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U.S. DEPARTMENT OF COMMERCE
National Oceanic And Atmospheric Administration
National Weather Service

FORECASTING ICE IN COOK INLET ALASKA

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ANCHORAGE, ALASKA

ALASKA REGION
Anchorage,
Alaska
August 1972

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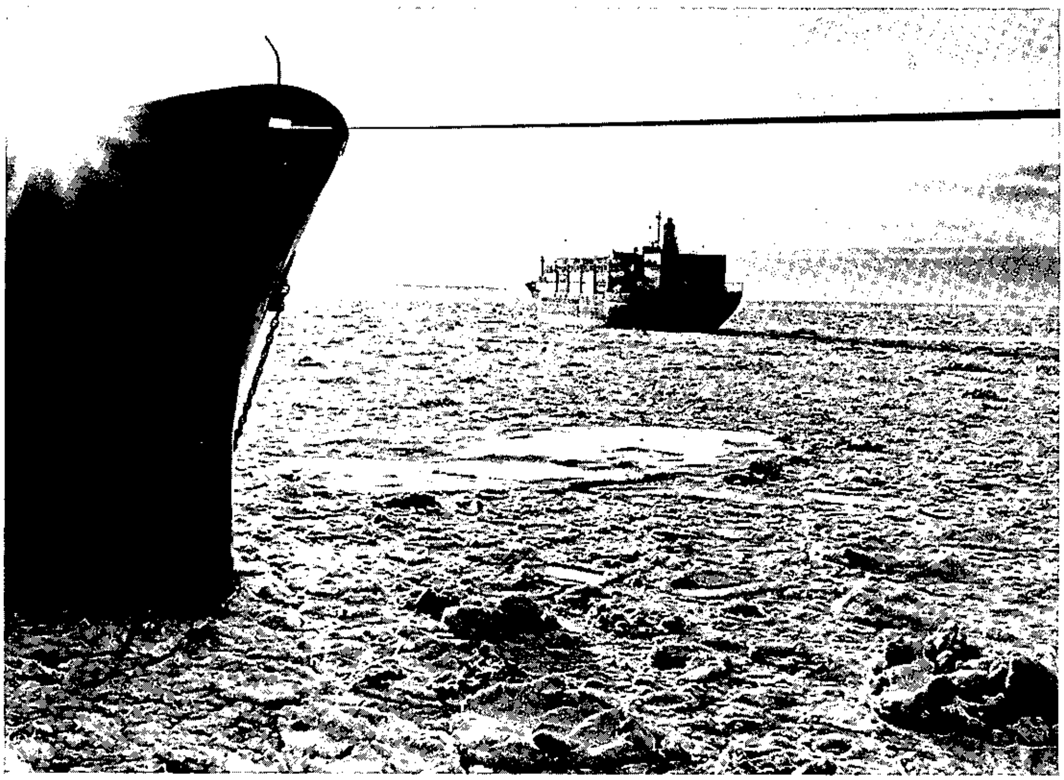
1. Freeze-Thaw Cycle in the Coastal Arctic of Alaska - 1968.

2. Climate Along A Pipeline from the Arctic to the Gulf of Alaska - 1968.

3. Coastal Weather and Marine Data Summary for Gulf of Alaska, Cape Spencer Westward to Kodiak Island - 1969.

4. Climate of the North Slope of Alaska. Harold Searby and Marcelle Hunter. February 1971.

5. Forecasting Ice in Cook Inlet, Alaska. Richard J. Hutcheon. August 1972.



Outbound From The Port of Anchorage
February 11, 1971

Picture — Courtesy
Anchorage Times

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

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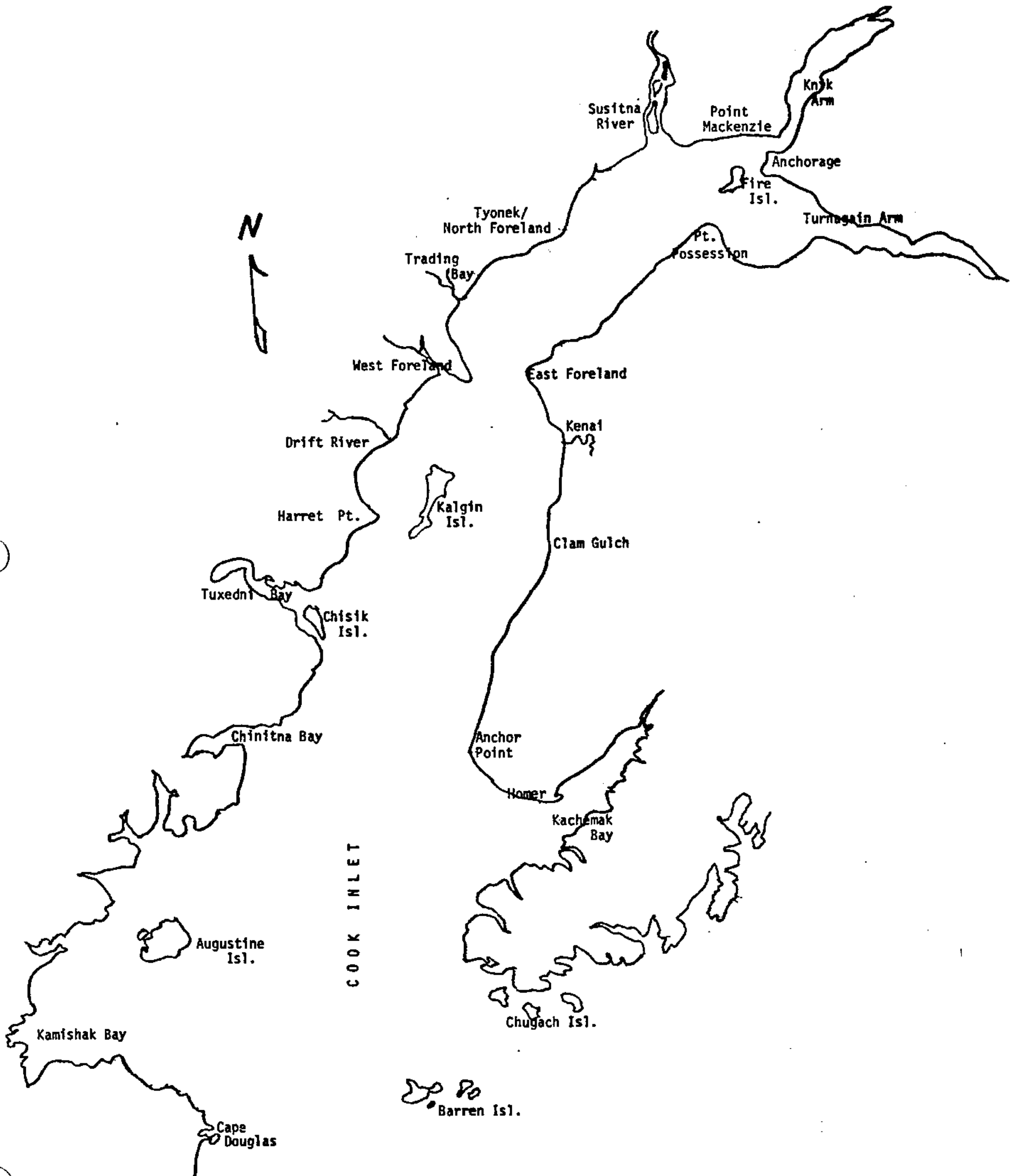
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Pt.
Possession
West Foreland
East Foreland
Kenai
Drift River
Kalgin
Isl.
Harret Pt.
Clam Gulch
Tuxedni Bay
Chisik
Isl.
Chinitna Bay
Anchor
Point
Homer
Kachemak
Bay
COOK INLET
Augustine
Isl.
Chugach Isl.
Kamishak Bay
Barren Isl.
Cape
Douglas

FORECASTING ICE IN COOK INLET

Richard J. Hutcheon
WSFO, Anchorage, Alaska

The unique character of Cook Inlet makes the forecasting, and even the study of ice conditions highly complex. The usual computations of ice thickness using the accumulated frost degree days is complicated by the occurrence of a number of periods during the winter when the average daily temperatures rises above freezing. The tidal action in the Inlet further complicates any study of ice conditions by creating huge piles of ice on the mud flats and occasionally lifting them free. In addition a number of rivers drain into the Inlet, creating areas of mostly fresh water, as well as releasing large fresh water ice cakes during river breakup.

TYPES OF ICE. The ice in Cook Inlet comes from four different sources (6).

1. Sea Ice. This type is formed in sea water, first developing a thin crust on the surface and growing through the addition of ice on the bottom of the surface layer. Sea ice is the predominant type of ice in Cook Inlet.
2. Beach Ice. The large tidal range in the Inlet accounts for the sudden appearance of a considerable amount of ice on the mud flats early in the winter. The ebbing tide exposes the mud to cold air, freezing the upper layer of mud. On flood tide, the water adjacent to the frozen mud also freezes. Growth may be as much as an inch or more a day. Generally, however, a thickness no greater than about 20 inches is reached before the ice is pulled free of the mud. Some beach ice is lifted higher on the beach and some is carried out into the Inlet, where it grows much the same as sea ice.
3. Stamukhas. Observers have seen ice cakes greater than 20 feet thick on the mud flats. These result from beach ice which has broken free, been deposited higher on the mud flats, and frozen to the underlying mud. Ice floes floating toward the beach are caught on top of the higher piece of ice and, as the tide recedes, the overhanging pieces break off leaving a stack of layered ice with nearly straight sides. This process is repeated many times, being limited only by the height of the tides and the strength with which the original beach ice is frozen into the mud. On high tide, occasional stamukhas of massive proportions are carried into the Inlet. Stamkhas 20 feet high, 30 feet wide and 60 feet long grounded on Middle Ground Shoal were observed by Pan American personnel in 1964.
4. Estuary and River Ice. Fresh water ice forms during the winter in estuaries and rivers around Cook Inlet. The estuary ice grows in the same manner as sea ice but is much harder. The river ice is unaffected by tidal actions and remains in the rivers until spring breakup. At that time, a considerable quanity of river ice with thicknesses up to 6 or 7 feet may be discharged into the Inlet.

ICE THICKNESS. K. A. Blenkarn (2) of Pan American Petroleum Corporation, during the winter of 1964-65, obtained quantitative information on the movement of ice in Cook Inlet. His study indicated that ice tends to move out of the Inlet at speed varying between about 2 and 5 miles a day. Assuming the slower speed of 2 miles a day, an ice floe would have approximately 30 days to grow in the northern part of the Inlet before reaching warmer water south of the Forelands. Therefore, when computing sea ice thickness in the Inlet an average growth period of 30 days must be used.

Kriskern and Potocsky (3) computed sea ice growth at 60 Arctic stations using cumulative frost degree days. Numerous equations are available to forecast the ice growth. Bilello (1) summarizes these as follows:

"Using 19 stations in the Kara, East Siberian, Chukhotsh, Barents, and Laptev seas for 24 station years of observations, Levedev found the accretion of sea ice (under average snow cover conditions) related to the sum of negative mean daily air temperature as follows:

$$h = 1.33 \ (\Sigma\theta)^{0.58}$$

h = ice thickness in centimeters
$\Sigma\theta$ = sum of negative air temperature (below 0°C)

"An equation of the same form

$$h = 1.53 \ (\Sigma\theta)^{0.59}$$

fits data obtained by Graystone in Button Bay near Churchill Canada, when snow cover was negligible.

"Zubov expresses ice thickness as

$$h^2 + 50h = 8\Sigma\theta$$

for stations in the Kara and Chukhotsh seas.

"Lebdev also introduces the formula

$$h = (1.245) \ (\Sigma\theta)^{0.62} \ (h_s)^{-1.5}$$

which defines the dependence of ice accretion h on negative air temperature θ (below 0°C) and the thickness of snow cover on ice in centimeters h_s. This equation, however, was based on only one year of data on fresh water ice from the Yana River at Kazach'ye and the Kolyma River at Konzoboy in northeast Russia.

"Assur presents the relation

$$h = (K)\ 1.06\sqrt{S}$$

where h = ice thickness in inches

K = coefficient, considering snow cover stream flow and other local conditions

S = accumulated degree days of frost since freeze-up (below 32°F)"

Bilello (1) presents the following equation as approximately describing sea ice accretion of snow-free ice:

$$I = 3.55\sqrt{\Sigma FDD}$$

I = ice thickness in centimeters FDD = frost degree days.

or

$$I = 1.4\sqrt{\Sigma FDD}$$

where I is in inches.

This equation is based on 30°F, and was chosen for this study.

A graph of Bilello's equation is shown in Figure 1. From this graph and the maximum and minimum temperatures at Anchorage International Airport, the ice thickness in the northern part of the Inlet can easily be determined by summing the number of degrees that the average daily temperature is below 30°F. Figure 2 shows the normal ice growth in the northern part of the Inlet using Bilello's equation with 42 years of temperature data and assuming that the ice moves out of the Inlet in 30 days.

SNOW COVER. The effect of snow cover on the growth of ice can not be over emphasized. The Hand Book of Geophysics for Air Force Designers (5) says that 1 inch of normal snow will have about the same insulating effect as 16 inches of ice. Under one inch of snow cover, a thin layer of ice will grow at the same rate as 16 inches of ice with no snow cover. Figure (3) is a series of graphs which show the rate of ice growth under different amounts of snow cover. It can be seen from this figure that just a few inches of snow dramatically alters the growth of ice. It can be assumed that ice floes which have more than 6 inches of snow on them will not increase in thickness.

DECREASE IN ICE THICKNESS. As with ice growth, the decrease in ice thickness can be described by a number of equations. Bilello (1) empirically developed the following equation for the decrease in ice thickness.

$$\Delta I = 0.22 \Sigma WDD$$

ΣWDD = accumulation of warming degree days (~~below~~ above 30°F)

ΔI = decrease in ice thickness in inches.

A graph of this equation appears in Figure 4. From the graph, the decrease in ice thickness can be obtained.

Figures 3 and 4 describe ice growth and disintegration knowing only air temperatures. It is interesting to note that while it requires 450 frost degree days to grow ice 30 inches thick, only 135 warming degree days are needed to melt 30 inches of ice.

The results of the scheme developed in this paper for determing ice thickness in Cook Inlet are not unreasonable. The maximum accumulation of degree days over a 30-day period occurred in 1964-65 when 1075 degree days accumulated. Figure 3 indicates that bare ice would have grown to about 4 feet with this accumulation. This agrees well with observations by Captain Collar of ice off Point Possession during the winter of 1964-65. Figure 2 indicates that an ice thickness of nearly 3 feet can be expected during a "normal" year.

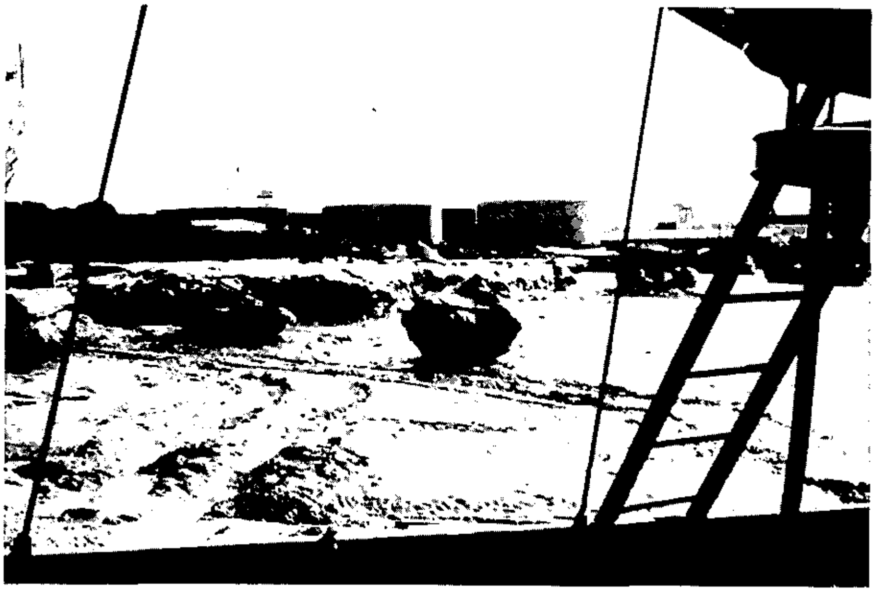
Ice on beach of Cook Inlet January 1969----Courtesy Captain B.J. Logan, American Institute of Marine Underwriters.

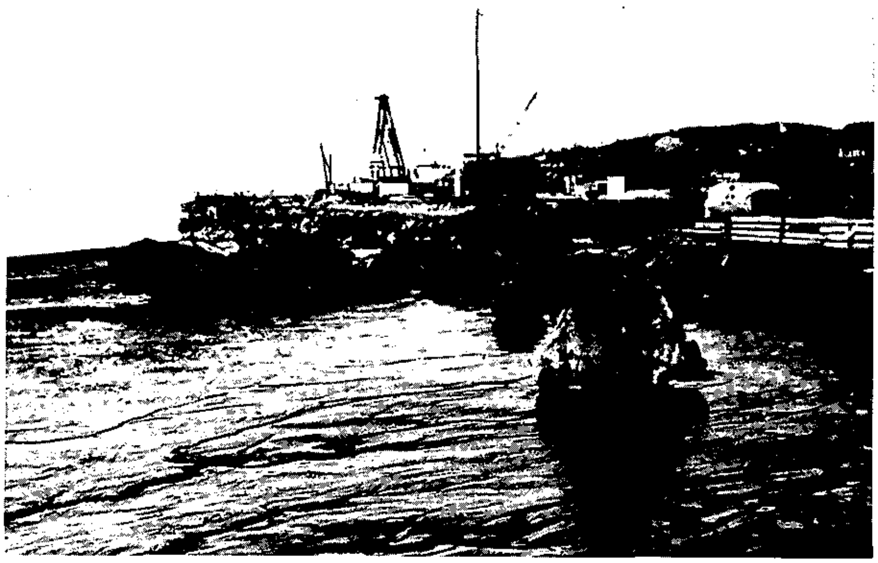
Brash, Cake and Floe ice around
supply boat in Cook Inlet 1969——

Brash and a few Cakes in Cook Inlet 1969———
Courtesy Captain B.J. Logan. American Institute
of Marine Underwriters.

Mud Flats at low tide North side Cook Inlet near Pt. McKenzie——National Weather Service

Mud Flats at low tide between Fire Island and Anchorage near International Airport——National Weather Service





Ice mixed with silt and gravel near Port of Anchorage—Courtesy Captain B.J. Logan, American Institute of Underwriters.

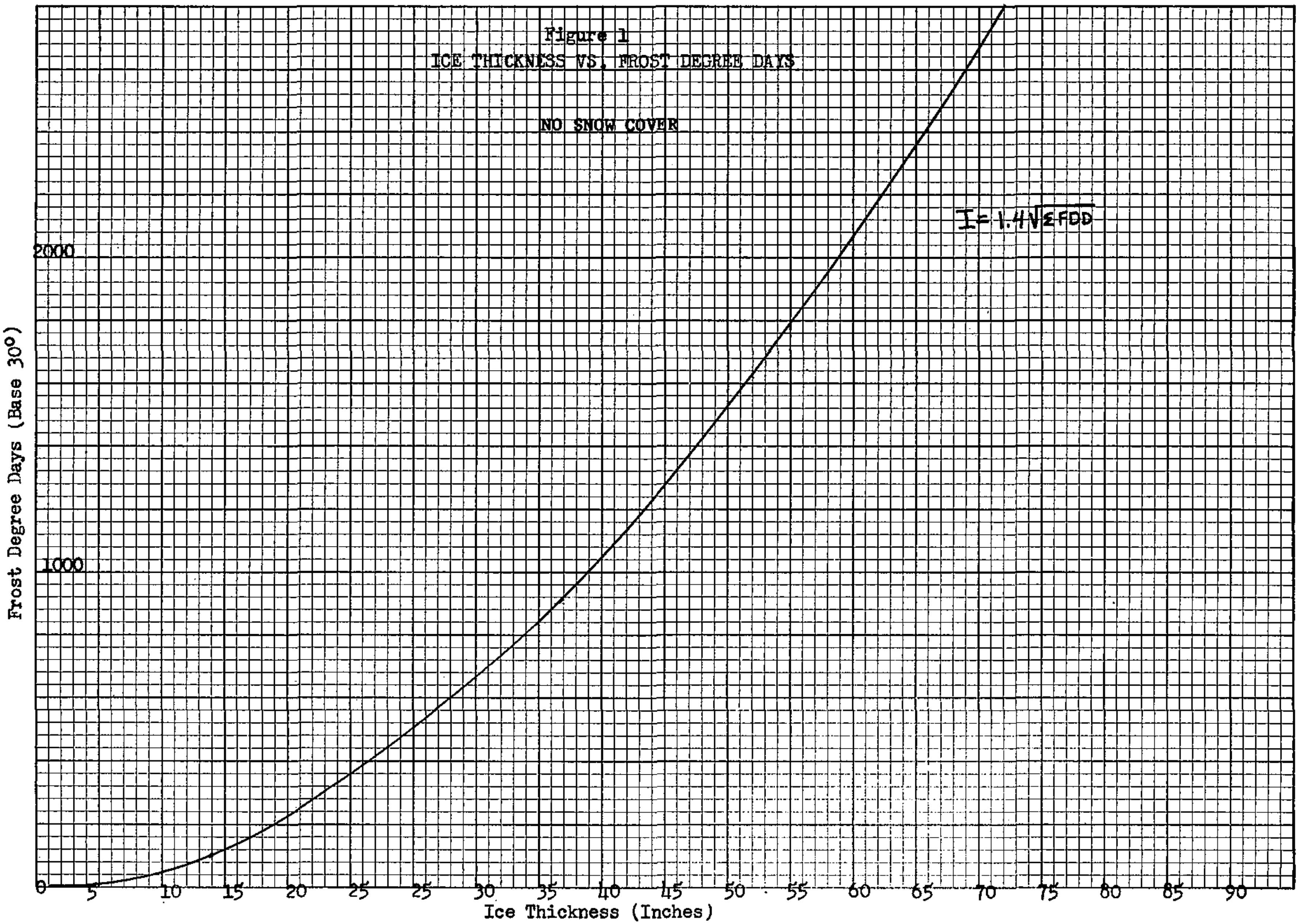


Figure 1
ICE THICKNESS VS. FROST DEGREE DAYS

NO SNOW COVER

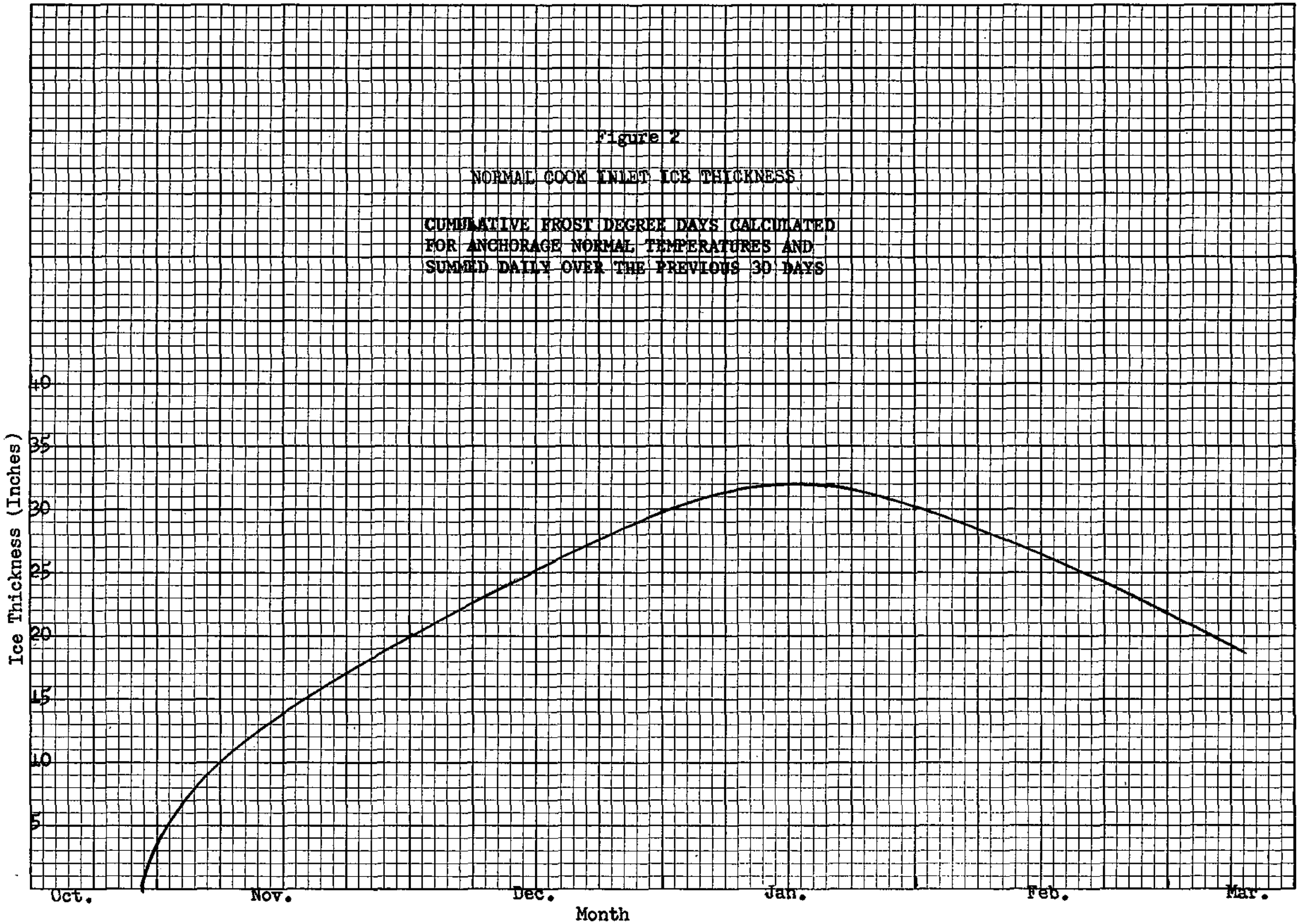


Figure 2
NORMAL COOK INLET ICE THICKNESS
CUMULATIVE FROST DEGREE DAYS CALCULATED
FOR ANCHORAGE NORMAL TEMPERATURES AND
SUMMED DAILY OVER THE PREVIOUS 30 DAYS
Ice Thickness (Inches)
40
35
30
25
20
15
10
5
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Month

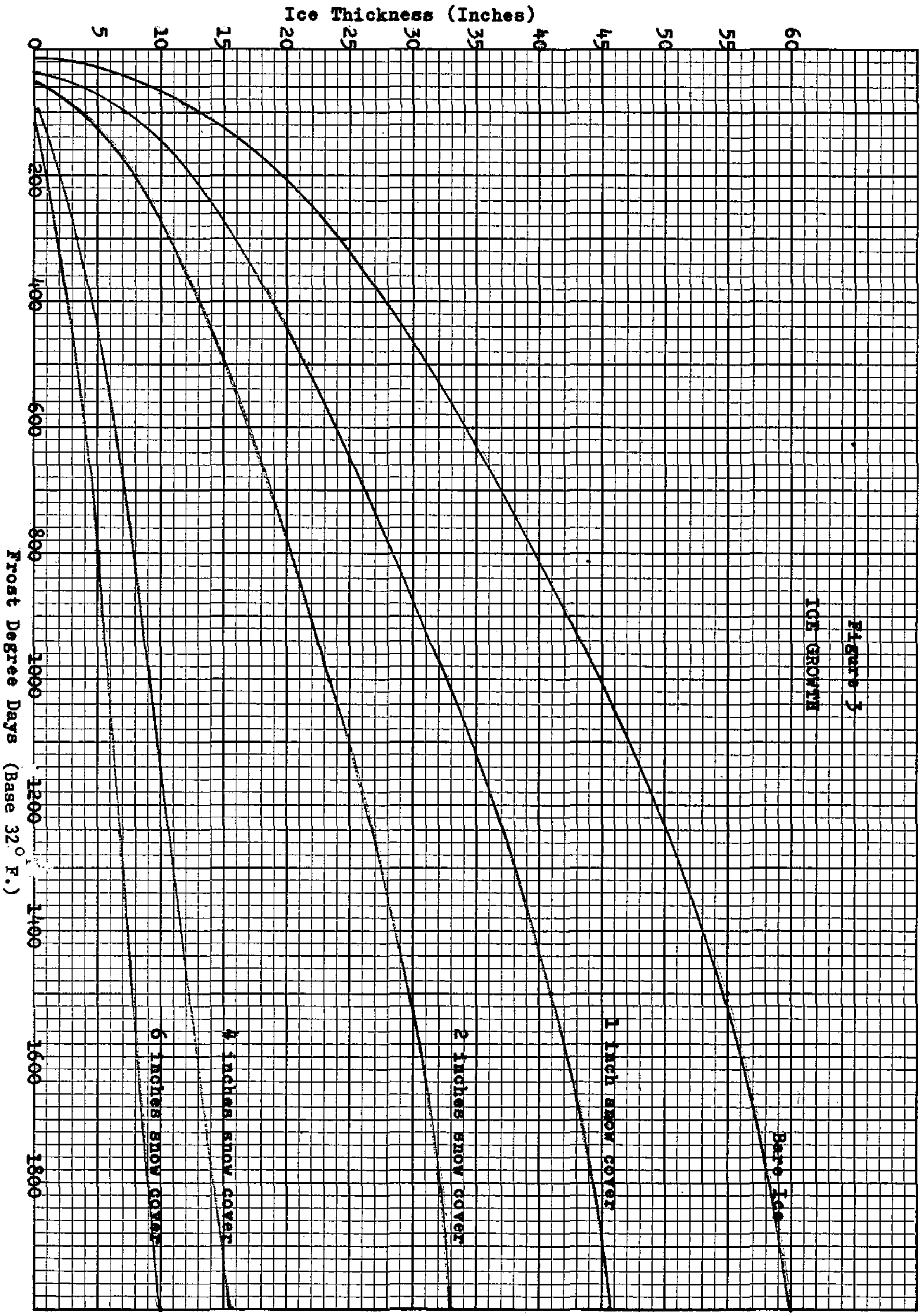


Figure 3
ICE GROWTH
Ice Thickness (Inches)
0
5
10
15
20
25
30
35
40
45
50
55
60
Frost Degree Days (Base 32° F.)
200
400
600
800
1000
1200
1400
1600
1800
Bare Ice
1 inch snow cover
2 inches snow cover
4 inches snow cover
6 inches snow cover

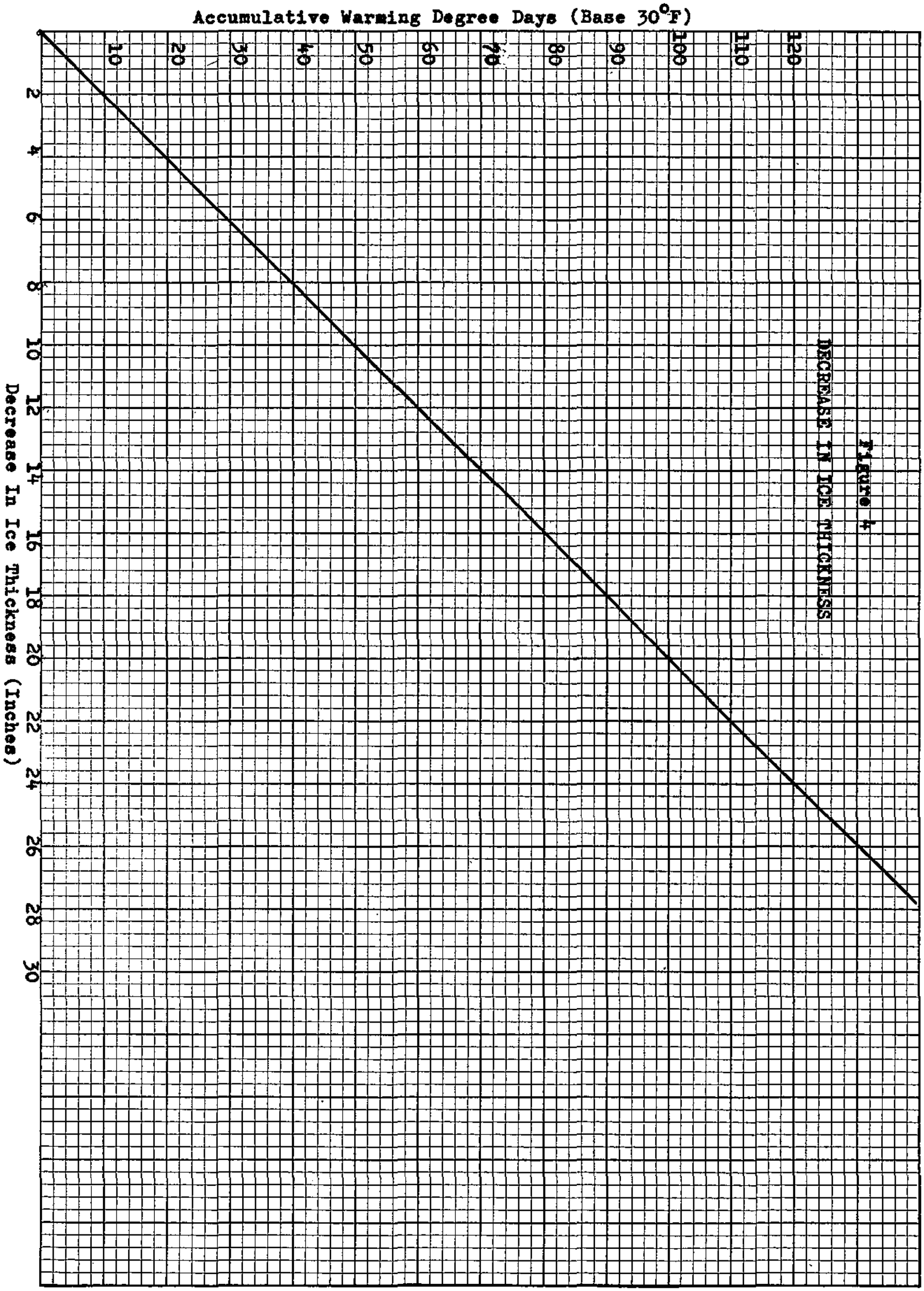


Figure 4
DECREASE IN ICE THICKNESS

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2. Blenkarn, D. A. Data Analysis, Cook Inlet Ice Studies. Pan American Petroleum Corporation. 1966.

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5. Handbook of Geophysics for Air Force Designer. Air Fore Cambridge Research Center, Cambridge, Mass. 1957.

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