NATIONAL BUREAU OF STANDARDS REPORT

4276

COMPARISON OF THREE INSULATED FOOD CONTAINERS

by

Minoru Fujii
C. W. Phillips

to

HEADQUARTERS, QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND

NATICK, MASS.

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
1003-10-4832	August 9, 1955	4276

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ABSTRACT

Tests were made to determine the cooling rate of water in three similar food containers insulated with block insulation, shredded insulation, and an air space, respectively. The lengths of time required for water to cool from an initial temperature of about 200°F to final temperatures of 130°F and 32°F were determined for each container during simultaneous tests in an ambient temperature of about -40°F. The cooling times to reach a water temperature of 32°F were: 29 hours for the specimen with block insulation, 26.5 hours for the specimen with shredded insulation, and 17.5 hours for the specimen with an air space for insulation. For the same final temperature of the water the heat transmission coefficients in Btu/hr (°F temp diff) (sq ft of exterior surface) were 0.17, 0.19, and 0.28 for the containers with block, shredded and air insulation, respectively.

1. INTRODUCTION

At the request of the Headquarters Quartermaster Research and Development Command, Quartermaster Research and Development Center, United States Army, by letter dated August 16, 1954, observations were made on the insulating characteristics of three types of Insulated Food Containers. Comparative outward heat flow through three types of insulated wall construction was determined in terms of the length of time required for water at an initial temperature of about 200°F in the container to be cooled to 130°F and to 32°F in an ambient temperature of about minus 40°F.

2. TEST SPECIMENS

The attached photograph, Fig. 1, shows the three specimen Insulated Food Containers. The three specimens were identical in dimension, configuration, and appearance. The materials used were the same except for the insulation which was identified only by the stamped description on the bottom panel of each container as block, shredded, and air, respectively. The specimens were not cut open to identify the insulating materials.

The insulated containers were manufactured by Ekco Products Company. The inside and outside linings were made of aluminum sheets, embossed with ridges and grooves. The handles and latches were also made of aluminum. A cellular rubber gasket was used for sealing the lid of the container.

Each insulated container enclosed three aluminum cans manufactured by the Knapp-Monarch Company. The three cans with aluminum lids fitted fairly tight in the insulated container. A rubber gasket was used for the seal between the can and the lid.

The overall dimensions of the insulated container, including the handles and latches, were, length 21", height 15 1/2", and width 10 1/2". The overall dimensions of an insert can were, 5 1/2"x6 1/4"x12".

The total weights of the three insulated containers with block, shredded and air insulation were 16 1/2 pounds, 16 3/4 pounds and 15 3/4 pounds, respectively including the three cans. Each insert can weighed one pound 4.7 ounces.

3. TEST PROCEDURE

Prior to the test, the insulated containers and the cans had been kept in an ambient room temperature of approximately 70°F. The cans were filled to within one inch from the top or 95% of the can volume with 10.9 lbs of water at a temperature of about 200°F. The cans were inserted in the insulated containers as soon as they were filled with hot water. The insulated containers were then put into a cold chamber where the average temperature was controlled at approximately minus 41°F.

Two thermocouples were placed along the vertical center line of each can; one an inch above the bottom of the can and the other one inch below the water surface. Readings of the temperatures were taken every 20 or 30 minutes until the water temperature of each insulated container reached 32°F.

4. TEST RESULTS

Fig. 2 shows the cooling curves of the water in the insulated food containers for three types of insulating materials when exposed to an ambient temperature averaging

-41°F. The temperature of the water plotted in Fig. 2 is the average of six thermocouple measurements taken one inch below the water surface and one inch above the can bottom in the three cans in each food container. It took 7.3 hours and 29 hours to cool the water from 203.5°F to 130°F and 32°F, respectively, for the food container with block insulation. The elapsed time to cool the water in the food container with shredded insulation from 202.0°F to 130°F and 32°F was 6.6 hours and 26.5 hours, respectively. For the food container with air insulation, the time required to cool from 199.4°F to 130°F and 32°F was 4.3 hours and 17.5 hours, respectively. These results are summarized in Table 1.

The effectiveness of the insulation in the three specimens can be compared more accurately by computation of the heat transmission rate for the entire box per unit temperature difference between water and ambient air or by evaluating the heat transmission coefficient in terms of the exterior surface area of the specimens. Such factors eliminate the effect of differences in the initial temperature of the water at the beginning of the test.

The heat transmission rates for the three specimens were evaluated for each food container for two different periods, from the beginning of the test until the water reached a temperature of 130°F, and from the beginning of the test until the water reached a temperature of 32°F. The results are summarized in Table 2. The specimen with block insulation had the lowest heat loss: 0.17 Btu/hr (°F temp diff)(sq ft of exterior surface area) for a final water temperature of 32°F. The heat loss rate of the specimen with shredded insulation was about 10% greater and the specimen with air insulation about 62% greater than for the specimen with block insulation. The heat transmission rate from the beginning of the test to a final water temperature of 130°F was about 18 percent higher than the value computed from the beginning of the test to a final water temperature of 32°F in each case. This is accounted for in part at least by the higher mean temperature of the insulation in the former case.

The heat transmission coefficients summarized in Table 2 were obtained with the food containers in a test chamber in which the air velocities were moderately high. Somewhat lower coefficients would be expected if the containers were surrounded by still air due to lower exterior film conductance.

Fig. 3 shows the cooling curves of the water in the insulated food container with shredded insulation. The water temperatures plotted in Fig. 3 are the average of three thermocouple measurements one inch below the water surface (one in each can) and the average of three thermocouple measurements one inch above the can bottom (one in each can). Figs. 4 and 5 show similar curves for the food containers with air insulation and block insulation, respectively. At water temperatures above 40°F, the differences between the water temperatures measured at one inch below the surface and one inch above the can bottom averaged 4.4°F for the food container with block insulation, 2.7°F with the shredded insulation and 10.6°F with the air insulation. The crossing of two curves in each figure at a water temperature of about 39°F indicates a reversal in the convection currents inside each can when the density of water reached the maximum value at 39.2°F. Downward movement of water at the exterior walls of the individual cans and upward movement in the center of the cans would be expected for water temperatures above 40°F. A resersal of this direction of flow would be expected when the water temperature dropped below 39°F. The observed temperatures shown in Fig. 3 to 5 indicate that this reversal did occur.

5. DISCUSSION AND CONCLUSION

The test results showed that the heat loss of the food container with air insulation was much larger than the food containers with block and shredded insulation in an ambient temperature of minus 41°F.

It is obvious from the test results that the food containers with block and shredded insulation would keep food warm longer and keep water from freezing longer than the one using an air space as insulation.

The water temperature spread between the top and bottom of the can was more pronounced in the case of the food container with air insulation than for the other two specimens. It is probable that the temperature difference between top and bottom of the container would be different for fluids of other viscosities than that observed for water in these tests.

TABLE 1

COMPARISON OF WATER COOLING RATES IN THREE INSULATED FOOD CONTAINERS

	Type of Insulation		
	Block	Shredded	Air
Initial water temperature, °F	203.5	202.0	199.4
Initial temp. difference compared to specimen with block insulation, °F	0	1.5	4.1
Time required for water to cool to 130°F, hr	7.3	6.6	4.3
Time required for water to cool to 130°F, compensated for initial temp. diff., hr	7.3	6.8	4.6
Time required for water to cool to 32°F, hr	29	26.5	17.5
Average water temperature difference between top and bottom of cans, °F	4.4	2.7	10.6

TABLE 2

HEAT TRANSMISSION RATES FOR THREE INSULATED FOOD CONTAINERS

	Type of Insulation		
	Block	Shredded	Air
Final Water Temp., 130°F			
Change in enthalpy of water, Btu	2407	2359	2271
Log mean temp. difference of water to ambient air, °F	206.2	205.1	204.1
Heat transmission, Btu/hr (°F)	1.60	1.74	2.59
Heat transmission coefficient, Btu/hr (°F)(sq.ft. exterior surface)	0.20	0.22	0.32
Final Water Temp. 32°F			
Change in enthalpy of water, Btu	5616	5562	5480
Log mean temp. difference of water to ambient air, °F	142.4	141.9	141.0
Heat transmission, Btu/hr (°F)	1.36	1.48	2.22
Heat transmission coefficient, Btu/hr (°F) (sq ft exterior surface)	0.17	0.19	0.28

Fig. 1

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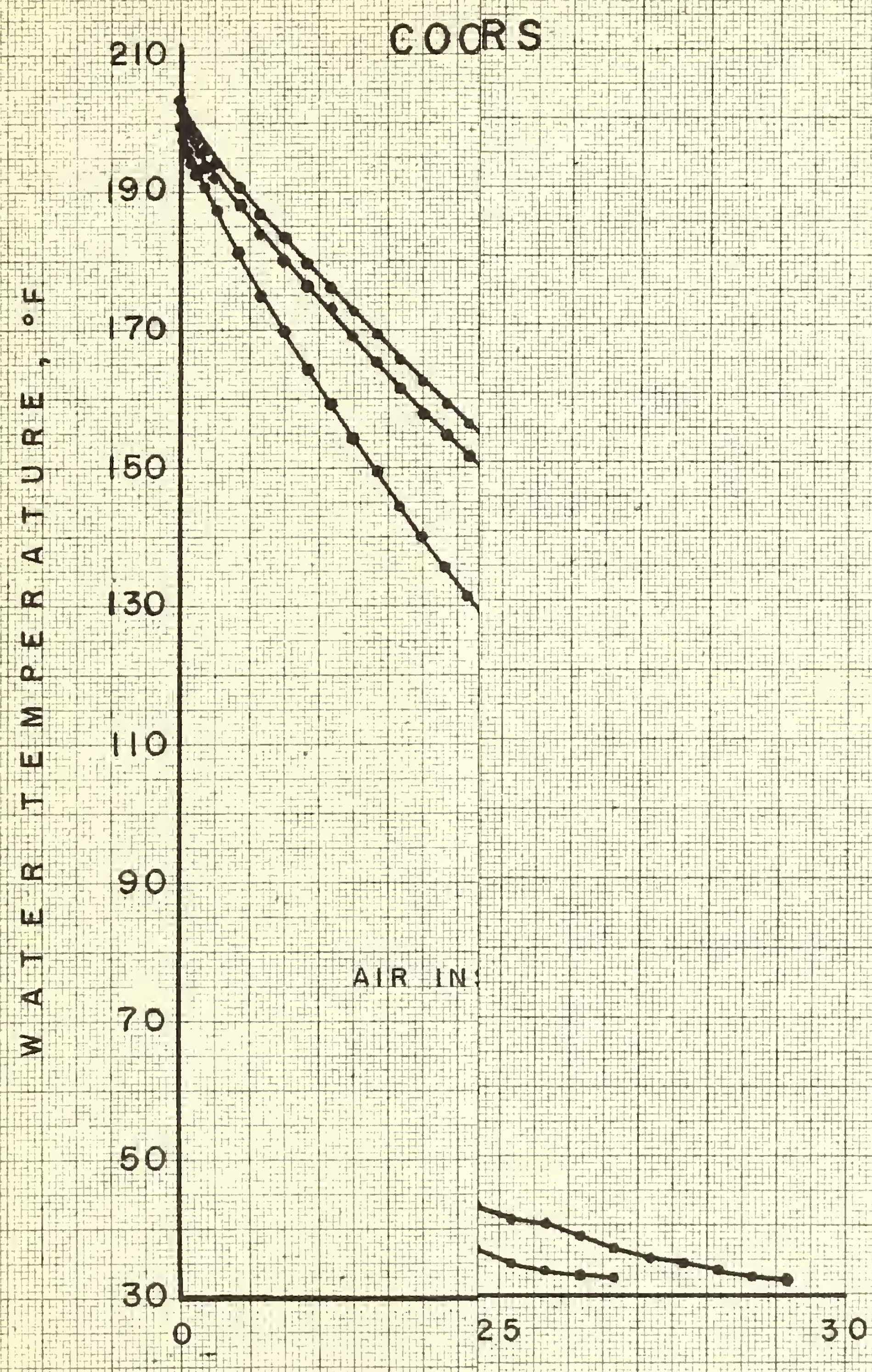

COORS
210
190
170
150
130
110
90
70
50
30
WATER TEMPERATURE, °F
AIR INS
0
25
30

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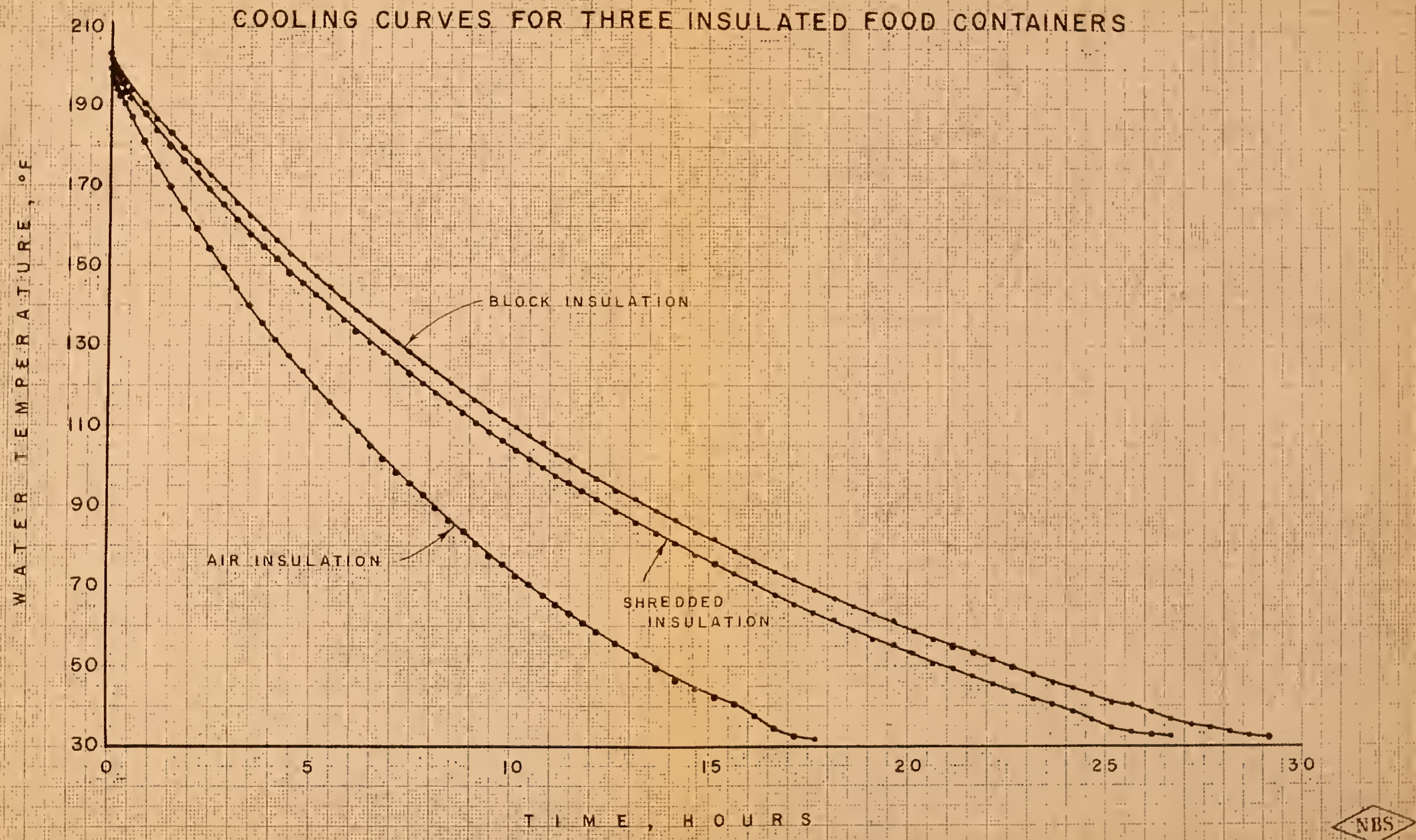
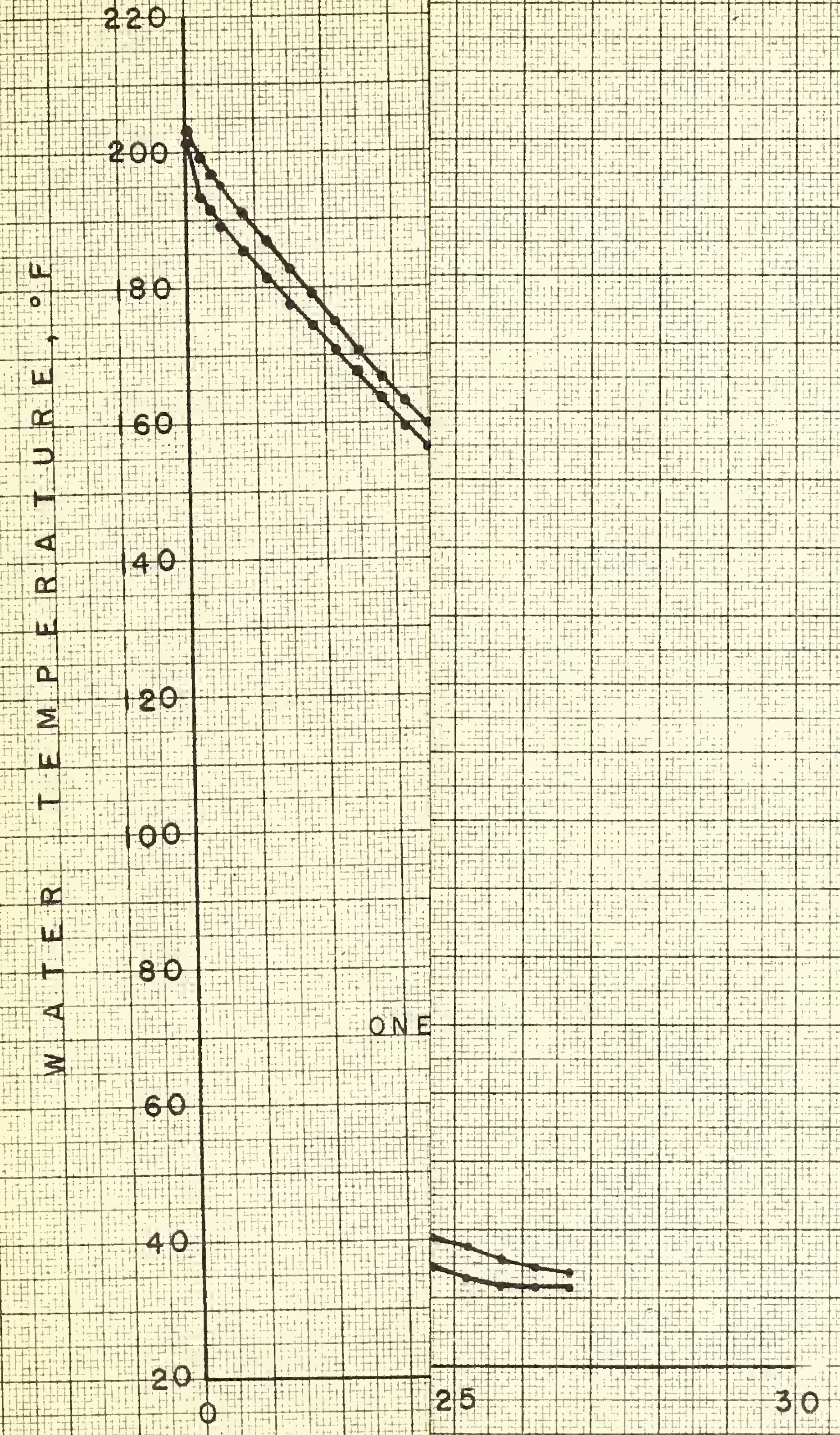

COOLING CURVES FOR THREE INSULATED FOOD CONTAINERS
210
190
170
150
130
110
90
70
50
30
WATER TEMPERATURE, °F
BLOCK INSULATION
AIR INSULATION
SHREDDED INSULATION
0
5
10
15
20
25
30
TIME, HOURS
NBS

FIG. 2



WATER TEMPERATURE, °F
220
200
180
160
140
120
100
80
60
40
20
0
25
30
ONE

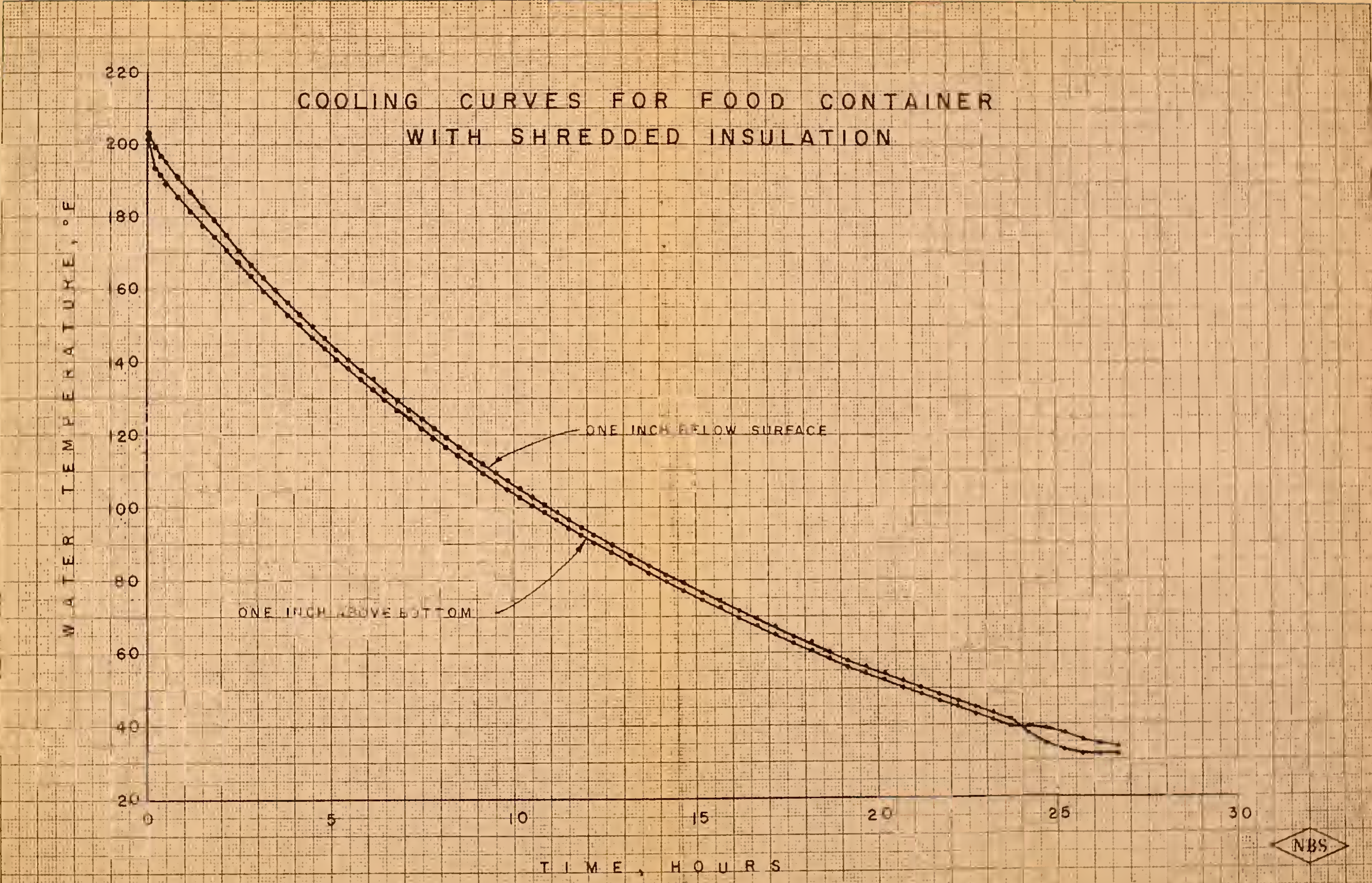
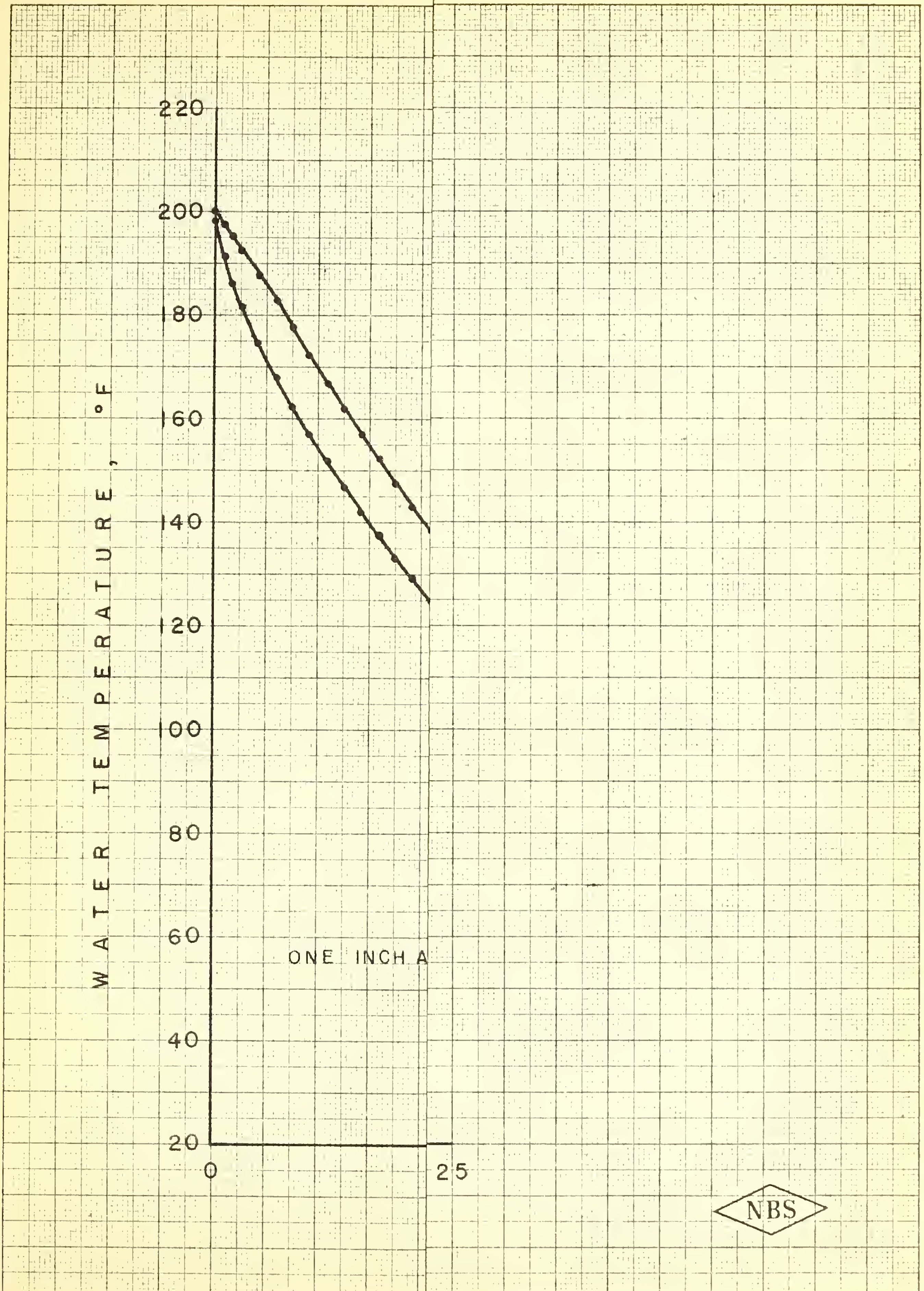

COOLING CURVES FOR FOOD CONTAINER
WITH SHREDDED INSULATION
ONE INCH BELOW SURFACE
ONE INCH ABOVE BOTTOM
WATER TEMPERATURE, °F
TIME, HOURS
220
200
180
160
140
120
100
80
60
40
20
0
5
10
15
20
25
30
NBS

FIG. 3



WATER TEMPERATURE, °F
220
200
180
160
140
120
100
80
60
40
20
0
25
ONE INCH A
NBS

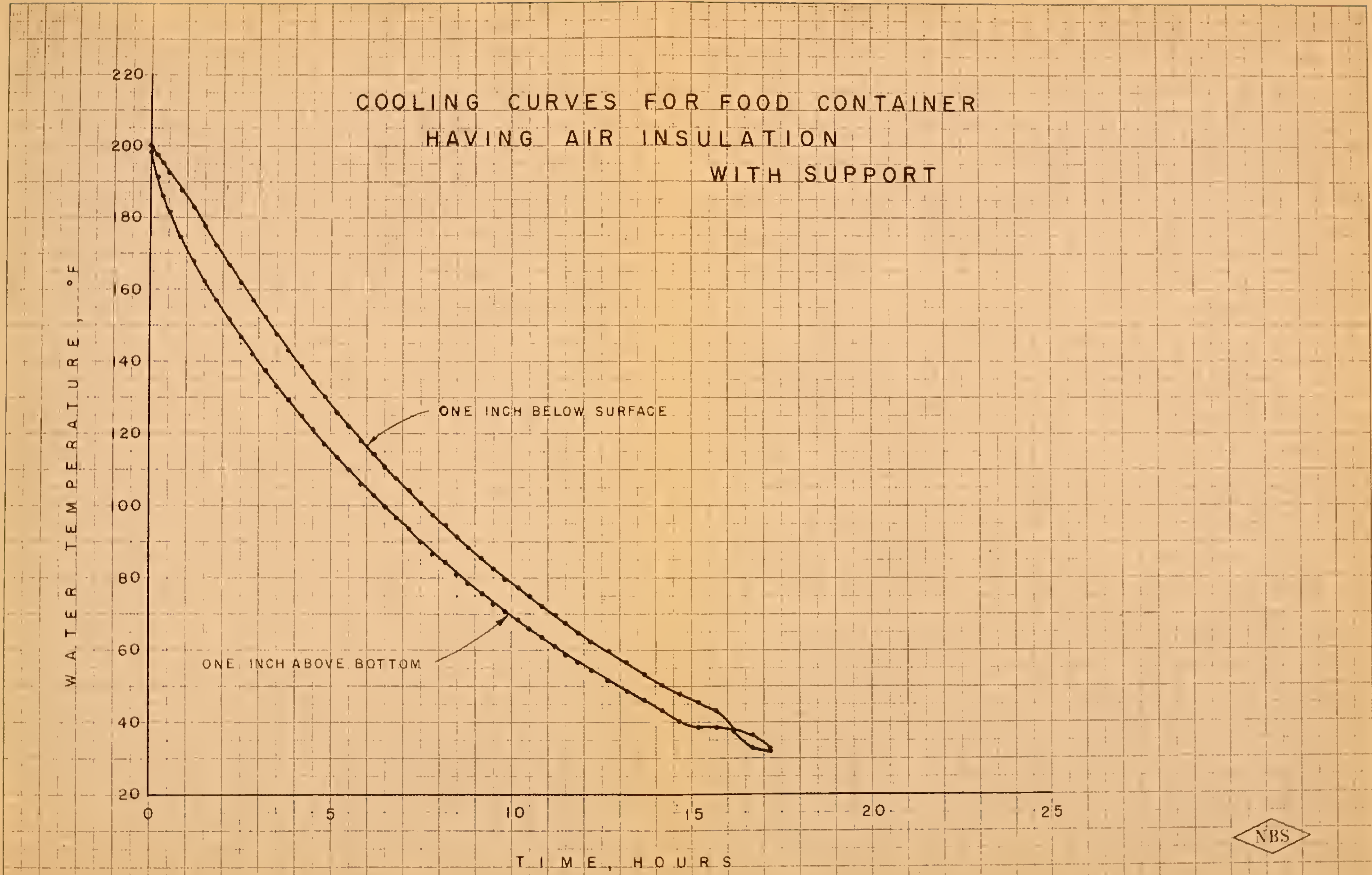
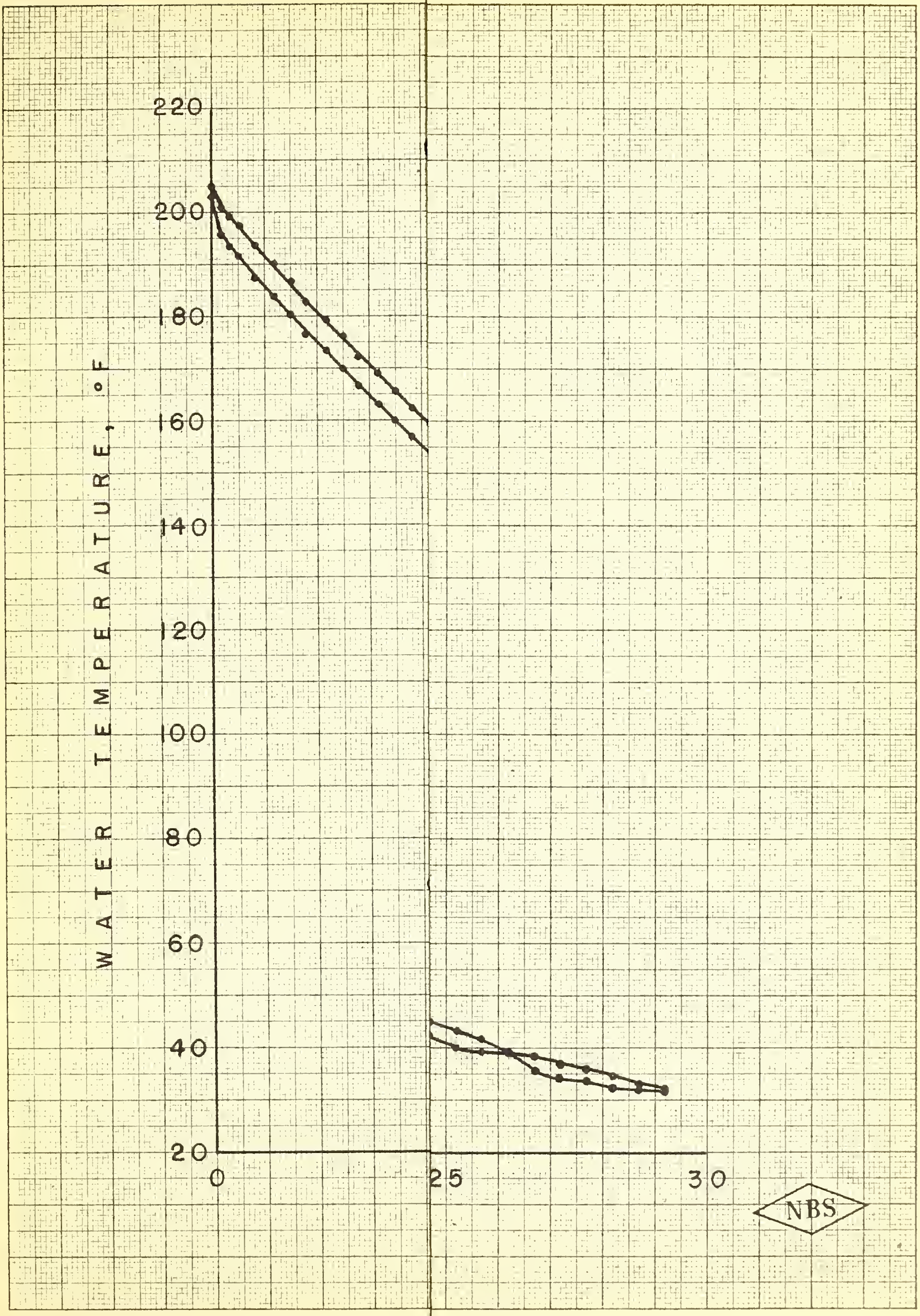

COOLING CURVES FOR FOOD CONTAINER
HAVING AIR INSULATION
WITH SUPPORT
ONE INCH BELOW SURFACE
ONE INCH ABOVE BOTTOM
WATER TEMPERATURE, °F
220
200
180
160
140
120
100
80
60
40
20
0
5
10
15
20
25
TIME, HOURS
NBS

FIG. 4



WATER TEMPERATURE, °F
220
200
180
160
140
120
100
80
60
40
20
0
25
30
NBS

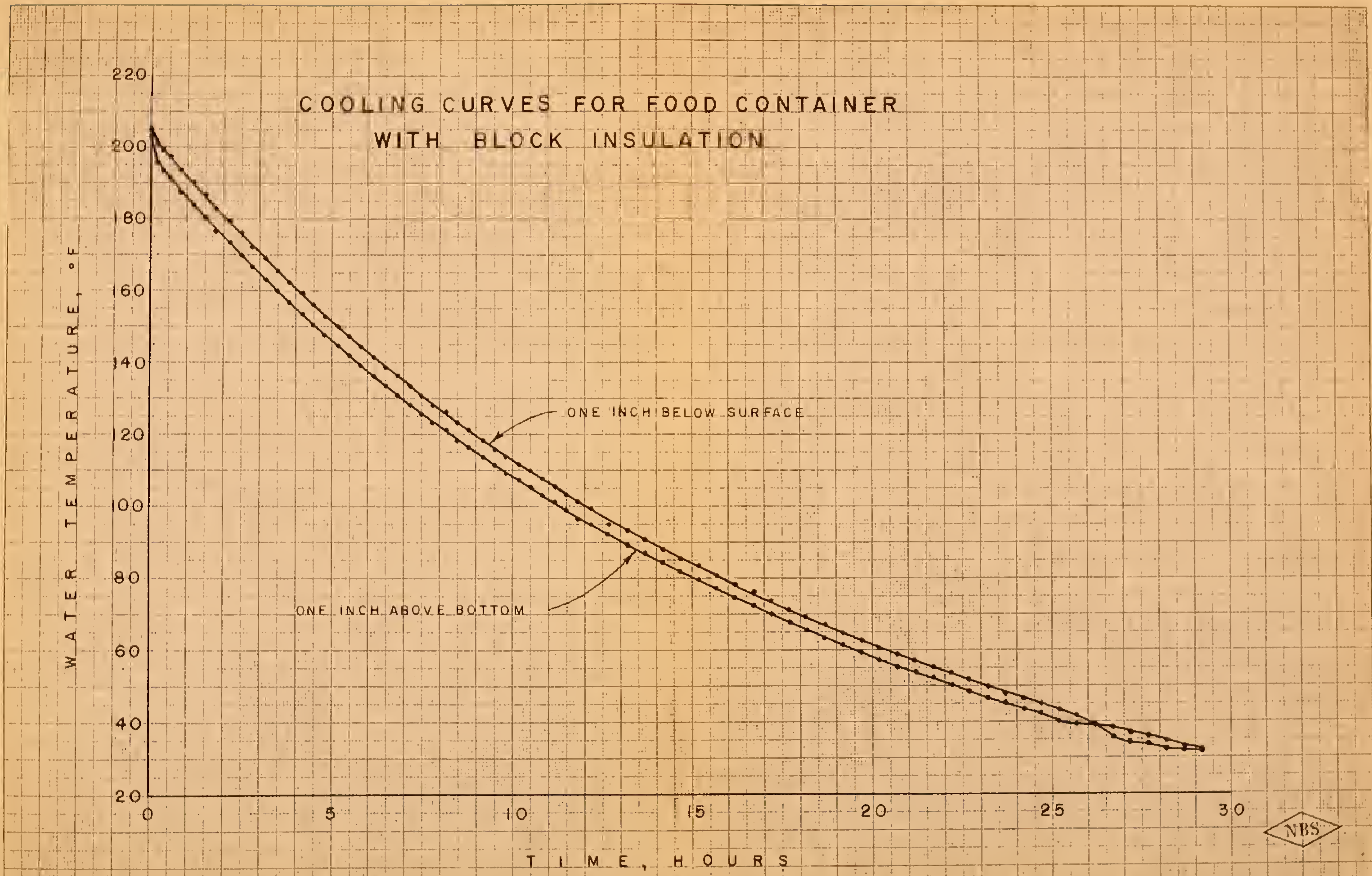

COOLING CURVES FOR FOOD CONTAINER
WITH BLOCK INSULATION
ONE INCH BELOW SURFACE
ONE INCH ABOVE BOTTOM
WATER TEMPERATURE, °F
220
200
180
160
140
120
100
80
60
40
20
0
5
10
15
20
25
30
TIME, HOURS
NBS

FIG. 5

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

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