CODE 451
S1-4-(1)(451)

NAVY DEPARTMENT
BUREAU OF SHIPS
WASHINGTON 25, D. C.

DDS3901-1
1 December 1948

To: All Holders of General Specifications for Building Vessels of the United States Navy, BuShips Mailing List 451-H.

1. Forwarded for information.
2. Section DDS3901-1 replaces that part of Tentative Ventilation Standard No. 10 dealing with heat transfer coefficients. This design data sheet simplifies the presentation of Tentative Ventilation Standard No. 10 where the increase of accuracy obtained was not commensurate with the accuracy of other variables in the basic calculation.
3. The numbers used to designate the type of insulation are in agreement with the numbers previously used on the *Heat Transfer Coefficients* selector as revised 1 May 1942. Either the new or the old values may be used at the designer's option except for uninsulated panels, Number 0, in which case the new values must be used.

C. M. Tooke
By direction of Chief of Bureau.

DESIGN DATA SHEET

NAVY DEPARTMENT, BUREAU OF SHIPS

SECTION DDS~~3901-1~~ 7-10-1 511-2
HEAT TRANSFER COEFFICIENTS

Reference: General Specifications for Building Vessels of the United States Navy, Section L-2.

DDS3901-1-a. General

1. Heat is a form of energy which is transferred as a result of a temperature difference by means of convection, conduction, and radiation. These three effects are evaluated and combined herein into a single over-all coefficient of transmittance **U**. Tables 1 and 2 give data for finding **U** values for different arrangements of insulated bulkheads and decks using fibrous glass board, together with sufficient data for computing **U** values for wood decks, uninsulated steel boundaries, and refrigeration space type insulation. Table 1, the surface coefficients based on ambient air temperatures, are presented in three groups. The f_p values are for the plane side of the bulkhead or deck. The f_s values are for the stiffener side for destroyer and battleship frame spacing respectively. Previously published data gave consideration to whether the surface was bare or insulated and to whether beams and stiffeners were partially or completely covered. Since analysis of these curves showed that they could be combined with little sacrifice of accuracy, the simplified presentation is made herein.

2. Calculations for **U** are divided into two groups, surface-to-air, and air-to-air.

(a) Surface-to-air coefficients evaluate the effect of heat transfer from surface temperatures on one side of a boundary to the air temperature on the other side.

(b) Air-to-air coefficients apply to all other conditions. These values have been further subdivided into classifications of *inside air to inside air* and *weather air to inside air*.

3. Table 3 gives selected values which are an average of values calculated from the data in tables 1 and 2 for the entire range used in naval design. The actual calculated value for any particular temperature differential is within 10 percent of the average **U** value given in table 3, and since the boundary gains or losses form only a part of the total load, the use of average values is considered justifiable in the interest of simplification.

4. Tables 4 and 5 give data for finding **U** values for fibrous glass with sheathing, and cork, respectively. While these materials no longer have wide application, the data has been included for use as necessary.

DDS3901-1-b. Definitions and formulae

H = Heat flow, Btu./hr.
***A** = Boundary area, sq. ft.
U = Overall transmittance, Btu./sq. ft./hr./degree F. temperature difference.
t_i = Air temperature inside of compartment, degrees F.
t_o = Air temperature outside of the compartment, degrees F.
C = Conductance of the structure and insulation, Btu./sq.ft./hr./degree F. temperature difference.
f_p = Surface coefficient on the smooth side of the bulkhead or deck, Btu./sq. ft./hr./degree F. temperature difference.
f_s = Surface coefficient on the stiffener side of the bulkhead or deck, Btu./sq. ft./hr./degree F. temperature difference.

1. The heat flow through a structure is given by the formula

$$H = UA(t_i - t_o)$$

In which

$$U = \frac{1}{\frac{1}{f_p} + \frac{1}{C} + \frac{1}{f_s}} \qquad \text{Air to air}$$

$$U = \frac{1}{\frac{1}{C} + \frac{1}{f_s}} \qquad \text{Surface to air}$$

The mean temperature to be used in selecting the C value is

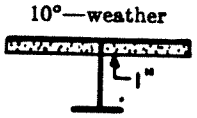
$$= \frac{t_i + t_o}{2}$$

*This is the plane boundary area and does not include surface area of the stiffeners.

801930—48

DDS3901-1-c. Examples of the calculation of U

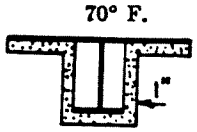
1. Compute the value of U for heat flow up through deck to atmosphere, 21 inch frame spacing.



From table 1, for a deck exposed to the weather $f_p = 7.0$
From table 1, heat flow up, at 65° F., $f_s = 2.10$
From table 2, for a mean temperature of 37.5° F., C = 0.698

$$U = \frac{1}{\frac{1}{7.0} + \frac{1}{.698} + \frac{1}{2.10}} = 0.49 \text{ Btu./sq. ft./hr./degree F. temperature difference}$$

2. Compute the value of U for heat flow down from one compartment to another, 48" frame spacing.



From table 1, heat flow down, 70° F. $f_p = 1.0$.
From table 1, heat flow down, 50° F. $f_s = 1.14$.
From table 2, for mean temperature of 60° F. C = 0.32.

$$U = \frac{1}{\frac{1}{1.0} + \frac{1}{.32} + \frac{1}{1.14}} = 0.20 \text{ Btu./sq. ft./hr./degree F. temperature difference}$$

3. Compute the value of U for heat flow from a weather deck with a surface temperature of 120° F. to a compartment (surface to air), 21 inch frame spacing.

Weather side-surface temperature 120° F.

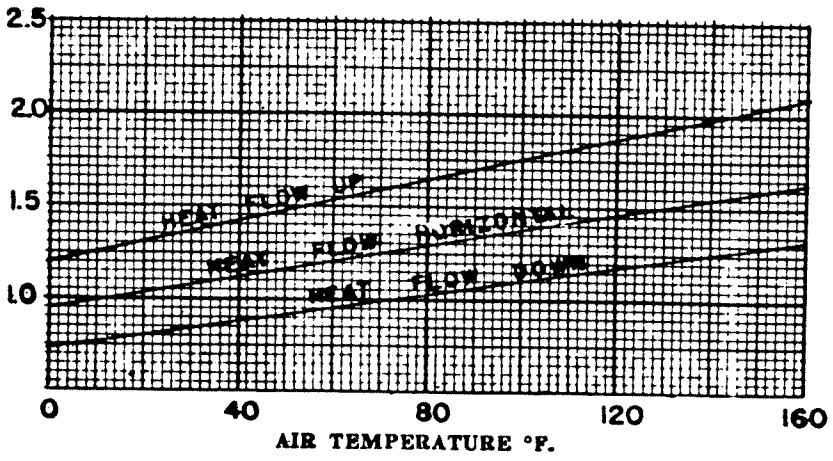
Compartment temperature 98° F

The surface coefficient (f_p) on the weather side does not apply since the temperature of this side is a surface temperature.
From table 1, heat flow down, 98° F. $f_s = 1.48$
From table 2, for mean temperature of 109° F. C = 0.53

$$U = \frac{1}{\frac{1}{.53} + \frac{1}{1.48}} = 0.39 \text{ Btu./sq. ft./hr./degree F. temperature difference}$$

Table 1.—Values of surface coefficients f_p and f_s

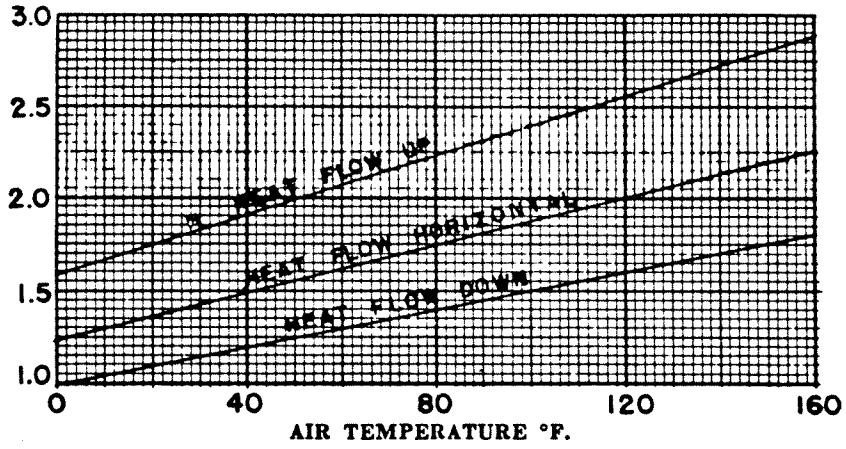
PLANE SIDE



Note: $f_p = 7.0$ for bulkheads or decks exposed to weather, temperature range 10° F. to −10° F. This is an average coefficient which evaluates the effect of wind, spray, and rain.

Table 1.—Values of surface coefficients f_s and f_a—Continued

STIFFENER SIDE—21-INCH FRAME SPACING



STIFFENER SIDE—48-INCH FRAME SPACING

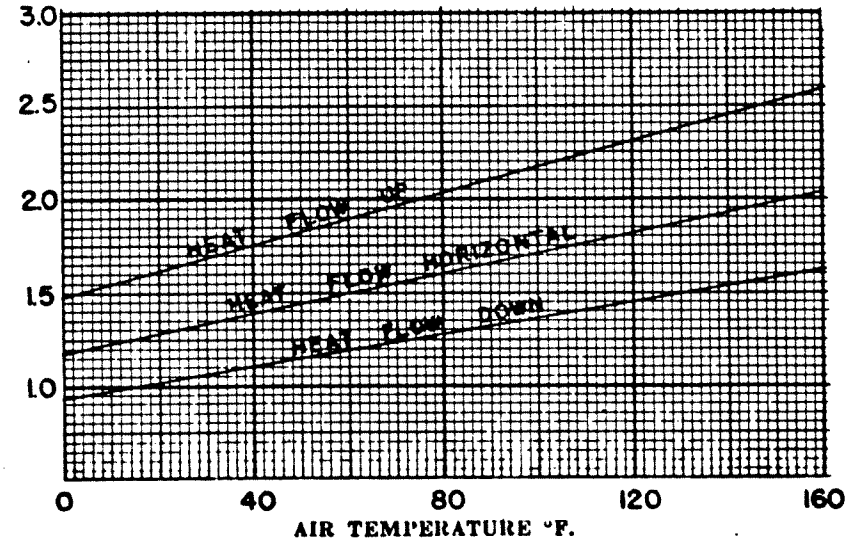


Table 2.—Values of C

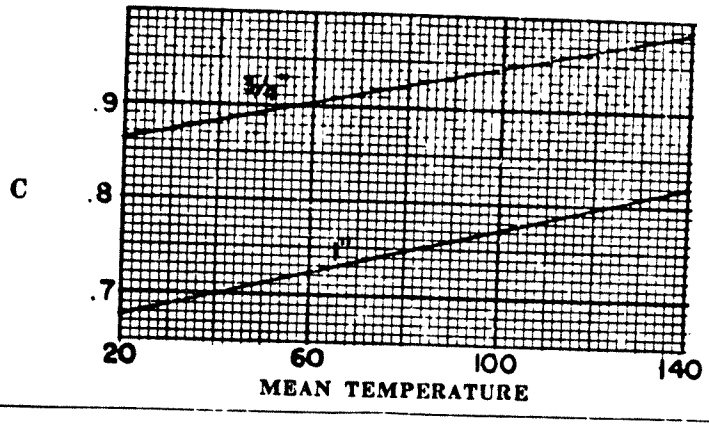
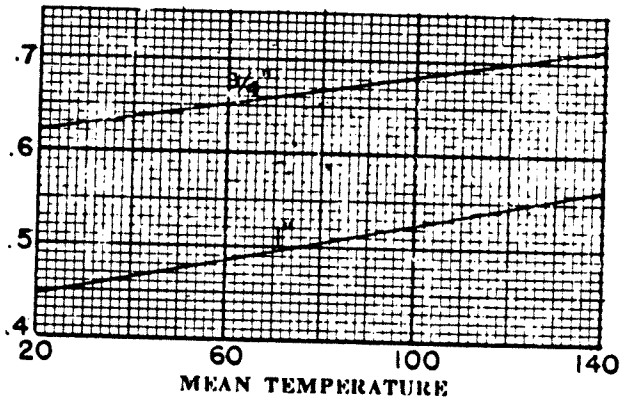
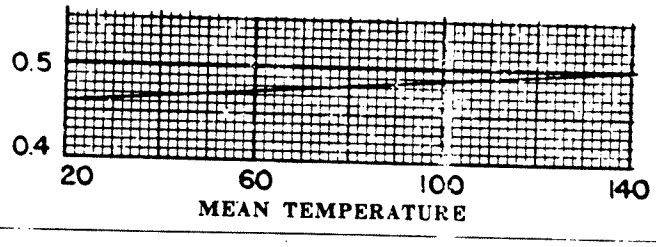
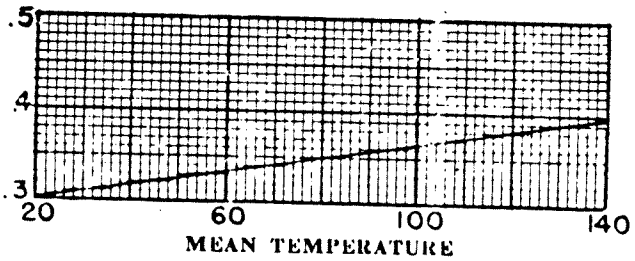
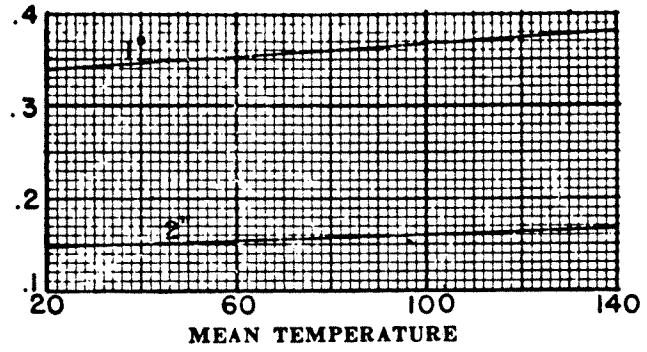
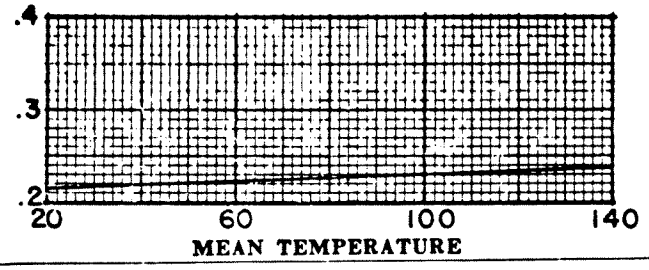
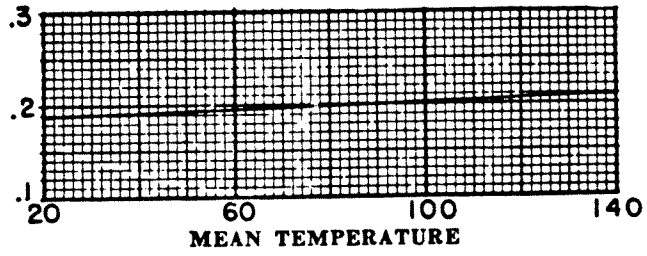
FIBROUS GLASS BOARD INSULATION—21-INCH FRAME SPACING	
CONSTRUCTION	C
	
	
	
	

Table 2.—Values of C—Continued

FIBROUS GLASS BOARD INSULATION—21-INCH FRAME SPACING—Continued	
CONSTRUCTION	C
	
	
	

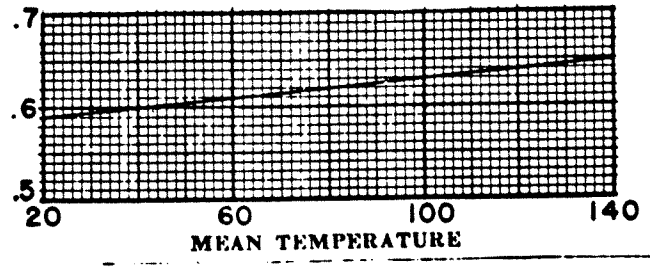
FIBROUS GLASS BOARD INSULATION—48-INCH FRAME SPACING	
CONSTRUCTION	C
	

Table 2.—Values of C—Continued

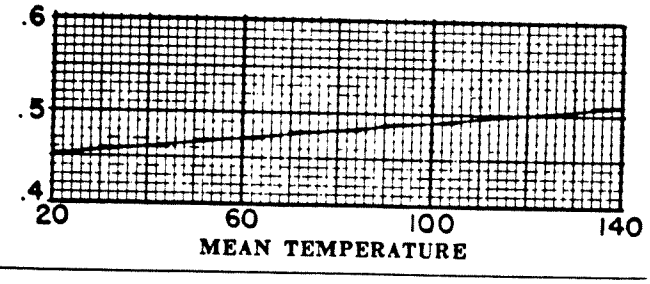
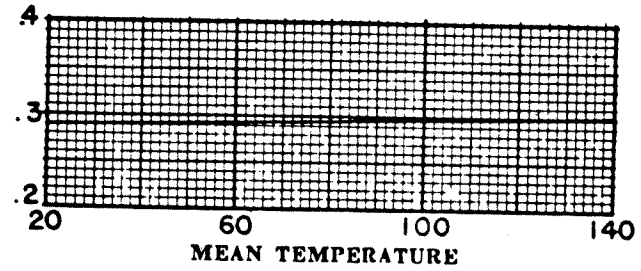
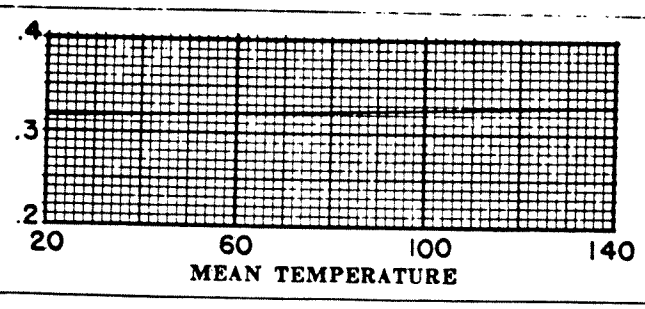
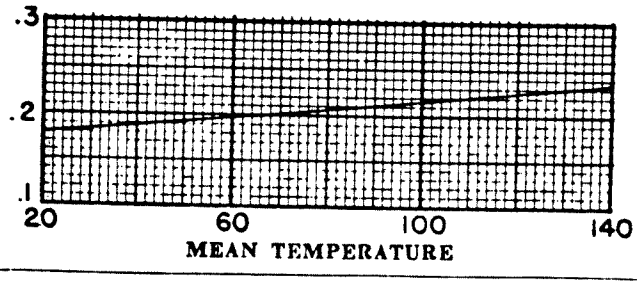
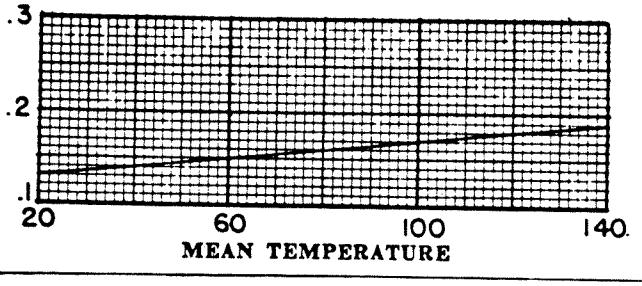
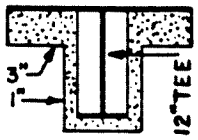
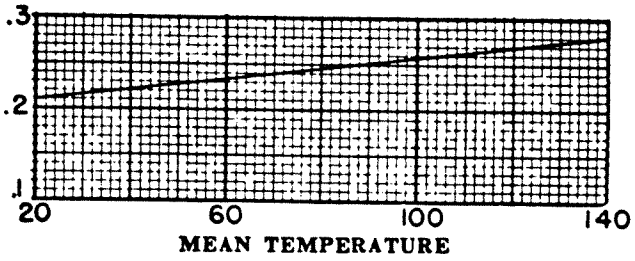
FIBROUS GLASS BOARD INSULATION—48-INCH FRAME SPACING—Continued	
CONSTRUCTION	C
	
	
	
	
	

Table 2.—Values of C—Continued

FIBROUS GLASS BOARD INSULATION—48-INCH FRAME SPACING—Continued

CONSTRUCTION	C
	

PAINTED STEEL, WOOD DECK & REFRIGERATION INSULATION

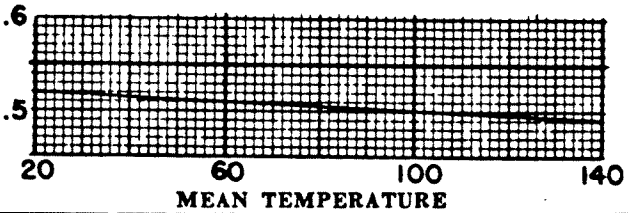
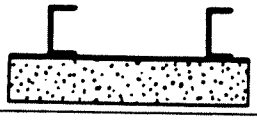
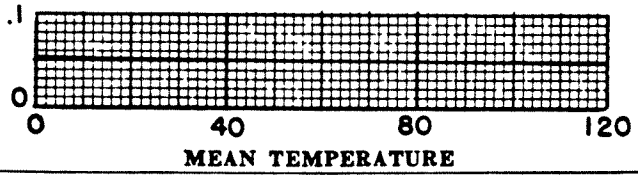
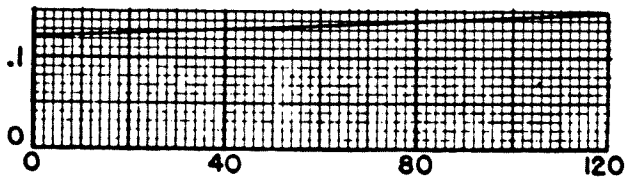
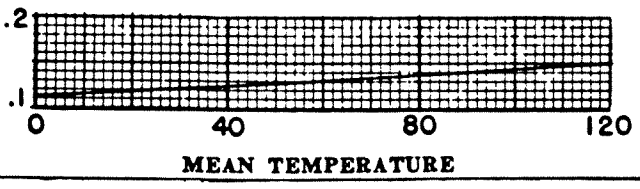
CONSTRUCTION	C
No insulation Painted 21" & 48" frame spacing 	C (for steel) = 300 Btu./hr./sq. ft./degree F./inch. Since $\frac{1}{C}$ is so small it may be neglected. $U = \frac{1}{\frac{1}{f_p} + \frac{1}{f_o}}$
2" wood deck 48" frame spacing 	
Refrig. insulation 6" fibrous glass Bulkheads & overheads 	
Refrig. insulation 6" fibrous glass Insulation on deck 	
Refrig. insulation 6" fibrous glass Bulkheads & overheads 	

Table 2.—Values of C Continued

PAINTED STEEL, WOOD DECK & REFRIGERATION INSULATION Continued

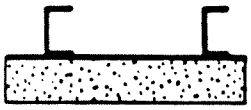
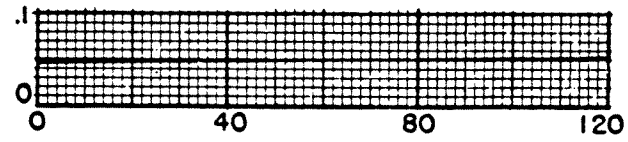
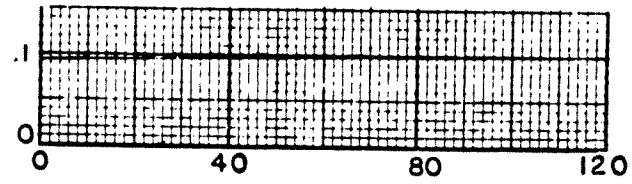
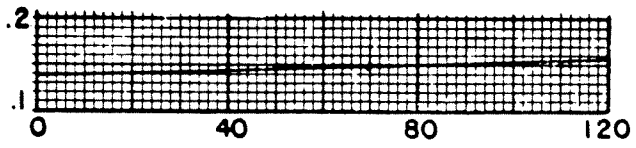
CONSTRUCTION	C
Refrig. insulation 6" cork Bulkheads & overheads 	
Refrig. insulation 6" cork Insulation on deck 	
Refrig. insulation 6" cork Bulkheads & overheads 	

Table 3. --Values of U

			BB 48 inch frame space			DD 21 inch frame space		
			h ⟷	u ↑	d ↓	h ⟷	u ↑	d ↓
No. 10 	Air to air	Inside air to inside air	------	------	------	0. 34	0. 37	0. 31
		Weather air to inside air.	------	------	------	. 43	. 45	. 36
	Surface to air	Outside surface to inside air.	------	------	------	. 49	. 50	. 47
No. 11 	Air to air	Inside air to inside air	------	------	------	. 39	. 45	. 36
		Weather air to inside air.	------	------	------	. 53	. 57	. 44
	Surface to air	Outside surface to inside air.	------	------	------	. 61	. 64	. 58
No.12 	Air to air	Inside air to inside air	0. 28	0. 31	0. 25	. 29	. 32	. 27
		Weather air to inside air.	. 34	. 35	. 30	. 31	. 36	. 30
	Surface to air	Outside surface to inside air.	. 37	. 37	. 36	. 39	. 39	. 40
No. 13 	Air to air	Inside air to inside air	. 33	. 36	. 29	. 36	. 40	. 32
		Weather air to inside air.	. 40	. 43	. 35	. 46	. 49	. 38
	Surface to air	Outside surface to inside air.	. 45	. 47	. 43	. 52	. 54	. 51

Table 3.—Values of U—Continued

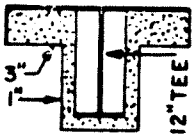
			BB–48 inch frame space			DD–21 inch frame space		
			h ⟷	u ↑	d ↓	h ⟷	u ↑	d ↓
No. 14 	Air to air	Inside air to inside air	.22	.24	.20	.24	.25	.22
		Weather air to inside air.	.25	.26	.24	.27	.28	.25
	Surface to air	Outside surface to inside air.	.27	.28	.26	.30	.31	.30
No. 15 	Air to air	Inside air to inside air	.20	.21	.19	------	------	------
		Weather air to inside air.	------	------	------	------	------	------
	Surface to air	Outside surface to inside air.	.23	------	.22	------	------	------
No. 16 	Air to air	Inside air to inside air	.15	.15	.14	.16	.17	.15
		Weather air to inside air.	------	------	------	------	------	------
	Surface to air	Outside surface to inside air.	------	------	.16	------	------	.18
No. 17 	Air to air	Inside air to inside air	.21	.22	.19	.23	.25	.22
		Weather air to inside air.	.24	.25	.22	.26	.27	.23
	Surface to air	Outside surface to inside air.	.25	.26	.24	.29	.30	.29
No. 18 	Air to air	Inside air to inside air	.16	.17	.15	.17	.18	.16
		Weather air to inside air.	.16	.17	.15	.19	.19	.17
	Surface to air	Outside surface to inside air.	.18	.18	.19	.20	.21	.20
No. 21 	Air to air	Inside air to inside air	------	------	------	.29	.31	.26
		Weather air to inside air.	------	------	------	.34	.36	.30
	Surface to air	Outside surface to inside air.	------	------	------	.38	.38	.37
No. 0 No insulation 	Air to air	Inside air to inside air	.77	.98	.62	.81	1.03	.64
		Weather air to inside air.	1.25	1.51	.86	1.34	1.61	.86
	Surface to air	Outside surface to inside air.	1.62	1.96	1.35	1.77	2.04	1.48
No. 8 2" wood deck 	Air to air	Inside air to inside air	------	------	------	------	------	------
		Weather air to inside air.	------	.46	------	------	.48	------
	Surface to air	Outside surface to inside air.	------	------	.36	------	------	.37

Table 3.—Values of U—Continued

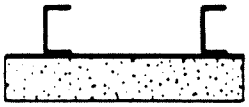
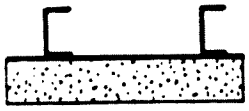
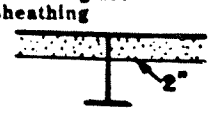
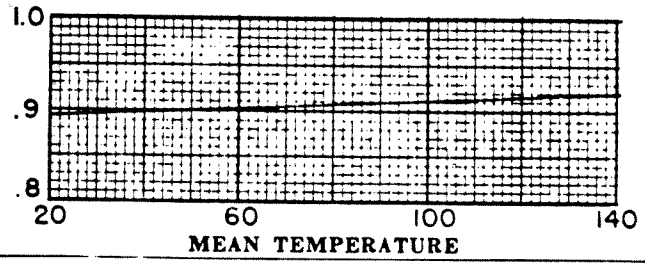
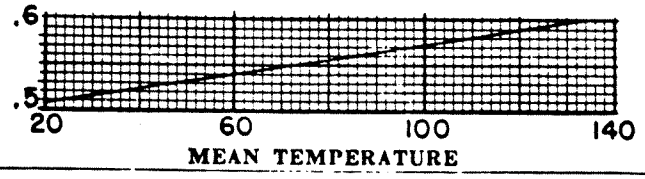
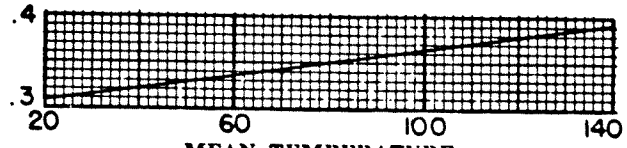
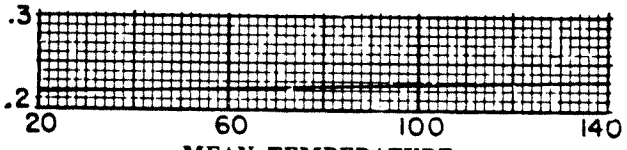
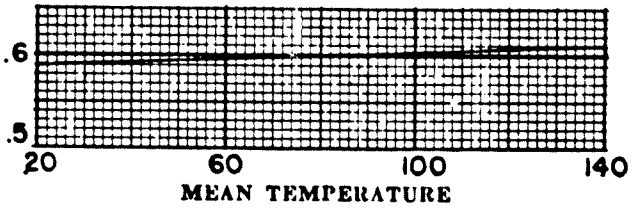
			HB–48 inch frame space			DD–21 inch frame space		
			h ⟷	u ↑	d ↓	h ⟷	u ↑	d ↓
REFRIGERATION INSULATION								
No. 43 6″ fibrous glass 	Air to air	Inside air to inside air	0. 045			0. 045		
No. 46 6 fibrous glass 	Air to air Surface to air	Inside air to inside air Outside surface to inside air.	. 102 . 111	 0. 115	0. 10	. 102 . 111	 0. 115	0. 10
No. 49 6″ fibrous glass 	Air to air	Inside air to inside air		. 107			. 107	
No. 44 6″ cork 	Air to air	Inside air to inside air	. 045			. 045		
No. 48 6″ cork 	Air to air Surface to air	Inside air to inside air Outside surface to inside air.	. 112 . 124	 . 124	. 11	. 112 . 124	 . 124	. 11
No. 51 6″ cork 	Air to air	Inside air to inside air		. 082			. 083	
ACOUSTIC INSULATION								
No. 5 2″ fibrous glass & sheathing 	Air to air Surface to air	Inside air to inside air Weather air to inside air. Outside surface to inside air.		0. 31 . 35	0. 27 . 36		0. 34 . 43	0. 29 . 43

Table 4.—Values of C

FIBROUS GLASS & SHEATHING—21-INCH FRAME SPACING	
CONSTRUCTION	C
	
	
	
	
	

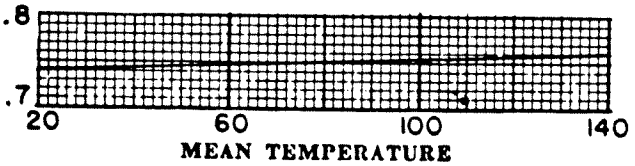
FIBROUS GLASS & SHEATHING—48-INCH FRAME SPACE	
CONSTRUCTION	C
	

Table 4.—Values of C--Continued

FIBROUS GLASS & SHEATHING—48-INCH FRAME SPACING

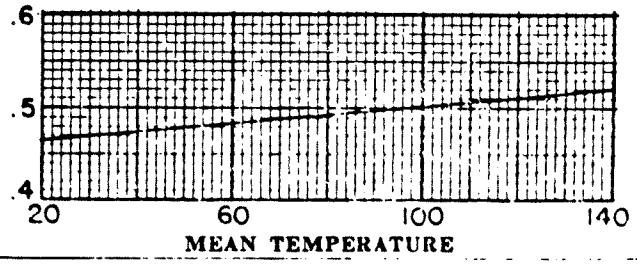
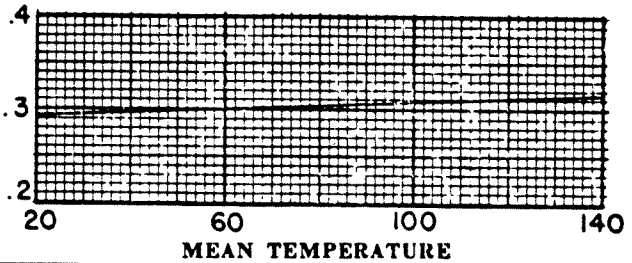
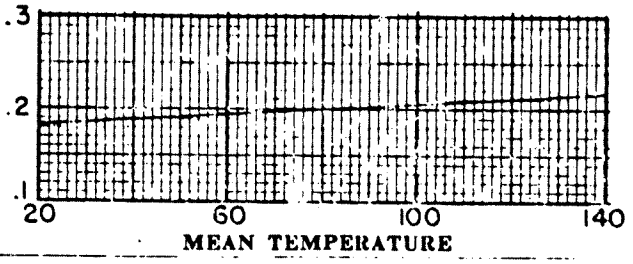
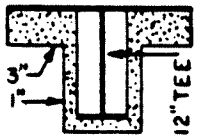
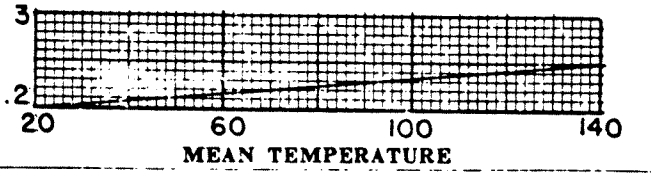
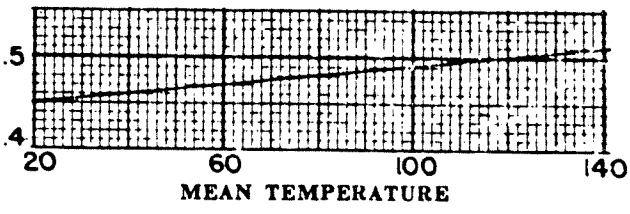
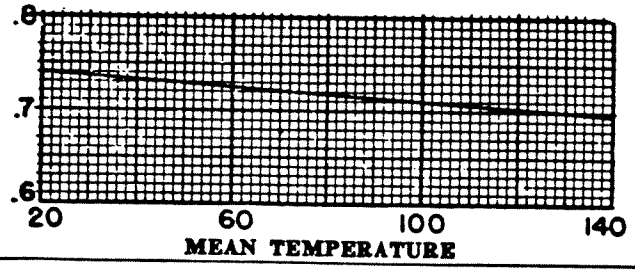
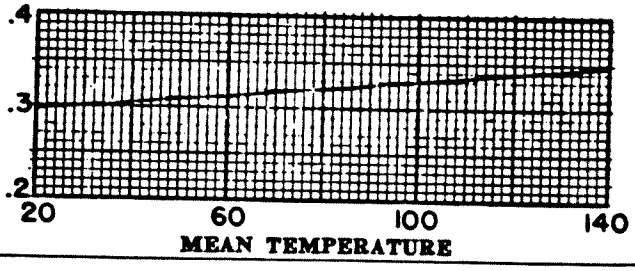
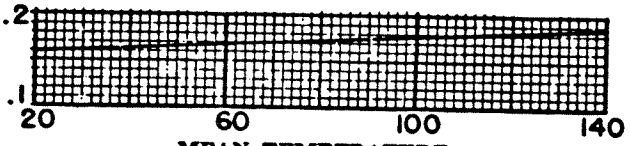
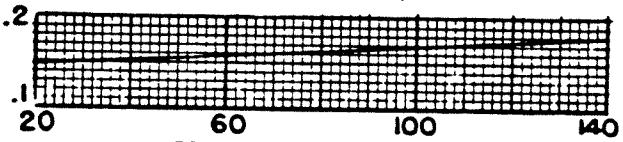
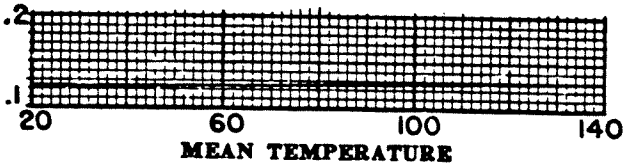
CONSTRUCTION	C
	
	
	
	
	

Table 5.—Values of C

CORK INSULATION—21-INCH FRAME SPACING

CONSTRUCTION	C
	
	
	
	
	

CORK INSULATION—48-INCH FRAME SPACING

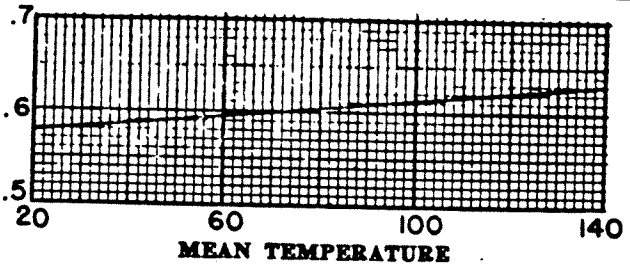
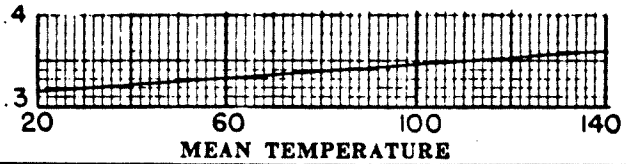
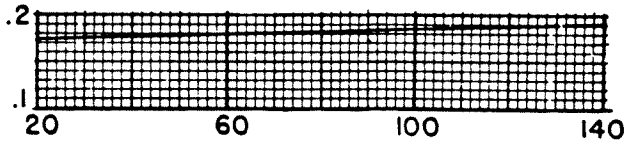
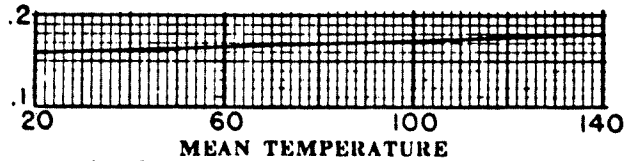
CONSTRUCTION	C
	

Table 5.—Values of C—Continued

CORK INSULATION—48-INCH FRAME SPACING—Continued

CONSTRUCTION	C
	C 
	C 
	C 
	C