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PREPARATION OF COLD STRAIN MAPS

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This report has been prepared for the purpose of explaining the technique used in compiling a series of maps showing the relative amounts of cold strain on the QM-equipped soldier in different environments. The maps were used primarily for indoctrination and display purposes to show the improvement in protection provided by the current standard cold weather clothing over that provided by the previous standard uniform. On the maps in Figures 1 and 2 (representative of the series), the current standard clothing is referred to as the 1955 uniform, and the previous standard clothing is called the 1945 uniform. Major components of these uniforms are listed in Table I.

The data on which the maps are based were derived by use of the equation below, developed by Dr. Douglas H. K. Lee, Office of R&E, OQMG. By using this equation, it is possible to determine an index number (G) for cold strain, i.e., the effect of the environment on man's ability to keep warm under severe cooling conditions.

$$G = 1.11 \left\{ \frac{5.55\ (34-t)}{I_a + I_c} + M \left[.153 + .0015\ (34-t) \right] - (M-W) \right\}$$

Where t = air temperature in °C
I_a = insulation of the boundary air layer in clo
I_c = insulation of clothing in clo
M = metabolic rate in Kcal/m^2/hr
W = energy expended in external work in Kcal/m^2/hr

This formula is based on a range of G values from 0 at the point of thermal equilibrium to 200 when the mean body temperature is dropping at a rate of 5C°/hr (beyond the limits of human endurance).

Because the above equation is designed for use in assessing cold strain in specific situations, several assumptions were made in order to use it for map construction. For Figures 1 and 2, it is assumed that men are standing, and have an average metabolic rate of 70 Kcal/m^2/hr. It is further assumed that $W = 0$; in other words, no energy is expended in external work. As may be noted, the insulation on the man is separated into two kinds, the intrinsic insulation of the clothing and the insulating properties of the thin layer of still air surrounding the clothing. For practical mapping purposes, the insulation of the clothing is considered to remain constant, but the thickness of the boundary still air layer varies with the wind speed, so that it has a range of clo values from 0.72 for still air to 0.13 for wind at 30 mph. Figure 3 is a graph showing how the insulation of the boundary air layer varies with wind speed.

The determination of the insulation provided by the clothing was made on a copper man in still air. Because the measurements included the value of I_a for still air (0.72 clo), this amount had to be subtracted

in order to determine the actual values for I_c. The final values of I_c were 2.58 clo for the 1945 uniform and 3.48 clo for the 1955 uniform.

The most satisfactory climatic data readily available for this study were mean wind speeds and mean daily minimum temperatures. These data are adequate in the present circumstance where two uniforms are compared, but they may not be satisfactory in an absolute sense - the cold strain values would approach reality only during the times when the temperatures and wind speeds are near their respective mean values.

In constructing the cold strain maps, mean wind speeds and mean daily minimum temperatures for January were collected for approximately 500 stations in the Northern Hemisphere. After the data were punched on IBM cards, the cold strain equation was solved by machine for each position for both uniforms. The index numbers for both uniforms were then plotted, and isograms were drawn at selected intervals.

As may be seen from the maps, cold strain index values exceed 100 in extreme northern North America for men wearing the 1945 standard uniform, but for men wearing the current standard clothing, cold strain values never reach 100. Also, it may be seen that the newer uniform adds the north-central United States and most of Canada to the area where general safety is provided for periods of over an hour. The maps show, too, that the southern limit for expected cold strain is considerably farther south for the 1945 uniform than for the 1955 uniform.

The general technique, although developed for depicting relative protection provided by clothing systems, can, after proper modification, be used in illustrating operational capabilities of both the soldier and items of military materiel.

Acknowledgments

The maps described in this report are a product of several elements of the Environmental Protection Research Division. Credit for the idea and for the basic formula used belongs, as noted earlier, to Dr. Lee, OQMG. Mr. Alfred Koch, Biophysics Branch, determined the clo value of the uniforms. Mrs. Jane Westbrook, Environmental Analysis Branch, plotted many of the index values, and, along with Mr. George Reynolds, Environmental Analysis Branch, searched out the climatic data. Mr. James Dillon, Statistical Office, supervised the whole function of converting the climatic data into cold strain index values. Cartographic work was done by Mr. Roland Frodigh, Miss Gertrude Barry, and Miss Rebecca Brocklebank, all of the Regional Environments Research Branch.

TABLE I: MAJOR COMPONENTS OF 1955 AND 1945 COLD WEATHER UNIFORMS

1945	1955
Upper Body Clothing	**Upper Body Clothing**
Undershirt, winter	Undershirt, winter
Shirt, flannel, OD	Shirt, man's, wool
Sweater, high neck	Liner, coat, man's, (Jacket liner)
Jacket, field, pile	Coat, man's, single breasted (Jacket shell)
Parka, field, pile	Liner, parka
Parka, field, cotton, OD	Parka
Lower Body Clothing	**Lower Body Clothing**
Drawers, winter	Drawers, winter
Trousers, field, wool, OD	Trousers, intermediate, w/liner
Trousers, field, cotton, OD	Liner, trousers, Arctic, field
	Trousers, man's, cotton, wind-resistant
Footwear	**Footwear**
Boot, mukluk (with appropriate sockgear)	Boot, mukluk (with appropriate sock-gear)
Headwear	**Headwear**
Cap, field, cotton, OD	Hood, winter
	Cap, field, cotton, pile
Handwear	**Handwear**
Mittens, Arctic, trigger finger, w/inserts	Mittens, inserts, wool, 3-finger
	Mittens, set, Arctic, cotton, OD

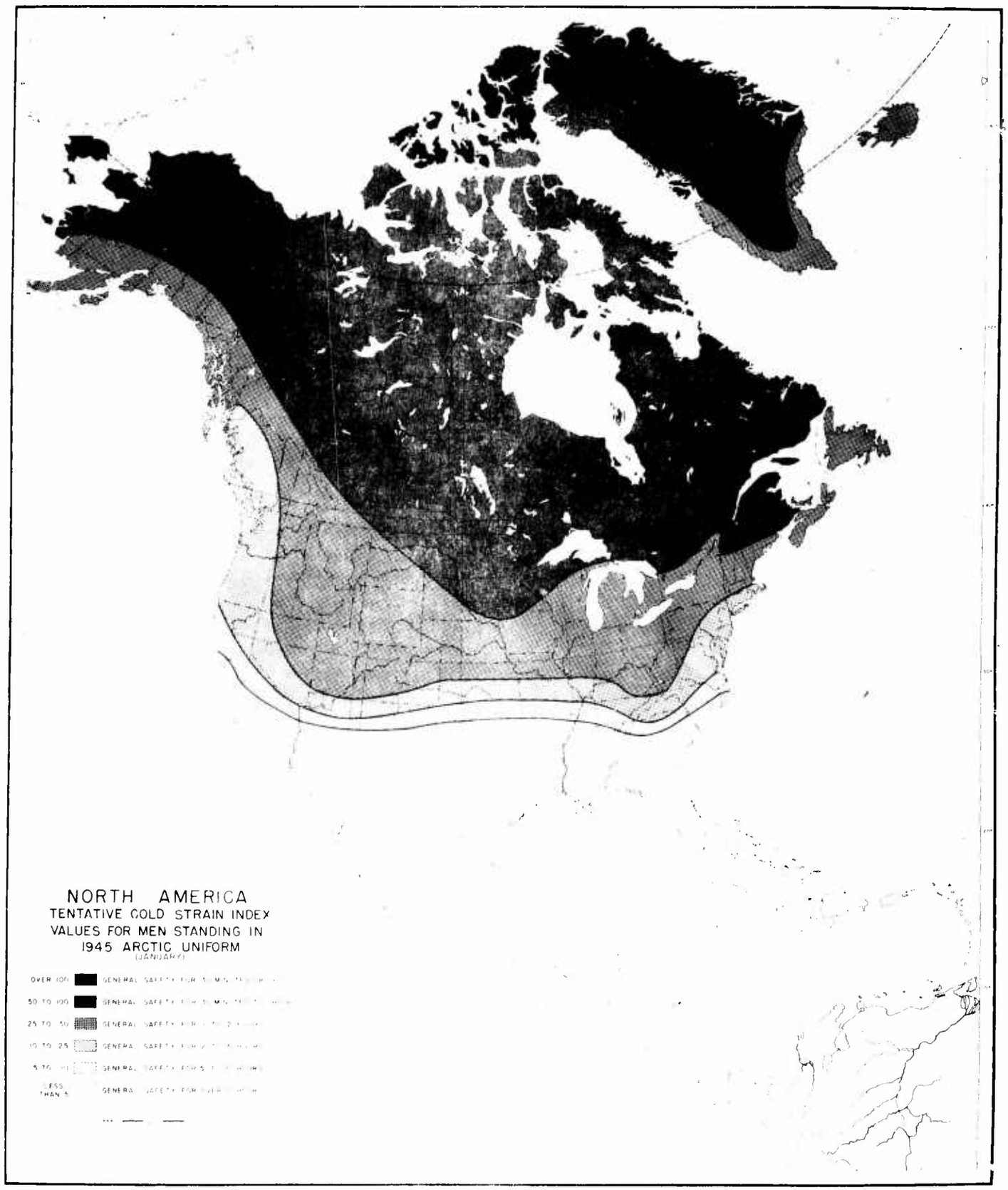
NORTH AMERICA
TENTATIVE COLD STRAIN INDEX
VALUES FOR MEN STANDING IN
1945 ARCTIC UNIFORM
(JANUARY)
OVER 100
50 TO 100
25 TO 50
10 TO 25
5 TO
LESS THAN 5

Figure 1

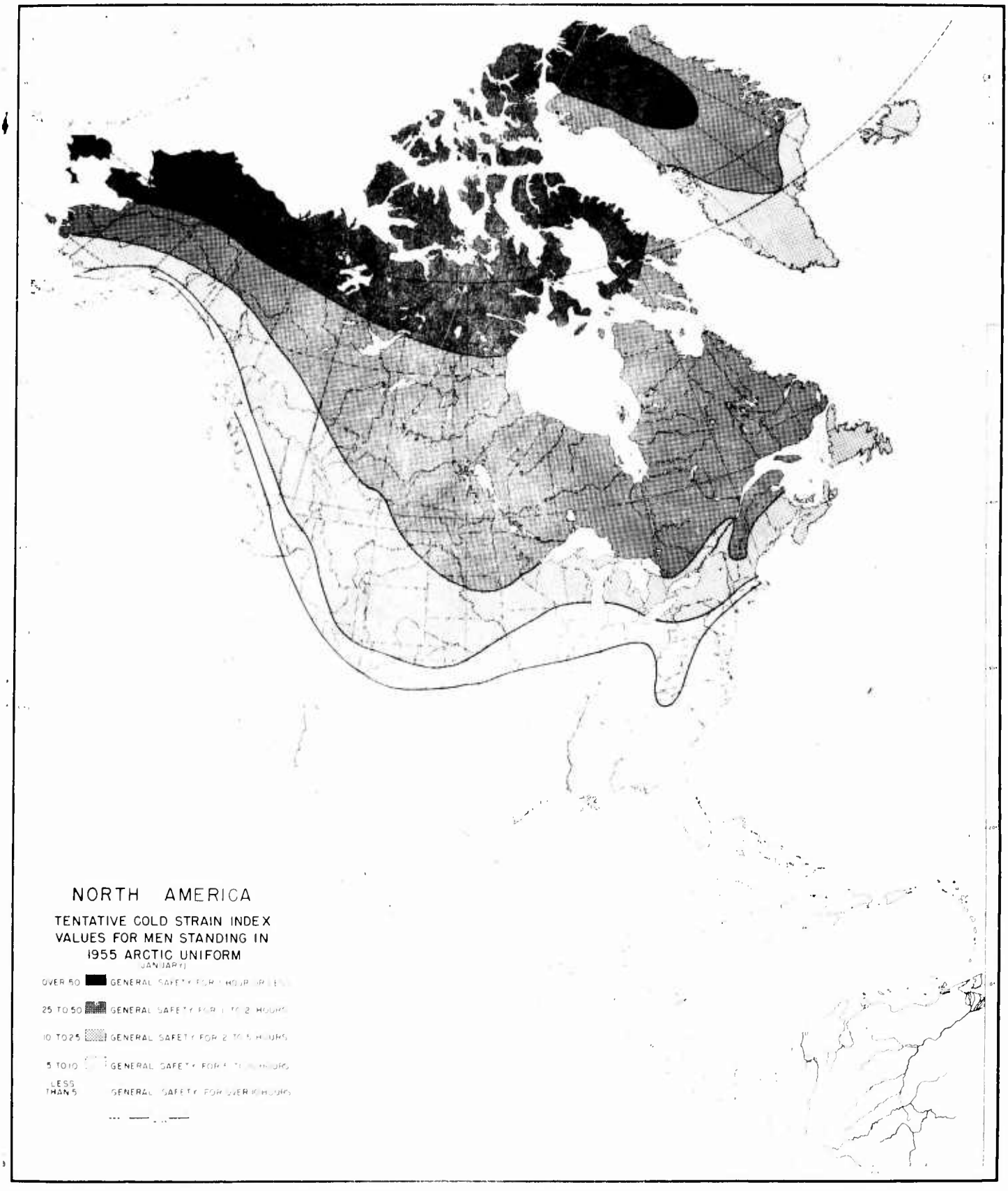
NORTH AMERICA
TENTATIVE COLD STRAIN INDEX
VALUES FOR MEN STANDING IN
1955 ARCTIC UNIFORM
(JANUARY)
OVER 50
25 TO 50
10 TO 25
5 TO 10
LESS THAN 5

Figure 2

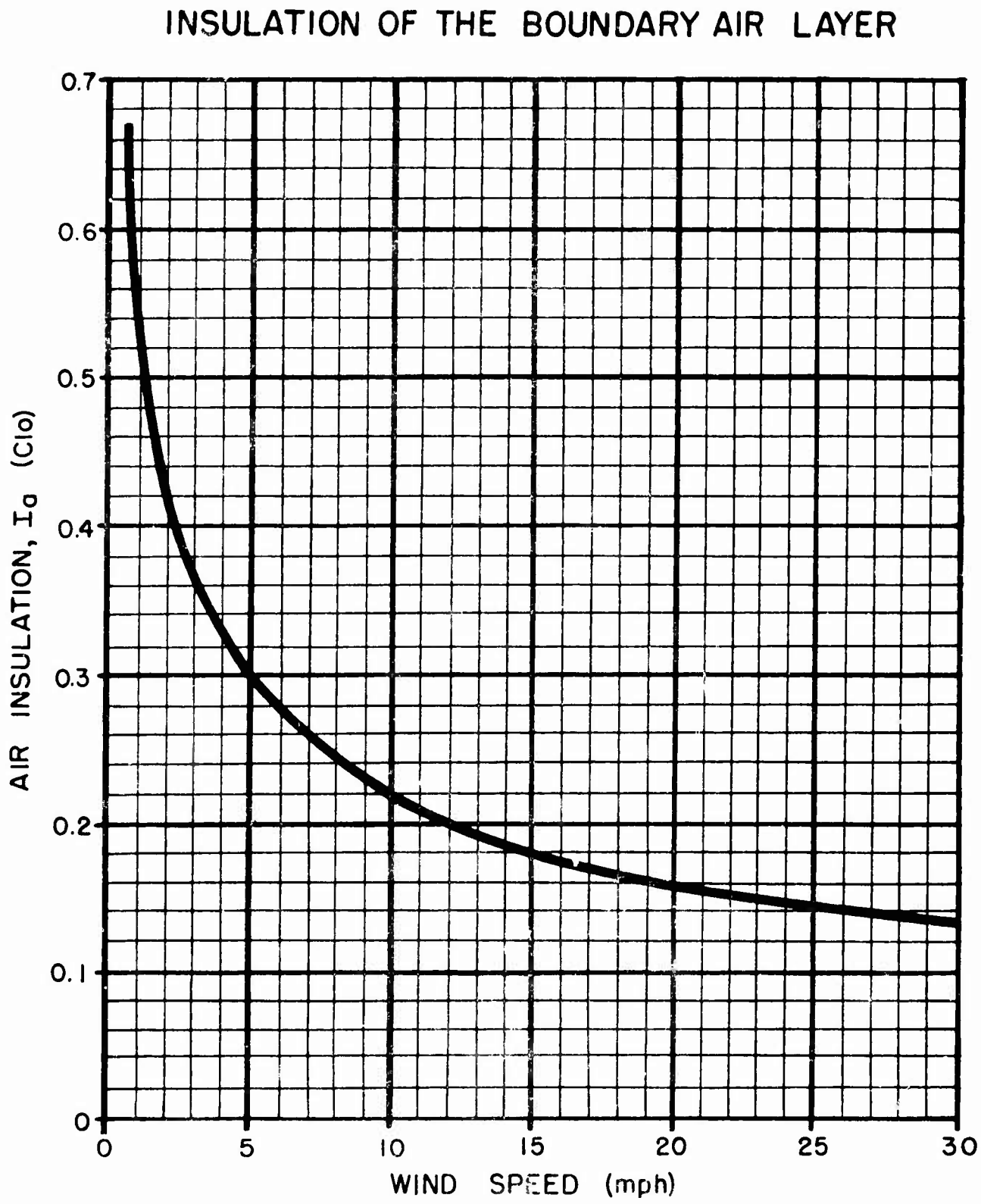
INSULATION OF THE BOUNDARY AIR LAYER
AIR INSULATION, Ia (Clo)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
WIND SPEED (mph)

Figure 3