August 4, 1951

To the Graduate Council:

I am submitting herewith a thesis written by Willis Earl Huston entitled "Development of Electric Radiant Heating Panels". I recommend that it be accepted for 9 quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Engineering.

M A Sharp

Major Professor

We have read this thesis and recommend its acceptance:

William G. Wheeler

C. E. Kirkman

Accepted for the Council:

E. G. Walters

Dean of the Graduate School

DEVELOPMENT OF ELECTRIC RADIANT HEATING PANELS

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the Degree of
Master of Science

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by

Willis Earl Huston

August, 1951

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To Professor M. A. Sharp, the writer owes a debt of gratitude for his constructive criticism of the set-up for the experimental work and for his guidance and suggestions in preparation of this thesis.

The author also is indebted to the staff of the Agricultural Engineering Department for their co-operation and assistance throughout this study.

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CHAPTER I

INTRODUCTION

Heating systems can be classified into four main groups, namely; (1) Warm-air furnace, (2) Steam, (3) Hot water, and (4) Radiant.[1] The first three named depend on convection and conduction for the heat transfer. Therefore, in most cases, it takes large expensive equipment to supply the heat to the individual parts of the building. The efficiency is low, the space required is high, the initial cost is high, and they need constant care and maintenance.

Radiant heating systems have many advantages over other types of heating systems, namely; (1) Space requirement small, (2) No labor, (3) Clean, (4) Convenient, (5) No maintenance, (6) Safe, and (7) Automatic.

Electric radiant heating can be broken down still further into wall heaters and panels. The panel type of radiant heating is more efficient, has better heat distribution, and less space is required.

The Tennessee Valley Authority has encouraged the use of electricity to heat homes by the use of the step rate system. Because of the low rates charged by the Tennessee Valley Authority, interest in electric radiant

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[1]Allen, Walker, and Herbert, Heating and Air Conditioning, (McGraw-Hill Book Company) pp. 58-59.

heating has increased to many times the original demand. Electricity for heating the home now compares favorably in price with other types of heating systems.

Studies at the University of Tennessee brings out the need for additional work on radiant electric heating panels. One objective of such studies has dealt with designing a heating panel that could be used for dry wall construction. Most of the work that has been done on panel heating is on wet wall construction. This study brought out the need for additional information relative to the efficiency and practicability of panel heating.

The panels can be constructed in four ways:

(1) By putting the grid on a board.

(2) By having the grid between two boards.

(3) By painting, brushing or spraying the grid on the ceiling in place or before it is put in place.

(4) By having the grid placed on the ceiling, and plastering or painting over it.

Therefore, further study is needed to determine which method of heating is more efficient in terms of cost, energy, uniformity and time of heating.

CHAPTER II

REVIEW OF LITERATURE

The ten years prior to 1951 accentuated the need for better panel heating. During this period the cost of electrically heating the home was lowered. Several people had experimented with panels but no low cost panel was developed. Until now very little has been done with radiant panel heating.

Uskon, manufactured by U. S. Rubber Company, used a natural rubber to which has been added special materials permitting the conduction of electricity. There are no electrical wires within the panel other than two aluminum foil leads to the conductive rubber layers. The rubber itself conducts electricity and provides the radiant heat.

The conductive rubber layer is sealed between layers on insulation. Asbestos board is used to make the panel rigid. The panels operate on 220 volts A-C, have two standard wattage ratings of 17 watts per square foot, and 22 watts per square foot.

The manufacturer claims the panel will exceed 100^{o}F with outside temperature as low as 0^{o}F, and for a panel operating continually, the surface temperature will not exceed 120° F under any outside weather conditions.[1]

Radiant Glass Heating Panels - - - Radiant glass heating panels are manufactured by the Continental Radiant Glass Heating Corporation; also Blue Ridge Glass Company, Bristol, Tennessee, and by Appleman Glass Works. The three companies' products are similar in construction, appearance, and operation.

The heating element is made of plate or tempered glass, sixteen by twenty-four inches, approximately one-fourth inch thick. An alloy aluminum grid is used. The panel is mounted in a steel frame. The glass panel has a maximum temperature of 340° F.

The limited amount of work on radiant heating panels indicates that more information is needed to determine which method of panel construction is more efficient in terms of cost, uniformity of heating, and time of temperature-rise.

Raber and Hutchinson[2] states that there is not enough experience, and it does not cover a wide enough variety of panels, to warrent any general statement concerning the relative first cost of a panel system, as compared to radiator, convection, or forced air systems.

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[1]U. S. Rubber Company, USKON, "Electric Radiant Heat From The Ceiling,"(1-5) November 1, 1949, Form W 49-4-A.

[2]Raber and Hutchinson, "Cost", Panel Heating and Cooling Analysis, (New York: John Wiley & Sons, Inc.) (22) p. 38.

CHAPTER III

OBJECTIVES AND DEFINITION OF TERMS

Objectives

Preliminary studies made at the University of Tennessee indicate that very little information is available regarding electric radiant heating panel construction, design, and performance. Therefore, this study is concerned with the development of an electrical radiant heating panel that is: (1) Low in initial cost; (2) A temperature of 120° to 140° F (MAX); (3) Minimum time lag; (4) Economical to construct and operate; (5) Automatically controlled; (6) Easy to install; (7) Requires little maintenance; (8) Safe; (9) Efficient; and (10) Permanent.

Definition of Terms

Panel - The completed assembly including the cement asbestos board, grid, electrodes, and terminals.

Grid - The part of the panel that conducts the electricity.

Electrodes - All foil strips or wire to which the voltage is applied.

Binder - Materials used to fasten electrodes, grids or asbestos paper to the cement asbestos board.

Board - Cement asbestos board.

CHAPTER IV

INSTALLATION, DESIGN, AND CONSTRUCTION

Installation

The heating panel should be attached to one inch by two-inch strips running at right angles across the ceiling joists. Figure 1 shows the construction layout. The joists are twenty-four inches on center with the one by two-inch strips, perpendicular to the joist, sixteen inches on center. Thus all joints are formed over framing members. A two inch margin is provided around each panel for securing the panel to the strips running across the ceiling joists. The panel should be fastened with rows of screws every sixteen inches on center and the screws should be sixteen inches apart except around the outer edges. These edges will be held secure by a molding nailed or screwed to the framing. An opening of one-eighth to one-fourth inch should be left between panels to provide for expansion due to moisture. The holes for the screws should be drilled a sixteenth of an inch larger than the screws and counter sunk so the holes can be filled before the panel is painted. Figure 2 shows the panels installed. The space between the panel shown in Figure 2 was left so that further tests could be made. Asbestos paper was pasted over the grid for safety. The most desirable arrangement for the panel is around the edges of the room with the center part of the ceiling being filled in with a standard building board. This arrangement is advantageous in that it provides a greater degree of direct radiation to the person within the room and provides a slight air circulation which is desirable from a comfort standpoint.[1]

The panels are designed to operate on 220 volts, two wire service, and each branch circuit should be fused separately with a maximum of 20 amperes per circuit. The 220 operating voltage is used to reduce the number of electrical circuits required. Number 12 AWG type wire is used for each branch circuit.

Panel Construction and Design

Bronze Wire Panel

American wire gauge No. 28 bronze wire was used as a grid for the heating element. The length of wire was determined by connecting the voltage to different lengths until the temperature desired was obtained. The heating element was placed on a 4 ft by 8 ft by 3/16 in or 1/4 in asbestos-cement board to make the panel rigid. The wire was placed lengthwise of the board two inches from each edge and one inch apart. The wiring layout is shown in Figure 3. The wire is started at one side of the board and placed in one-eighth to one-fourth inch slots made with a hack saw. The

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[1]U. S. Rubber Company, USKON, August 1, 1949, Issue No. 6JB, p. 2.

Fig. No. 1
View of the Ceiling Before
Panels Were Installed.

Fig. No. 2
View of the Ceiling After
Panels are Installed.

wire then is taken to the other end and brought down under the board through a slot and up through the next slot. This continues until the entire board is covered with wire. In order to be sure the wire was tight against the board the ends of the board were raised about four inches, letting the middle drop down. After the panel was completed the board was then placed level on the table. Several binders were used to hold the wire in contact with the board, namely; (1) Oil paint, (2) Casine paint, (3) Quick-drying concrete, and (4) Asbestos paper glued with wheat paste made by LePages, Inc. Bronze screws, washers, and nuts were used for the terminals.

The Graphite Panel

Colliodal graphite, furnished by Acheson Colliods Corporation, with aluminum foil strips as electrodes was used. The panel is shown in Figure 4. The heating element was sprayed and brushed on 4 ft by 8 ft by 3/16 in or 1/4 in asbestos-cement boards. To determine the amount of grid needed to give the desired temperature, the aluminum foil strips were placed at eight inch intervals over half of the panel so that different widths of the panel could be used as a heating element. The aluminum foil strips for electrodes were fastened down by cascamite glue, oil paint, casine paint, asphaltum varnish, and foil seal No. 6. The asphaltum varnish was made by Pratt and Lambert Company, and the foil seal No. 6 was furnished by the Southern Paint Company.

Aluminum Foil Panels

Two gauges (.00075 in and .0015 in) of aluminum foil were used as heating elements. The foil was in sheets of twelve inches for .00075 in and sixteen inches for .0015 in and fifty feet in length. The foil was pasted down with casine paint. The asbestos board was covered with aluminum foil with the edge of each sheet lapping over the other by one-fourth of an inch to insure good contact. The foil sheets were then cut by a cutter one-fourth of an inch wide on the thin foil with a one-half inch space between each strip. The heavy foil strips were one-fourth of an inch wide with one-eighth of an inch between each one.

The strips are continuous over the entire panel. The grid layout is shown in Figure 5. The strips were cut with a cutter made from two washers that were sharpened. Angle irons were used as a straight edge to guide the cutter. The length of the grid was determined by experiment with different lengths and widths of foil until the desired temperature was obtained.

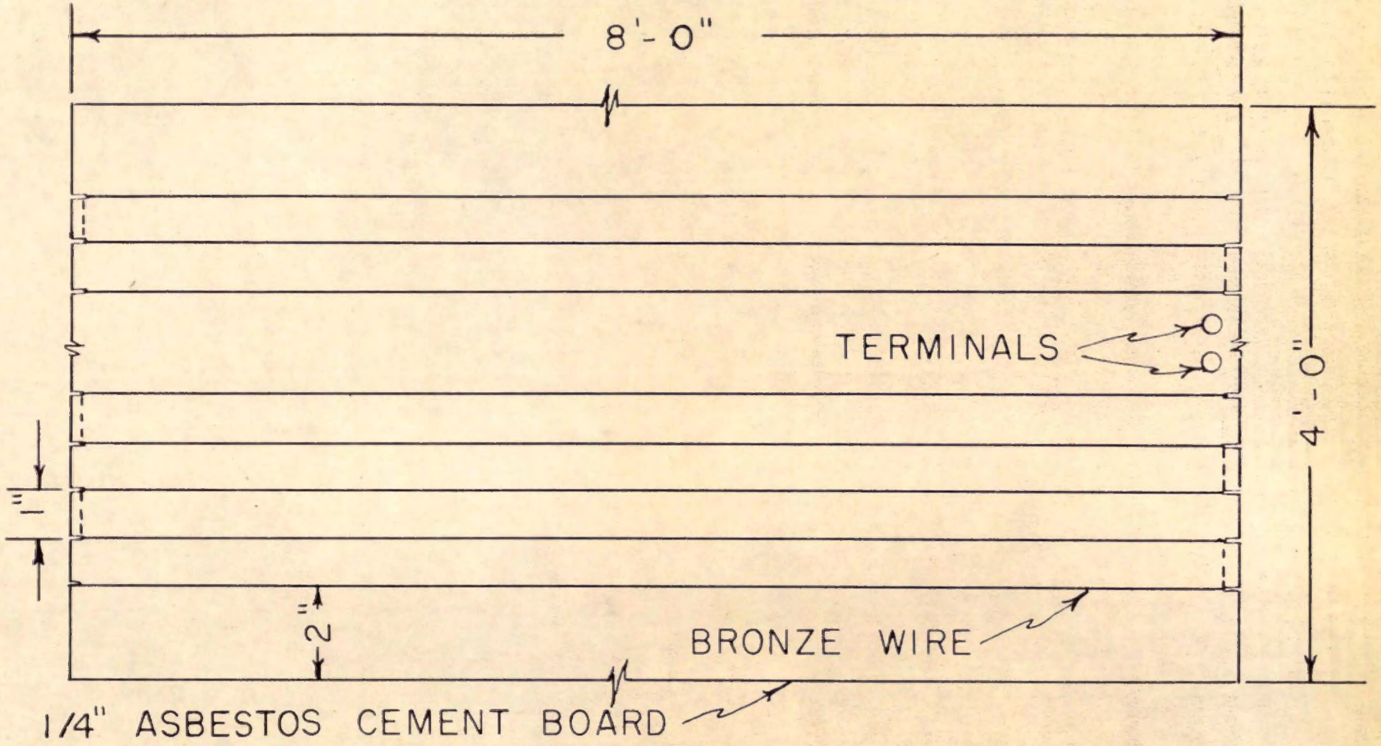

FIG. 3 PLAN VIEW OF BRONZE WIRE PANEL

Fig. No. 4
View of Graphite Panel.

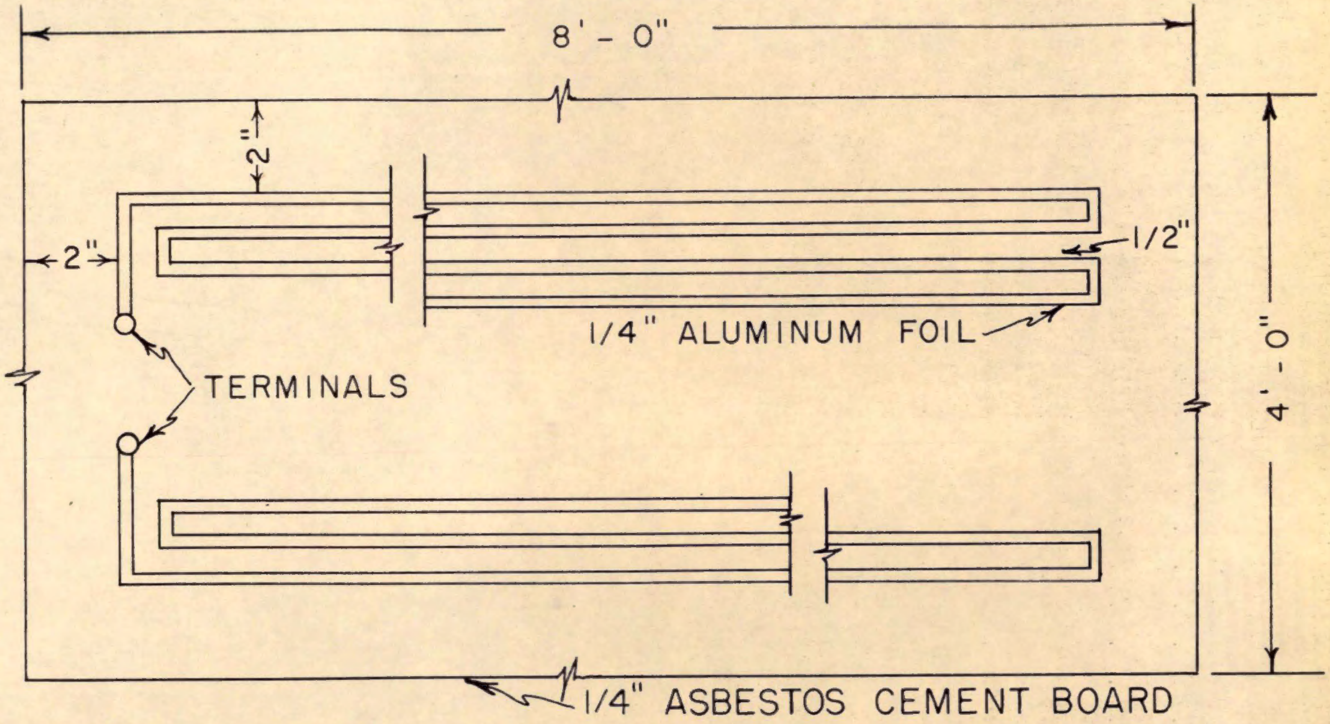

FIG. 5 PLAN VIEW OF ALUMINUM FOIL PANEL

CHAPTER V

EXPERIMENTAL

A laboratory calorimeter was constructed as illustrated in Figure 6. Construction details are shown in Figures 7 and 7A. This unit consists essentially of a steel pan, box to hold the pan and insulation, box for the panel, volt-ampere meter, wattmeter, thermometer, rheostat, and insulation.

The wooden box was filled with four inches of vermiculite insulation packed around the pan. The panel was placed over the pan with a box to hold different types and thicknesses of insulation. The panel box was four feet square and ten inches in depth. Adequate space and supports were provided for a four by four foot panel and seven inches of insulation. Asbestos paper was provided to cover the panel to keep the grid from shorting on the insulating material. The calorimeter was provided with an opening, so the temperature could be taken while the test was being run, and a drain was placed in the bottom of the pan, with a notch in it, so the water would be at the same level at all times.

Tests on 4 by 4 Panels

The panels were placed in the calorimeter with the grid up next to the insulation. The temperature of the water and panel, voltage, ampherage, and wattage were recorded at one hour intervals to check the efficiency of the panel. Different depths of insulation were placed over the grid to see if there was any difference in efficiency due to the insulation, and to determine the opitum depth of insulation to use for the most economical operation. Checks were made with the grid turned down next to the water, with the other equipment the same as above. The above tests were run for four different types of grids, namely: (1) Heavy aluminum foil .00150 inches thick, (2) Light aluminum foil .00075 inches thick, (3) Bronze wire, (4) Graphite.

It was decided to use a panel four feet square for testing the efficiency of the unit. This panel is one-half the regular size, so 115 volts were used instead of 230. These tests were run for four hours with the reading recorded every hour, because it was impossible to read the thermometer closer than .5 of a degree.

The procedure for calculating the efficiency of the panel was as follows: Fill the pan to desired capacity with water and bring the pan and water to the same temperature. Arbitrarily, select a depth and type of insulation. Record the time, watts input, and the temperature of the water. The room temperature remains constant throughout the test. To determine the amount of

BTUs received by the water, multiply the pounds of water times the rise in temperature of water, times the number of hours. In order to calculate the BTU input, multiply the watt hour meter readings by 3.412. The weight of the entire pan was converted to its equivalent in pounds of water. One watt hour is equal to 3.412 BTUs. The efficiency was calculated by dividing the output by the input. This procedure was repeated for the different panels and insulation.

Tests on 4 by 8 Panels

Tests were run on the temperature rise of the panel. The panel was placed in a 4 by 8 box, and tests made with no insulation varying to five inches of insulation. The temperature was recorded at different intervals of time for the various depths of insulation. Three samples were taken. A laboratory unit for testing 4 ft by 8 ft panels was constructed as illustrated in Figures 8 and 8A. The 1 in by 2 in strips were placed sixteen inches on center, with the other strips across them sixteen inches on center. One inch No. 12 wood screws, placed sixteen inches on center in counter sunk holes, were used to hold the panel in place. No screws were placed around the outer edge. A wooden molding, one and one-half inches wide, was used to hold the edges in place. This gave the panel room for expansion or contraction.

Fig. No. 6
View of Laboratory Calorimeter
Showing Wattmeter, Cutter,
Voltmeter, and Insulation.

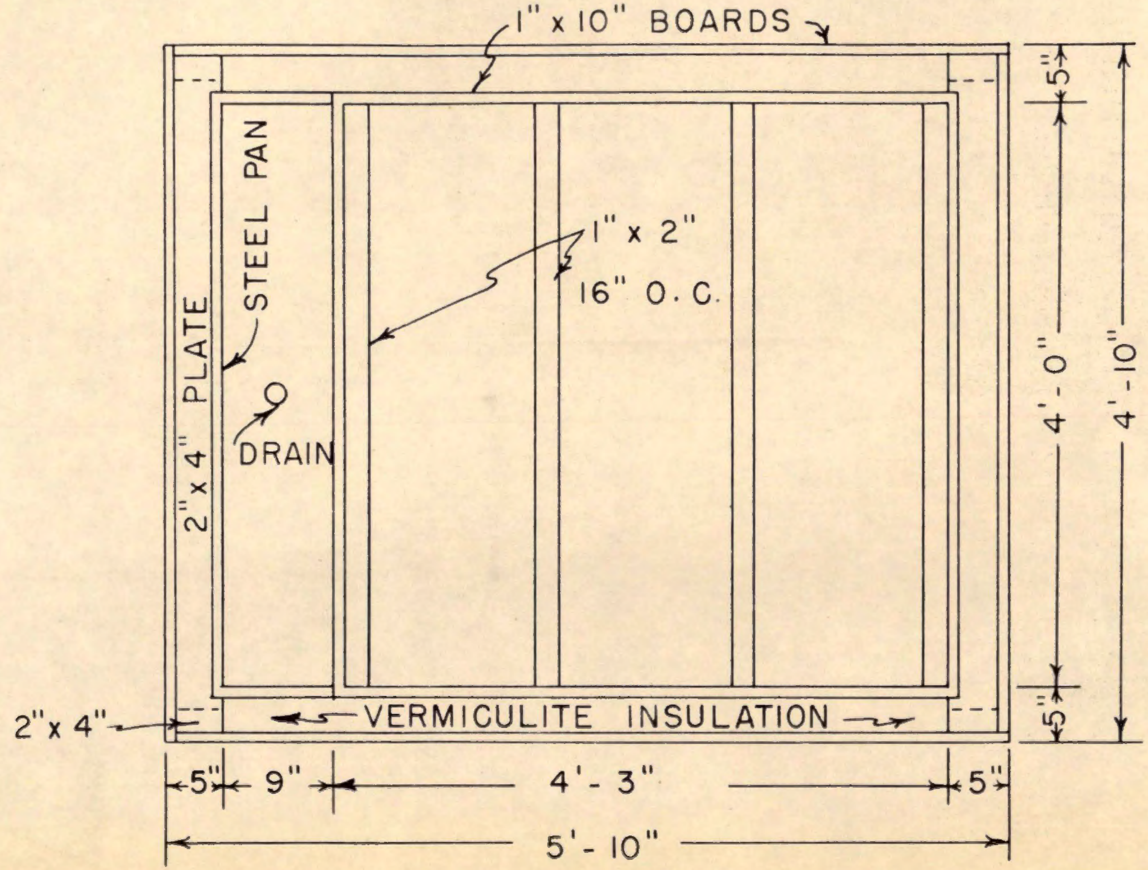

FIG. 7 PLAN VIEW OF LABORATORY CALORIMETER.
SCALE 3/4" = 1'- 0"

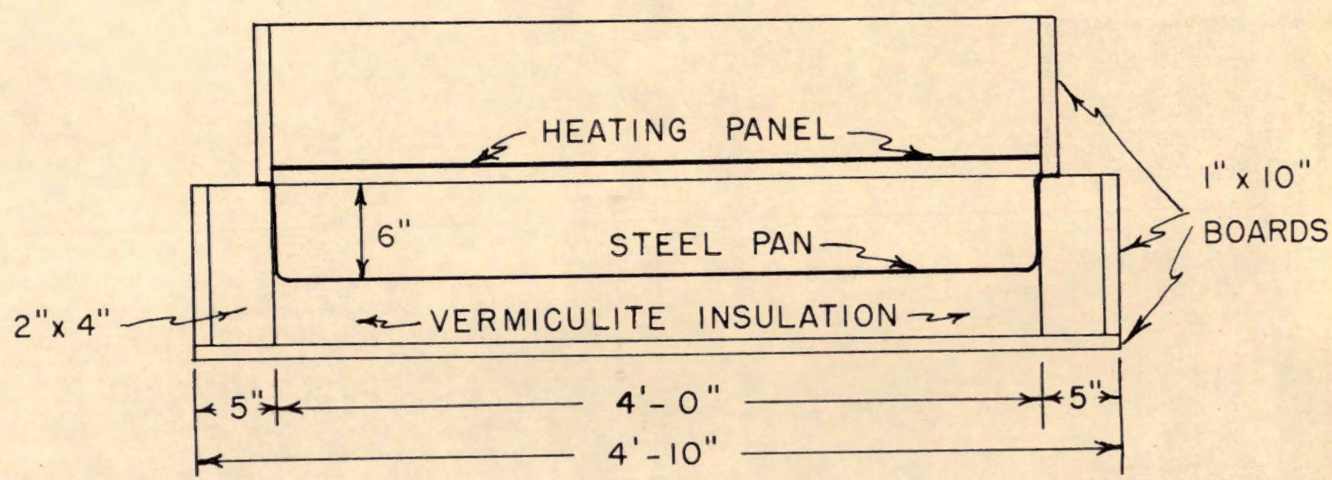

FIG. 7A END VIEW OF LABORATORY CALORIMETER
SCALE 1" = 1'-0"

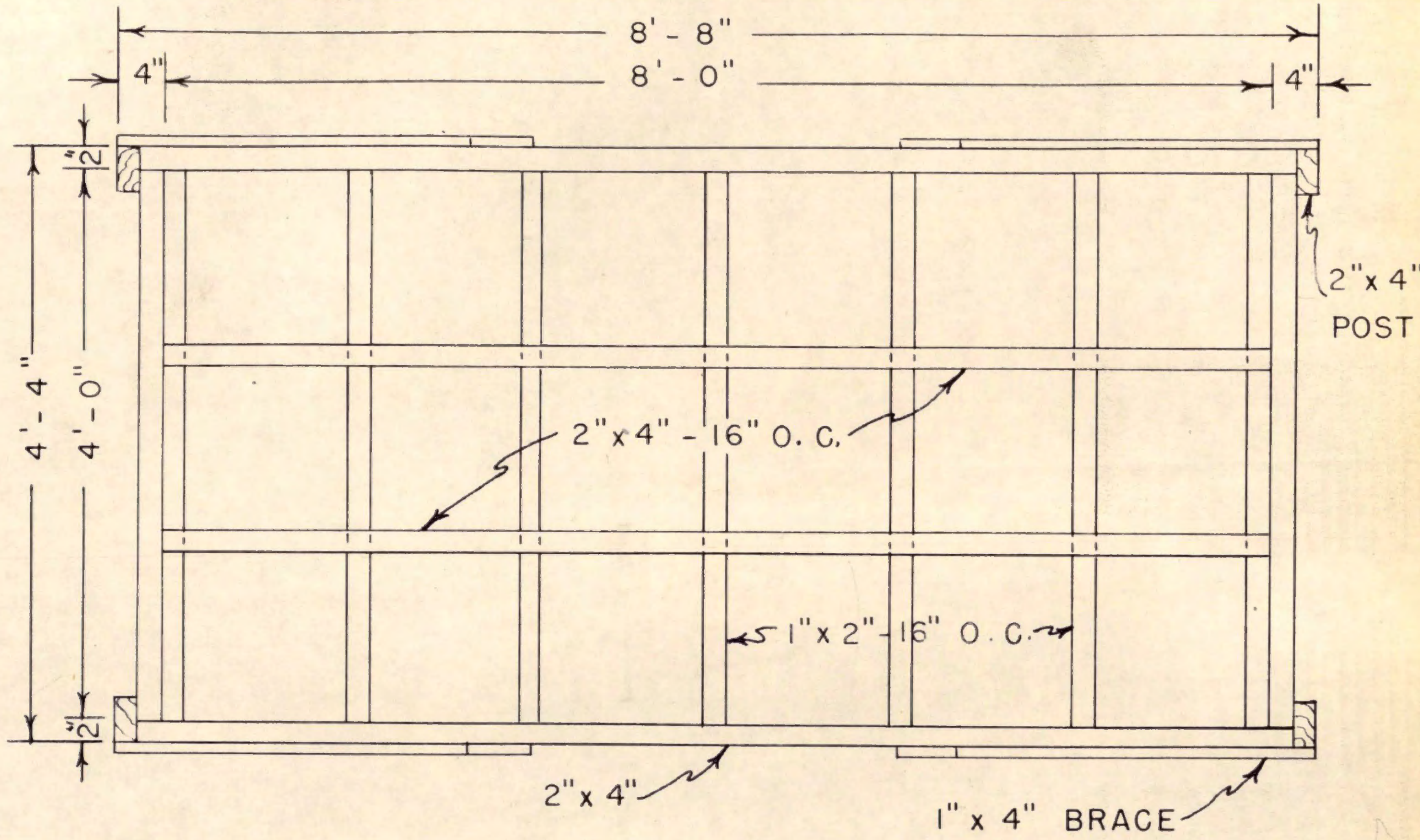

FIG. 8 PLAN VIEW OF LABORATORY PANEL TEMPERATURE - RISE TESTING UNIT

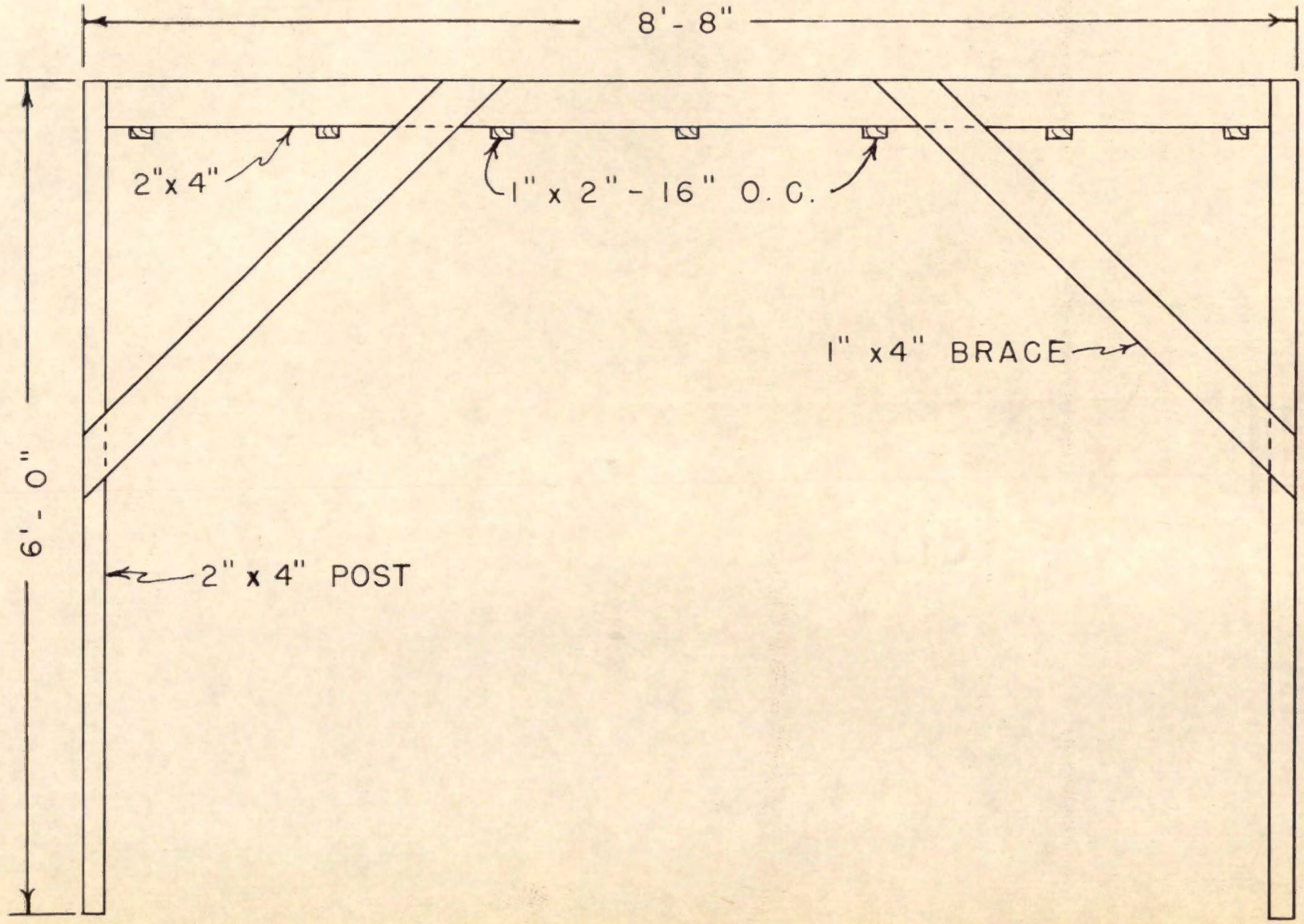

FIG. 8A SIDE VIEW OF LABORATORY PANEL TEMERATURE-RISE TESTING UNIT

CHAPTER VI

ANALYSIS OF DATA

In order to determine which of several panels is best, it is essential that all tests be on a comparable basis. Each of the factors affecting the heating, other than one variable factor, should be the same in each test conducted for making the comparisons. If these factors are not the same, it is necessary that they be isolated or adjusted. Tests were selected from each condition set up for this study. The tests were selected on the basis of having as many of the factors affecting the heating process as nearly equal as possible.

The temperature rise of the different panels is shown in Tables I, II and III. Figure 9 illustrates graphically the temperature rise. The data were compiled in the following manner: The temperature rise of the panels was recorded at five minute intervals for the first hour and at various times until the maximum temperature was reached. The thickness of insulation, time the test started, the BTU input, and the BTU output were recorded. These tests were run three times and Tables I, II and III are the average results. The temperature rise was sharp in the first hour, then decreased until the maximum temperature was reached.

The electrical energy for each of the panels was computed as the average between the initial and final wattmeter readings. The efficiency for each of the panels was calculated on a percentage basis. The grids of the panels were placed next to the insulation and also down away from the insulation, in order to study the differences in efficiency of the panels. The checks were made using the same condition of operation. The room temperature was constant throughout the experiment, and the initial temperature of the water remained close to 55°F.

In order that the results may be more easily understood, they are compared in different ways as follows: (1) Maximum temperature with no insulation, (2) Maximum temperature with three inches of vermiculite insulation, (3) Maximum temperature with five inches of vermiculite insulation, and (4) By the efficiency of each panel with five inches of vermiculite insulation.

TABLE I

HEAVY ALUMINUM FOIL GRID WAS PLACED UP AND COVERED WITH FIVE INCHES OF VERMICULITE INSULATION.

	Average of Three Tests	
Time	Temperature Rise Degrees F	Watts
8:40	76	672
8:45	80	672
8:50	88	672
8:55	98	672
9:00	108	672
9:05	117	672
9:10	124	672
9:15	132	672
9:20	137	672
9:25	141	672
9:30	145	672
9:35	150	672
9:40	155	672
11:45	179	672
2:40	182	672
4:40	182	672

TABLE II

GRAPHITE GRID WAS PLACED UP AND COVERED WITH FIVE INCHES OF VERMICULITE INSULATION.

Time	Average of Three Tests	
	Temperature Rise Degrees F	Watts
9:25	78	572
9:30	83	572
9:35	88	572
9:40	93	572
9:45	97	572
9:50	100	572
9:55	103	572
10:00	106	572
10:05	109	572
10:10	111	572
10:15	113	572
10:20	115	572
10:25	117	572
12:35	133	572
4:30	136	572
8:35[1]	144	572
9:35	144	572

[1] 8:35 A. M.

TABLE III

THE BRONZE WIRE GRID WAS PLACED UP AND COVERED WITH FIVE INCHES OF VERMICULITE INSULATION.

Time	Average of Three Tests	
	Temperature Rise Degrees F	Watts
8:45	75	515
8:50	79	515
8:55	83	515
9:00	89	515
9:05	95	515
9:10	100	515
9:15	104	515
9:20	107	515
9:25	110	515
9:30	112	515
9:35	114	515
9:40	116	515
9:45	118	515
11:30	124	515
3:30	132	515
8:30[2]	133	515
8:30[3]	137	515
4:40	137	515

[2]8:30 A. M.

[3]8:30 A. M. 24 hours later

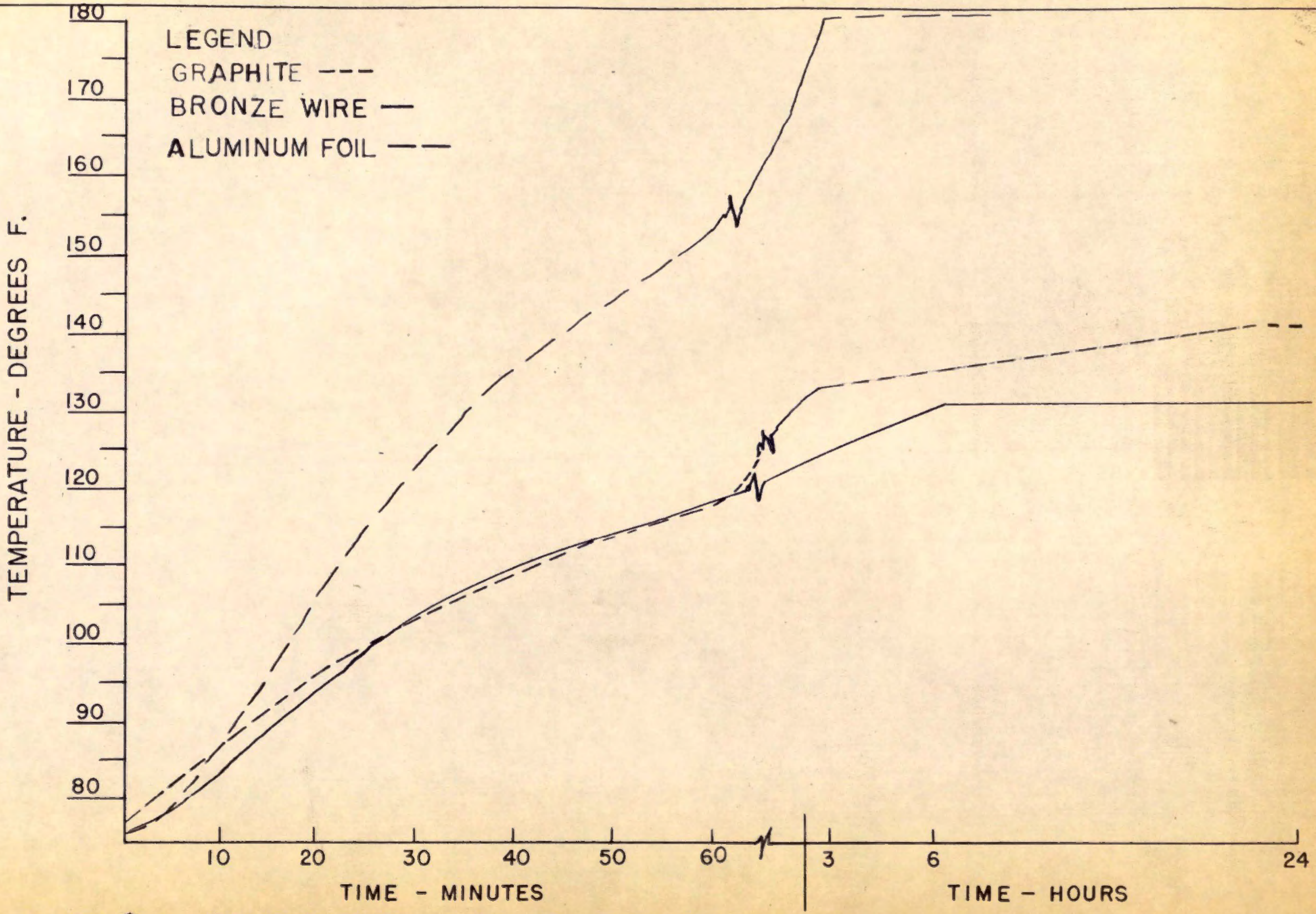

FIG. 9 TEMPERATURE - RISE OF THE PANELS

TABLE IV

COMPARISON BY DEPTH OF INSULATION

Maximum Temperature of Panels

Type Grid	Temperature Degrees F				
	No Insulation	3 Inches Vermiculite	5 Inches Vermiculite	Watt	Watt/ft 2
Graphite	108	136	144	572	18.0
Aluminum Foil[4]	148	160	182	672	42.0
Bronze Wire	104	118	133	515	16.0

[4]The above was on a four by four foot panel.

TABLE V

EFFICIENCY OF THE PANEL

The grids were placed up next to five inches of vermiculite.

Type Grid	BTU Input	BTU Output	Time in Hours	Percentage of Efficiency
Graphite	1625	2268	4	71
Aluminum Foil[5]	1760	2215	4	79
Bronze Wire	1600	2179	4	74

5The above was on a four by four foot panel.

TABLE VI

THE HEAVY ALUMINUM GRID WAS PLACED UP NEXT TO THE ONE-HALF INCH INSULATION BOARD WITH NO ALUMINUM INSULATION ON THE BOARD. JUST ONE-HALF INCH BOARD FIBER WAS USED FOR INSULATION.

Time	Water Temperature	BTU Output	Watts	BTU Input	EFF.
9:07	54°F	- -	640	2184	
10:07	63°F	1350	640	2184	
11:07	72°F	1350	620	2115	
12:07	78.5°F	975	620	2115	57%
		1225 Average		2148 Average	

THE HEAVY ALUMINUM GRID WAS PLACED DOWN NEXT TO THE WATER WITH ONE-HALF INCH OF INSULATION BOARD WITH NO ALUMINUM ON IT FOR INSULATION.

Time	Water Temperature	BTU Output	Watts	BTU Input	EFF.
1:25	54°F	- -	640	2184	
2:25	62°F	1200	620	2115	
3:25	70°F	1200	610	2081	
4:25	82°F	1200	610	2081	56.7%
		1200 Average		2115 Average	

TABLE VII

COMPARISON OF INSULATING VALUE FOR DIFFERENT INSULATING MATERIALS.

	BTU Output	BTU Input	EFFICIENCY Average
VERMICULITE INSULATION TEST			
No Insulation	861	2310	37%
1" Vermiculite	1375	2168	63.5%
2" Vermiculite	1483	2195	67%
3" Vermiculite	1525	2099	76%
4" Vermiculite	1487	2071	74%
5" Vermiculite	1624	2060	78%
6" Vermiculite	1620	2171	75%
PAPER PAINTED WITH ALUMINUM PAINT ON BOTH SIDES			
Three Thicknesses	1066	2206	48%
Four Thicknesses	1130	2240	50%
Six Thicknesses	1100	2180	51%
Eight Thicknesses	1250	2225	56%
REYNOLDS ALUMINUM FOIL FOR INSULATION			
Three Thicknesses	1100	2227	49%
Six Thicknesses	1150	2177	53%
KIMSUL INSULATION			
Standard	1020	1914	53%
Heavy	1500	2184	68%

TABLE VII

COMPARISON OF INSULATING VALUE FOR DIFFERENT INSULATING MATERIALS. (Continued)

	BTU Output	BTU Input	EFFICIENCY Average
ONE-HALF INCH FIBER BOARD INSULATION			
	1200	2115	56.7%
FIBER BOARD WITH ALUMINUM FOIL ONE SIDE			
	750	1187	63%
FIBER BOARD WITH ALUMINUM FOIL BOTH SIDES			
	1525	2194	68%

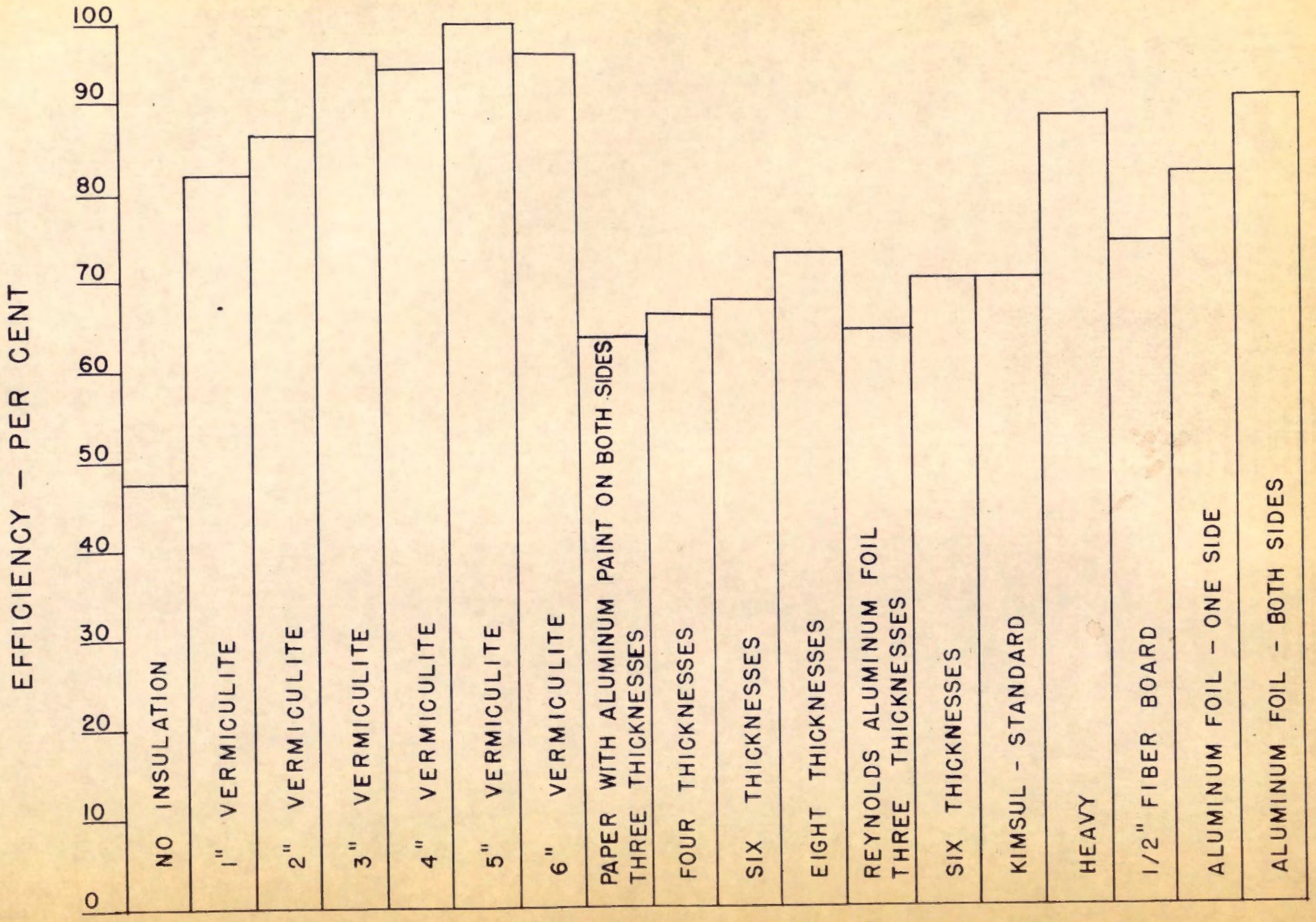

FIG.10 COMPARISON OF INSULATING MATERIALS

From Table IV, it may be noted that the heavy aluminum foil grid has a higher maximum temperature than either other panel. However, the temperature-rise for the first hour (see Figure 9) is greater. The wattage per square foot of panel is greater, which accounts for the higher temperature-rise.

Table V shows that the efficiency of the aluminum foil panel is greater than the graphite or bronze wire, but the difference is so small that it is impossible to determine which panel would prove to be the most efficient under the testing condition of the study.

It may be noted from Table VI, that the efficiency of the panel is approximately the same, regardless of whether the grid was placed down next to the floor or up next to the insulation. All the panels gave similar results under the same conditions.

The results shown in Table VII are for various insulating materials on the market. They are the averages of three tests. Figure 10 shows the results graphically. Since most commercial companies recommend that four to five inches of insulation be used, five inches of vermiculite was used as the basis for the comparisons. It was considered to be a hundred percent efficient and the others are in proportion to it.

There appears to be an error in the three, five and six inch tests on vermiculite. Five inches of vermiculite gave the best efficiency. The tests on three and five inches of vermiculite were higher than the test on six inches. Obviously there was some error in the data.

CHAPTER VII

DISCUSSION

Results for this study were obtained from tests selected from each of the tests conducted, using the different types of panel constructions. The rate of heating is higher at the beginning of the heating period, then decreases in rate until a point is reached where the temperature does not increase any more, regardless of the amount of energy delivered to the panel. The data is not entirely correct, but is correct for all practical purposes under the condition of the experiment.

The atmospheric air conditions and the air entering the laboratory were not the same for each test conducted. However, tests were selected with room air conditions as nearly the same as possible.

The primary objective of the experiment was to compare the temperature rise of different heating panels; the methods of installations; compare the radiations of different heating elements; cost of construction, and efficiency of the several heating elements used.

Practically no information is available on the use of panel heating. However, Raber and Hutchinson[5] reported that preliminary tests indicated a more uniform heating

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[5]Raber and Hutchinson, _Panel Heating and Cooling Analysis_.

was available when the entire surface of a panel was used as a radiating surface. About one-third of the heating tests were accomplished, using a graphite grid where the entire surface was covered and the remaining one-half of testing was done with varying amounts and types of elements. The difficulty was finding a material that would cover the entire surface, and would not expand or contract, causing the element to crack, which would result in an arc. This made the panel unsafe and impractical. Figure 11 shows the result of the element cracking. The graphite cracked in several directions and shapes, usually starting at one of the aluminum foil strips used for the voltage connections.

Two methods of applying the graphite grid were tried, Namely: Brushing with an ordinary paint brush, and spraying with a paint gun. It was difficult to get an even distribution of graphite on the board; therefore, there were hot and cold spots, causing the element to break down and arc across the breaks. These probably were caused by the fast drying of the graphite. The asbestos board would absorb the moisture of the graphite in a matter of seconds. It was hard to get a smooth even finish. The broken parts of the panel could be repainted with fair results. The aluminum foil electrodes would expand and cause an arcing between the graphite and aluminum foil, because of the small amount of contact area between the foil strip and graphite grid. Bronze screen wire was used as a grid, instead of aluminum foil, giving more contact area for the graphite, and proved successful, but there was not enough data to determine the feasibility of recommending it as an electrode.

There were an insufficient number of tests run to definitely discard this type of heating element, but it showed that more work needs to be done on it.

The aluminum foil panel gave a favorable time temperature rise curve, but the cost of construction was higher than graphite or bronze wire. The foil has a high co-efficient of expansion, causing a problem of fastening the foil strips to the board. If some way were developed to fasten the strips and to mount them on the board economically, they would prove satisfactory as a heating element.

The time-temperature rise of the bronze wire was very low, compared to aluminum foil grids, but the ease of construction, cost, and life of the wire were much more favorable.

The bronze wire on a four by eight panel can be installed by one man in approximately fifteen minutes. It is an easy process and Figure shows how the panel is constructed. The primary objection to the bronze wire is that the time of reaching a desired temperature is slow. Tests show by having the wire in contact with the panel, the overall efficiency compares favorably with the graphite or aluminum foil panels. The wires can be painted or plastered over without too much trouble.

Tests show that little difference occurred, whether the grid was placed next to the insulation, or down on the face of the ceiling. Table VI shows results of these tests. The heavy aluminum foil panel was used to show the results. The other panels under the same conditions gave similar results.

Several methods and materials were used to fasten the different heating elements to the asbestos boards. To fasten the aluminum foil in place, oil paint, cascamite glue, and asphaltum were not satisfactory. The cascamite glue would flake off; the oil paint would remain wet, and the asphaltum would not stick to the aluminum foil. Casine paint, aluminum foil seal No. 6, and deck enamel were used with good results. The aluminum foil seal No. 6 proved to be the best, as it would remain sticky over a long period of time.

To hold the bronze wire in place, fast and slow drying concrete was used without desirable results. The water from the concrete was absorbed by the asbestos board, before there was time for it to set-up. Casine paint and paste with asbestos paper were used with good results. The filler was poured off the paint, leaving only a thick pigment. This was tried on the panel, but this method of holding the wires in place was too expensive, since it took a quart of paint per four by four panel.

It should be emphasized that considerably better results were obtained with the bronze wire panels, than the other panels tested, except for the time-temperature rise. The results from this study indicate that the bronze wire panel should be recommended from the standpoint of cost, permanency, and safety. The aluminum foil is also highly desirable as to temperature rise, and safety.

The asbestos board was greatly affected by air condition, temperature and moisture. Water was absorbed by the board in considerable quantities. If the board warps out of shape, it could be restored by wetting the board, and placing on flat surface, weighted down, and allowed to dry in place. Not enough tests were run on the board concerning moisture content to give any definite figures.

Fig. No. 11
View of Element Cracking.

CHAPTER VIII

RESULTS

It must be emphasized that the results of this study are based on laboratory conditions and that more information is needed in actual operating conditions over a period of time. With these limitations in mind, the data was evaluated and the following results appear to be warranted:

(1) Temperature for the bronze wire and graphite grids was similar under the same conditions.

(2) The higher the wattage per square foot of panel, the greater the final temperature will be.

(3) Maximum temperature a panel will reach depends on the wattage per square foot of panel and the thickness of insulation.

(4) Maximum temperature and the rate of radiation for the graphite panel using five inches of vermiculite was 144°F.

(5) Maximum temperature for bronze wire panel using five inches of vermiculite was 133°F.

(6) Maximum temperature for the aluminum foil panel using five inches of vermiculite was 182°F.

(7) Temperature curve is steep for the first hour, then levels off until a maximum temperature is reached.

(8) The efficiency of the panels tested were nearly equal.

(9) The grid can be up or down and not affect the efficiency of the panel.

(10) Panel can be either painted or plastered.

(11) Panel can be installed on the ceiling with aluminum foil over it for insulation.

(12) Panels can be constructed with standard farm tools.

(13) The panels can be constructed by one man.

(14) No special tools are needed for installing the panels.

(15) Two men can install the panels.

(16) Oil paints should not be used as a binder to hold grid to the asbestos cement board.

(17) Asbestos board will absorb moisture very readily.

(18) Asbestos paper should be placed over the grid for safety.

(19) The bronze wire panel proved more satisfactory in terms of cost, construction and permanence.

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