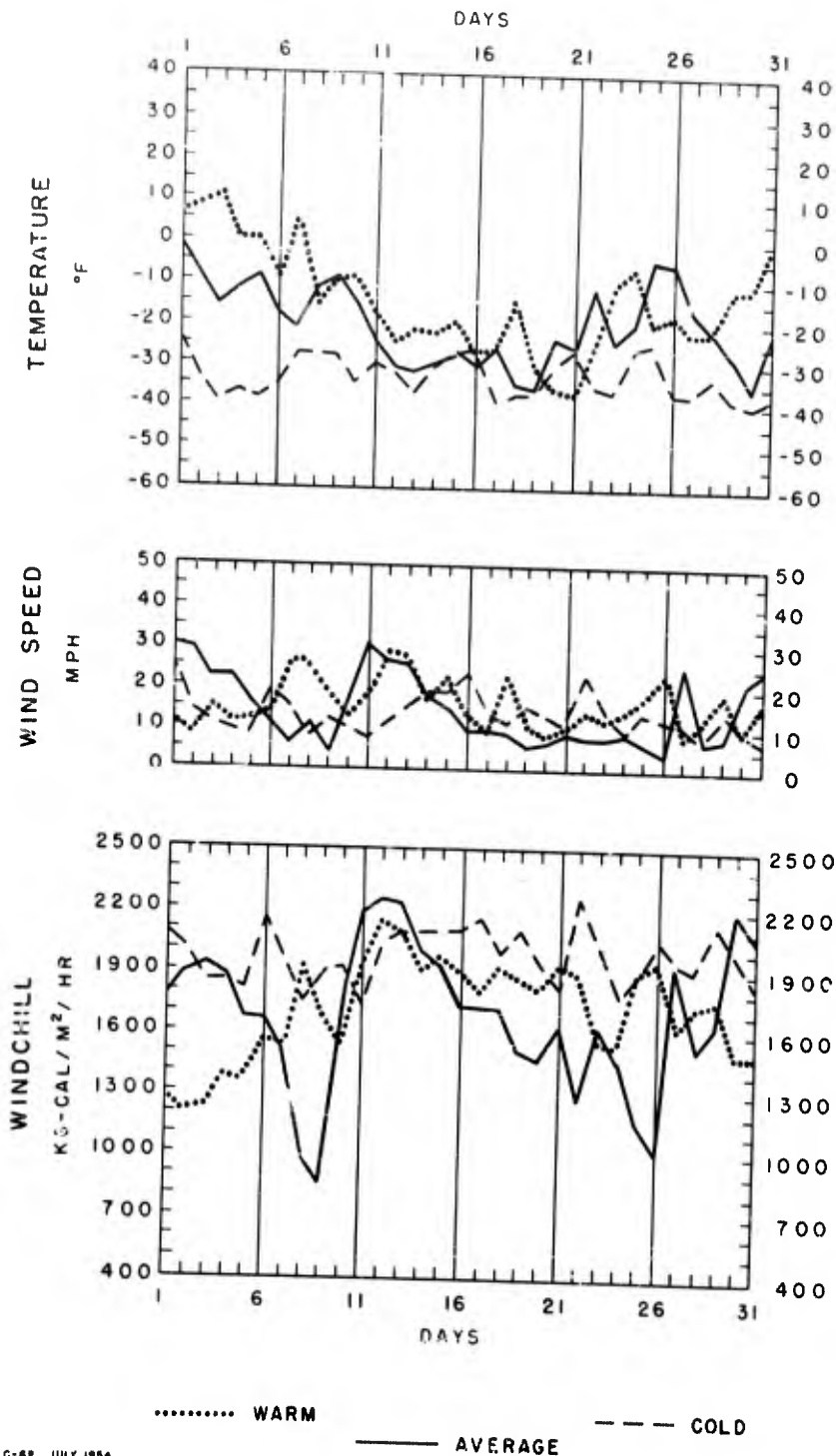
TABLE VIII: NUMBER OF CONSECUTIVE HOURS PER COLD SPELL WITH TEMPERATURES AT OR BELOW -25°F AND -40°F
 Period of Record: 6 to 7 Years

<u>MONTH</u>	<u>-25°F</u>		
	<u>Average*</u>	<u>Greatest Number**</u>	<u>Mean No. of Cold Spells***</u>
January	26.5	156.0	3.0
February	30.3	170.0	2.6
March	17.0	53.0	1.2
April	3.0	3.0	0.2
May	0.0	0.0	0.0
June	0.0	0.0	0.0
July	0.0	0.0	0.0
August	0.0	0.0	0.0
September	0.0	0.0	0.0
October	0.0	0.0	0.0
November	5.0	5.0	0.2
December	16.3	63.0	1.6

<u>-40°F</u>			
January****	7.7	16.0	1.3
February****†	7.8	14.0	0.6

*Average number of consecutive hours per cold spell.
 **Greatest number of consecutive hours per cold spell.
 ***Mean number of cold spells of at least average length.
 ****Temperatures at or below -40°F occurred only in January and February.

MEAN DAILY VALUES OF TEMPERATURE WIND SPEED AND WINDCHILL FOR JANUARY AT FORT CHURCHILL, CANADA



7. Temperature and Wind

Acute discomfort, because of windchill, is experienced by persons exposed to wind in combination with low temperatures. At extremely low temperatures the wind speed need not be very great in order to impose severe physiologic stress. In general, extreme low temperatures are usually associated with calm or near calm conditions. At Fort Churchill, however, during winter, wind speeds of 10 to 20 mph occur frequently with low temperatures, and high values of windchill are recorded. In Figure 5 the mean daily values of temperature, wind speed and windchill are presented graphically for a warm, average and cold January taken from the seven-year period of record used in the study. The average January chosen was one whose mean temperature most closely approximated the mean January temperature for the entire period. The daily values of windchill for the month of January vary from a minimum value of 860 kg-cal/m²/hr. to a maximum value of 2,275 kg-cal/m²/hr. with the average value being 1,765 kg-cal/m²/hr.

8. Acknowledgments

Appreciation is expressed to Sir Hubert Wilkins for his aid in preparing this report, and to Mrs. Odette Taft for the preparation of graphs and charts.

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