TECHNICAL HANDBOOK
THERMALUX Electric Heating

H-1

THERMALUX
ELECTRIC HEATING

Technical Handbook

UNITED STATES GYPSUM COMPANY

H-1, U.S.G. Rev. 12/65

Printed in U.S.A

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont)

TABLE OF CONTENTS (Cont)

LIST OF TABLES

LIST OF ILLUSTRATIONS

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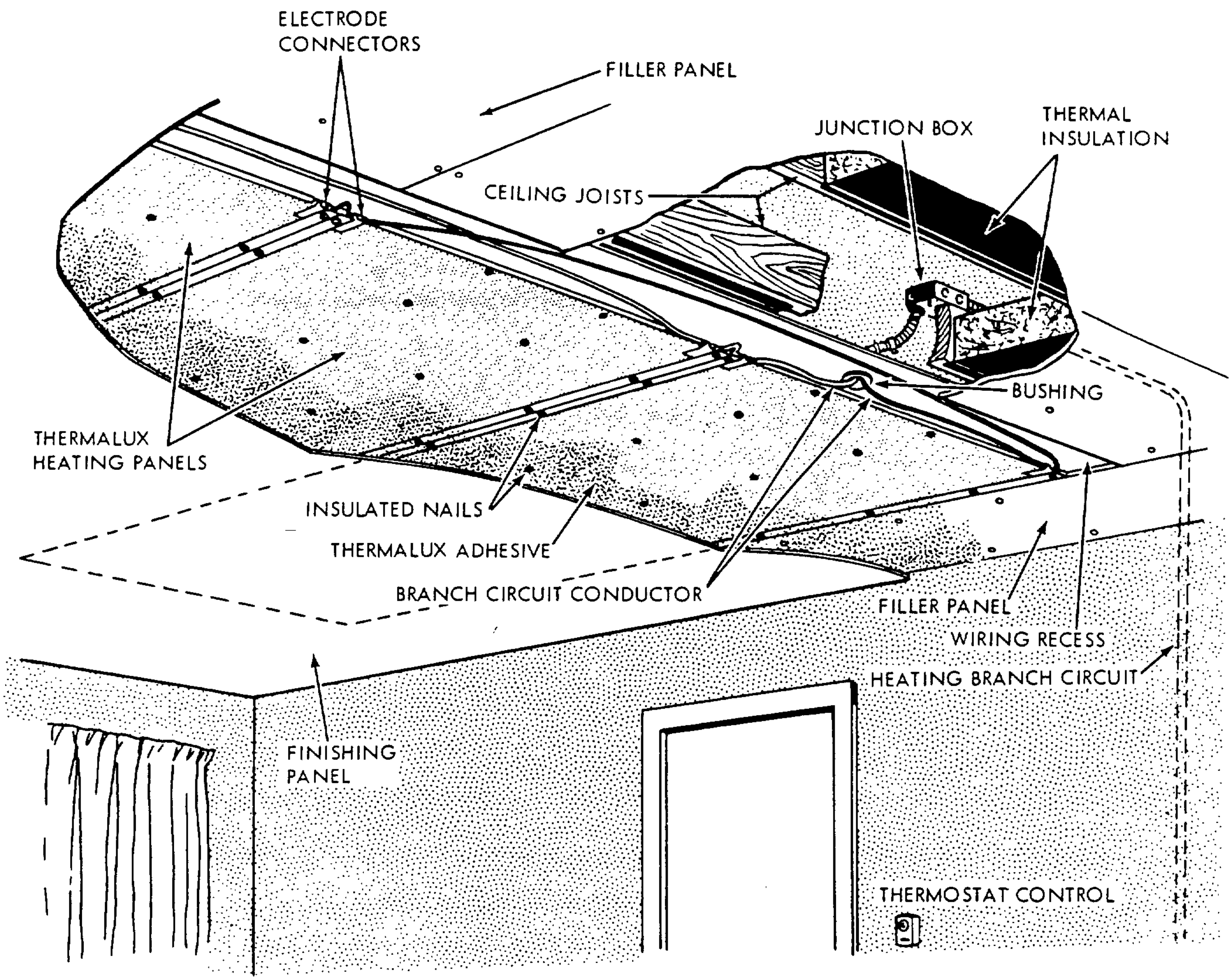

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Figure 1-1. The THERMALUX Electric Radiant Heating System

CHAPTER 1

THERMALUX — AN IMPORTANT ADVANCE IN ELECTRIC HEATING

To meet the increasing demand and need for a highly efficient and economical electric heating system, United States Gypsum has developed and perfected THERMALUX Electric Radiant Heating.

The THERMALUX System marks the coming-of-age of electric heating. Revolutionary, but simple, THERMALUX enhances the inherent advantages of electric heating and combines them with new flexibility of design, ease of installation, and economy of operation.

With the THERMALUX System, United States Gypsum continues its long record of leadership in developing ever-better products and systems for the building industry. An integral member of the United States Gypsum product family, the THERMALUX Electric Heating System has all the family characteristics of quality, safety, durability, efficiency, and economy.

Safety

The unusually low operating temperature of THERMALUX, and the incombustible, electrically non-conducting gypsum panels throughout the system, provide outstanding safety. Being flameless, the system eliminates the potential fire, explosion, and air contamination hazards inherent in combustion heating plants. THERMALUX also does away with hot elements and high-temperature operation.

The THERMALUX Electric Heating System is approved by Underwriters Laboratories, conforms with the National Electrical Code, and meets Federal Housing Administration standards.

Comfort

The low-temperature, even-radiation of warmth from broad ceiling areas to all parts of the room provides exceptional comfort. There is no forced air movement to create uncomfortably hot or drafty areas. The air retains its natural freshness and does not become hot and dry. Each room contains its own "heating system" and thermostat. The warmth level most suitable to the occupants and activities can be selected without affecting the comfort level of other rooms.

Cleanliness

Heat is produced by direct conversion of electric energy. There is no smoke, soot, or fumes to soil drapes, furniture, or walls. Heat distribution is by radiation. There are no strong air currents to spread dust and dirt over the room. Cleaning and redecorating are reduced to a minimum.

Economy

Since the THERMALUX Electric Heating System also is the ceiling, it can be installed with minimum labor and material. Panels can be cut to the exact length needed, and no large stock of varied lengths has to be kept on hand to meet different requirements. Operation is efficient and economical because the entire panel heating surface is a uniform, low temperature that minimizes heat loss.

Convenience

No periodic maintenance, lubrication, parts replacement, servicing, or system cleaning is required. There are no moving parts. Since the heating system is an integral part of the ceiling, there is complete freedom of architectural design and interior decoration. Furniture can be arranged without concern about blocking heat sources.

Space Economy

No furnace consumes valuable space in a closet, utility room, or basement. There are no chimneys or ducts to interfere with improvement of the basement or other areas into useful living space.

Quiet

Because there are no moving parts, THERMALUX Electric Radiant Heat is as silent as a light bulb.

A NEW PRODUCT FOR THOSE IN THE BUILDING TRADE

Architects, builders, heating system specialists, and contractors now have available to them this great new U.S.G. product. This Handbook covers design and installation of THERMALUX Heating Systems to assist these businessmen in capitalizing on the THERMALUX System.

CHAPTER 2

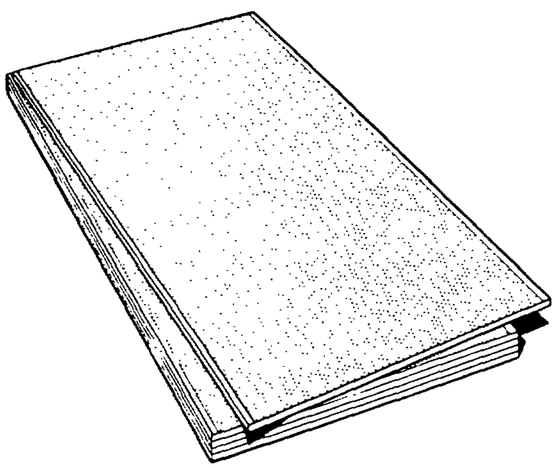
THERMALUX SYSTEM COMPONENTS

U.S.G. – ONE SOURCE FOR A COMPLETE SYSTEM

United States Gypsum, originator of the THERMALUX Electric Radiant Heating System, produces all of the materials necessary to install a complete system other than the controls and those standard electrical components enumerated under Complementary Products in this Chapter. However, all of the electrical controls used in the system are designed to meet rigid U. S. G. requirements. A full description of each THERMALUX System component follows.

Heating Panels

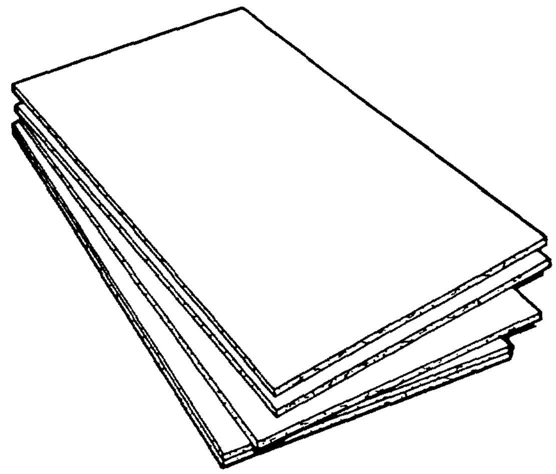
THERMALUX Heating Panels consist of an electrical resistor (heating element) on an inert, incombustible gypsum base. The resistor extends over the entire panel and contains two copper electrodes for connection to an electric power source. THERMALUX Heating Panels are designed for 120 Volt AC-DC operation. At the design voltage, current input is nominally 0.125 ampere per square foot, and power input is 15 watts for each square foot of area installed, or approximately 50 Btu/hr./sq.ft. Operating temperature is 115° Fahrenheit or lower. Heating panels must be electrically connected in parallel to standard heating branch circuits. The panels are controlled by special THERMALUX low-voltage thermostats and transformer relays.



THERMALUX Heating Panels are manufactured 1/2 in. thick, 4 ft. wide, and in various lengths up to 12 ft. The Heating Panels are available in two types – with heating element over the entire area (A-60-48.48), and with heating element on just one-half the area (A-30-24.48). Selected by length and width according to heating requirements, room configuration, and desirable location, panels can be cut to the exact length when necessary. Cutouts may be made in the panels for installation of lighting fixtures and other ceiling appliances.

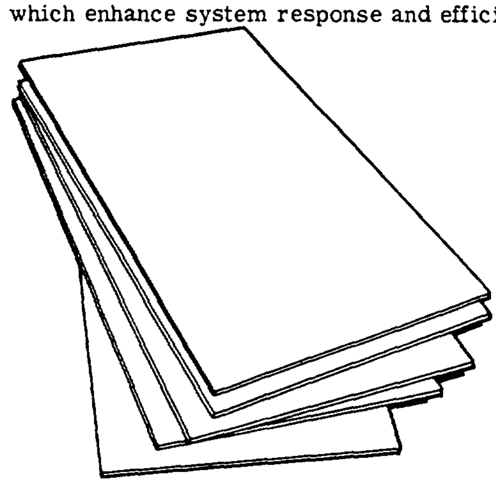
Filler Panels

THERMALUX Filler Panel is installed as a base layer in ceiling areas where heating panels are not required and is used in wiring recess construction. These are 1/2 in. thick, electrically non-conducting, incombustible gypsum panels.



Finishing Panels

THERMALUX Finishing Panels, specially designed 1/4 in. high-density gypsum panels, are used as the surface layer of the ceiling. Finishing Panels have excellent heat transmission and radiation characteristics which enhance system response and efficiency.



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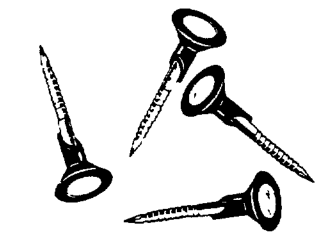
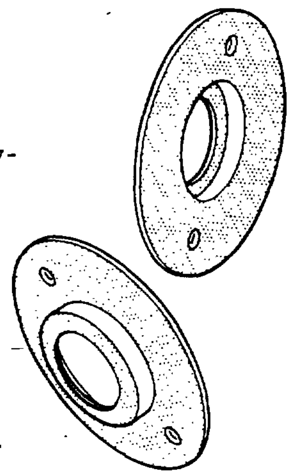
Insulated Nails



Insulated nails, specially developed for the THERMALUX Heating System, are used to attach the Heating Panels to wood ceiling framing. A nylon sleeve insulates these annular ring nails from the electrical resistor, eliminating shock hazard from any misdriven nails. The nails drive easily, are designed so correct usage is obvious, and are readily visible to electrical inspectors.

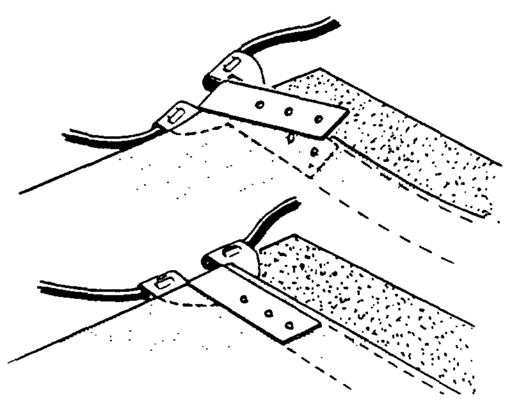
Branch Circuit Bushings



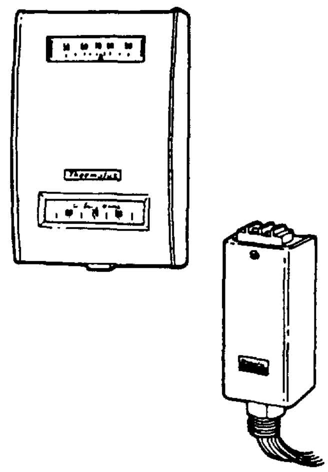
Branch circuit bushings serve as the wiring recess entrance for branch circuit conductors supplying power to the THERMALUX Heating Panels. The specially designed bushing accommodates all standard types of branch circuit raceway/wiring systems. The use of these bushings meets the requirements of the National Electrical Code and simplifies installation.

Electrode Connectors

Electrode connectors are used to connect branch circuit conductors to installed THERMALUX Heating Panels. The connectors are first secured to branch circuit conductors with a pressure-type connection. Then the connector is positively connected to copper electrodes in the THERMALUX heating element. The connector-electrode connection utilizes the proven method of electrical contacting with multiple points which pierce insulation and electrodes.



Controls



Controls are low-voltage thermostats and transformer/relays which provide room-by-room control to maintain each room at the desired temperature level. The THERMALUX thermostats and transformer/relays have been specially designed to provide optimum comfort with the THERMALUX System. The controls are very sensitive, and give quick system response to temperature changes and heat demand.

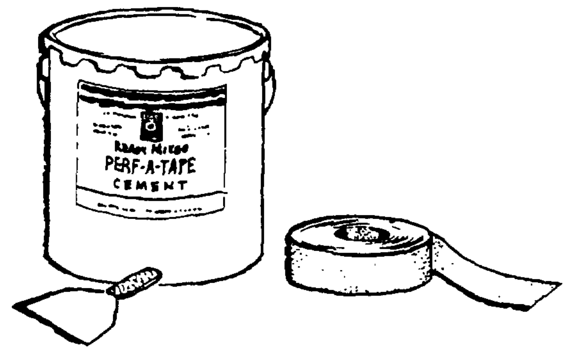
The THERMALUX Humidistat, to automatically control operation of an exhaust fan, is recommended to maintain humidity at a desireable level.

THERMALUX Adhesive

THERMALUX Contact Adhesive, for on-the-job lamination of Finishing Panels, is specially formulated for use in a THERMALUX Electric Heating System. It is easy and quick to use and provides a strong bond of the ceiling Finishing Panels to the Heating and Filler Panels without the use of nails or other fasteners.

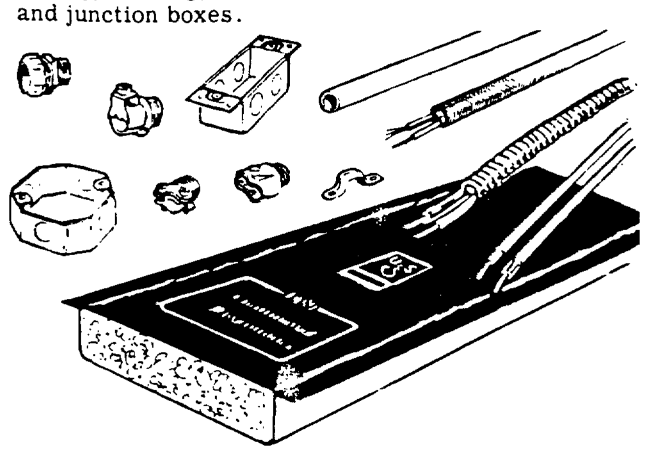
THERMALUX Joint Finishing Materials

A smooth, monolithic ceiling surface is created when the THERMALUX System is finished with ready-mixed PERF-A-TAPE® Compound (THERMALUX-formula) and PERF-A-TAPE Reinforcement Tape. Then the ceiling can be decorated with any conventional water-thinned or oil-based paints.



Complementary Products

Complementary products are United States Gypsum THERMAFIBER mineral wool insulation in batt or nodular form, and standard electrical raceways, wiring, cabling, service boxes, circuit breakers, and junction boxes.



THERMALUX SYSTEM DESIGN

To assure maximum comport and efficiency, each THERMALUX System is custom designed to meet the specific needs of the building and its occupants. Heat loss is calculated for each room in accordance with the recommendations of the American Society of Heating, Refrigerating, and Air Conditionion Engineers.

The THERMALUX Heat Loss Calculators simplify design work on standard types of construction. Heating Panel layout is then worked out for each room on the basis of the heat loss calculations, room configuration, and comfort requirements. Electrical branch circuit design for best load balance, safety, and economy completes the plan. After the system is installed, it is tested and inspected to insure optimum performance. A typical THERMALUX installation is illustrated in Figure 2-1.

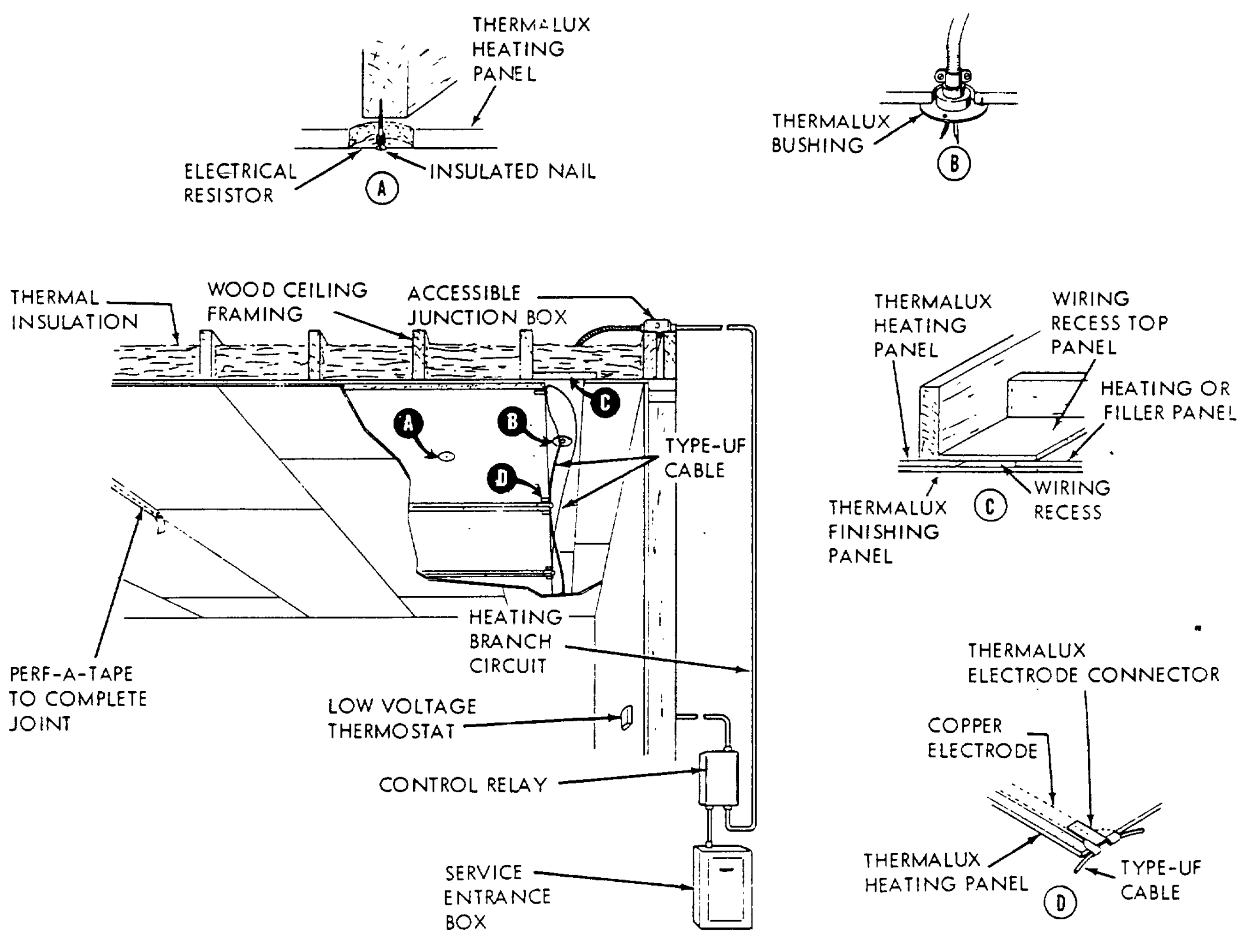


Figure 2-1. A Typical THERMALUX Electric Radiant Heating System Installation

HEAT SOURCE FUNDAMENTALS

ENERGY

Heat is a form of energy, as are electricity, light, mechanical energy, chemical energy, and atomic energy. If something is able to do work, it is said to possess energy. For example, a man can do work and so he possesses energy; a mixture of gasoline and air possesses energy since, when it is ignited, it is able to push the piston within the cylinder of an automobile engine; the spring of a screen door possesses energy since, when the door is opened, it is able to close the door.

Energy exists in many different forms. For example, coal has chemical energy, a streched spring has mechanical energy, a charged capacitor has electrical energy, and a hot substance has heat energy.

The amount of energy which something possesses is equal to the amount of work it can do. Thus, if a heavy object can do 500 foot-pounds of work in falling, it had 500 foot-pounds of energy before it fell. Work and energy are essentially the same kind of quantity and expressed in the same units.

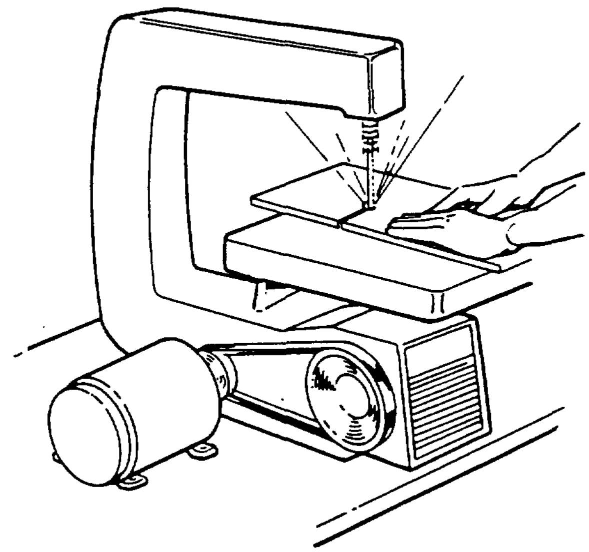


Figure 3-1. Electrical-to-Mechanical Energy Conversion

Power

In practically all cases where work is done, both the amount of work and the time during which the work is done are important. This "time rate of doing work" is called power and may be expressed as

$$\text{Power} = \frac{\text{Amount of Work}}{\text{Time Interval}}$$

For example, electrical energy can do the work of turning a motor. The rate at which the electricity is used in turning the motor is the power involved.

ENERGY CONVERSION

One form of energy can be converted into another. Figure 3-1 indicates that, in turning an electric motor, electrical energy is converted to mechanical energy. At a hydro-electric plant, Figure 3-2, the opposite conversion is made as the mechanical energy of the moving water is converted to electricity. Another common type of energy conversion occurs in an automobile engine, where the chemical energy in the fuel is converted to mechanical energy.

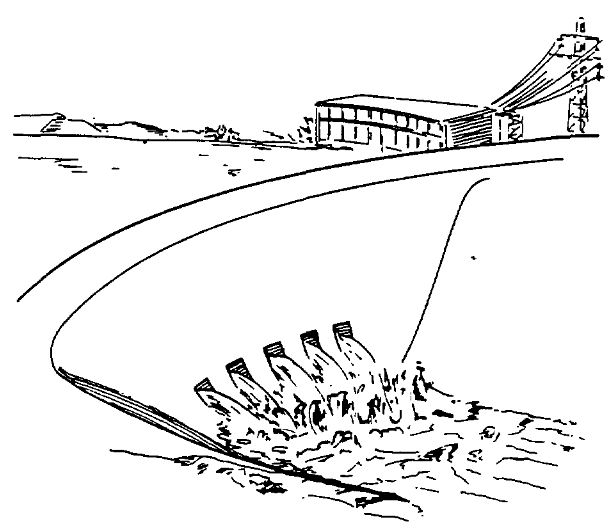


Figure 3-2. Mechanical-to-Electrical Energy Conversion

The process of energy conversion is never 100% efficient as some energy is always wasted in the process. In an automobile, for example, only a fraction of the chemical energy in the gasoline actually goes into mechanical energy driving the wheels. As indicated in Figure 3-3, part of the energy of gasoline is wasted because combustion is not complete; part is wasted in heating up the engine block, part of it goes out the exhaust, and part of it is lost in friction (which converts to heat).

It is important to realize here that energy is never really "lost" but merely transformed or converted to another type of energy. The energy given up by

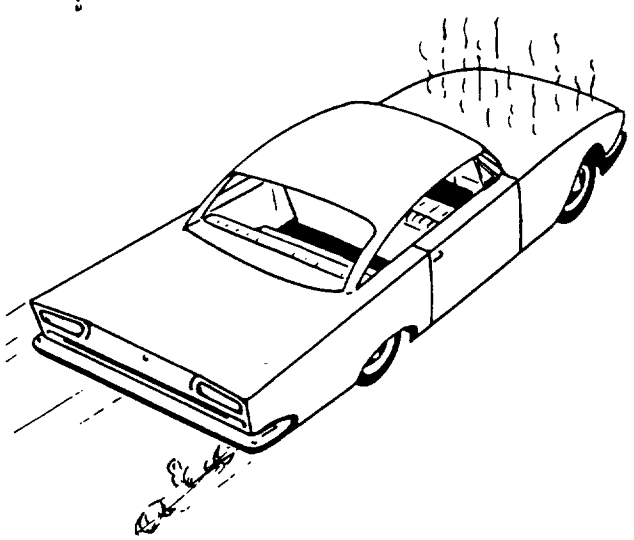


Figure 3-3. Inefficiency of Energy Conversion in an Automobile

a body is imparted to other bodies without loss. Therefore, within any imaginary boundry through which no energy is lost or gained, the total amount of energy remains unchanged. This illustrates a general thermodynamic law known as the "Law of Conservation of Energy." This law states that "energy can neither be created nor destroyed," and that therefore "the total amount of energy in the universe remains constant."

TRANSFER OF ENERGY

Energy can be transferred, or moved from one point to another, in various ways. The most common way is through some kind of connection, or contact. As in Figure 3-4, when you hit a golf ball with a club, mechanical energy from the club is transferred to the ball at impact and this energy becomes kinetic energy of the ball in motion. Similarly, the mechanical energy from an automobile engine is transferred to the wheels through a series of gears and other mechanical connections. Electrical energy, also, flows from one point to another through various conductors and connectors.

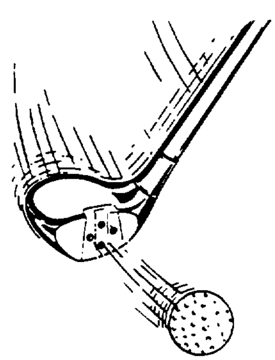


Figure 3-4. Example of Mechanical Energy Transfer

Another, and completely different, method of transferring energy is by means of radiation. There is no contact or connection whatsoever, from the source of radiation, but there is a definite transfer of energy. Radiation, as shown in Figure 3-5, is the means in which we get energy from the sun, the source of all energy on the earth.

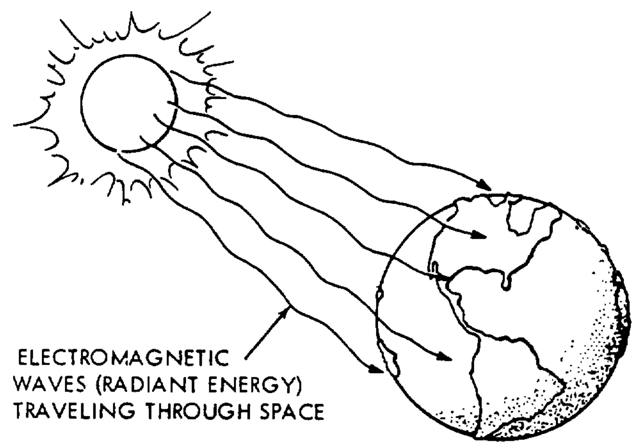


Figure 3-5. Radiation Energy Transfer

GENERATION OF HEAT

In home heating systems, heat is generated through conversion of either chemical energy or electrical energy — that is, through the burning of fuel or through the flow of electricity through a resistor, as indicated in Figure 3-6.

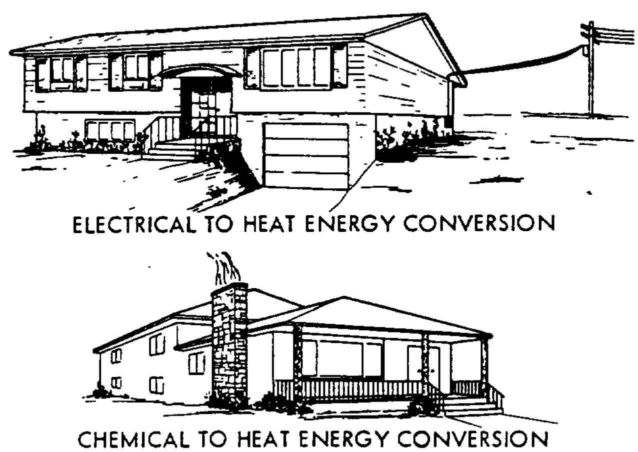


Figure 3-6. Chemical-to-Heat and Electrical-to-Heat Energy Conversion

Of the two, the conversion of electricity into heat is far more efficient. In fact, it is the only perfect energy conversion man can make because there are no intermediate steps — it is a direct conversion. There are no moving parts to cause friction and no fuel combustion to be incomplete.

When fuel oil is burned to produce heat, the conversion is approximately 60% efficient. The conversion of gas to usable heat is at an efficiency of approximately 67%. However, the direct conversion of electrical energy to heat is 100% efficient. Because of its efficiency, electricity is frequently called the "perfect" fuel.

Of course, if the entire conversion process of electricity to heat were considered on the basis that electricity is derived from the chemical energy of the burning of coal or the mechanical energy of moving water, the conversion efficiency would be less than 100%. However, in practical terms, the efficiency of electric heating must be based on the "electrical fuel" consumed.

HOW HEAT IS TRANSFERRED

Heat travels in three ways – by conduction, convection, and radiation. It may travel by one, two, or all of these methods at the same time.

Conduction

Conduction of heat is its transfer through physical matter. When one end of a metal rod is heated, as in Figure 3-7, the other end becomes hot because the heat is conducted through the rod. Similarly, when the heated rod is held against another object, that object becomes hot because of conduction.

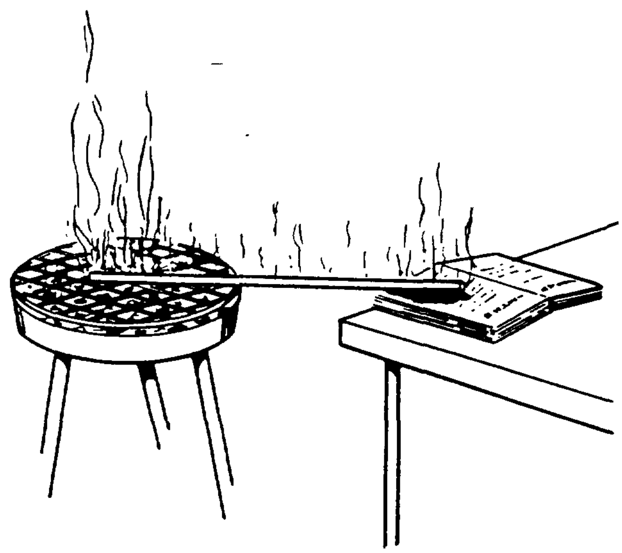


Figure 3-7. Heat Transfer by Conduction

Convection

Convection is the transfer of heat by actual movement of the heated material and applies to liquids and gasses. Motion of the material is caused by density changes that accompany the heating process. An interesting fact to remember is that heat transfer by convection cannot occur alone. Convection must always be preceded by another heat transfer process such as conduction. For example, water in a tea kettle, Figure 3-8, is heated by convection and conduction. The kettle is heated by conduction. Then the kettle conducts heat to the water in contact with it. The heated water decreases in density (becomes lighter) and moves upward to provide heat transfer by convection.

Figure 3-8. Heat Transfer by Convection

Radiation

Radiation of heat is heat transfer through space by rays or waves. The sun radiates electromagnetic energy. That is, the sun sends out rays, or waves, which travel through space and bring energy of various kinds to the earth and other planets. This radiant energy covers a complete range, or spectrum, of closely related kinds of energy. Some of it is visible light, some of it infra-red and ultra-violet, some heat, some cosmic rays, some X-rays, and so on.

Radiant heat, like light, travels in straight lines. Like light, it is transmitted almost instantaneously.

The waves from the sun go out in all directions and continue in a straight line until they hit some object which obstructs them. Then the energy waves are either absorbed by the object or reflected from it in a straight line. The most important characteristic of radiant energy from the sun is that it transfers heat many millions of miles without any kind of contact or connection.

Radiant heat does not appreciably warm the air through which it passes. Only the objects which receive radiant energy get warm. This is well exemplified by the heat we get from the sun, Figure 3-9, which can melt snow even when the air temperature is very cold. The atmosphere away from the earth is very cold because there is nothing solid for the radiant heat from the sun to warm. Near the earth, however, the air is heated because of the water vapor and dust particles (solids) which partially absorb radiant energy.

As a matter of convenience, heat units are based on the change of temperature of definite quantities of water. The quantity of heat required to produce a given rise of temperature is directly proportional to the amount of water heated and may be expressed as:

QUANTITY OF HEAT (BTU) = UNIT OF WATER x TEMPERATURE CHANGE

Thus, it would take twice as much heat to raise a given amount of water through, say 100 degrees than it would through 50 degrees.

The unit generally used for measuring heat production or heat loss is the British Thermal Unit, or Btu. A Btu is defined as the amount of heat required to raise the temperature of one pound of water, at 60° Fahrenheit, one degree Fahrenheit.

Terms such as cold, cool, warm, and hot are common in everyday speech to indicate the temperature of something. But, these terms are not specific enough and have led to the adoption of certain thermometric scales, Figure 3-11. These scales are set up using two standard, easily reproduced, temperatures. The reference temperatures chosen are the melting point of ice and the boiling point of water, both at standard atmospheric pressure of 76 centimeters (29.92 inches) of mercury.

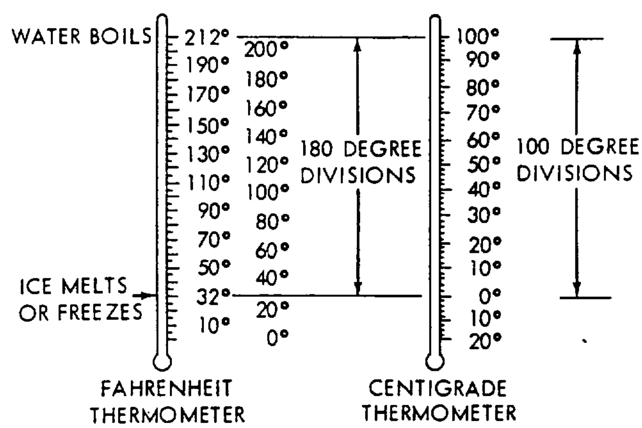


Figure 3-11. Heat Measuring Instruments

The most important temperature systems are the Fahrenheit scale, which establishes $212^{\circ}F$ as the boiling point of water and $32^{\circ}F$ as the melting point of ice, and the Centigrade scale, which has a $0^{\circ}C$ melting point and $100^{\circ}C$ as the boiling point.

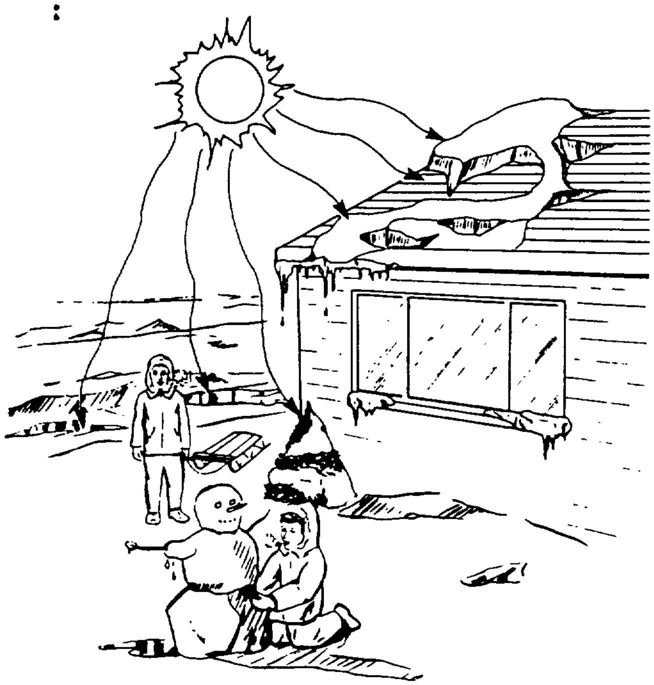


Figure 3-9. Heat Transfer by Radiation

On earth, too, heat is transferred by radiation. As shown in Figure 3-10, we get heat from a campfire by radiation. The human body is also a source of heat which can be emitted or radiated.

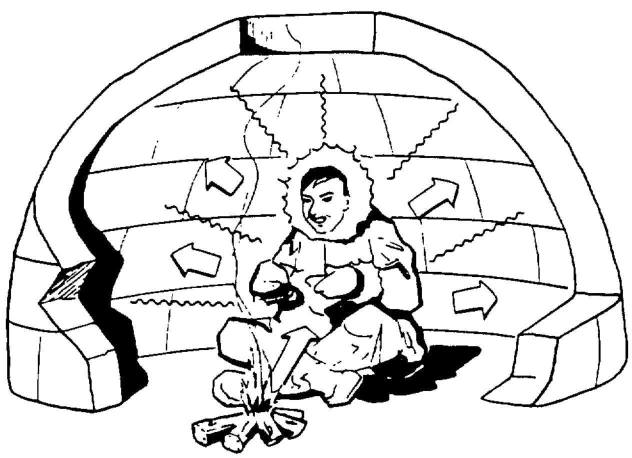


Figure 3-10. Emission of Radiant Heat by The Human Body

HEAT AND TEMPERATURE

Heat is a form of energy. When heat is applied to an object it raises the energy level and causes an increase in "temperature." Temperature is a term used to express how cold or how hot an object is; cold implies a low temperature and hot a high temperature.

MAINTAINING THE HEAT BALANCE

People

Human beings are heat-producing machines. We convert food energy by a metabolic process into heat energy. Even when we're idle, our "motors" are running and are producing heat. To stay comfortable (and alive) we have to continuously throw off body heat.

Normally, this is easy. As shown in Figure 3-12, our bodies are at about 98.6°F, the temperature around us is at about 70°F. Since heat always travels from points of higher temperature to points of lower temperature, the body can lose heat and presumably be comfortable.

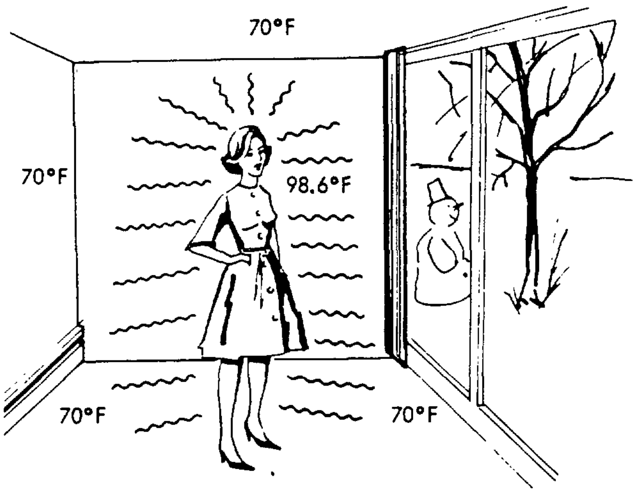


Figure 3-12. Transfer of Body Heat

When the temperature about us gets too cold, however, our bodies throw off heat too rapidly, and we become uncomfortable. That's why we need heating systems for our homes in winter — not to heat our bodies, but to keep them from losing heat too rapidly. The proper clothing (Figure 3-13) is also vital to control heat loss from our bodies — not too fast — and not too slow — if comfort is the goal.

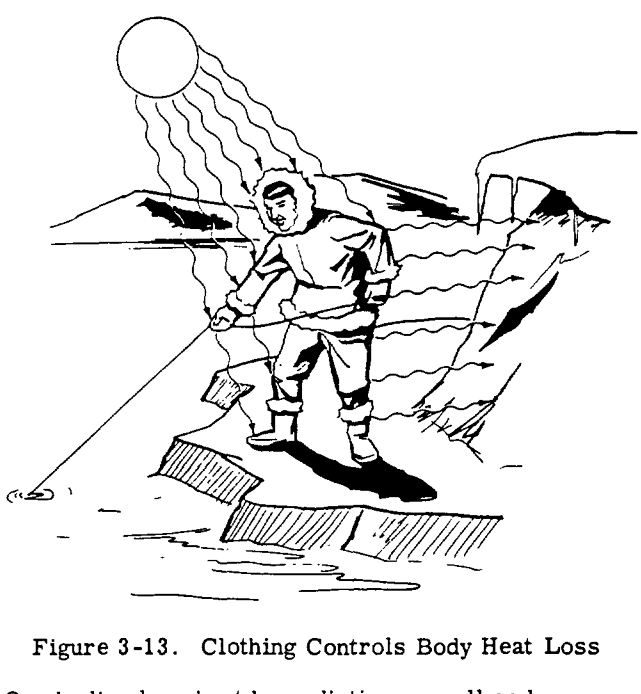


Figure 3-13. Clothing Controls Body Heat Loss

Our bodies lose heat by radiation as well as by convection and evaporation. In fact, an average adult under comfortable indoor conditions will lose about 400 Btu per hour — 100 Btu by evaporation, 150 Btu by convection, and 150 Btu by radiation.

Just having the right air temperature in a room is not enough to assure us of comfort if the room heat is not properly balanced. For example, Figure 3-14 illustrates a room which has a source of heat on one side and a big picture window on the other. Let's assume that the room has a heat source hot enough to bring the air temperature in the room to an average 70°F. A person near the picture window can be extremely uncomfortable because of convective heat loss to the cooler air and radiant heat loss to the window. Another person, close to the heat source, in the direct path of the heat, can be too hot. As measured by a thermometer, the room is warm enough. As measured by human comfort, it is poorly heated and uncomfortable because of the heat imbalance. Having balanced heat in a house is almost as important as having enough heat.

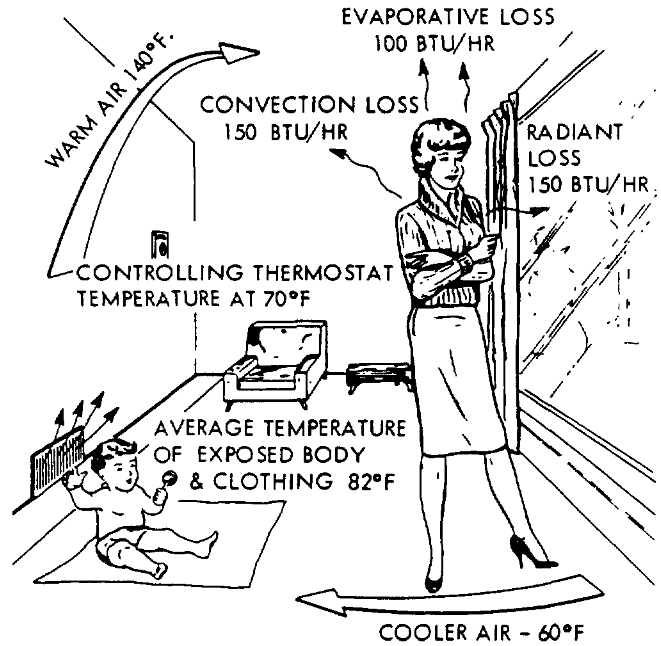


Figure 3-14. Unbalanced Room Heat

Houses

In winter, heated buildings are always losing heat to the atmosphere. To maintain comfort, heating systems must produce just the right amount of heat in the right places to keep the balance of heat input equal to heat loss. Creating and controlling a comfortable environment has not been easy, and man has been experimenting for a long time to find the answer. With fires, fireplaces, and stoves, of course, a person was too hot near the fire and too cold away from it; besides, it took a great deal of work to keep a fire going in each room.

Heat radiating from a fireplace, as shown in Figure 3-15, heats walls and contents of a room unevenly. Air, contacting room surfaces, becomes heated by conduction, then circulates by convection to transfer heat throughout the room.

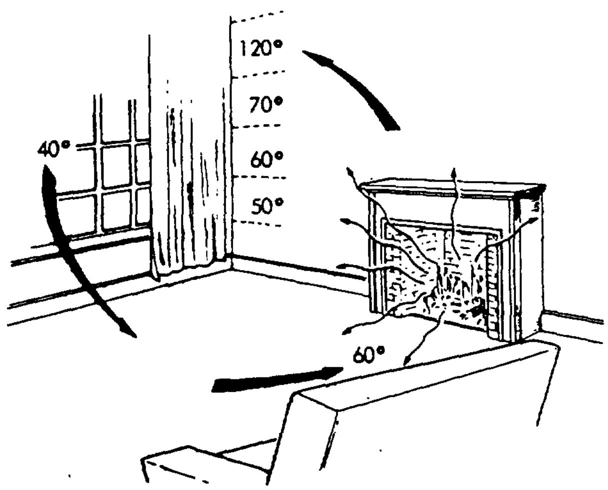


Figure 3-15. Heating With a Fireplace

The advent of central heating systems eliminated the need for many fireplaces (or pot-bellied stoves), and reduced the burning of fuel to a furnace in just one location.

Now, heat could be generated by burning coal, oil, or gas, and transferred with steam, hot water, and warm air. Results obtained are indicated in Figures 3-16 and 3-17.

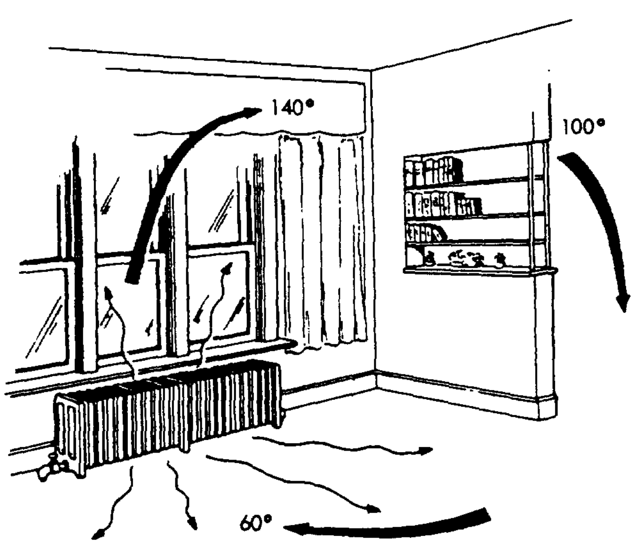


Figure 3-16. Heating With Radiators

Air, by a steam or hot water radiator, is heated by conduction. The warm air expands and rises, transferring heat by convection. As the air circulates, it transfers heat by conduction to walls, windows, and contents of the room and becomes cool again. Heat transfer also occurs by direct radiation from the hot radiator.

Air, heated in a furnace, is circulated by a blower to distribute heat by convection. When the warm air contacts walls, windows, and contents of the room, it heats by conduction. Heat transfer by radiation does not occur in such heating systems.

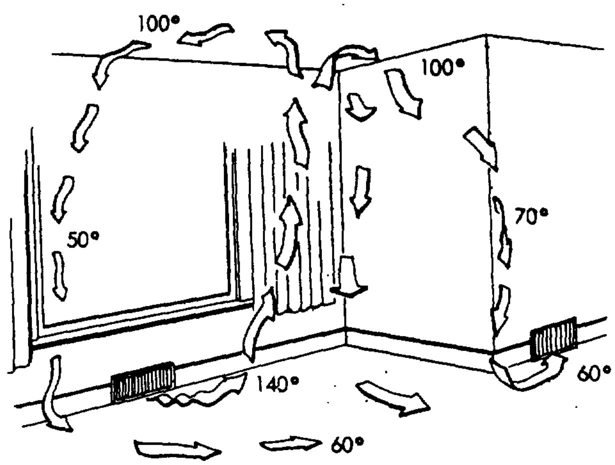


Figure 3-17. Heating With a Forced Warm Air System

The thermostat further improved comfort by providing semi-automatic heat control. This system is based mainly on the constant availability of fuel, with its feed controlled by a single thermostat. Comfort is fairly constant in the general area of the thermostat. Away from it, though, in other parts of the house, maintaining the right temperature is still a real problem with most heating systems.

With all the advances that have been made in heating systems, the problem is still the old one of how to add just the right amount of heat in each room and distribute it so that every part of the room is comfortable.

THERMALUX Electric Heating solves that problem most effectively. THERMALUX Electric Heating provides a thermostat in every room. Therefore each room can be automatically maintained at the temperature most suitable to its occupants and activities, without regard to the comfort level selected for adjacent rooms.

Because THERMALUX Heating Panels heat uniformly throughout, there are no hot spots. As large-area heat sources, THERMALUX Heating Panels do not concentrate heat in one location and cause wide differences of temperature elsewhere. Heat radiates from a THERMALUX ceiling in all directions, as shown in Figure 3-18, like rays of light, reaching and warming every part of the room — floors, walls, furnishings, people. Then, as the walls and floors are warmed, the air next to them are warmed by conduction. This heated air sets up very gentle convection currents which circulate the warmed air imperceptibly. People are completely comfortable.

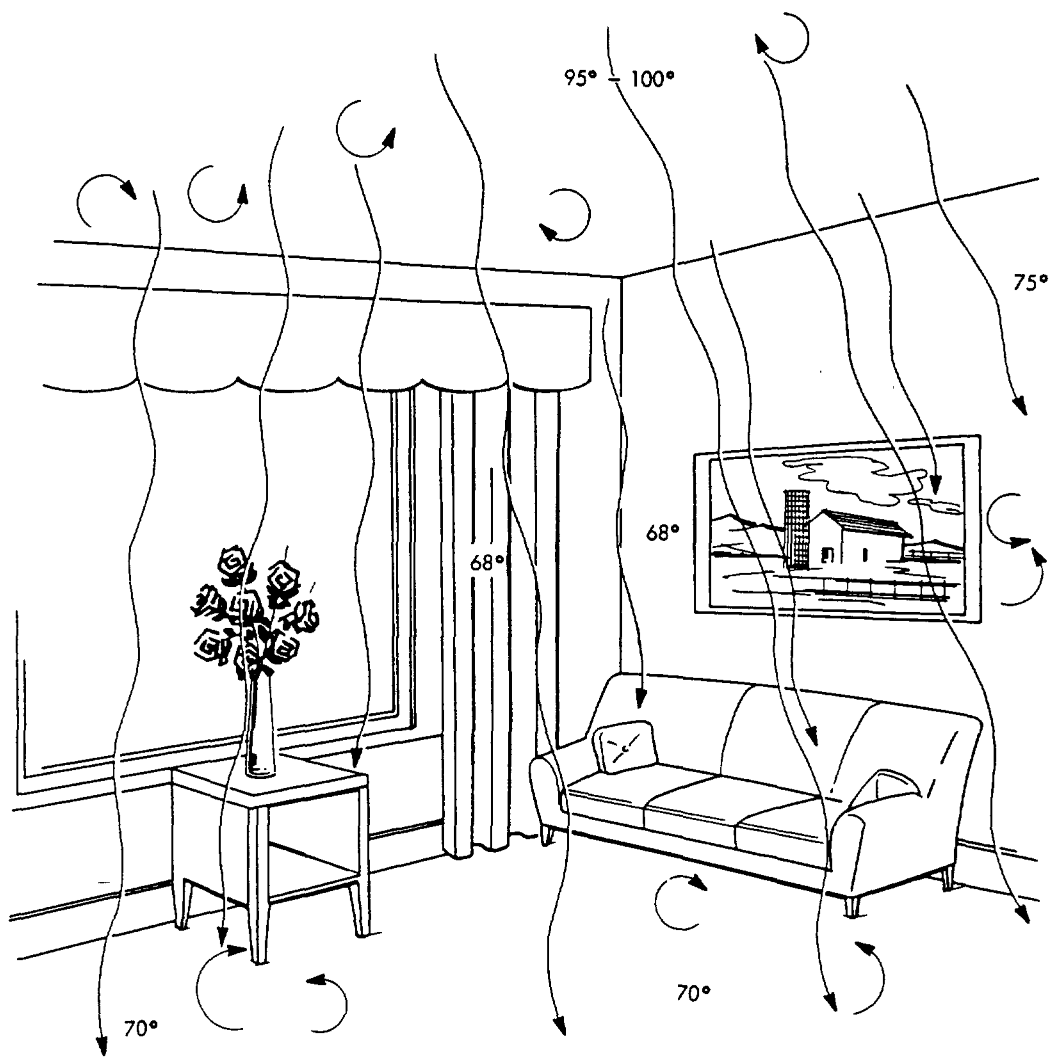


Figure 3-18. Heating With the THERMALUX Electric Radiant Heating System

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CHAPTER 4

FUNDAMENTALS OF ELECTRICITY

THERMALUX Electric Heating is based on the principle that electric current flowing through a resistor produces heat. THERMALUX Heating Panels, illustrated in Figure 4-1, are very large, special, electrical resistors on a gypsum base. The resistor, comprised of a conductive coating and two copper electrodes in an asbestos envelope, functions as a heating element. The gypsum panel serves as an incombustible, electrically non-conductive base for the resistor. When electric power is connected to the Heating Panel electrodes, current flows through the resistor and the entire panel warms uniformly to a temperature of 115°F, or lower.

BASIC ELECTRICAL RELATIONSHIPS

Electric heating is based on the fundamental principles of electricity. The purpose of this chapter is to give the electrical fundamentals that are needed to design a THERMALUX Electric Radiant Heating System.

There are four basic units of electricity. These are: the volt, the ampere (amp), the ohm and the watt.

The Volt

The volt is the electrical unit of force. Just as water pressure is measured in pounds per square inch, electric pressure is measured in volts. House power is normally either 120 volts or 240 volts.

The Ampere

The ampere is the electrical unit of flow. Just as water flow is measured in gallons per minute, the flow of electricity (current) is measured in amperes (amps).

The Ohm

The ohm is the electrical unit of resistance. Just as a water pipe offers resistance to the flow of water, an electrical conductor offers resistance to the flow of current. When a water pipe is made larger, resistance decreases and more water will flow through the pipe with the same water pressure applied. When an electrical conductor is made larger, there is less resistance and more current (amps) will flow through the conductor with the same voltage applied.

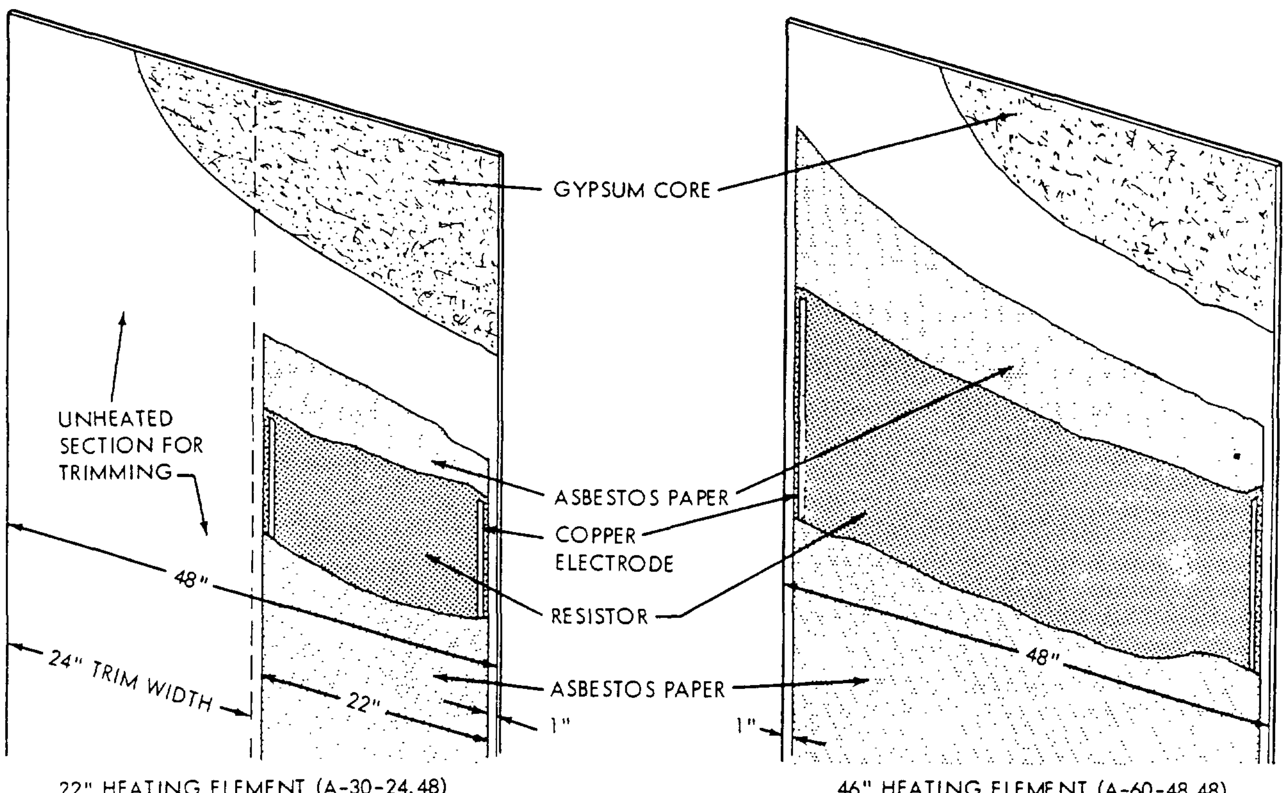

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Figure 4-1. Cutaway View of THERMALUX Heating Panels

The Watt

The watt is the unit of electrical power and expresses the amount of energy the electric system is using.

OHM'S LAW

Ohm's law is the first law of electricity and states that a force of one volt will cause a current of one amp against a resistance of one ohm. Arithmetically this is stated as:

$E = IR$	E = voltage (volts) I = current (amperes) R = resistance (ohms)

The terms of Ohm's law can also be transposed to establish the following relationships:

$$I = \frac{E}{R}$$

$$R = \frac{E}{I}$$

All three formulas say the same thing but in a different form. The formula used depends on what electrical properties are known and what must be calculated.

EXAMPLE:

An electrical resistor rated at 30 ohms is connected into a 120 volt circuit. What is the current flow through the resistor?

$$I = \frac{E}{R} = \frac{120}{30} = 4 \text{ amperes}$$

WATT'S LAW

Watt's law is the second law of electricity and states that a force of one volt causing a current of one amp uses the power of one watt. Arithmetically this is stated as:

$P = EI$	P = power (watts) E = voltage (volts) I = current (amps)

Since, according to Ohm's law, $E = IR$, substitution of like quantities in Watt's basic law give the alternate versions:

$P = I^2R$	(by substituting IR for E)
$P = \frac{E^2}{R}$	(by substituting $\frac{E}{I}$ for R)

Again, all three variations of Watt's formula say the same thing in different form, and the choice of formula depends on what electrical factors are known and what must be determined.

EXAMPLE:

How much power is consumed by the 30 ohm resistor, connected to 120 volts and drawing 4 amperes current?

$$P = EI = 120 \times 4 = 480 \text{ watts}$$

$$P = I^2R = 4 \times 4 \times 30 = 16 \times 30 = 480 \text{ watts}$$

$$P = \frac{E^2}{R} = \frac{120 \times 120}{30} = \frac{14400}{30} = 480 \text{ watts}$$

CURRENT, VOLTAGE, AND POWER IN A PARALLEL CIRCUIT

In the parallel circuit shown in Figure 4-2, resistors R_1, R_2, and R_3 have their terminals joined together at points X and Y. Current divides at point X with part of it going through R_1, part through R_2, and the remainder through R_3. All of the individual currents re-combine at point Y and flow to the positive terminal of the battery. The voltage across each of the three resistors is equal to the potential difference between points X and Y and is equal to the applied voltage of the battery. Therefore, the voltage across each resistor is 120 volts ($E_1 = E_2 = E_3 = 120v$).

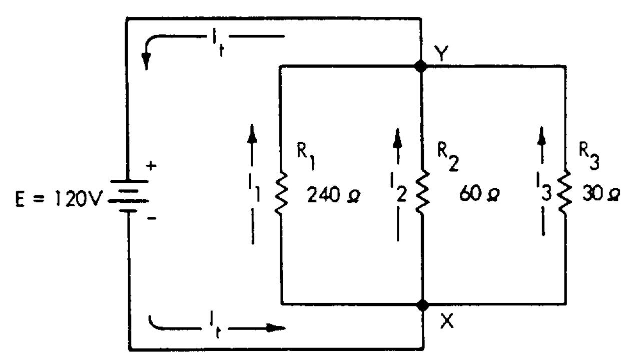

Figure 4-2. Parallel Circuit

To find the total current supplied by the battery to the combination of parallel resistors, first find the current through each individual resistor, and then find the sum of the individual currents. You can readily find the individual currents by Ohm's law ($I = E/R$).

1. Current through R_1 is
$$I_1 = \frac{E_1}{R_1} = \frac{120}{240} = 0.5 \text{ ampere.}$$
2. Current through R_2 is
$$I_2 = \frac{E_2}{R_2} = \frac{120}{60} = 2 \text{ amperes.}$$
3. Current through R_3 is
$$I_3 = \frac{E_3}{R_3} = \frac{120}{30} = 4 \text{ amperes.}$$

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4. The total current, I_t; is

$I_t = I_1 + I_2 + I_3 = 0.5 + 2 + 4 = 6.5$ amperes.

The total power expended by the battery is equal to the sum of the power expended in the individual resistors. This can be found by the power formula, P = EI.

1. Power in R_1 is

$P_1 = E_1 I_1 = 120 \times 0.5 = 60$ watts.

2. Power in R_2 is

$P_2 = E_2 I_2 = 120 \times 2 = 240$ watts.

3. Power in R_3 is

$P_3 = E_3 I_3 = 120 \times 4 = 480$ watts.

4. The total power, P_t; is

$P_t = P_1 + P_2 + P_3 = 60 + 240 + 480 = 780$ watts.

Since the total current is already known, the total power can also be found by

$P_t = E_t I_t = 120 \times 6.5 = 780$ watts.

Application of the schematic representation shown in Figure 4-2 to THERMALUX Heating Panels gives a practical parallel circuit, as indicated in Figure 4-3.

The calculations for Figure 4-2 are still valid here and represent the figures necessary to produce the heat required (P = 15 watts/sq. ft.) with a constant voltage drop of 120 volts across each panel.

For example, the power expended in R_1 is 60 watts. The area (A_1) of Heating Panel is 4 square feet (see Figure 4-3). Therefore, the power per square foot is:

$$P_1/\text{sq.ft.} = \frac{P_1}{A_1} = \frac{60}{4} = 15 \text{ watts/sq.ft.}$$

RESISTANCE IN PARALLEL CIRCUITS

When the total current is known, the total resistance in a parallel circuit may be found by the Ohm's law formula, R = E/I. Thus, the total resistance in the circuits of Figures 4-2 and 4-3 is:

$$R_t = \frac{E_t}{I_t} = \frac{120}{6.5} = 18.46 \text{ ohms.}$$

Note that the total resistance of 18.46 is less than any one of the individual resistors R_1, R_2, and R_3. The resistance of two or more branches in parallel is always less than the resistance of any of the component branches.

When resistors are connected in parallel the total resistance is given by the formula:

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \frac{1}{R_n}$$

When THERMALUX is connected in parallel the total resistance can also be found by using the short cut formula: $R_t = 960/A$; where A is the total area of all the Heating Panels in the circuit.

To summarize, in a parallel circuit, which is the only way THERMALUX Heating Panels can be connected, the voltage to each panel is the same (120 volts), while the current to each panel varies according to the panel resistance. Therefore, the current draw and heat output per square foot of panel area are equal and proportional to area of Heating Panel installed.

SERIES CIRCUIT

The THERMALUX Heating Panels in the circuit of Figure 4-4 are connected in series. When resistances are connected in series they are additive. That is: $R_t = R_1 + R_2 + R_3$. Therefore, the total series resistance is 240 + 60 + 30 = 330 ohms. Power is equal to E^2/R. Therefore, 120 x 120/330 = 14400/330 = 43.33 watts; less than the power expended by the smallest panel when the panels are connected in parallel.

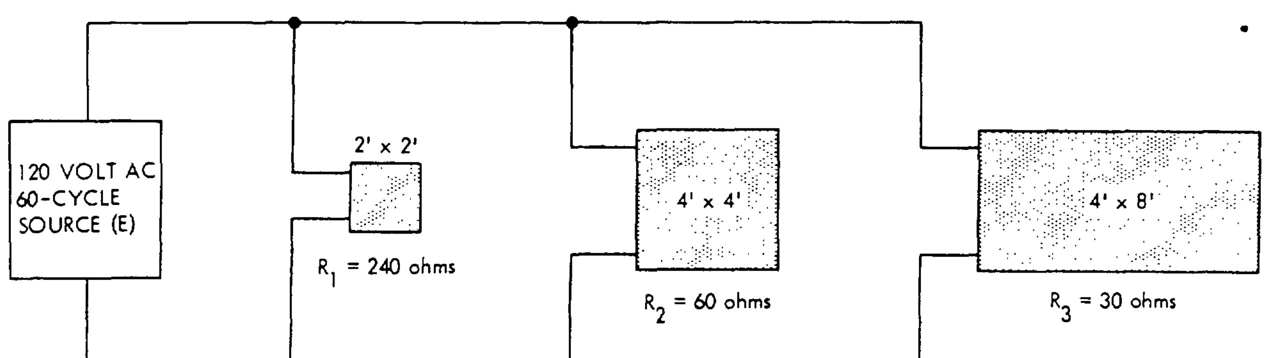

Figure 4-3. Practical Parallel Circuit of THERMALUX Heating Panels

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This shows that when THERMALUX Heating Panels are connected in series the heat output for the circuit is less than the heat output that can be gotten from one panel.

NEVER connect THERMALUX Heating Panels in series.

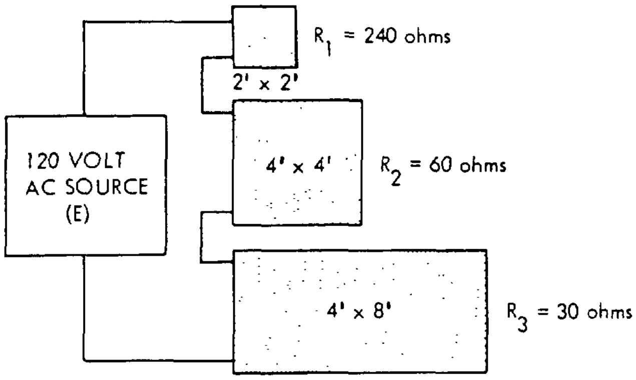

Figure 4-4. Impractical Series Circuit of THERMALUX Heating Panels

POWER DISTRIBUTION

Electric Power Supply

Electric power is supplied to a building from a utility distribution line (pole) by means of a service drop or underground service, as shown in Figure 4-6. The service drop or underground service is installed by the power company in most localities.

The cable or raceway system that brings electric power into the house is called the service entrance. At the service entrance is a power meter which records the number of kilowatt hours of electricity used in the house. The service equipment at the service entrance includes grounding and guarding, a means of overcurrent protection, and a main disconnect device.

The chief item of service equipment is the service box. It generally includes some type of main disconnect device and some kind of overload protection. The main disconnect device is used to turn off the power for the entire electrical system within the house. This may be a switch or a removable fuse block. A set of main fuses provides overload protection for the entire electrical system. The main fuse block may be designed for easy removal; in that case, it serves as the main disconnect device, and no separate disconnect device is required.

Within the service box, power is connected for distribution through the house by means of branch circuits.

One branch circuit, for example, might supply the power for the electric range, several more branch circuits for other appliances and lights in the kitchen, and other branch supplying power for the lights and convenience outlets in other rooms. There are also branch circuits for the THERMALUX Heating Panels in each room.

A separate overload protector (fuse or circuit-breaker) is provided for each branch circuit. Generally, these overload protectors are also contained in the common service box. Each branch circuit breaker is rated to handle the load current of its associated branch circuit. If the load current does not equal a standard breaker rating, the breaker used must have the next higher standard rating. (For example, an 18-ampere load would require a 20-ampere breaker.)

The service-drop, service-entrance, and main-fuse ratings are determined by the total load demand. "Load demand" is not the sum of all individual load currents, but is based on a "demand factor" which represents the percentage of all loads that are likely to be turned on simultaneously (This may make the main fuse ratings appear somewhat low at first glance.).

There are two types of branch circuits: 2-wire and 3-wire. The 2-wire branch circuit is used for general purpose loads such as lighting, small appliances and electric heating loads which require relatively little current. Where large amounts of current are required, such as an electric kitchen range or an electric heating system, heavier wire is needed. A 3-wire branch circuit has the advantage of requiring less wire. Therefore, it is less costly than its equivalent using the 2-wire branch circuit method.

THERMALUX Heating Panels can be connected in two ways: by a 2-wire branch circuit and by a 3-wire branch circuit. Both methods produce the same results within their respective loads (R_t's). Note, in Figure 4-5, however, that two 2-wire branch circuits (4 wires) are required as compared to one 3-wire branch circuit to obtain the same result.

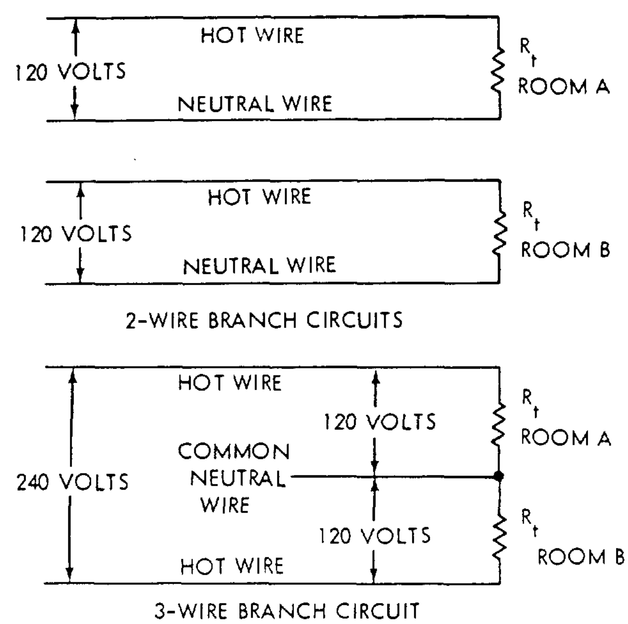

Figure 4-5. Equivalent Connections to the Same Loads By 2-Wire and 3-Wire Methods

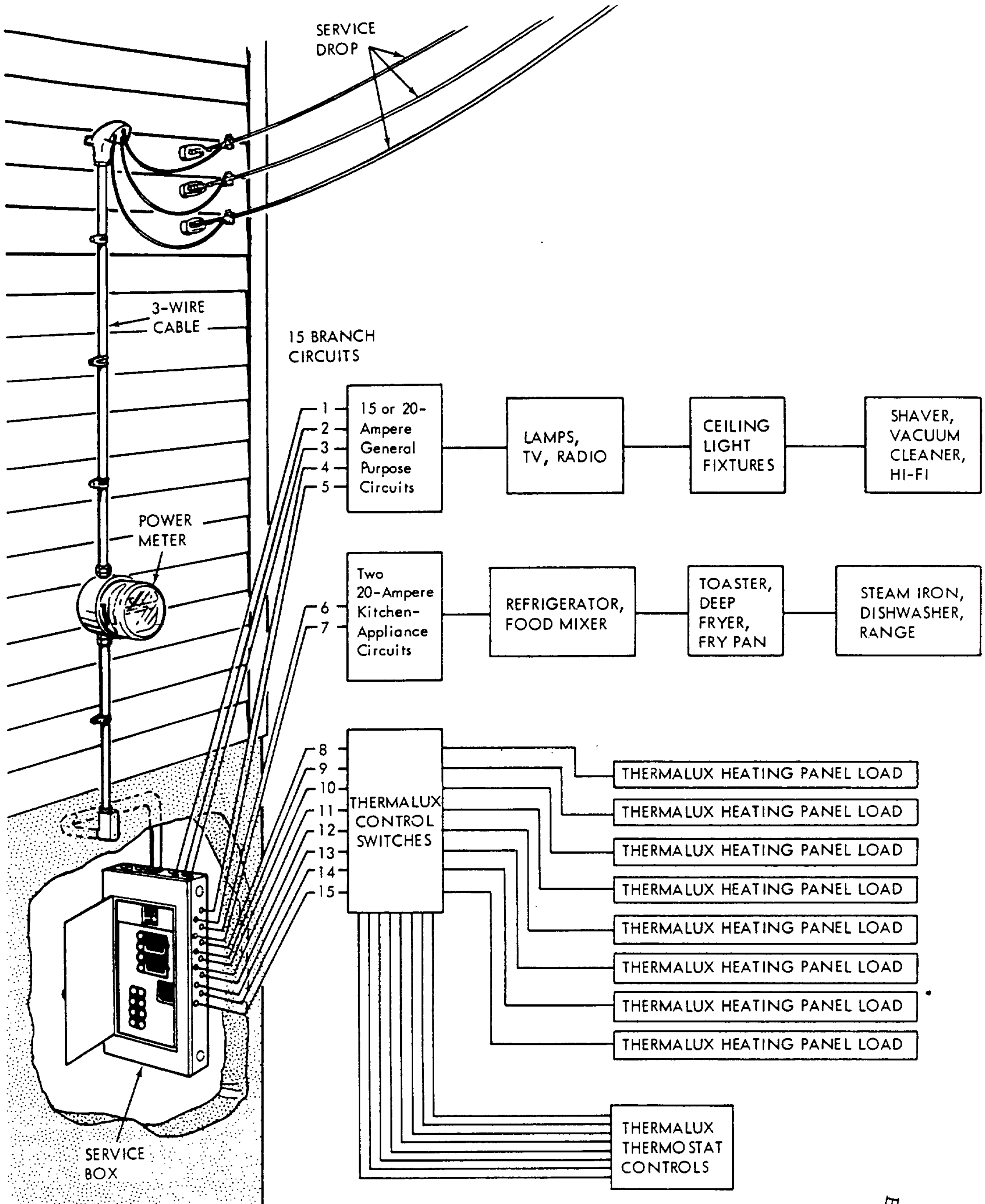

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Figure 4-6. Power Distribution System for a Building

THERMALUX ELECTRICAL PROPERTIES

THERMALUX Heating Panels are designed for connection to 120 volt AC-DC power circuits. When power supply is different than 120 volts, determine variation in heat output from Figure 7-3.

The THERMALUX Heating Panels have resistance relationships carefully established at the factory so that current draw and heat output are equal for each square foot of panel area. To determine electrical and heating properties, the 22-inch wide element on A-30-24.48 panel is considered to be 24 inches or fully 2 feet wide. Similarly, for design purposes the 46-inch element on A-60-48.48 is established at 4 feet wide.

Current used by THERMALUX Heat Panels is as follows:

CURRENT

Panels draw 0.125 amps (1/8 amp) per square foot of element area.

The A-30-24.48 panel draws 0.25 amps (1/4 amp) per lineal foot.

The A-60-48.48 panel draws 0.50 amps (1/2 amp) per lineal foot.

The current used by each type panel is printed on the heating elements.

Power used and Heat Output by THERMALUX Heating Panels is as follows:

POWER

Panels use 15 watts of power and produce 15 watts of heat energy per square foot of element area.

The A-30-24.48 panel produces 30 watts of heat per lineal foot.

The A-60-48.48 panel produces 60 watts of heat per lineal foot.

The power consumption and heat production of each type panel is printed on the heating elements.

Determine total heat output of a THERMALUX System by multiplying the square foot area of heating panel by 15 watts. Heat capacity can also be calculated from lineal footage of each type panel installed.

Actually, from the standpoint of designing and installing THERMALUX Heating Systems it is only necessary to know current requirements and heat output of the Panels. However, it is sometimes useful to know the installed resistance of Heating Panels. This can be quickly and simply determined from the following equation:

$$R = \frac{960}{A}$$

R = resistance (ohms)
A = area of heating element (square feet)

EXAMPLE:

A standard 12 foot THERMALUX Panel A-30-24.48 must be reduced to an 8 foot length for installation. What is resistance of installed part?

Area (installed part) = 8 x 2 = 16

$$R = \frac{960}{16} = 60 \text{ ohms}$$

A 12 foot THERMALUX Panel A-60-48.48 is cut into 4 foot and 8 foot pieces. What is resistance of each piece?

Area (4 ft.) = 4 x 4 = 16

$$R_{4\text{ ft.}} = \frac{960}{16} = 60 \text{ ohms}$$

Area (8 ft.) = 4 x 8 = 32

$$R_{8\text{ ft.}} = \frac{960}{32} = 30 \text{ ohms.}$$

THERMALUX BRANCH CIRCUIT

Figure 4-7 schematically illustrates the basic THERMALUX circuit. Branch-circuit power is supplied from the service box to a control relay. The relay unit (actually a line voltage switch), is controlled by a low voltage thermostat to connect or disconnect power to Heating Panels. Power is provided by a heating branch circuit, through a junction box into panel feeder wires. Radiant heat from the Heating Panels operates the thermostat to complete the control system. The junction box is necessary to permit running panel feeder wires (UF cable) into a gypsum enclosure (wiring recess) where they are connected to the Heating Panel electrodes with THERMALUX Electrode Connectors. The panel feeders enter the wiring recess through a specially designed type of bushing (THERMALUX Bushing).

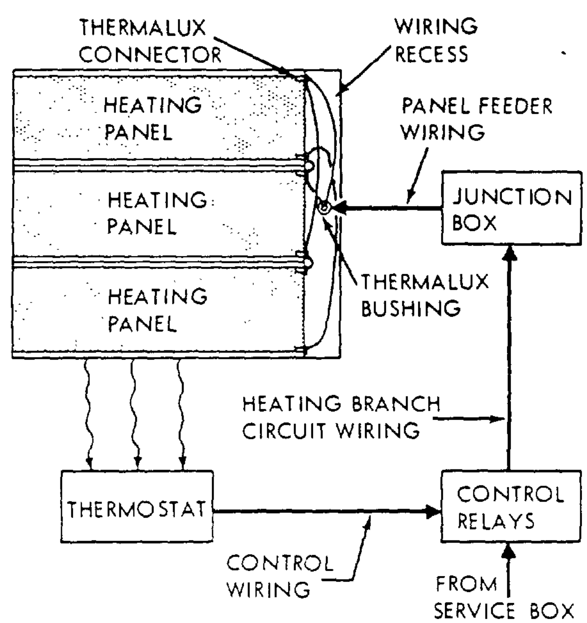

Figure 4-7. Basic THERMALUX Branch Circuit

THERMALUX CONTROL CIRCUIT

The thermostat functions as a temperature-sensitive or automatic switch. It turns on the power to the Heating Panels when the room temperature drops below its setting and turns off the power when the room temperature reaches the set value. The THERMALUX system uses low voltage switching for safety, economy and optimum comfort control.

Low-voltage switching requires a low-voltage thermostat and a control relay, as illustrated in Figure 4-7. The thermostat controls the low-voltage relay which in turn controls power to Heating Panels through a line voltage switch. The transformer reduces the line voltage to a low voltage to operate the relay. Two types of control relays are available: a single and a double. The single type has one line voltage switch, as shown in Figure 4-8, which can handle a maximum load current of 22 amperes. The double type has two line voltage switches, each rated for 22 amperes (max.), and can be wired for control by either one or two thermostats.

Complete directions for installing THERMALUX Thermostats and Control Relays are available in separate data sheets.

ELECTRICAL CODE REQUIREMENTS

The electrical code, adopted by each local government is the specification that must be followed for all types of electric wiring and apparatus. Generally, local electrical codes are the National Electrical Code, which is a standard of the National Board of Fire Underwriters. (It is important to realize that the National Electrical Code is only advisory until adopted by a government body. Then it becomes regulatory.) However, some local codes modify or prohibit some practices permitted by the NEC. For example, a local code may adopt the NEC but prohibit the use of knob-and-tube wiring, non-metallic sheathed cable, and armored cable for new work.

The sections of the 1962 National Electrical Code which apply to installations of the THERMALUX Electric Radiant Heating System are referenced in this chapter. The following are the general sections:

1. The index in the National Electrical Code is a complete alphabetical listing by subject. The NEC has many sections which are interrelated but not necessarily cross-indexed. Therefore, it is important to be familiar with the entire code.

2. Article 90 of the National Electrical Code is a short introduction that outlines the purpose and content of the code. The basic purpose is that of "safety" — not specification or restriction upon the use of particular products. THERMALUX has been deemed safe by extensive Underwriters Laboratories testing. A U/L listing is given only to products that can be installed in conformance with NEC requirements. THERMALUX is listed by U/L.

3. Article 100 is a definition of terms and their use. It is important to know the terms to understand the code.

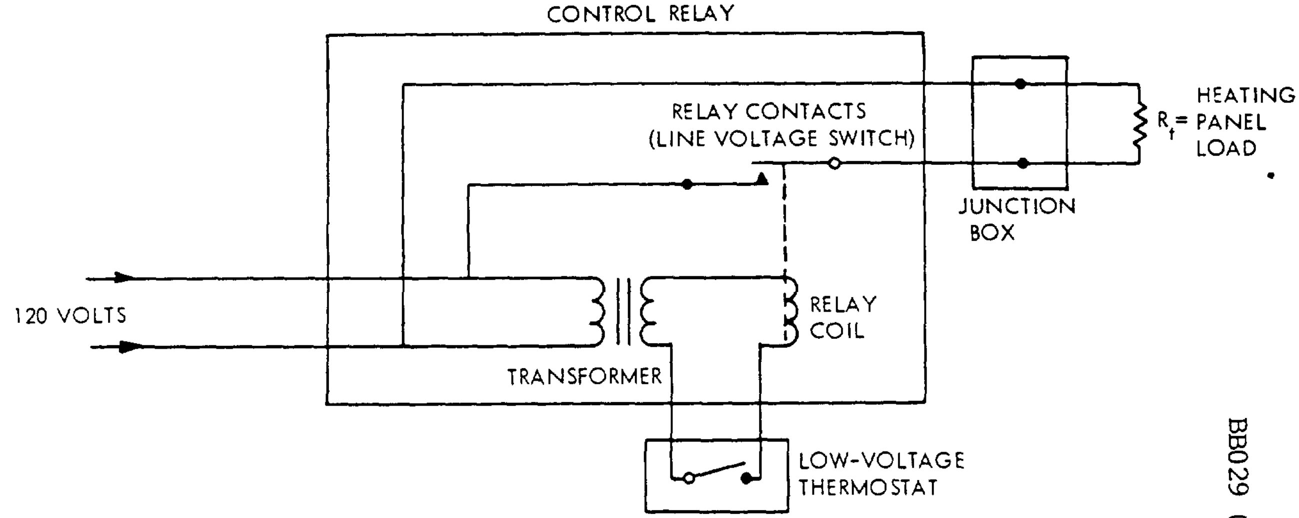

Figure 4-8. Low-Voltage Thermostat Circuit

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4. Article 110 describes general wiring methods and procedures.

Electric Power Supply

The complete electrical service (service drop, underground service, service entrance, and service equipment) is covered by Article 230 of the National Electrical Code.

Service Drop

The service drop is covered in Article 230-C.

Underground Service

This type of service is covered in Article 230-D.

Service Entrance

The service entrance (conductors, cables, raceways, and fittings) is covered by Articles 230-E and 230-F of the National Electrical Code. The size of service-entrance conductors is determined in accordance with Article 230-41 and the calculations in Article 220. An unusual installation may require feeder conductors and the added consideration of voltage drop as covered by Article 215-3.

Service Equipment

Service equipment is covered by Articles 230-G, 230-H, 230-J, and 230-K. Article 230-G gives general information. Grounding and guarding is covered by Articles 230-H and 250. Article 230-J covers disconnecting means. Article 230-K and Article 240 cover overcurrent protection.

Load Demand

The methods of calculating load demand are given in Article 220 of the National Electrical Code.

THERMALUX Electrical Circuits

By examining the functional block diagram of one THERMALUX branch circuit, as shown in Figure 4-7, one may understand the complete system operation since all THERMALUX branch circuits operate in the same basic manner. Branch circuit power is supplied from the circuit breaker or fuse in the service box to the control relay by conventional wiring. Power from the control relay to the junction box is also carried by conventional branch circuits. Up to the junction box, any wiring that meets local code requirements for all other branch circuits is satisfactory for THERMALUX branch circuits. Figure 4-9 illustrates some of the types of wiring that may be used.

Only the wiring from the junction box to the THERMALUX Heating Panels is a special requirement designed to meet the needs of the THERMALUX System. Type UF cable (single conductor) is used for this purpose. For clear reference, the wires in this part of the branch circuit (the Type UF cable from junction box to Heating Panel) are called panel feeders in this Handbook.

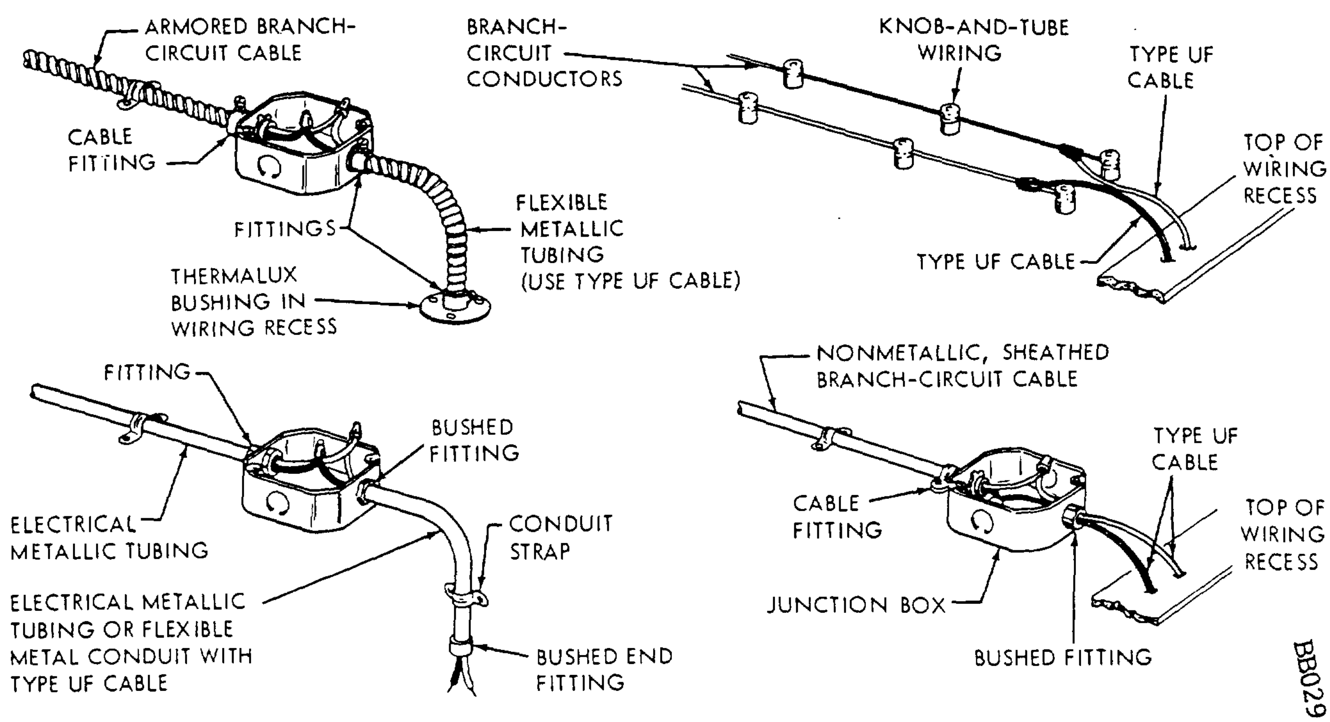

Figure 4-9. Acceptable Methods of THERMALUX Branch-Circuit Wiring

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The only other special provision is that panel feeder connections to the Heating Panels must be surrounded on all sides with incombustible electrically non-conductive material when the ceiling is completed. To meet these requirements, the THERMALUX Electric Heating System uses wiring recesses in the ceiling. Ends of Heating or Filler Panels forming the sides of the recess and Filler Panel forms the top and ends of the recess. The wiring recess provides clearance for the panel feeders and their connection to the Heating Panels. The bottom is open so that the wiring can be completed, tested, and inspected. After the electrical installation has been approved, the final layer of Finish Panels is bonded to the Heating Panels. These form the bottom of the wiring recess and complete the enclosed, continuous recess of non-conductive, non-combustible gypsum.

From the junction box to the point of its entry into the wiring recess, Type UF cable may be used alone or carried in metal conduit, as specified by the local electrical code. The entry of the Type UF cable into the wiring recess may be through a THERMALUX Bushing, bushed end fitting, or simply through a hole in the gypsum panel. The method used must comply with the local electrical code.

Control Circuits

THERMALUX control circuits must comply with the requirements for class 2 control circuits as specified in Article 725 of the National Electrical Code. Design and installation are conventional.

Branch Circuits

Branch circuits are covered in general by Article 210 and 300 of the National Electrical Code. Specific types of wiring using non-metallic cable, thin wall conduit (EMT) and flexible metal conduit are covered in Articles 318 through 356 of the National Electrical Code. The size of conductors used is specified by the code (Article 310-12), depending on the amount of current they may have to carry. However, if a circuit has to carry current for long periods, it is derated by reducing the current-carrying capacity of the conductors. Conductors used in THERMALUX branch circuits and direct Heating Panel connections must be derated 20% in current-carrying capacity in conformance with Article 210-23(b). This is required since the THERMALUX System may be operating continuously for a number of hours during very cold weather.

Branch circuit conductors for THERMALUX Systems conform with Articles 422-42 and 422-47 of the NEC. In most cases, careful system design and installation will avoid the need for derating because of temperature.

By Article 370-19 of the National Electrical Code, junction boxes must be accessible after all construction and decorating have been completed, and connections in the junction box must be available for inspection at any time, by removal of the junction box cover plate. This Code provision applies to the THERMALUX System as the UF cables must be run from the connector clips back to an accessible junction box. However, Article 370-19 is not applicable to the electrode connectors made in the field since those connections are accessible for inspection before the Finish Panel is applied.

THERMALUX Heating Panels

Article 422 of the National Electrical Code covers appliances, and many sections of this article apply to THERMALUX Heating Panels, which are considered "fixed appliances", in the application of the code. Article 422-E specifically deals with fixed electrical space heating.

However, Article 422-43 of the National Electrical Code, which prohibits the cutting of panels and cables, does NOT apply to THERMALUX Heating Panels. This restrictive article was made necessary by the design of ceiling cable, and other electric heating elements, in order to limit their power density and avoid possible danger from elevated operating temperatures which result from varying manufactured size. Chapter 6 describes the methods in which THERMALUX Heating Panels may be cut.

THERMALUX SYSTEM DESIGN

The design of a THERMALUX heating system is based on the same fundamental principles of heat transfer used to plan any high quality heating installation. Generally, what must be done is to determine heat loss from the building, then design a THERMALUX System to replace the lost heat wherever and whenever it is needed.

HEAT LOSS

Heat may be lost from a building in two ways; by transmission heat loss and by infiltration heat loss. Each is described below.

Transmission Heat Loss

The heat loss that results from the flow of heat through the building materials is called the transmission heat loss. As shown in Figure 5-1, each material used in a building section, such as a wall, transmits heat. However, each material does so in different amounts because of its inherent "resistance" to heat transmission. The more resistance, the less heat lost.

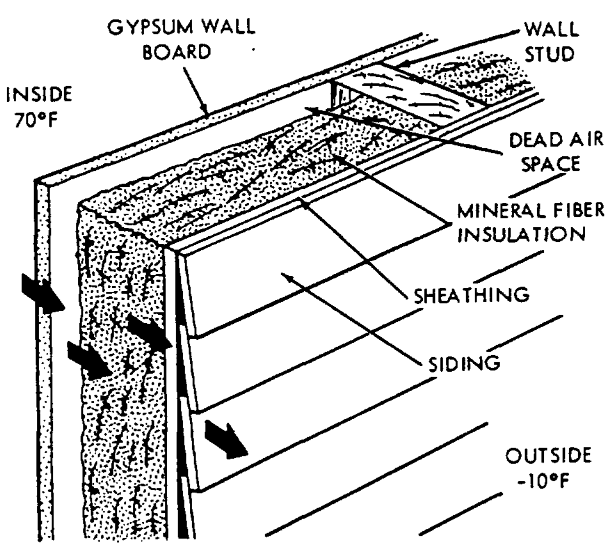

Figure 5-1. Transmission Heat Losses through Building Materials

The amount of transmission heat loss depends on three factors:

1. How well (or poorly) the building materials conduct heat.

2. How much area is exposed to the cold.

3. The difference between the inside and outside temperatures.

This relationship may be stated as:

$$HL_{trans} = W \times A \times TD$$

where

HL_{trans} = Transmission Heat Loss (watts)

W = Coefficient of Heat Transmission for Building Section (watts per square foot of surface area per degree of TD)

A = Surface Area (square feet)

TD = Temperature Difference (degrees F.)

Infiltration Heat Loss

The heat loss that results from direct exchange of cold outside air with the warm air in the house is called the infiltration heat loss. When windows or doors are opened, the warmer air rushes to the outside, and is replaced by colder air. Or the cold air may be forced in by the wind (Figure 5-2), through cracks around doors and windows, and through minute openings in the structure itself.

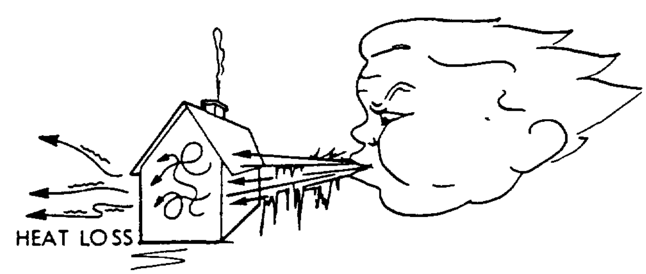

Figure 5-2. Heat Loss by Cold Air Infiltration

The amount of infiltration heat loss depends on four factors:

1. The coefficient of infiltration heat loss (specific heat of air).

2. The cubic volume of the room.

3. The number of times the air in the room changes per hour.

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4. The difference between the inside and the outside temperature.

This relationship may be stated as:

$$HL_{infil} = 0.0053 \times V \times CH \times TD$$

where

HL_{infil} = Infiltration Heat Loss (watts)

0.0053 = Coefficient of Infiltration Heat Loss (watts per cubic foot of air per degree TD)

V = Total Volume (cubic feet)

CH = Number of Air Changes (per hour)

TD = Temperature Difference (degrees F.)

HEAT TRANSFER

Since each building material and overall building section transmits different quantities of heat, some measures must be established for the heat transfer relationships.

As a result, the following basic units of heat transfer have been defined:

W This is the overall coefficient of heat transmission for a building section (such as a complete wall, ceiling, floor, etc.). W is a measure of the heat loss in watts which will pass through a one square foot area of the building section for each degree of temperature difference between surfaces.

U This is also an overall coefficient of heat transmission for a building section. U is similiar to W, except that it expresses heat loss in Btu's per hour passing through one square foot of the section per degree temperature difference.

k Thermal conductivity measures the heat transmission characteristics for one inch of a material. It is used only where heat transfer is directly proportional to material thickness. It is expressed as the number of Btu's per hour that will pass through one square foot area per inch of material thickness per degree temperature difference. It can also be stated with watts as the heat unit.

C Thermal conductance measures the heat transmission properties of a material having a specific thickness. It is expressed as the number of Btu's per hour that will be transmitted through one square foot area of the designated material at specified thickness per degree temperature difference. It can also be stated with watts rather than Btu's per hour as the heat unit.

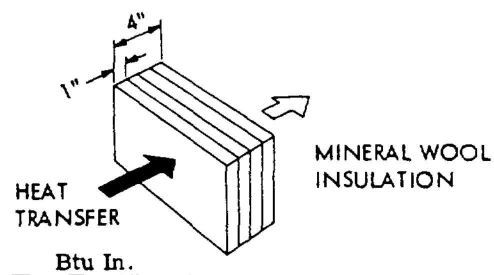
R Thermal resistance is a measure of how poorly a material or a building section transfers heat. (Note: R for a building section is designated as R_T.)

Thus R for a material is equal to the reciprocal of any heat transfer coefficient, and:

$$R = \frac{X}{k} \quad \text{(X = material thickness in inches)}$$

$$R = \frac{1}{C}$$

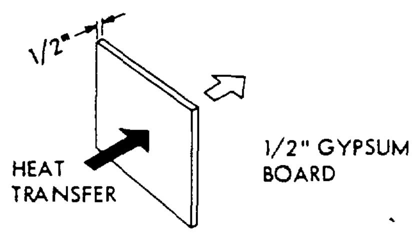
Figure 5-3 illustrates the resistance to heat transfer provided by two common building materials like mineral wool insulation and gypsum board. Note that the mineral wool, which is a good insulator, has a high R, and conversely, that gypsum board, which readily transfers heat, has a low resistance.



$$k = 0.27 \frac{\text{Btu In.}}{\text{Hr. Sq. Ft. } ^{o}\text{F}}$$

X = 4 inches

$$R = \frac{X}{k} = \frac{4}{0.27} = 14.80 \frac{\text{Hr. Sq. Ft. } ^{o}\text{F}}{\text{Btu}}$$



$$C = 2.25 \frac{\text{Btu}}{\text{Hr. Sq. Ft. } ^{o}\text{F}}$$

$$R = \frac{1}{C} = \frac{1}{2.25} = 0.45 \frac{\text{Hr. Sq. Ft. } ^{o}\text{F}}{\text{Btu}}$$

Figure 5-3. Calculating Resistance (R) from Conductivity (k) and Conductance (C)

R_T for a building section is equal to the total resistance of the materials and other heat transfer factors of the building section (such as dead air spaces and air films). Therefore:

$$R_T = R_1 + R_2 + R_3 + \ldots R_N$$

Figure 5-4 shows the resistance to heat transfer provided by a complete wall section. It is interesting to note that four inches of mineral wool insulation (Figure 5-3) provides almost three times more resistance to heat transfer than the complete wall section in Figure 5-4.

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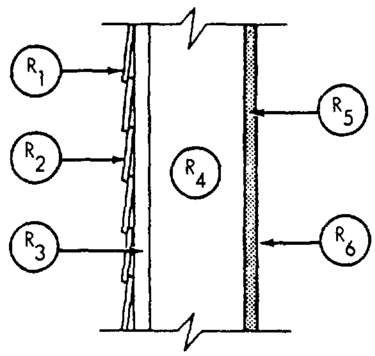


Item	Material	R Value
R_1	Outside air film (15 MPH)	0.17
R_2	Wood siding	0.85
R_3	25/32" insulating sheathing	2.17
R_4	Air space	0.97
R_5	1/2" gypsum board	0.45
R_6	Inside air film (still air)	0.68
R_T		5.29

Figure 5-4. Calculating R_T for a Wall Section

The heat transfer properties, k, C, and R, of most construction materials, air spaces, and air films, are listed in Table 7-2.

Overall Coefficients of Heat Transmission

The relationship between the total resistance (R_T) of a building section, and the overall coefficients of heat transmission is as follows:

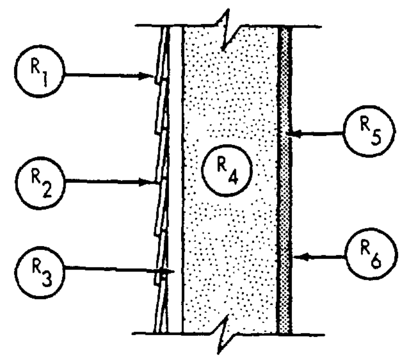
$W = \frac{1}{R_T}$ (when R values are expressed in watts)

$U = \frac{1}{R_T}$ (when R values are expressed in Btu's per hour)

To find the U or W factor for a building section, such as the insulated wall in Figure 5-5, the following steps are necessary. First, find the R value of each element from Table 7-2. Then, add the R's to determine R_T. Finally, calculate U (or W) by dividing R_T into 1.

HEAT ENERGY EQUIVALENTS

For many years, Btu's per hour was the measure for heat loss and heating requirements. However, with the advent of electric heating, it became popular and practical to use the electrical equivalent of Btuh, which is watts.



Item	Material	R Value
R_1	Outside air film (15 MPH)	0.17
R_2	Wood siding	0.85
R_3	25/32" insulating sheathing	2.17
R_4	3-1/2" mineral wool	13.00
R_5	1/2" gypsum board	0.45
R_6	Inside air film (still air)	0.68
R_T		17.32
$U = \frac{1}{R_T}$	Btu/Hr./Sq. Ft./°F	0.06

Figure 5-5. Calculating R_T and U (or W) for a Wall Section

Since 3.413 Btu per hour provides the same amount of heat as 1 watt, the relationships between these heat energy units can be expressed as follows:

Convert Btuh to Watts

$$W = U/3.413 = 0.293U$$

$$K_{watts} = K_{Btuh}/3.413 = 0.293\ K_{Btuh}$$

$$C_{watts} = C_{Btuh}/3.413 = 0.293\ C_{Btuh}$$

$$R_{watts} = 3.413\ R_{Btuh}$$

Convert Watts to Btuh

$$U = 3.413\ W$$

$$K_{Btuh} = 3.413\ K_{watts}$$

$$C_{Btuh} = 3.413\ C_{watts}$$

$$R_{Btuh} = R_{watts}/3.413 = 0.293\ R_{watts}$$

INSULATION

Effective insulation lowers operating costs, improves comfort, and reduces the initial cost of the heating system. The All Weather Comfort Standard of the National Mineral Wool Association has been established as a guide to the minimum amount of insulation to use in electrically heated buildings.

All Weather Comfort Standard

The All Weather Comfort Standard of the Mineral Wool Association stipulates that enough insulation be used to achieve the heat transmission values shown in Table 5-1.

Table 5-1. All Weather Comfort Standards

Building Section	U	R_{Btu}	W	R_{Watts}
Ceilings*	0.05	20.0	0.0147	68.0
Walls	0.07	14.3	0.0223	45.6
Floors over vented crawl spaces	0.07	14.3	0.0223	45.6

*For quality installations, minimum heat loss, and operating economy, ceilings of THERMALUX heated homes should be insulated to R-24 standards. This gives a U of 0.04.

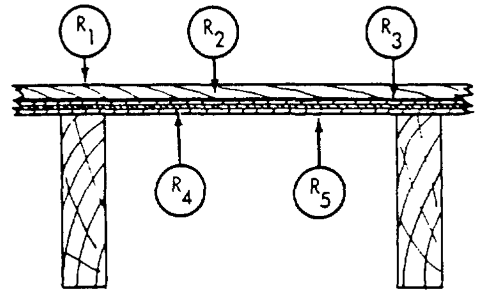
Determining the Required Insulation

In order to determine the amount of thermal insulation required to satisfy the All Weather Comfort Standards, find total R for the uninsulated building section and subtract that from the Standard value of R_T.

For example, Figure 5-6 illustrates a common floor construction before insulation is added. The R values were obtained from Table 7-2, and R_T and U were calculated as explained for wall sections.

Assuming the floor is over a vented crawl space, the All Weather Comfort Standards will be met if enough insulation is added to provide 11 units of resistance. This was determined by subtracting the R of the uninsulated floor (3.36) from the Standard value of R_T (14.3), or 14.3-3.36 = 11.

The same procedures used to calculate insulation required in a floor to meet All Weather Comfort Standards can also be used to determine the amount of (and the R-value for) insulation for walls and ceilings.



Item	Material	R Value
R_1	Air film (still, flow down)	0.92
R_2	13/16" Hardwood	0.68
R_3	Building Paper	0.06
R_4	5/8" Plywood	0.78
R_5	Air film (still, flow down)	0.92
R_T		3.36
$U = \frac{1}{R_T}$	Btu/Hr./Sq.Ft./°F	0.30

Figure 5-6. Determining Amount of Insulation Required

Specifying Insulation

For years the insulation industry had specified insulation according to thickness. Thus, it was very popular to refer to so many inches of insulation in the ceiling, walls, and floors. Even in the early stages of electric heat marketing this was done, and the famous 6-4-2 formula (6 inches in ceilings, 4 inches in wall and 2 inches in floors) became well known.

However, inches is a poor measure of insulation, since different materials have significantly different insulating properties. For example, the k-value of mineral wool is 0.27, and a 3 inch batt has an R of 11. But glass wool, with a k of 0.30 requires a batt 3.33 inches thick to provide 11 units of installed resistance.

In an endeavor to provide an accurate way of specifying insulation, the mineral wool industry has adopted the R value designations for standard products. Accordingly, products are identified by installed resistance values, such as R-11, R-13, R-19, and R-24. All of these basic products meet or exceed the All Weather Comfort Standards when properly installed.

U.S.G. THERMAFIBER mineral wool insulation fulfills all the requirements for effective building insulation. It is available in batt, blanket, or nodular form. It combines the qualities of convenient packaging, ease of installation, low cost, durability, and fire, water, and vermin resistance. THERMAFIBER insulation batts are designated by the "R" value of the installed insulation.

HEAT TRANSMISSION OF WINDOWS AND DOORS

The heat transmission of windows, doors, glass block sections, and skylights is very complicated to determine accurately. Therefore, results have been worked out experimentally for many popular products, then averaged, and the data tabulated as follows.

Windows

Find the coefficient of heat transmission for windows as follows:

Find the W of the glass from Table 5-2.

Table 5-2. W of Vertical Glass Sheets (watts per square foot per ^{o}F)

Air Space	One Sheet	Two Sheets	
	None	1/4"	1/2" or more
Outdoor exposure	0.33	0.18	0.16
Indoor exposure	0.22	0.15	0.13

Now multiply the W of the glass by the correction factor in Table 5-3.

Table 5-3. Correction Factors for Window Framing

Type of Window		Factor		
Sash	% Glass	Single Glass	Double Glass	Window with Storm Sash
Wood	80	0.9	0.95	0.9
Wood	60	0.8	0.85	0.8
Steel	80	1.0	1.20	1.0
Aluminum	80	1.1	1.30	1.1

Example: A single pane window with storm sash covers a wall opening of 4' 3" x 3' 6". The sash is of wood and occupies about 20% of the opening. Then, from Table 5-2, the W value of the glass is 0.16 and, from Table 5-3, the correction factor for a wood sash window (where the glass area is 80%), that has a storm sash, is 0.9. Now 0.9 x 0.16 = the W value of the window. Window heat loss is calculated by basic heat loss formula, HL = W x A x TD.

Skylights

Find the coefficient of heat transmission for skylights as follows:

Find the W of the glass from Table 5-4.

Table 5-4. W of Horizontal Glass Sheets (watts per square foot per ^{o}F)

Air Space	One Sheet	Two Sheets	
	None	1/4"	1/2" or more
Outdoor exposure	0.41	0.20	0.19
Indoor exposure	0.28	0.17	0.16

Now multiply the W of the glass by the appropriate correction factor in Table 5-3 to get W of the skylight.

Hollow Glass Block

The W of wall sections made of hollow glass block is listed in Table 5-5.

Table 5-5. W of Wall Sections of Hollow Glass Block (watts per square foot per ^{o}F)

Size of Block	Outside Wall Section	Inside Wall Section
5-3/4"x5-3/4"x3-7/8" thk	0.18	0.14
7-3/4"x7-3/4"x3-7/8" thk	0.17	0.13
11-3/4"x11-3/4"x3-7/8" thk	0.15	0.12

Doors

The W of solid wood doors is listed in Table 5-6.

Table 5-6. W of Solid Wood Doors (watts per square foot per ^{o}F)

Nominal Thickness	Actual Thickness	Exposed Door	With Glass Storm Door
1"	25/32"	0.19	0.11
1-1/4"	1-1/16"	0.16	0.10
1-1/2"	1-5/16"	0.14	0.09
1-3/4"	1-3/8"	0.14	0.09
2"	1-5/8"	0.13	0.08
2-1/2"	2-1/8"	0.11	0.08
3"	2-5/8"	0.09	0.07

TEMPERATURE DIFFERENCE

Temperature difference (TD) is the difference, in degrees Fahrenheit, between the inside design temperature and the outside design temperature. This can be expressed as:

$$TD = T_{inside} - T_{outside}$$

Calculating Temperature Differences

Assume Inside Design Temperature is 70°F. One house is located in an area where Outside Design Temperature is 10°F, while a similiar house is situated where Outside Design Temperature is 20°F below zero. What are the design TD's for these houses?

Calculate from formula: $TD = T_{inside} - T_{outside}$

House 1: $TD = 70 - 10 = 60^{o}F$

House 2: $TD = 70 - (-20) = 90^{o}F$

Inside Design Temperature

Since the normal inside temperature for homes is 70°, this is the established inside design temperature. However, for bathrooms, an inside design temperature of 75° or 80° should be used.

In areas such as playrooms and workshops, where people are active and generate more body heat, a lower inside design temperature should be used. Similarly, in rooms where machinery or appliances generate heat, for example laundry rooms, an inside design temperature of 60° or 65° may be used.

An even lower inside design temperature should be used for rooms not designed as living areas. The inside design temperature for a heated garage, for example, can be figured at about 35° to 40°.

In most localities, there are generally accepted indoor design temperatures proved out by long experience and used by most heating system designers. These are probably the ones best suited to the area and should be used in THERMALUX System design.

Outside Design Temperature

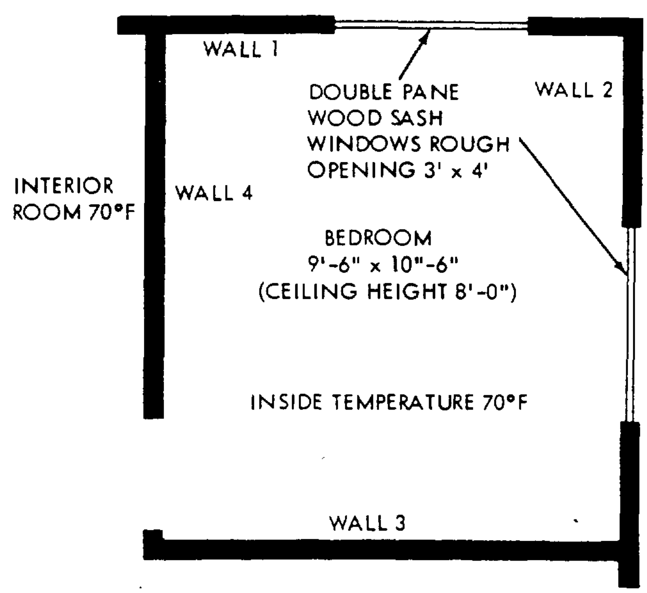
To provide enough heating capacity for severe winters, it is necessary to use the coldest temperature which frequently occurs during a heating season as the outside design temperature. However, it is not necessary to use the coldest temperature ever recorded for the area, for the temperature would rarely drop to that level.

The Outside Design Temperature specified for any area is the result of considerable judgement and experience. These values for selected localities are shown in Table 7-1.

The Isotherm Map of Winter Outdoor Design Temperatures (Figure 7-2) can be used to get approximate data for localities not listed in Table 7-1. Perhaps a better procedure is to check with the nearest Weather Bureau office and local heating authorities to determine the accepted Outside Design Temperature.

FINDING TRANSMISSION HEAT LOSS

All of the factors which are used in typical transmission heat loss calculations have now been considered in this Chapter. Of course, the basis for these calculations is the formula HL = W x A x TD, which Figure 5-7 applies, determining heat loss for a bedroom.



Building Section	W	Area Sq. Ft.	TD	Heat Loss Watts
Wall 1 } Wall 2 }	0.020	136	90	244
Wall 3	-	-	0	0
Wall 4	-	-	0	0
Floor	0.020	100	90	180
Ceiling	0.015	100	90	135
Window 1 } Window 2 }	0.153	24	90	333
Total HL				892

Figure 5-7. Finding Transmission Heat Loss

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Temperature Difference (TD)

Inside design temperature, as shown in Figure 5-7, is 70°F and the outside design temperature is -20°F. Therefore, on exterior walls 1 and 2 TD = 70° - (-20°) = 90°F.

On walls 3 and 4 the TD is 70° - 70° = 0. Thus, there will not be any heat loss through those sections.

Floor and Ceiling Area

Floor and ceiling area, shown in Figure 5-7, is 9' - 6" by 10' - 6", or 9.5 x 10.5 = 99.75 sq. ft. (approximately 100 sq. ft.).

The designed W of the floor is 0.020. Therefore, HL_{trans} = W x A x TD = 0.020 x 100 x 90 = 180.

The ceiling heat loss for the same room would be; HL_{trans} = W x A x TD = 0.015 x 100 x 90 = 135 watts.

Assume the same room has an 8' ceiling. The gross area of exterior walls 1 and 2 is (9.5' + 10.5') x 8' = 160 sq. ft. Deducting window areas of 24 sq. ft. (2 x 3' x 4') leaves 136 sq. ft. (160 - 24) of net area that have W = 0.020. Then, HL_{trans} = W x A x TD = 0.020 x 136 x 90 = 244 watts.

Window Area

The two window openings in Figure 5-7 cover an area of 24 square feet. If each is a double pane window with a wood sash and the two panes of glass are 1/4" apart, the glass covers 60% of the opening. It can be determined from Tables 5-2 and 5-3 that the W-factor for these windows is 0.18 x 0.85 = 0.153. Therefore, HL_{trans} = W x A x TD = 0.153 x 24 x 90 = 333 watts.

Floor Slab Heat Loss

Tests have shown that heat loss through a concrete floor slab at or near grade level can best be figured on the basis of its perimeter. The heat loss varies with the amount of edge insulation and with outside design temperature, as shown in Table 5-7.

Table 5-7. Floor Slab Heat Loss
(watts per lineal ft. exposed slab edge)

Outside Design Temperature	24" Insulation (Horizontal + Vertical)		No Insulation
	2" thick	1" thick	
-20° to -30°	15	17	22
-10° to -20°	13	15	19
0° to -10°	11	13	18
Above 0°	9	11	15

It is recommended that 2" thick edge insulation be used, but a 1" thickness is acceptable. Figure 5-8 illustrates the location of edge insulation around floor slabs.

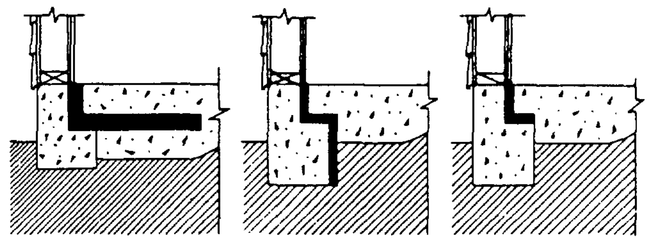


Figure 5-8. Examples of Edge Insulation Around Floor Slabs

Basement Heat Loss

On cold winter days, the temperature of the ground a foot or more below the surface is higher than the outside temperature, as Figure 5-9 illustrates. Therefore, the design heat loss through the part of the basement wall which is more than a foot below grade and through the basement floor is less than that through the higher part of the wall.

In figuring basement heat loss, use the outside design temperature to find the TD for the wall from one foot below grade and up. For the wall below that and for the basement floor, use an outside design temperature equal to well water temperature at depths of 30 to 60 feet. The nearest Weather Bureau office will have the approximate well water temperature for your area, which varies from about 40°F to about 60°F.

Example: A 10" concrete basement wall is 24' long and 7' high, 2' of this above grade. The outside design temperature is -10°F and well water temperature in the area is 50°F. The basement is heated. What is the design heat loss? The W of a 10" concrete wall is 0.37 watts per square foot per °F. For the top 3' of the wall, the design TD is 80 and the area is 72 square feet. For the bottom 4 feet (area 96 sq. ft.) the design TD is (70°F - 50°F.), or 20°F. Therefore, HL_{trans} = 0.37 x 80 x 72 + 0.37 x 20 x 96 = 2110 + 700 = 2810 watts.

Indoor Temperature Differences

In calculating the heat loss for a room, consider the heat loss to other rooms as well as to the outside. In a room over an unheated basement, for example, heat is lost through the floor to the basement. The same is true for a room over a crawl space, and for heat loss through a ceiling into an unheated attic. In a room next to an enclosed garage, there is a heat loss to the garage.

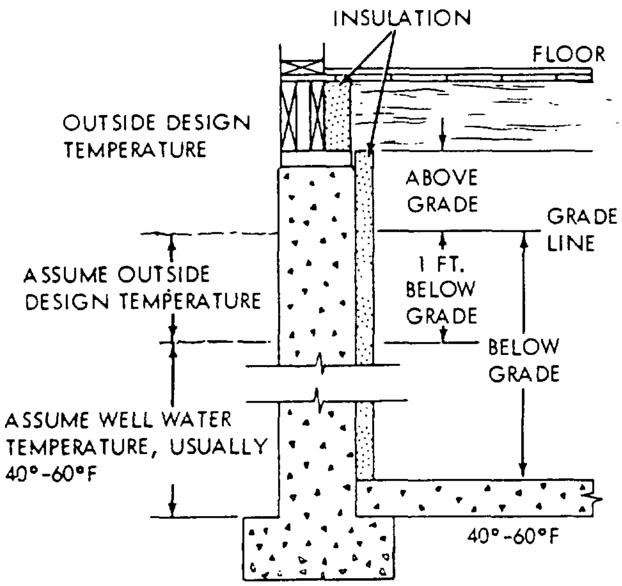


Figure 5-9. Typical Basement Wall Section

In general, unheated rooms and spaces which are enclosed by <u>insulated</u> building sections with about the same W <u>and about</u> the same outdoor exposure as the rest of the house will have a design temperature about half way between the outdoor design temperature and the indoor design temperature for the rest of the house. Figure 5-10 illustrates acceptable indoor temperature differences.

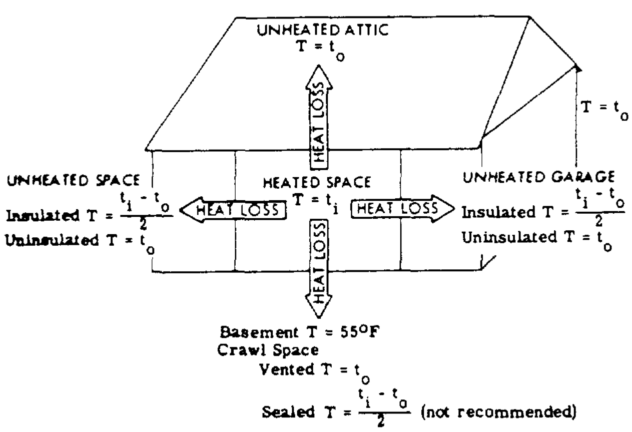


Figure 5-10. Design Temperature Differences

Thus, for a well insulated, 12' x 12' floor with a W factor of 0.02 above a vented crawl space, with 70°F inside temperature and 0°F outside temperature, the heat loss is:

$$HL_{trans} = W \times A \times TD$$

$$HL_{trans} = 0.02 \times 144 \times 70 = 207 \text{ watts.}$$

However, with the same design temperature conditions, the heat loss through an 8' x 24' wall (area = 192 sq. ft.), with a W of 0.0233, into an insulated garage would be:

$$HL_{trans} = 0.0233 \times 192 \times 35 = 155 \text{ watts.}$$

Here again, in any community, there are probably design temperatures widely accepted and used in heating system design. Use these accepted values when making heat loss calculations. In fact, this applies even to outdoor design temperatures. If common local practice is to use a figure somewhat different from that in Figure 5-10 or Table 7-1, use the commonly accepted figure.

FINDING INFILTRATION HEAT LOSS

The total air volume in a room will change completely from 1/2 to 2 times per hour. Each time the air is changed, the new air must be heated from the outside temperature to the inside temperature.

The number of air volume changes depends on many things such as: tightness of construction; insulation; the number, area, and type of windows and doors; and, prevailing wind forces. Usage also makes a big difference. Frequent opening and closing of an outside entrance door to a room will substantially increase infiltration heat loss for that room and adjacent rooms.

As noted earlier in this chapter, the amount of infiltration heat loss depends on these factors:

1. Coefficient of infiltration heat loss.
2. Temperature difference between inside and outside air.
3. Air changes per hour.
4. Volume.

Room Air Changes

The number of air changes per hour (CH) can be estimated by using Table 5-8.

Table 5-8. Room Air Changes Per Hour

Type of Room	Air Changes Per Hour	
	Without Storm Sash on Windows and Doors	With Storm Sash on Windows and Doors
1 side exposed	1	1/2
2 sides exposed	1-1/2	3/4
3 sides exposed	2	1
4 sides exposed	2	1
Entrance Hall	2 to 3	1 to 1-1/2

The infiltration heat loss for the room (Figure 5-7) discussed in transmission heat loss is found as follows.

The size of the room is 100 square feet and the ceiling height is 8 feet. Therefore, the volume is 100 x 8 = 800 cubic feet. The room has two sides exposed and has storm sash. Thus, from Table 5-8, the air changes per hour (CH) = 3/4.

Recalling the formula for infiltration, heat loss for the room is:

$$HL_{infil} = 0.0053 \times V \times CH \times TD$$

$$HL_{infil} = 0.0053 \times 800 \times .75 \times 90 = 286 \text{ watts}$$

FINDING TOTAL HEAT LOSS

The total heat loss for a room is the sum of the transmission heat loss and the infiltration heat loss.

$$HL_{total} = HL_{trans} + HL_{infil}$$

Using the room in Figure 5-7 as an example, total heat loss is 892 + 286, or 1178 watts. Of course, the total heat loss for a building is the sum of heat loss for all rooms and miscellaneous space.

SHORT-CUT METHODS OF FINDING HEAT LOSS

The preceeding parts of this chapter covered the basic ways of calculating heat loss. These methods, derived mathematically and experimentally, are very accurate, proven by years of practice, and are recommended in the "Guide of the American Society of Heating, Refrigerating and Air-Conditioning Engineers".

In addition to the ASHRAE methods for calculating heat loss, there are many other simplified ways that have been devised. The short-cut techniques range from crude, rule-of-thumb approximations up to types such as the THERMALUX Heat Loss Calculator which is very accurate.

An example of the THERMALUX Heat Loss Calculator is located in the back of this chapter. Close examination of this practical, time-saving device will reveal that it is based on the ASHRAE heat loss calculation methods. Actually, what has been done is to "precalculate" the heat loss formulas for most popular constructions, amounts of insulation installed, and for established design temperature differences. By doing the arithmetic calculations in advance, the heat loss data can be presented in handy nomagraph form.

These technical aids are easy to use, and both speed and accuracy will be gained with brief practice.

The Area Calculator

This is used for calculating areas of floors, ceilings, walls, windows, doors, and any other surfaces through which heat will be transmitted.

The calculator is designed with dimensions (in feet) noted across the top and vertically on the left.

Area is determined by reading from the dimension scales to an intersect in the chart. For example, the room in Figure 5-7 had dimensions of 9-1/2' and 10-1/2'. Read across the top of the area calculator to the column headed 9-1/2'. Then read down the left scale to the column headed 10-1/2'. Read out into the calculator to where columns intersect. Note figure 100, which is the floor area in square feet.

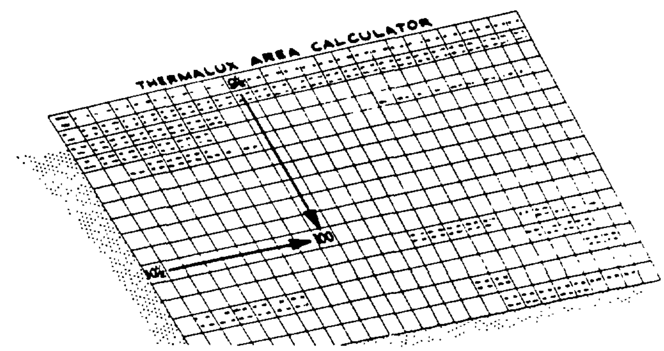


Figure 5-11. Using the Area Calculator

The Volume Calculator

The Volume Calculator is used to determine the number of cubic feet enclosed by a room or structure. This data is then used in calculating heat loss due to infiltration.

This calculator, Figure 5-12, is somewhat similar to the Area Calculator. However, volume is determined by multiplying floor area by ceiling height, so these are the factors built into the calculator.

Again using the room in Figure 5-7 as an example, the floor area of 100 square feet was previously determined. Now, by locating the number 100 in a column headed AREA SQ. FT. on the Volume Calculator, read across to the number 8 in the column for CEILING HEIGHT. The figure where the columns intersect is the room volume, 800 cubic feet.

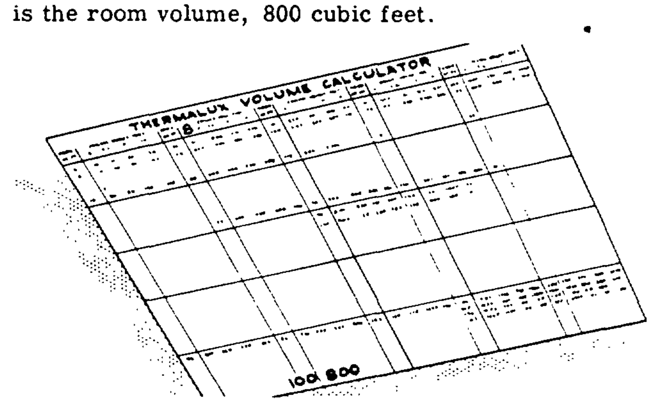


Figure 5-12. Using the Volume Calculator

Use of Heat Loss Charts

The THERMALUX Heat Loss Calculators are designed with a complete set of charts for every 5° increment of Design Temperature Difference, such as 50°F TD, 55°F TD, 60°F TD, 90°F TD, etc.

The set of charts for each TD is comprised of individual charts for heat loss of different building sections such as walls, ceilings, floors, and windows-doors. Heat loss by infiltration and for concrete slab floors also are determined on separate charts.

Since all charts are used in the same way, the room from Figure 5-7 will illustrate how heat loss is easily calculated. From previous calculations the net area of walls 1 and 2 was established as 136 sq. ft. These walls are constructed to meet the All Weather Comfort Standard, and have 3-inches of insulation with an R-value of 11.

Using this data, the heat loss can now be determined from the chart illustrated in Figure 5-13. First, locate wall area on left of chart. Read out horizontally from the 136 point to the sloping line designated R11 and 3" of insulation. Now read vertically downward to determine heat loss at the base of the chart. The value is 240 watts, a close approximation of the 244 watts calculated.

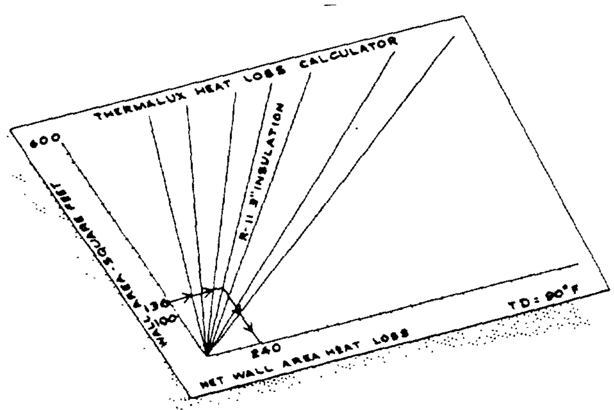


Figure 5-13. Using THERMALUX Heat Loss Calculator

ACCURACY OF CHARTS

The answers determined by using formulas and charts will differ slightly, since the charts are accurate within plus or minus 3%-5%.

Such accuracy is well within allowable tolerances, considering the variations that can be encountered from construction, insulation, and other job-oriented factors.

While charts are convenient time-savers, it is important to be fully aware of how they were derived and what limitations they contain. Incorrect use of a chart can result in gross errors in the heat loss calculation, incorrect system design, and unacceptable system performance.

ANNUAL ENERGY CONSUMPTION

The annual consumption of electric power by an electric heating system depends upon the length and severity of the heating season.

To determine annual consumption, a quantity known as Degree Day is used to measure severity of the heating season as gauged by high and low temperatures during the winter.

The length or duration of a heating season is based on the total number of Degree Days occurring through the winter in the locality where the building is to be located.

Degree Days

A degree day (DD) is defined as a day on which the mean temperature is 1° below 65° (64°). If the mean temperature of a day is 50°, that day is counted as 15 degree days (65° - 50° = 15°). This may be expressed as

$$DD = 65 - \frac{T_{high} + T_{low}}{2}$$

where T_{high} and T_{low} are the highest and lowest temperatures recorded for a given day.

For example, if the highest temperature for a given day is 40° and the lowest is 18°, the number of degree days (DD) for that day would be:

$$DD = 65 - \frac{40 + 18}{2} = 65 - 29 = 36$$

The temperature of 65° is chosen as the base for figuring degree days because long experience has shown that heating generally does not start until the outdoor temperature drops below 65° and stops when the outdoor temperature rises above 65°.

Over the years, heating experience has shown that the amount of fuel consumed varies in direct proportion to the number of degree days. Therefore, the Weather Bureau has records of the average number of degree days per year at the weather stations throughout the country. The degree days for many cities are shown in Table 7-1.

Annual Consumption Formulas

Two formulas are generally used in estimating how much electricity will be required annually to heat a building; the National Electrical Manufacturers Association (NEMA) formula; and, the Federal Housing Administration (FHA) formula.

The FHA formula is:

$$KWH = \frac{HL \times DD}{TD \times 185}$$

where

KWH = Total annual consumption in kilowatt-hours

HL = Design heat loss in Btu/hr

DD = Annual number of degree days (see Table 7-1)

TD = Design temperature difference (see Table 7-1).

Example: A house with design heat loss of 30100 Btu/hr is in Chicago where DD is 6310 and TD is 80. What is the annual consumption of electricity by the FHA formula?

$$KWH = \frac{30100 \times 6310}{80 \times 185} = \frac{189931000}{14800}$$

KWH = 12833 kilowatt-hours

The National Electrical Manufacturers Association (NEMA) formula is

$$KWH = \frac{HL \times DD \times C}{TD}$$

where

HL = Design heat loss in kilowatts

C = Usage factor (usually 17.0)

DD = Annual number of degree days (see Table 7-1)

TD = Design temperature difference (see Table 7-1).

Example: Using the same house as in the previous example, what is the annual consumption? To find HL, convert the design heat loss from Btu/hr to kilowatts.

$$HL = \frac{30100}{3413} = 8.819 \text{ kilowatts}$$

$$KWH = \frac{8.819 \times 6310 \times 17.0}{80} = \frac{946097}{80}$$

KWH = 11826 kilowatt-hours

Notice that using the NEMA formula gives a different answer than the FHA formula. That is because NEMA uses a C-value of 17.0 while the FHA formula is based on C = 18.5. Since the factor C is a variable, selected to adjust for "usage" of the residence the correct value is difficult to determine. Therefore, if it is common practice in the particular locality to use some value other than 17.0 for C in figuring annual consumption of electricity, follow the local practice. Generally, the local electric utility is the best source of information in such matters.

ANNUAL HEATING COST

After the annual fuel consumption has been determined, then annual heating cost is readily calculated. Simply multiply consumption by the local electric heating rate.

Example: Annual consumption for heating is 12868 kilowatts hours (results from NEMA formula when C = 18.5. Note similiarity with FHA data). Electric heating rate is 1.25 cents per kilowatt hour. What is annual heating cost?

Heating Cost = KWH x Rate

= 12868 x 1.25 cents = $158.58

Another way to determine heating cost is with the THERMALUX Heating Cost Calculator, included with the charts at the end of this chapter.

To use the chart proceed as follows:

1. Draw a line from the center of the target to the outside design temperature (top left scale) for your climate.

2. Draw a line from the center of the target to the power rate (top right scale) for your area.

3. Draw a vertical (straight up) line from the winter degree days for your area (bottom left scale).

4. Draw a horizontal line from the intersection of the lines drawn in steps 1 and 3 to the line drawn in step 2.

5. Draw a vertical line (straight down) from the intersection of the lines drawn in steps 2 and 4.

6. Read the annual operating cost per kilowatt of heat loss at the point where the line drawn in step 5 intersects the bottom scale.

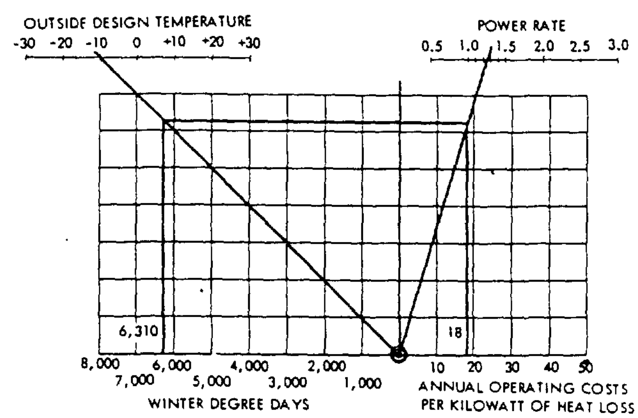


Figure 5-14. Using THERMALUX Heating Cost Calculator

When the same data from the previous example are applied to the calculator, results are as follows: Annual operating cost per kilowatt of heat loss is approximately $18.00. Since the heat loss was determined at 8.819 kilowatts, total annual cost will be about: $18.00 x 8.819 = $159.05. Note the very accurate comparative results between charted and calculated costs.

DESIGNING THE THERMALUX SYSTEM

Once the heat loss calculations for the building are completed, the data is available to finalize the System Design.

First, the quantity of Heating Panel required to make up for calculated heat loss in each room must be determined. Since THERMALUX Heating Panels have heat output of 15 watts per square foot, the total footage of Heating Panel needed is found by dividing heat loss by 15.

Example: The room in Figure 5-7 has a total heat loss of 1178 watts. Footage of THERMALUX Heating Panel needed to satisfy heat loss:

$$\text{THERMALUX Panel Required} = \frac{1178}{15} = 78 \cong 80 \text{ sq.ft.}$$

When the amount of heating panel needed for each room has been found, the panel sizes and layout may be determined.

Considering the 9-1/2' by 10-1/2' dimensions of the example room, and the fact that 80 sq. ft. of heating panel are required, the first choice would be to use two 4' x 10' panels.

Since the goal is to balance heat evenly over the room area, the panels must be located in proximity to the places of greatest heat loss. This means favoring panel placement by outside walls and cold areas, such as doors and windows, as indicated in Figure 5-15. However, compromises are always necessary since good design will not leave large areas of the ceiling without heating panel.

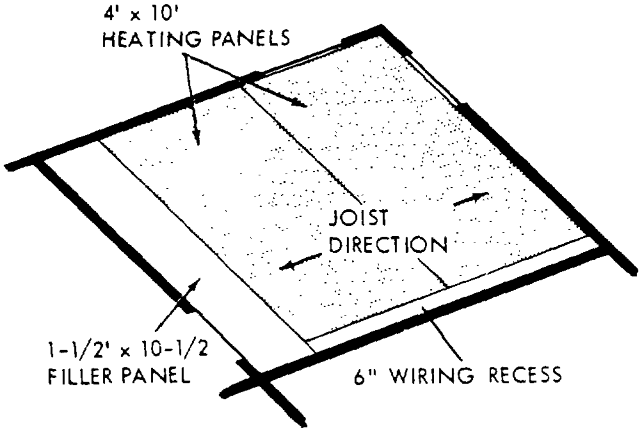


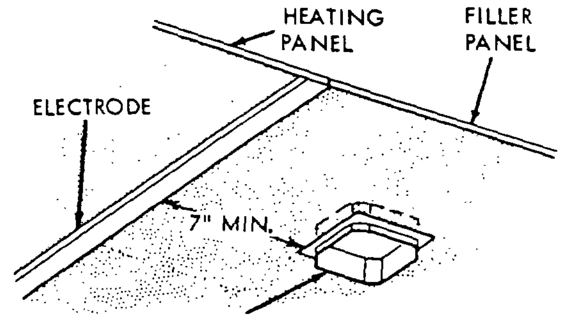
Figure 5-15. Heating Panel Layout

Layout of the System is best done on tracing paper over the floor plan. After the design is completed, suitable details and notations can be made on the working drawings.

Ceiling Irregularities

Wherever possible, use Filler Panel where there are ceiling fixtures such as light fixture junction boxes, exhaust fans, duct work, and pipes.

Heating Panels adjacent to Filler Panels must be separated by 8" from electrical boxes or conduit and 2" from all other metal located in Filler Panel areas as shown in Figure 5-16.



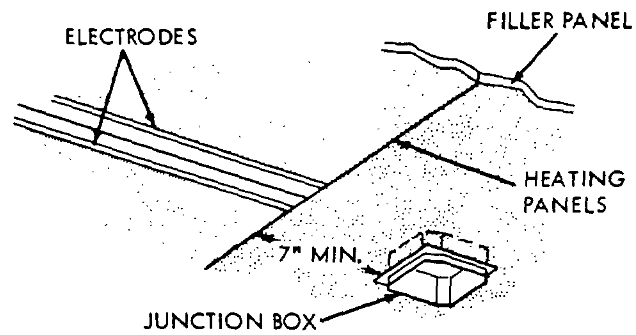


Figure 5-16. Light Fixture Junction Boxes Adjacent to Heating Panels

If cutouts in Heating Panels are necessary, provide the following minimum clearances from any edge of the cutout: 2" from the copper electrode, 6" from the end of the panel and 24" from the edge of an adjacent cutout in the same panel as shown in Figure 5-17. Make no more than one cutout in a panel 8' or less in length, and make a maximum of two cutouts in longer panels. Cutouts in A-30-24.48 panels (2' wide heating area) cannot exceed 16-1/2" wide. Each cutout creates a non-heating area in the panel represented by the shaded portions of Figure 5-17. To be conservative in design, these non-heating areas must be deducted from the total heating panel area to determine heat output at 15 watts per square foot.

Parallel or Perpendicular Installation

Heating panels may be installed with their long dimension either parallel or perpendicular to joists.

Perpendicular installation, where possible, is the most desirable since joist alignment and spacing are not critical and the wiring recesses are simpler to construct.

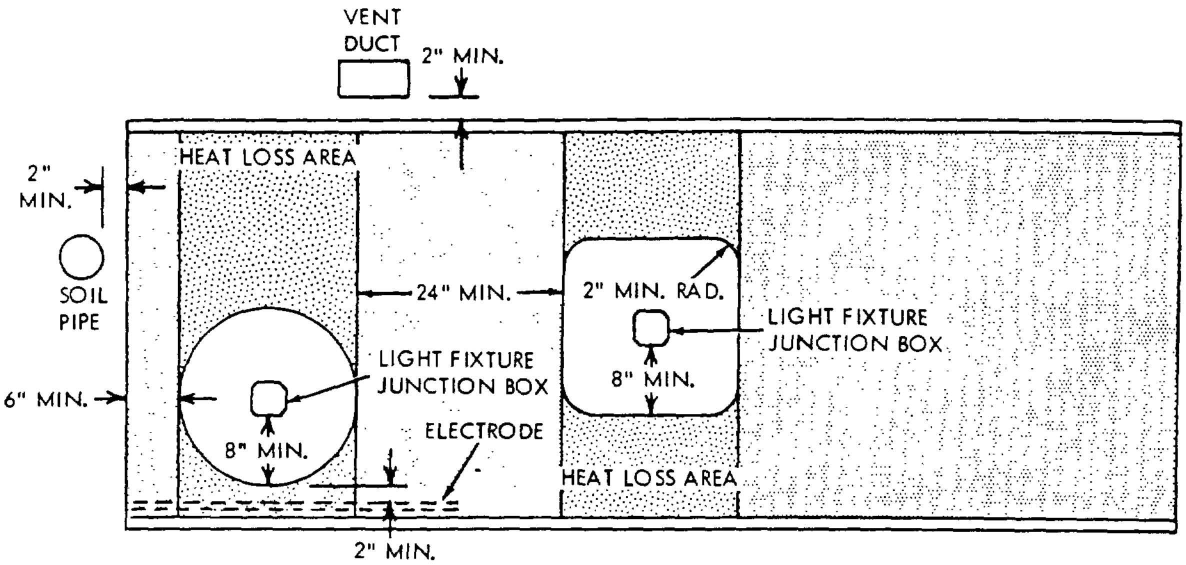


Figure 5-17. Clearances Required by Typical Cutouts in a Heating Panel

Wiring Recesses

Wiring recesses, as explained in Chapter 4, are used to completely enclose the Heating Panel feeder wires in non-combustible, non-conductive material. Typical types of recess construction are described and illustrated in Chapter 6.

Locate the Heating Panels so that the wiring recesses have a straight line shape wherever possible, locate bushings towards the center of the building or gables, away from eaves. The electrical raceways from the junction box to the bushing will be awkward to install in the attic when the bushing is too close to an eave. For the same reason, don't locate a wiring recess alongside an eave. Where the recess must be against an outside wall, make it the wall on the gable side. An inside wall is the most desirable location for the wiring recess and usually results in the simplest most economical electrical work.

Designate the required wiring recess depth on the System Design. Depth is readily determined since when one or two panels are being wired through one recess, only a 1/4" depth is needed, although a 1/2" deep recess will be completely acceptable. When three or more panels are being wired through one recess, a 1/2" depth is needed. Always build the recess that best fits the construction situation and meets or exceeds wiring recess depth requirements.

ELECTRICAL DESIGN

The quantity of Heating Panel which must be installed, and the amount of current that the panels will draw, is the basis for all the electrical design work.

Determining Room Current

Since THERMALUX Heating Panels draw 0.125 amps (1/8 amp) of current per square foot, the total current for a room can be readily determined. Simply divide panel area by 8. In the example room, 80 feet of Heating Panel are required. Therefore, current will be 80/8 = 10 amperes.

Determining Size of Branch Circuit Wiring

The size electrical wire which must be used in branch circuits depends on the amount of current which will be carried, and usually is stipulated in the electrical code.

Table 5-9, based on the National Electrical Code, indicates the maximum current and quantity of Heating Panel load which can be handled by 2-and 3-wire circuits of various sizes.

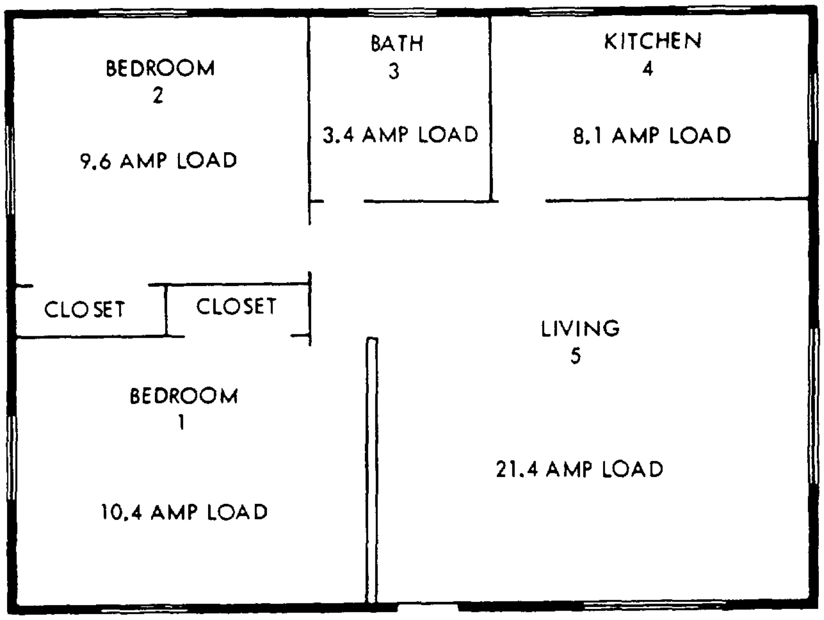
Table 5-9. Heating Branch Circuit Capacities

Branch Circuit Conductor		Maximum Installed Area of Heating Panel	
Size	Max. Load-Amps (20% Derated)	2-Wire Circuit	3-Wire Circuit
#14	12	96	192
#12	16	128	256
#10	24	192	384

Choice of 2-Wire or 3-Wire Circuits

Circuits should always be chosen with the smallest wire size that can handle the design load, Figure 5-18 illustrates how this is done. Note that current load on each leg of 3-wire circuit are almost equal. This balance must be attained for acceptable performance. In addition, a combination of 3-wire circuits, (which have the electrical capacity of two 2-wire circuits), should be used for economy.

Usually, the electrician can readily determine the best type of circuitry if the current loads are known.



Room	Current	Circuit
1	10.4	3-wire #14 } combined
2	9.6	3-wire #14 } combined
3	3.4	2-wire #14 } combined
4	8.1	2-wire #14 } combined
5	21.4	2-wire #10

Figure 5-18. Heating Circuit Loads and Sizes

Overload Protection

Overload protection (fuse or breaker) is required for each branch circuit conductor, exclusive of neutral conductors. If a load current does not equal a standard fuse or breaker rating, use a fuse or breaker having the next higher rating.

Locating Junction Boxes

Locate a junction box close to the wiring recess in each room or area. The junction box must be accessible for removal of the cover and inspection of the wiring. Attic, wall, and floor locations are all considered accessible.

Control Relays

Use THERMALUX Type 706 double control relays wherever possible for greater economy. Type 705 single control relays should be used where only one additional circuit is required. The Type 706 relay can handle a 3-wire circuit with maximum current of 44 amperes, and can be controlled by one Type 820E low voltage thermostat. Also, the 706 relay can serve two 22 amp circuits, each controlled with separate thermostats. The 705 relay is designed for one 22 amp circuit with an individual thermostatic control.

The recommended location for control relays is at or near the service entrance. However, in certain cases it may be more economical to locate the control relays near the rooms. When this is the case, one overload protector may be assigned to handle several small room loads. The size of the overload protector and the size of the wire from the overload protector to the control relays must be large enough to handle the total load.

Panel Feeders

The branch circuit cables from the junction boxes to the panels are referred to as panel feeders. These cables must be single conductor Type UF (Underground Feeder) wiring. Only #12 and #10 size conductors fit the THERMALUX Electrode Connectors.

Locate the bushed fittings, bushings, or feed-through holes as close to the branch circuit junction box as possible so that the wire runs are not unnecessarily long.

Locate the bushed fittings, bushings, or feed-through holes away from eaves or other inaccessible locations.

Plan recess wiring to keep adjacent electrode connectors at the same potential.

Use Table 5-9 to determine panel feeder wire size (but no smaller than #12 conductor).

Thermostat Location

Each room or area should be equipped with its own thermostat to provide just the right amount of heat for the room. Adjoining rooms with a 30" or other standard size door opening between them may have significantly different temperature requirements. In Figure 5-19, for example, room A has a greater heat loss through outside walls than room B, and a thermostat in A would provide too much heat for B, while a thermostat in B would not provide enough for A. For comfort and economy, each room should have a separate thermostat.

Areas or rooms separated by large archways or small divider partitions may use a common thermostat. This can be done where temperatures in both rooms or areas varies only a negligible amount.

The thermostat must be located as far as possible from points of maximum heat loss. Locate the thermostat on an inside wall away from doors, windows and exhaust fans. The thermostat must also be in a position to "see" a heating panel within the room from the shortest possible distance without obstruction. Locate the thermostat approximately 52" above the floor.

Service Drop

To determine the size of the service drop required, determine the service drop without electric heating and add the total current draw of the heating system. A 200-ampere service drop is typical of the average single-family dwelling with THERMALUX Electric Radiant Heating.

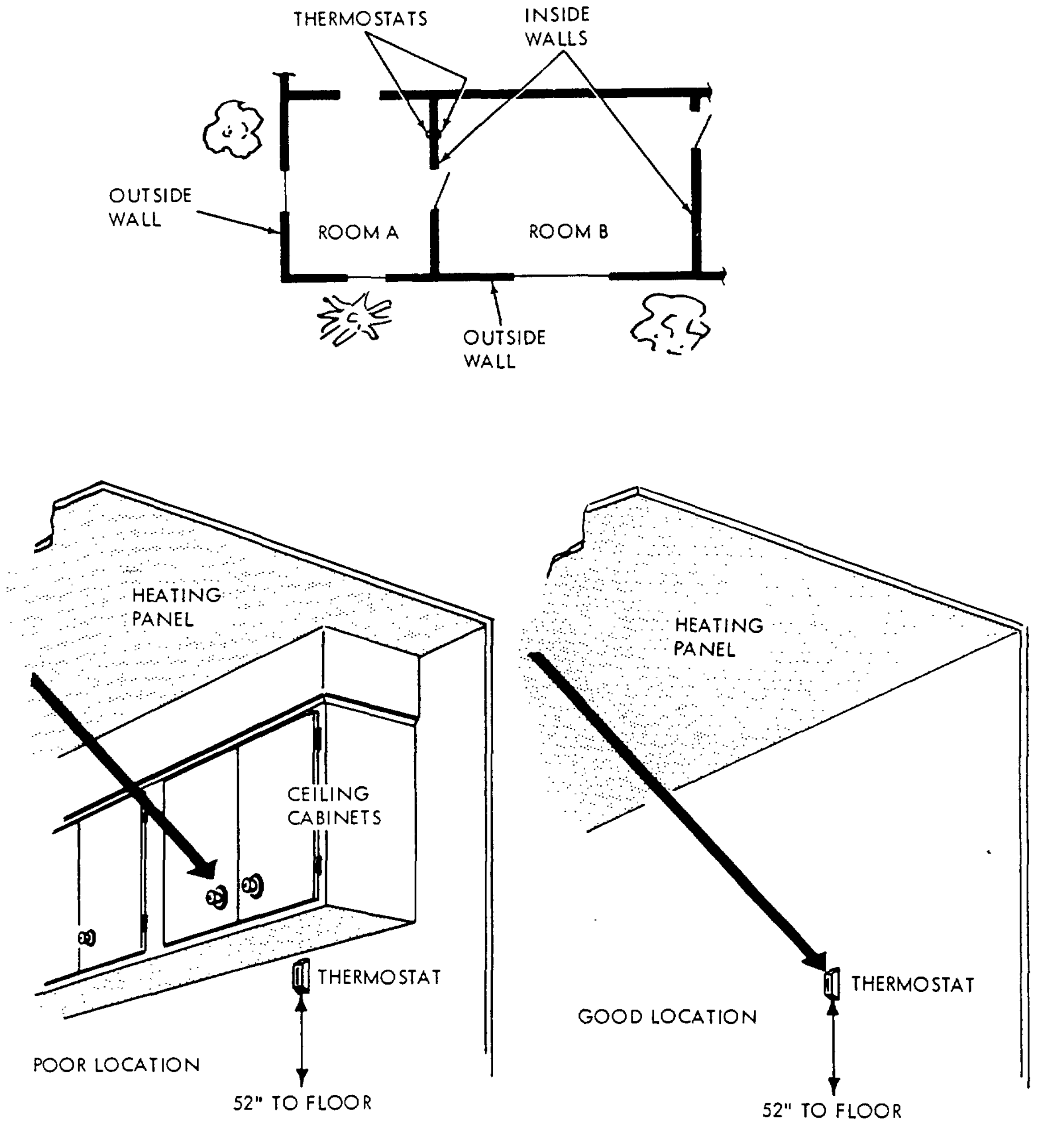


Figure 5-19. Thermostat Location

BB029 0534

THERMALUX

DESIGN DATA SHEET

NAME ______ JOB NO. ______

ADDRESS ______ PHONE ______ DATE ______

THERMALUX COST $ ______
INSTALLED

BUILDER ______ PHONE ______ AREA HEATED ______ SQ. FT

ARCHITECT ______ PHONE ______ COST/SQ. FT. $ ______ /SQ. FT

DRYWALL CONTRACTOR ______ PHONE ______ CONNECTED LOAD ______ KW

ELECTRICAL CONTRACTOR ______ PHONE ______ COST/KW $ ______ /KW

UTILITY REPRESENTATIVE ______ PHONE ______ HEATING COST $ ______ /YR.

CONSTRUCTION:

___NEW; ___REMODEL; ___ADDITION; ___RESIDENTIAL; ___COMMERCIAL; ___FRAME; ___MASONRY VENEER; ___ALL MASONRY;

OTHER (Describe): ______

INSULATION:

	RECOMMENDED	SPECIFIED
CEILING		
WALL		
FLOOR		
SLAB		
BASEMENT WALLS		

CEILING: ______ BLOWN; ______ BATT

MATERIAL:

______ MINERAL WOOL

______ OTHER; TYPE: ______

FLOOR: ___OVER HEATED BASEMENT; ___OVER UNHEATED BASEMENT;

___OVER VENTED CRAWL SPACE

WINDOWS-DOORS

WINDOWS: ______ SINGLE GLASS; ______ DOUBLE GLASS; ______ STORM SASH

DOORS: ______ SINGLE; ______ STORM DOORS

MOISTURE CONTROL

VENT FANS: ______ KITCHEN; ______ BATHROOMS; ______ LAUNDRY

HUMIDISTATS: ______ KITCHEN; ______ BATHROOMS; ______ LAUNDRY

VAPOR BARRIERS: ______ WALLS; TYPE ______

______ CEILING; TYPE ______

MISCELLANEOUS: ______

DESIGN DATA: TD ______ °F; DEGREE DAYS ______; COST/KWH ______

ANNUAL OPERATING COST:

$ ______ (\$/KW) x ______ (KW INSTALLED) KW = $ ______ /YR.

QUOTATION:

TOTAL MATERIAL $ ______

TOTAL LABOR $ ______

TOTAL DIRECT COST $ ______

OVERHEAD $ ______

PROFIT $ ______

PRICE QUOTED $ ______

BB029 0535

JOB ITEM	QUANTITY	UNIT COST	TOTAL COST	NOTES
THERMALUX SYSTEM				
HEATING PANEL A-30-24.48 10 FT. LONG				
HEATING PANEL A-30-24.48 12 FT. LONG				
HEATING PANEL A-60-48.48 10 FT. LONG				
HEATING PANEL A-60-48.48 12 FT. LONG				
INSULATED NAILS				
FILLER PANEL				
FINISH PANEL				
CONTACT ADHESIVE				
ADHESIVE SOLVENT				
ELECTRODE CONNECTORS				
CIRCUIT BUSHINGS				
AUXILIARY HEATING EQUIPMENT				
THERMOSTATS—CONTROLS				
820E LOW-VOLTAGE THERMOSTAT				
705 SINGLE RELAY				
706 DOUBLE RELAY				
LINE VOLTAGE THERMOSTAT				
843 HUMIDISTAT				
ELECTRICAL SUPPLIES				
TOTAL MATERIAL COST				
INSTALLATION—LABOR				
HEATING BRANCH CIRCUITS				
THERMOSTATS/CONTROLS				
HEATING PANEL WIRING				
AUXILIARY EQUIPMENT				
INSTALL FIRST LAYER—THERMALUX				
INSTALL FINISH LAYER—THERMALUX				BB029 0536
JOINT FINISHING—CEILING				
TOTAL LABOR COST				
TOTAL COST LABOR/MATERIAL				

THERMALUX
HEAT LOSS WORK SHEET

JOB NAME ______________________________ Job No. __________

ADDRESS ______________________________

ROOMS & BUILDING SECTION	DIMENSIONS	AREAS & VOLUME	HEAT LOSS-WATTS	NOTES
ROOM No. 1				
CEILING		Sq. Ft.		
FLOOR (Area or perimeter)		Sq./Lin. Ft.		
TOTAL OUTSIDE WALL		Sq. Ft.		
WINDOWS		Sq. Ft.		
DOORS		Sq. Ft.		
NET WALL (Less Windows & Doors)		Sq. Ft.		
INFILTRATION		Cu. Ft.		
		TOTAL HEAT LOSS, WATTS		
ROOM No. 2				
CEILING		Sq. Ft.		
FLOOR (Area or perimeter)		Sq./Lin. Ft.		
TOTAL OUTSIDE WALL		Sq. Ft.		
WINDOWS		Sq. Ft.		
DOORS		Sq. Ft.		
NET WALL (Less Windows & Doors)		Sq. Ft.		
INFILTRATION		Cu. Ft.		
		TOTAL HEAT LOSS, WATTS		
ROOM No. 3				
CEILING		Sq. Ft.		
FLOOR (Area or perimeter)		Sq./Lin. Ft.		
TOTAL OUTSIDE WALL		Sq. Ft.		
WINDOWS		Sq. Ft.		
DOORS		Sq. Ft.		
NET WALL (Less Windows & Doors)		Sq. Ft.		
INFILTRATION		Cu. Ft.		
		TOTAL HEAT LOSS, WATTS		
ROOM No. 4				
CEILING		Sq. Ft.		
FLOOR (Area or perimeter)		Sq./Lin. Ft.		
TOTAL OUTSIDE WALL		Sq. Ft.		
WINDOWS		Sq. Ft.		
DOORS		Sq. Ft.		
NET WALL (Less Windows & Doors)		Sq. Ft.		
INFILTRATION		Cu. Ft.		
		TOTAL HEAT LOSS, WATTS		
ROOM No. 5				
CEILING		Sq. Ft.		
FLOOR (Area or perimeter)		Sq./Lin. Ft.		
TOTAL OUTSIDE WALL		Sq. Ft.		
WINDOWS		Sq. Ft.		
DOORS		Sq. Ft.		
NET WALL (Less Windows & Doors)		Sq. Ft.		
INFILTRATION		Cu. Ft.		
		TOTAL HEAT LOSS, WATTS		

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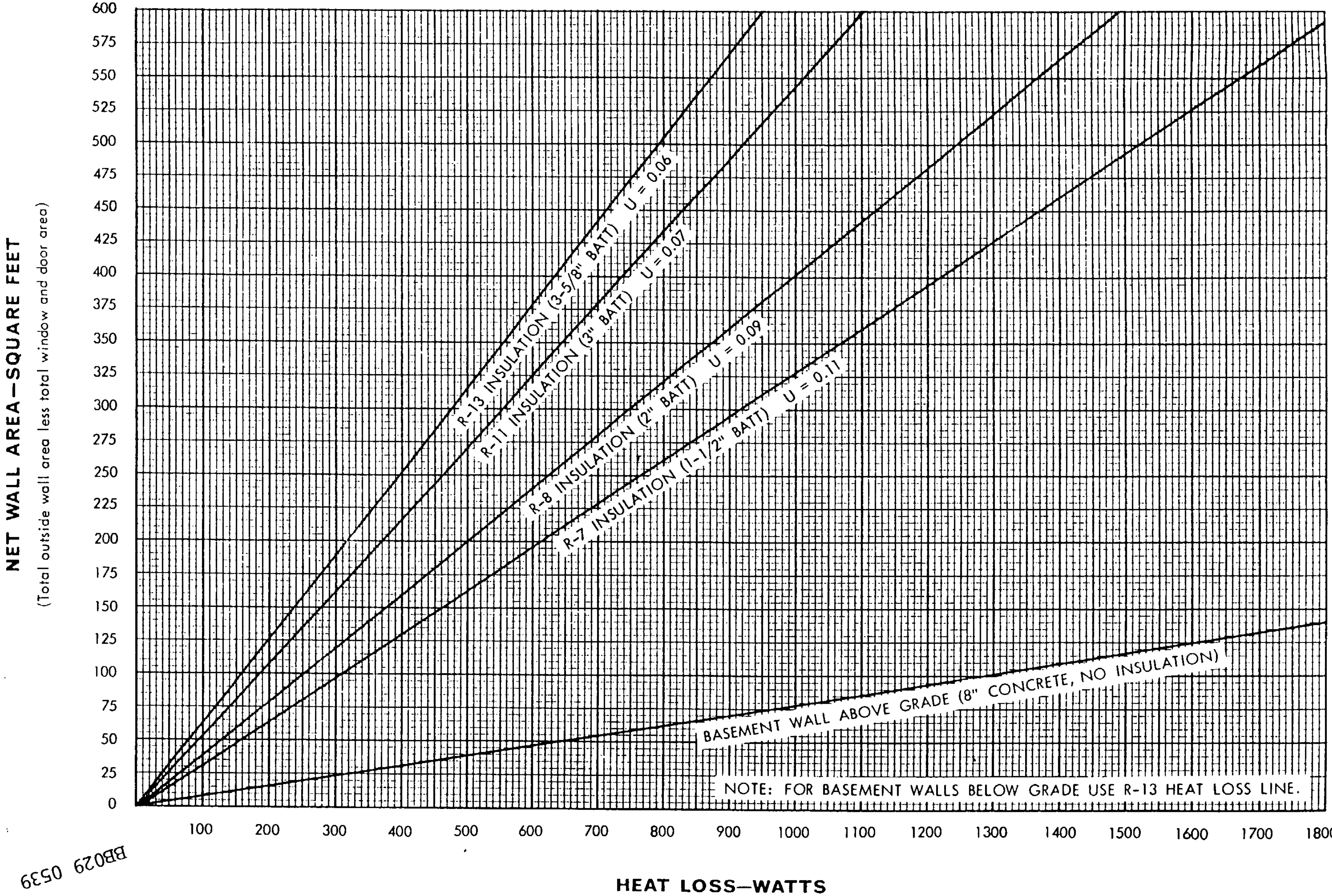
ROOM & BUILDING SECTION	DIMENSIONS	AREAS & VOLUME	HEAT LOSS-WATTS	NOTES
ROOM No. 6				
CEILING		Sq. Ft.		
FLOOR (Area or perimeter)		Sq./Lin. Ft.		
TOTAL OUTSIDE WALL		Sq. Ft.		
WINDOWS		Sq. Ft.		
DOORS		Sq. Ft.		
NET WALL (Less Windows & Doors)		Sq. Ft.		
INFILTRATION		Cu. Ft.		
		TOTAL HEAT LOSS, WATTS		
ROOM No. 7				
CEILING		Sq. Ft.		
FLOOR (Area or perimeter)		Sq./Lin. Ft.		
TOTAL OUTSIDE WALL		Sq. Ft.		
WINDOWS		Sq. Ft.		
DOORS		Sq. Ft.		
NET WALL (Less Windows & Doors)		Sq. Ft.		
INFILTRATION		Cu. Ft.		
		TOTAL HEAT LOSS, WATTS		
ROOM No. 8				
CEILING		Sq. Ft.		
FLOOR (Area or perimeter)		Sq./Lin. Ft.		
TOTAL OUTSIDE WALL		Sq. Ft.		
WINDOWS		Sq. Ft.		
DOORS		Sq. Ft.		
NET WALL (Less Windows & Doors)		Sq. Ft.		
INFILTRATION		Cu. Ft.		
		TOTAL HEAT LOSS, WATTS		
BASEMENT				
FLOOR		Sq. Ft.		
TOTAL WALL ABOVE GRADE		Sq. Ft.		
WINDOWS		Sq. Ft.		
DOORS		Sq. Ft.		
NET WALL ABOVE GRADE		Sq. Ft.		
TOTAL WALL BELOW GRADE		Sq. Ft.		
INFILTRATION		Cu. Ft.		
		TOTAL HEAT LOSS, WATTS		

SUMMARY—HEATING SYSTEM DESIGN

ROOM	HEAT LOSS—WATTS	THERMALUX SQ. FT. OR EQUIP. SIZE	CURRENT AMPS.	CIRCUIT SIZE	NOTES
1					
2					
3					
4					
5					BB029 0538
6					
7					
8					
BASEMENT					
TOTAL					

CALCULATIONS BY



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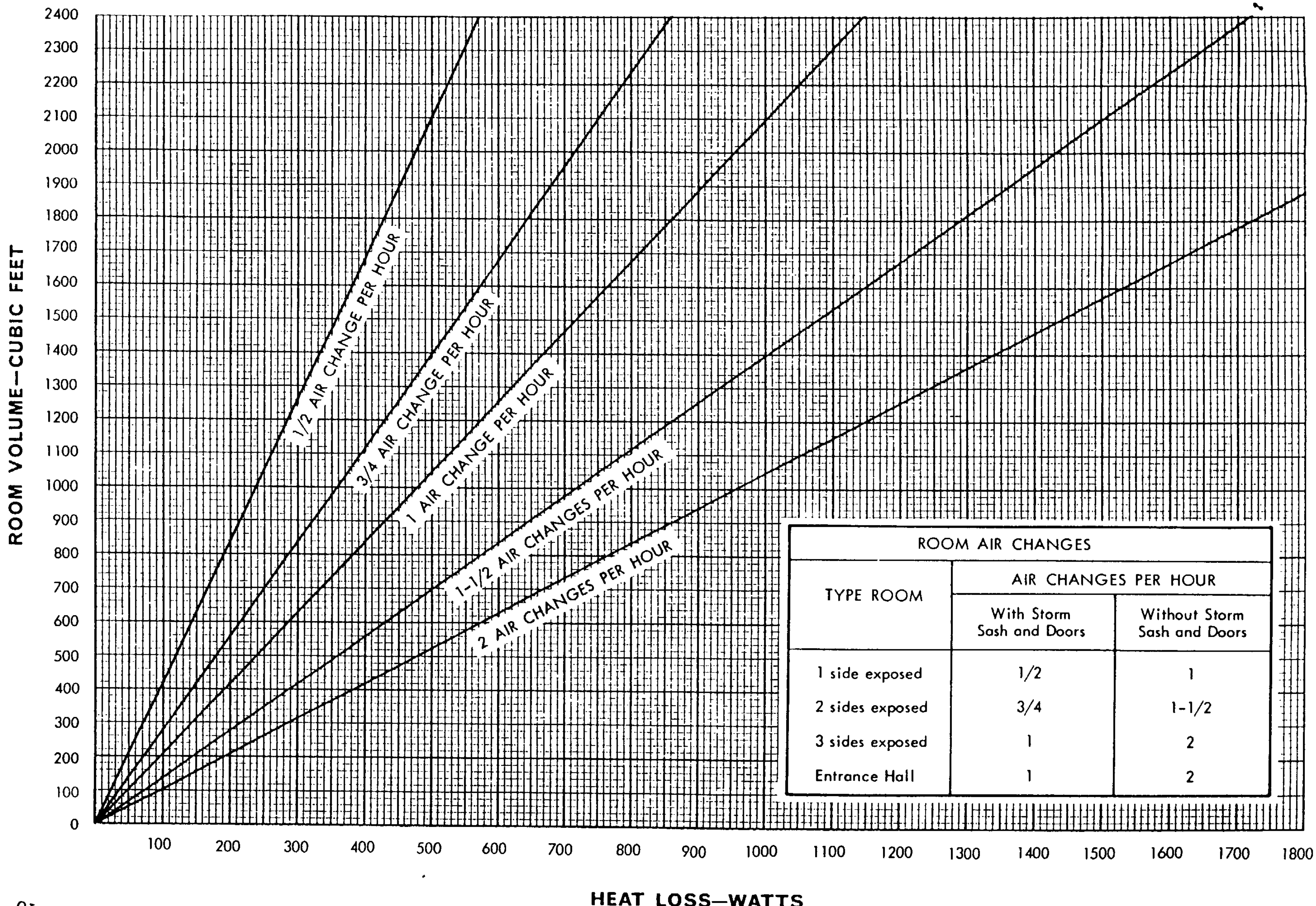
THERMALUX HEAT LOSS CALCULATOR

NET WALL HEAT LOSS 90° TD



ROOM AIR CHANGES		
TYPE ROOM	AIR CHANGES PER HOUR	
	With Storm Sash and Doors	Without Storm Sash and Doors
1 side exposed	1/2	1
2 sides exposed	3/4	1-1/2
3 sides exposed	1	2
Entrance Hall	1	2

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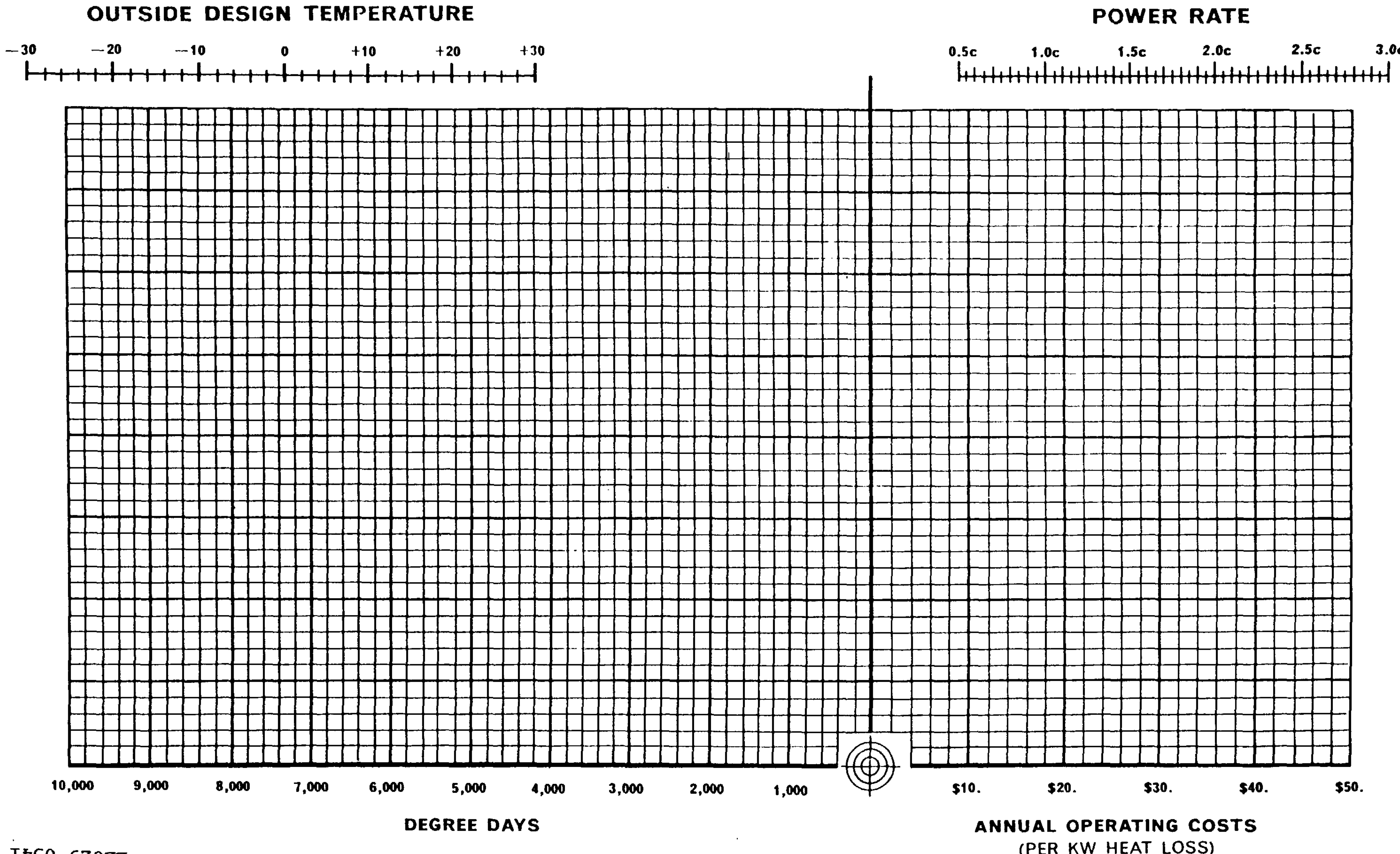
THERMALUX HEAT LOSS CALCULATOR

INFILTRATION HEAT LOSS **90° TD**



BB029 0541

THERMALUX

HEATING COST CALCULATOR

H-24 U S G. 7/64

BASED ON NEMA OPERATING COST FORMULA WITH C-FACTOR OF 17

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DIM. FT.	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	15½	16	16½	17	17½	18	18½	19	19½	20
1½	2	4	4	4	6	6	6	8	8	10	10	10	12	12	12	14	14	16	16	16	18	18	18	20	20	22	22	22	24	24	24	26	26	28	28	28	30	30
2	4	4	6	6	8	8	10	10	12	12	14	14	16	16	18	18	20	20	22	22	24	24	26	26	28	28	30	30	32	32	34	34	36	36	38	38	40	40
2½	4	6	6	8	8	10	12	12	14	16	16	18	18	20	22	22	24	26	26	28	28	30	32	32	34	36	36	38	38	40	42	42	44	46	46	48	48	50
3	4	6	8	10	10	12	14	16	16	18	20	22	22	24	26	28	28	30	32	34	34	36	38	40	40	42	44	46	46	48	50	52	52	54	56	58	58	60
3½	6	8	8	10	12	14	16	18	20	22	22	24	26	28	30	32	34	36	36	38	40	42	44	46	48	50	50	52	54	56	58	60	62	64	64	66	68	70
4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80
4½	6	10	12	14	16	18	20	22	24	28	30	32	34	36	38	40	42	46	48	50	52	54	56	58	60	64	66	68	70	72	74	76	78	82	84	86	88	90
5	8	10	12	16	18	20	22	26	28	30	32	36	38	40	42	46	48	50	52	56	58	60	62	66	68	70	72	76	78	80	82	86	88	90	92	96	98	100
5½	8	12	14	16	20	22	24	28	30	34	36	38	42	44	46	50	52	56	58	60	64	66	68	72	74	78	80	82	86	88	90	94	96	100	102	104	108	110
6	10	12	16	18	22	24	28	30	34	36	40	42	46	48	52	54	58	60	64	66	70	72	76	78	82	84	88	90	94	96	100	102	106	108	112	114	118	120
6½	10	14	16	20	22	26	30	32	36	40	42	46	48	52	56	58	62	66	68	72	74	78	82	84	88	92	94	98	100	104	108	110	114	118	120	124	126	130
7	10	14	18	22	24	28	32	36	38	42	46	50	52	56	60	64	66	70	74	78	80	84	88	92	94	98	102	106	108	112	116	120	122	126	130	134	136	140
7½	12	16	18	22	26	30	34	38	42	46	48	52	56	60	64	68	72	76	78	82	86	90	94	98	102	106	108	112	116	120	124	128	132	136	138	142	146	150
8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108	112	116	120	124	128	132	136	140	144	148	152	156	160
8½	12	18	22	26	30	34	38	42	46	52	56	60	64	68	72	76	80	86	90	94	98	102	106	110	114	120	124	128	132	136	140	144	148	154	158	162	166	170
9	14	18	22	28	32	36	40	46	50	54	58	64	68	72	76	82	86	90	94	100	104	108	112	118	122	126	130	136	140	144	148	154	158	162	166	172	176	180
9½	14	20	24	28	34	38	42	48	52	58	62	66	72	76	80	86	90	96	100	104	110	114	118	124	128	134	138	142	148	152	156	162	166	172	176	180	186	190
10	16	20	26	30	36	40	46	50	56	60	66	70	76	80	86	90	96	100	106	110	116	120	126	130	136	140	146	150	156	160	166	170	176	180	186	190	196	200
10½	16	22	26	32	36	42	48	52	58	64	68	74	78	84	90	94	100	106	110	116	120	126	132	136	142	148	152	158	162	168	174	178	184	190	194	200	204	210
11	16	22	28	34	38	44	50	56	60	66	72	78	82	88	94	100	104	110	116	122	126	132	138	144	148	154	160	166	170	176	182	188	192	198	204	210	214	220
11½	18	24	28	34	40	46	52	58	64	70	74	80	86	92	98	104	110	116	120	126	132	138	144	150	156	162	166	172	178	184	190	196	202	208	212	218	224	230
12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	156	162	168	174	180	186	192	198	204	210	216	222	228	234	240
12½	18	26	32	38	44	50	56	62	68	76	82	88	94	100	106	112	118	126	132	138	144	150	156	162	168	176	182	188	194	200	206	212	218	226	232	238	244	250
13	20	26	32	40	46	52	58	66	72	78	84	92	98	104	110	118	124	130	136	144	150	156	162	170	176	182	188	196	202	208	214	222	228	234	240	248	254	260
13½	20	28	34	40	48	54	60	68	74	82	88	94	102	108	114	122	128	136	142	148	156	162	168	176	182	190	196	202	210	216	222	230	236	244	250	256	264	270
14	22	28	36	42	50	56	64	70	78	84	92	98	106	112	120	126	134	140	148	154	162	168	176	182	190	196	204	210	218	224	232	238	246	252	260	266	274	280
14½	22	30	36	44	50	58	66	72	80	88	94	102	108	116	124	130	138	146	152	160	166	174	182	188	196	204	210	218	224	232	240	246	254	262	268	276	282	290
15	22	30	38	46	52	60	68	76	82	90	98	106	112	120	128	136	142	150	158	166	172	180	188	196	202	210	218	226	232	240	248	256	262	270	278	286	292	300

AREA — SQUARE FEET

THERMALUX AREA CALCULATOR

H-22 U S G 7/64

VOLUME—CUBIC FEET

AREA	CEILING HEIGHT—FT. 8	8½	9	10
2	20	20	20	20
4	40	40	40	40
6	40	60	60	60
8	60	60	80	80
10	80	80	100	100
12	100	100	100	120
14	120	120	120	140
16	120	140	140	160
18	140	160	160	180
20	160	180	180	200
22	180	180	200	220
24	200	200	220	240
26	200	220	240	260
28	220	240	260	280
30	240	260	280	300
32	260	280	280	320
34	280	280	300	340
36	280	300	320	360
38	300	320	340	380
40	320	340	360	400
42	340	360	380	420
44	360	380	400	440
46	360	400	420	460
48	380	400	440	480
50	400	420	460	500

AREA	CEILING HEIGHT—FT. 8	8½	9	10
52	420	440	460	520
54	440	460	480	540
56	440	480	500	560
58	460	500	520	580
60	480	520	540	600
62	500	520	560	620
64	520	540	580	640
66	520	560	600	660
68	540	580	620	680
70	560	620	640	700
72	580	620	640	720
74	600	620	660	740
76	600	640	680	760
78	620	660	700	780
80	640	680	720	800
82	660	700	740	820
84	680	720	760	840
86	680	740	780	860
88	700	740	800	880
90	720	760	820	900
92	740	780	820	920
94	760	800	840	940
96	760	820	860	960
98	780	840	880	980
100	800	860	900	1000

AREA	CEILING HEIGHT—FT. 8	8½	9	10
102	820	860	920	1020
104	840	880	940	1040
106	840	900	960	1060
108	860	920	980	1080
110	880	940	1000	1100
112	900	960	1000	1120
114	920	960	1020	1140
116	920	980	1040	1160
118	940	1000	1060	1180
120	960	1020	1080	1200
122	980	1040	1100	1220
124	1000	1060	1120	1240
126	1000	1080	1140	1260
128	1020	1080	1160	1280
130	1040	1100	1180	1300
132	1060	1120	1180	1320
134	1080	1140	1200	1340
136	1080	1160	1220	1360
138	1100	1180	1240	1380
140	1120	1200	1260	1400
142	1140	1200	1280	1420
144	1160	1220	1300	1440
146	1160	1240	1320	1460
148	1180	1260	1340	1480
150	1200	1280	1360	1500

AREA	CEILING HEIGHT—FT. 8	8½	9	10
152	1220	1300	1360	1520
154	1240	1300	1380	1540
156	1240	1320	1400	1560
158	1260	1340	1420	1580
160	1280	1360	1440	1600
162	1300	1380	1460	1620
164	1320	1400	1480	1640
166	1320	1420	1500	1660
168	1340	1420	1520	1680
170	1360	1440	1540	1700
172	1380	1460	1540	1720
174	1400	1480	1560	1740
176	1400	1500	1580	1760
178	1420	1520	1600	1780
180	1440	1540	1620	1800
182	1460	1540	1640	1820
184	1480	1560	1660	1840
186	1480	1580	1680	1860
188	1500	1600	1700	1880
190	1520	1620	1720	1900
192	1540	1640	1720	1920
194	1560	1640	1740	1940
196	1560	1660	1760	1960
198	1580	1680	1780	1980
200	1600	1700	1800	2000

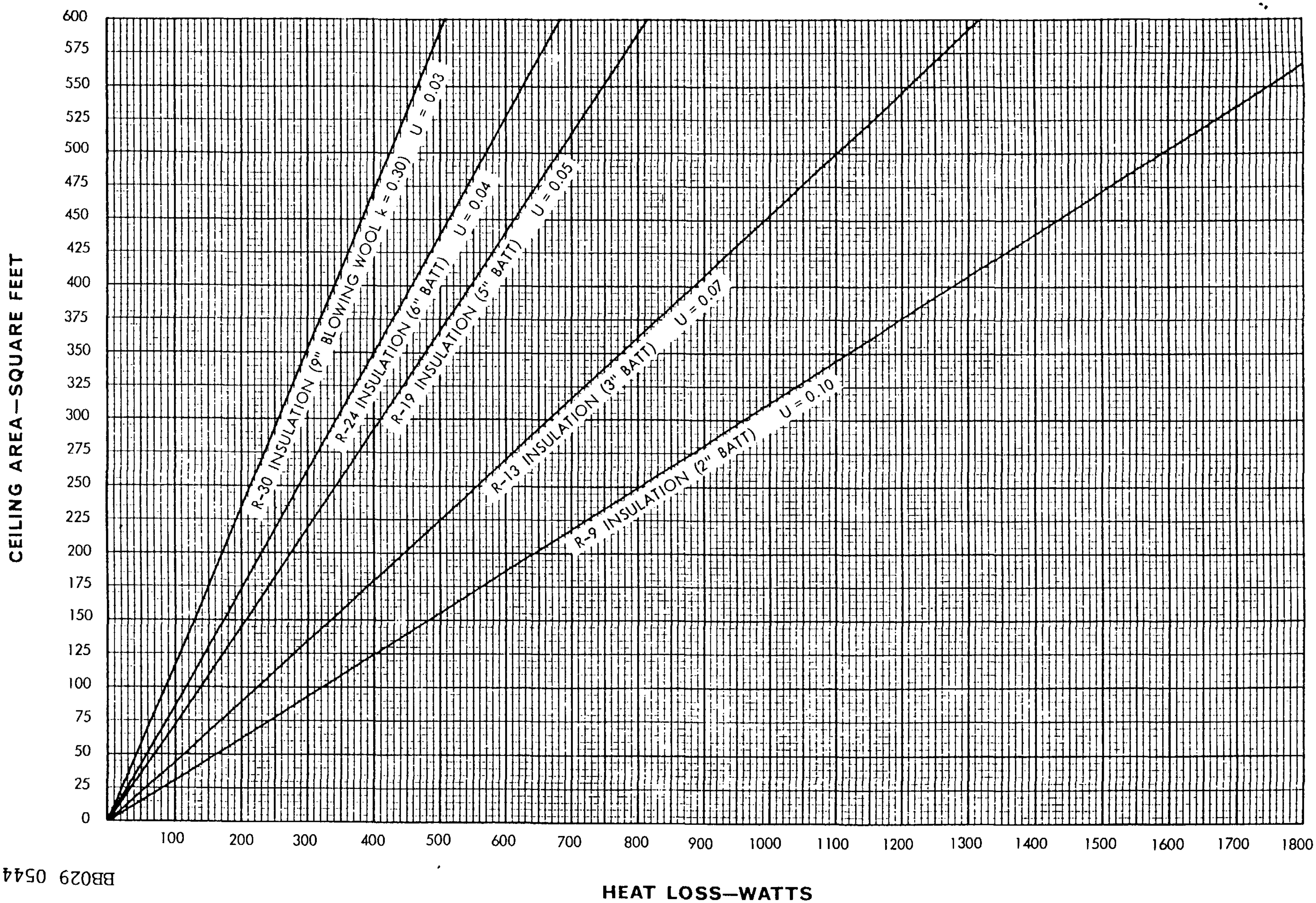
AREA	CEILING HEIGHT—F 8	8½	9	1
202	1620	1720	1820	20
204	1640	1740	1840	20
206	1640	1760	1860	20
208	1660	1760	1880	20
210	1680	1780	1900	21
212	1700	1800	1900	21
214	1720	1820	1920	21
216	1720	1840	1940	21
218	1740	1860	1960	21
220	1760	1880	1980	22
222	1780	1880	2000	2
224	1800	1900	2020	2
226	1800	1920	2040	2
228	1820	1940	2060	2
230	1840	1960	2080	2
232	1860	1980	2080	2
234	1880	1980	2100	2
236	1880	2000	2120	2
238	1900	2020	2140	2
240	1920	2040	2160	2
242	1940	2060	2180	2
244	1960	2080	2200	2
246	1960	2100	2220	2
248	1980	2100	2240	2
250	2000	2120	2260	2

BB029 0543

THERMALUX VOLUME CALCULATOR

H-23 U.S.G. 7/64

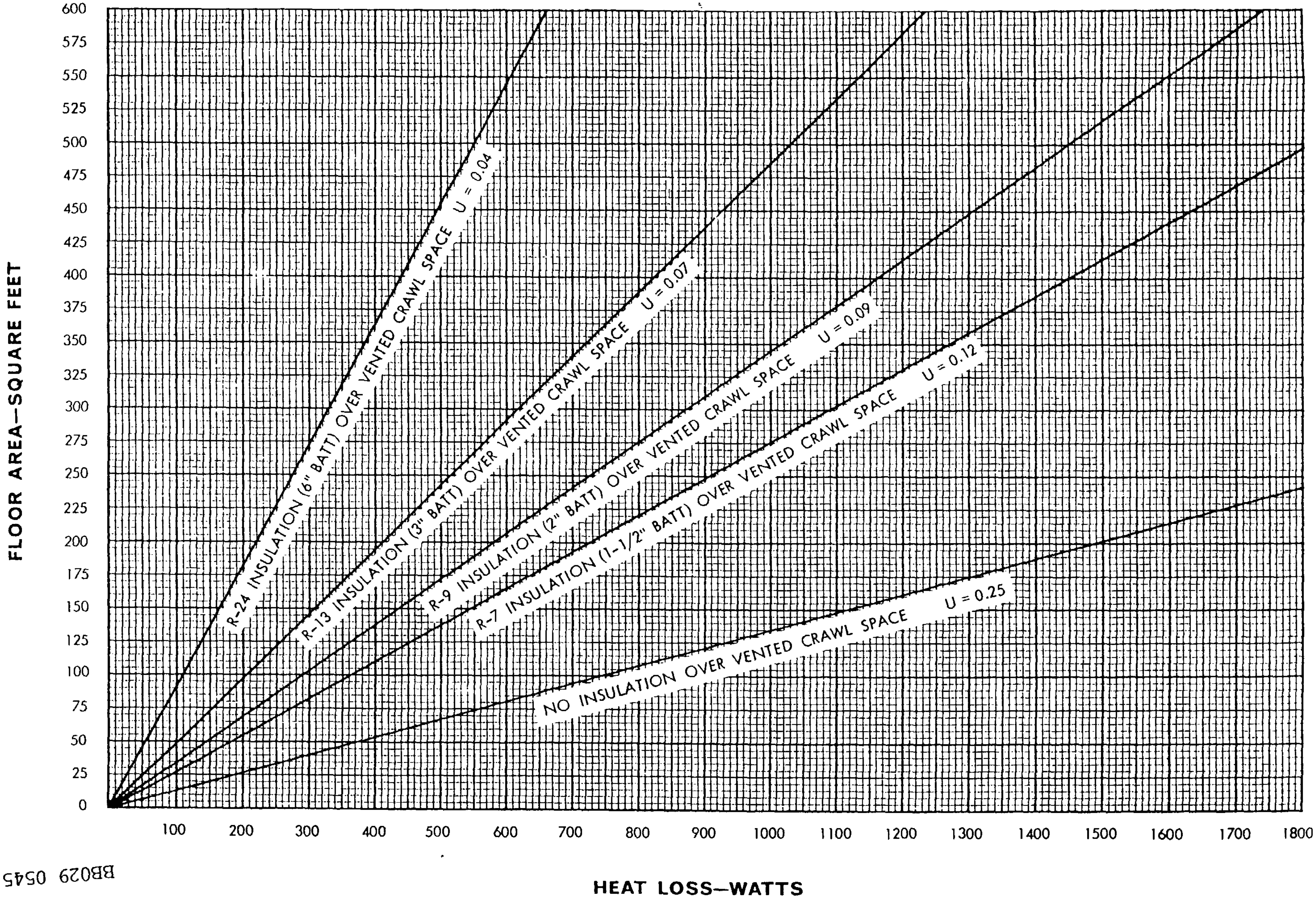
Printed in



BB029 0544

THERMALUX HEAT LOSS CALCULATOR

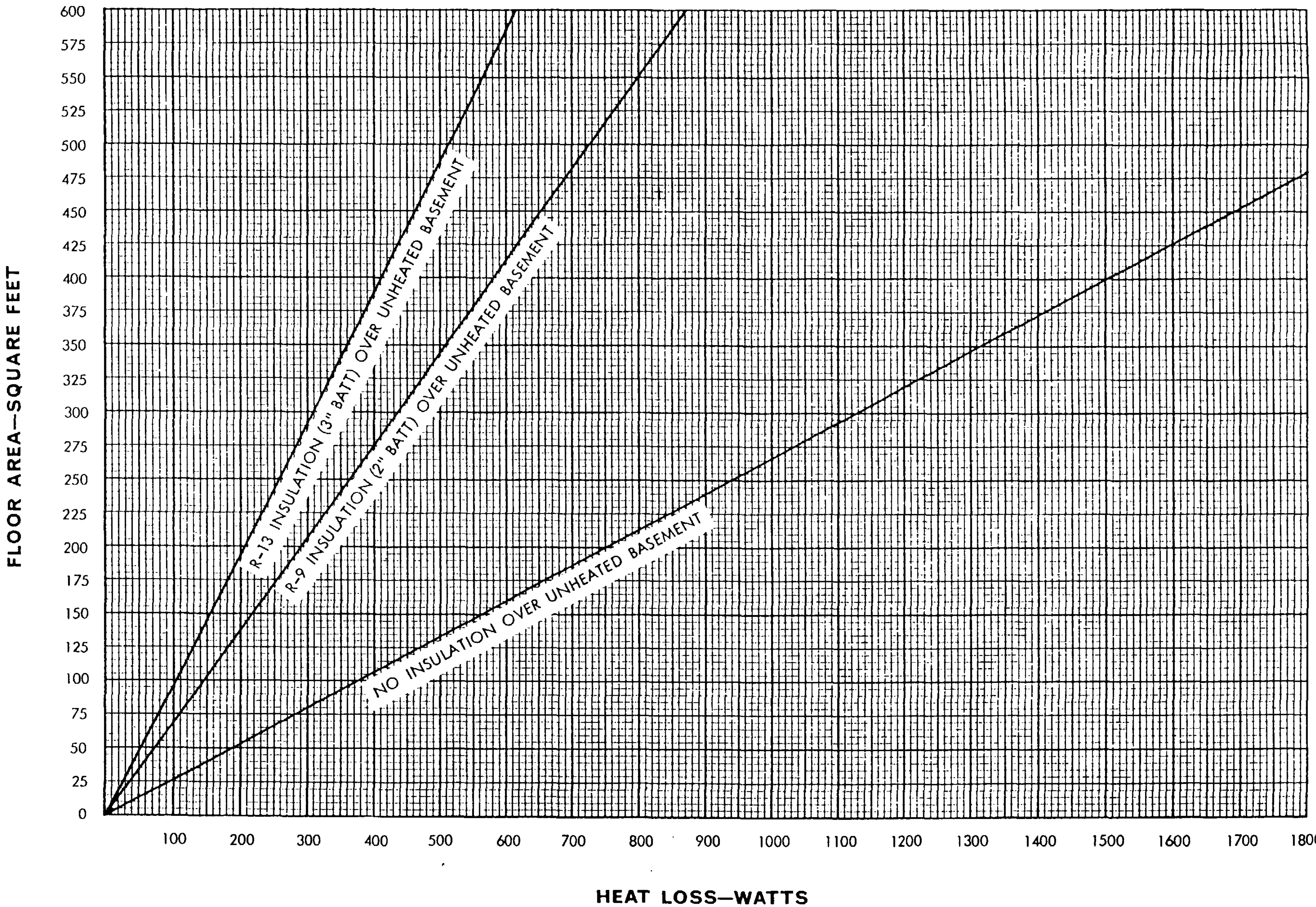
CEILING HEAT LOSS **90° TD**



BB029 0545

THERMALUX HEAT LOSS CALCULATOR

FLOOR HEAT LOSS **90° TD**



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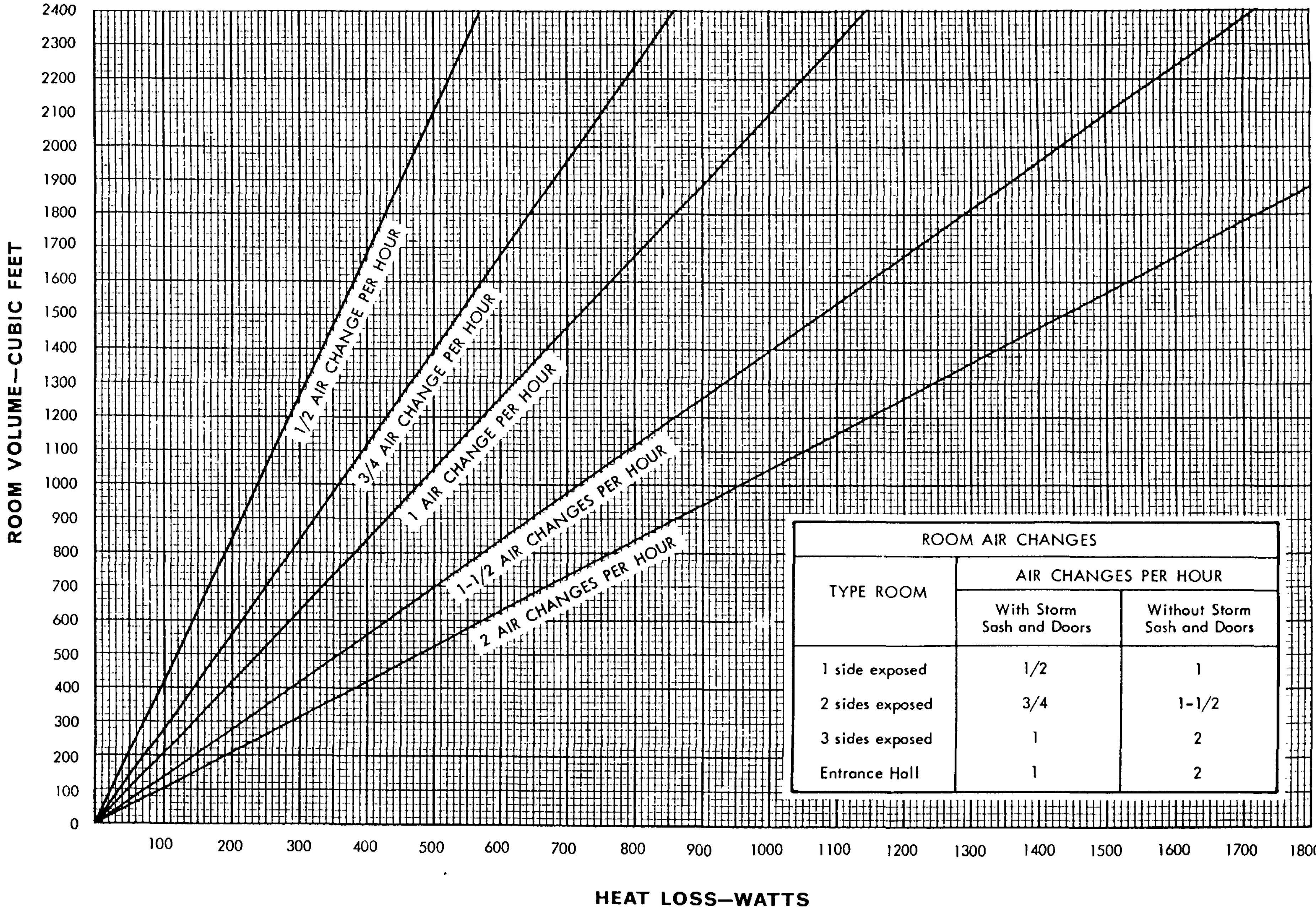
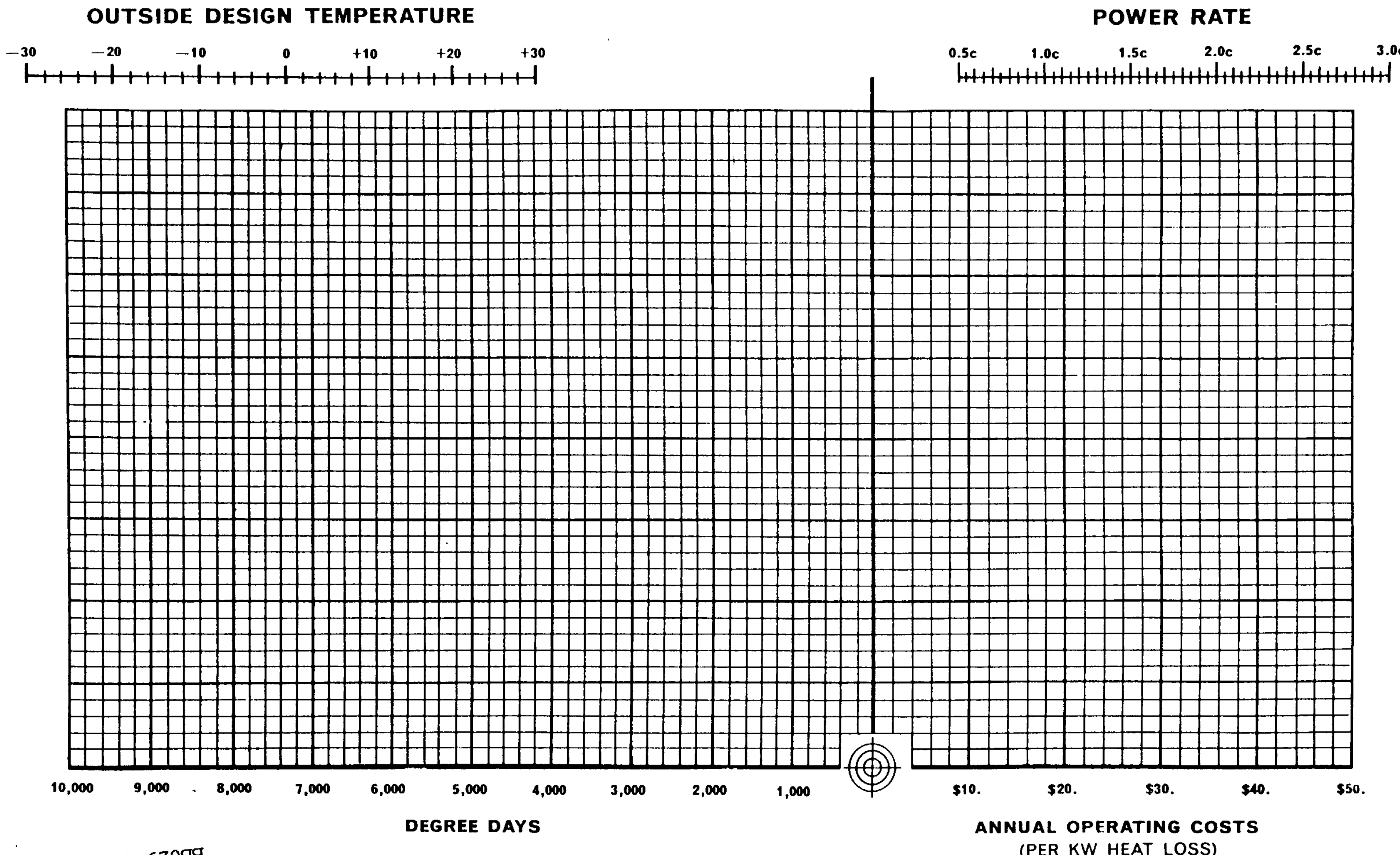
THERMALUX HEAT LOSS CALCULATOR

FLOOR HEAT LOSS **90° TD**



ROOM AIR CHANGES		
TYPE ROOM	AIR CHANGES PER HOUR	
	With Storm Sash and Doors	Without Storm Sash and Doors
1 side exposed	1/2	1
2 sides exposed	3/4	1-1/2
3 sides exposed	1	2
Entrance Hall	1	2

BB029 0547



THERMALUX

HEATING COST CALCULATOR

H-24 U.S.G. 7/64

BASED ON NEMA OPERATING COST FORMULA WITH C-FACTOR OF 17

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THERMALUX SYSTEM INSTALLATION

NECESSARY CONSTRUCTION KNOWLEDGE

Since the THERMALUX Heating System is basically a gypsum board ceiling, a knowledge of drywall construction is necessary. However, since THERMALUX is also an electric heating unit, competence in electrical wiring and familiarity with the National Electrical Code and local electrical code is essential.

MATERIALS REQUIRED FOR INSTALLATION

Chapter 2 of this Handbook fully describes the materials required for a complete THERMALUX System installation. Quantities of the required THERMALUX components will be readily determined from the System Design, prepared for each job on which THERMALUX is to be installed. System Designs are prepared in accordance with Chapter 5 of this Handbook.

TOOLS REQUIRED FOR INSTALLATION

The tools required to install, finish, and test the THERMALUX System are standard, familiar to contractors, and readily available. Necessary tools are:

- Straight edge
- Steel rule
- Trimming knife
- Wall board hammer
- Utility saw
- Circle cutter
- Rasp
- Rubber mallet
- Bit-brace with hole saw
- BOSTITCH T5-8gd stapling gun
- Roller for adhesive
- Electrician's pliers
- STA-KON WT-111 or WT-119 terminal pliers
- Long-nose pliers
- Electric fish tape
- Drill-bit extension and electrician's drill-bit
- Test lamp
- Volt-Ohmmeter
- Ammeter
- Conduit bender
- Conduit cutter and reamer
- Joint finishing tools
- Screwdriver

ELECTRICAL INSTALLATION

Power Supply

The service drop, service entrance, and service box, when a THERMALUX System is installed, are essentially the same as required for any structure except that capacity must be increased. However, added branch wiring and thermostat-control circuits for the THERMALUX System are required. The System Design will dictate the required number of branch circuits, thermostats, and control relays to be installed. The service box and control relays can be installed on a common mounting board as shown in Figure 6-1. Control relays also may be placed in other locations, according to System Design, to simplify wiring.

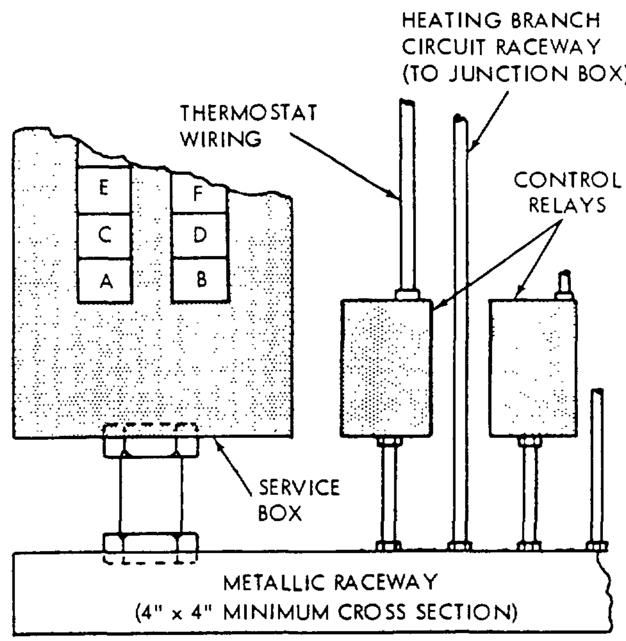

Figure 6-1. Installing The Power Supply

Local code regulations must be followed when installing heating branch circuits. The code will dictate the type of wiring to be used, such as electrical metallic tubing, flexible conduit, or armored cable. Since many localities require metallic raceways, much of the following discussion and many of the accompanying illustrations will reference such systems. If local code permits the use of non-metallic cable, armored cable, or knob-and-tube wiring, the raceways may be ignored. However, wire connections and wire routing, as discussed and illustrated, will still apply; only the mechanics of installation, such as anchoring the wiring, will differ.

The System Design will specify the choice of 2-wire or 3-wire circuits and the size of branch circuit conductors. These design factors are based on the square footage of Heating Panel (which determines amperage) and current load for each circuit.

Typical THERMALUX System wiring for 2-wire and 3-wire systems are shown in Figure 6-2.

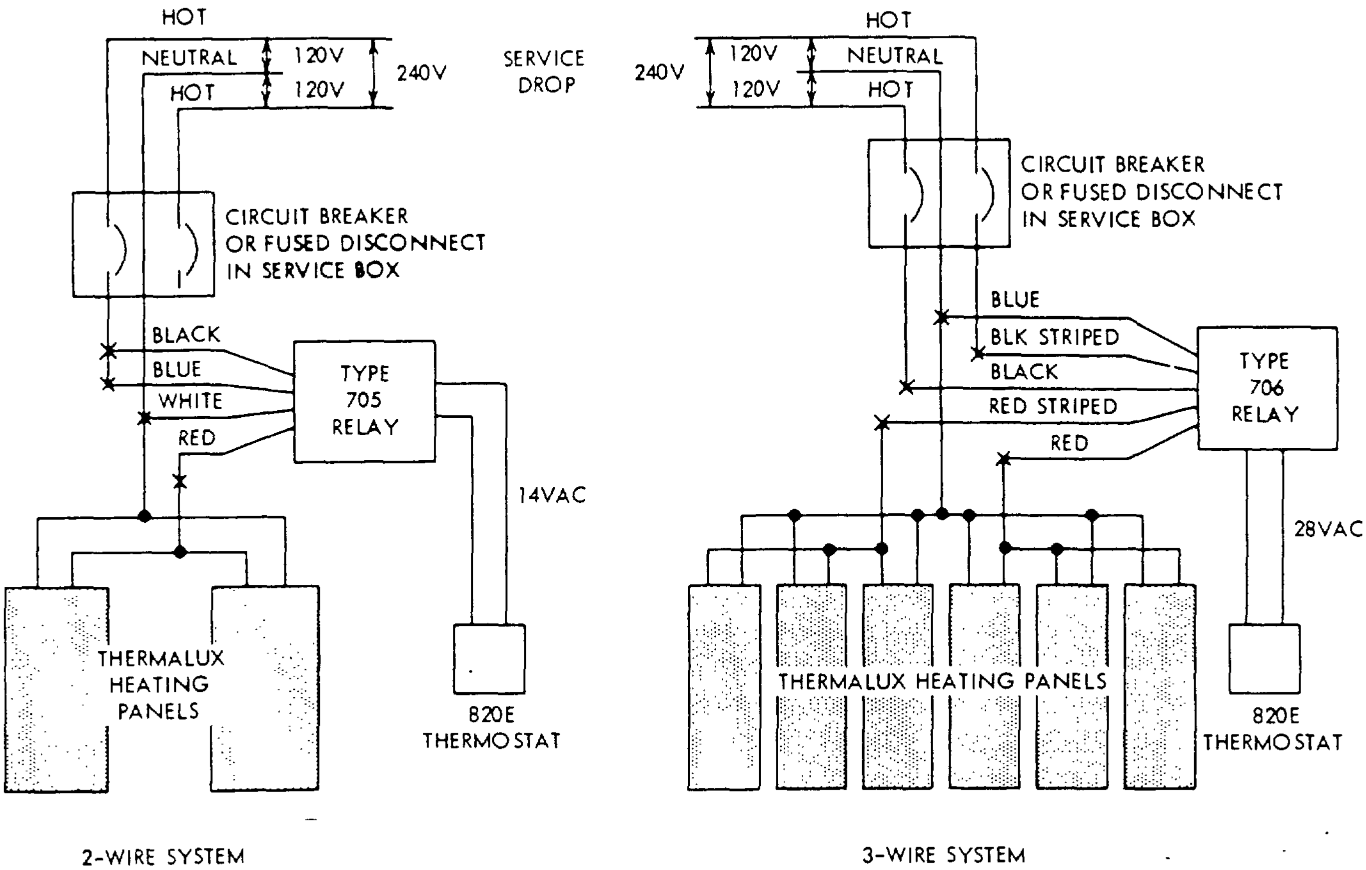

Figure 6-2. Typical THERMALUX Wiring Systems

Control Circuits

Two types of control relays may be used in a THERMALUX Heating System. The System Design will specify either a Type 705 or Type 706 for each of the branch circuits. Both work on the same principle with a Type 706 merely being two Type 705's in one enclosure.

The Type 705 control relay, schematically illustrated in Figure 6-3, has one 22-amp switch which can control one branch circuit with a maximum 22-amp load. One Type 820E thermostat is used in conjunction with this type control relay.

The Type 706 control relay has two 22-amp switches, each of which can be controlled by individual 820E thermostats; thus having two separate branch circuits with individual control circuits, as shown in Figure 6-4. For reasons of installation economy, this method should be used, rather than using two Type 705 control relays, whenever possible.

The Type 706 control relay can also be used with one 820E thermostat, as illustrated in Figure 6-5. This situation occurs where a large room requires two branch circuits to accommodate the current load required by the square footage of heating panels; yet it is desirable to control the temperature of the room with one thermostat. This situation could be covered using two Type 705 control relays but again, for economic reasons, the Type 706 should be used.

To supplement the control relay and thermostat wiring instructions included here, the United States Gypsum Company has available, on request, individual brochures on each of the control relays and the thermostat recommended for use in a THERMALUX System.

Line voltage thermostats can also be used with the THERMALUX Heating System. However, the designer should recognize that such thermostats do not have the sensitivity and response characteristics to provide highest quality comfort control.

Thermostat location must be in accordance with the System Design. Chapter 5 of this Handbook recommends to the system designer that the thermostat be mounted on an inside wall, 36 to 60 inches above the floor. Be sure the location selected is away from heat sources such as lamps, a television set, fireplace, or hot water pipes. Avoid cold area locations near windows, doors, or cold water pipes. Wiring, from the control relays to the thermostats, must comply with the National Electrical Code and local code requirements.

BB029 0550

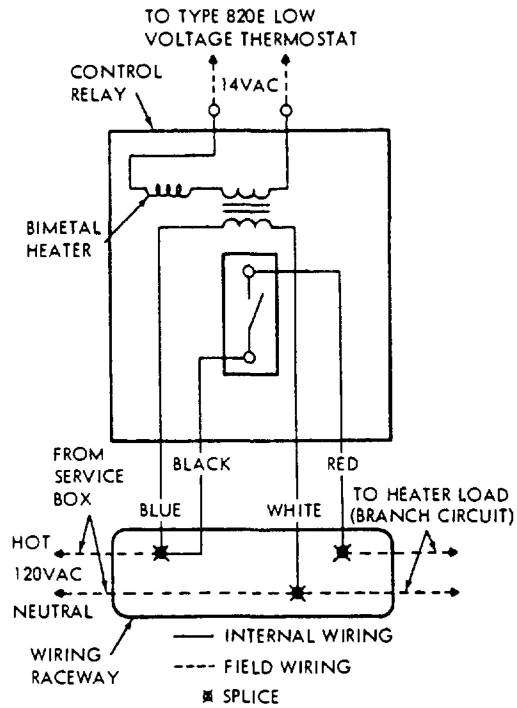

Figure 6-3. Type 705 Control Relay

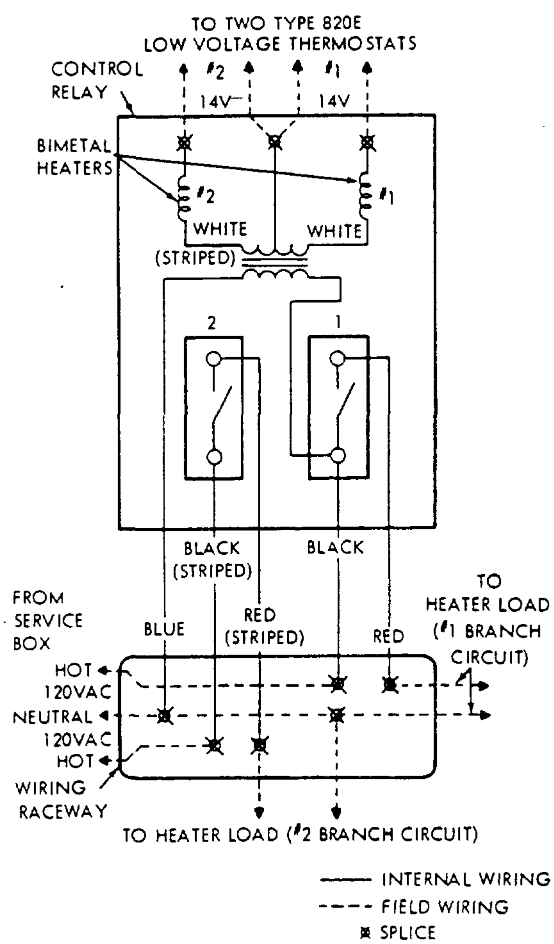

Figure 6-4. Type 706 Control Relay with Two Control Systems

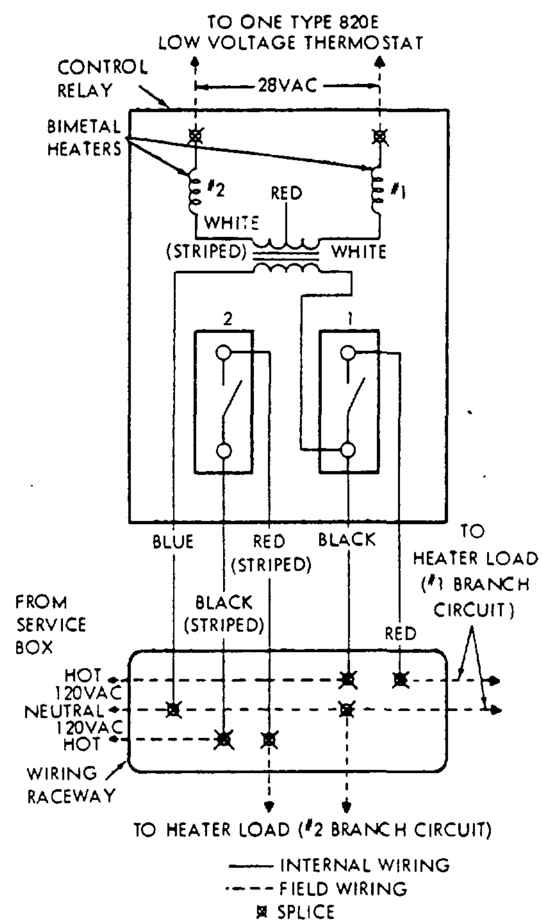

Figure 6-5. Type 706 Control Relay with One Control System

BB029 0551

Branch Circuits and Junction Boxes

Locate junction boxes in accordance with the System Design and install in an accessible position in compliance with Article 370-19 of the National Electrical Code. Raceways/wiring between the power supply and junction boxes must comply with code requirements and be installed in the structure in accordance with good electrical practice.

Generally, the System Design permits some flexibility in junction box location. However, they should be placed where readily accessible and as close as possible to the associated wiring recess.

Attic space provides a convenient location for junction boxes. Locations near the center of the house, rather than under the eaves, are preferred. Concealment of the boxes usually isn't necessary. Position the junction box near the wiring recess, to shorten conductor runs and make them readily accessible so wiring connections can be inspected and tested.

A wall is also a logical location for junction boxes although this position has two distinct disadvantages. First, additional wiring to the wiring recess will be required. Secondly, concealment of the junction box will be necessary. This can be accomplished by recessing the box into the wall. However, the cover will be apparent so it is desirable to locate the junction box in an unobstrusive place such as a closet.

The least desirable junction box location is in the floor of the area above the THERMALUX Panels. Junction box location in close proximity to the wiring recess is easily attained but concealment of the junction box cover is only possible by covering it with a rug or carpeting. Figure 6-6 illustrates typical attic, wall, and floor junction box installations.

The wiring from the junction boxes to the THERMALUX Panels, must be done after wiring recess construction and panel installation.

SUPPLEMENTARY THERMALUX PANEL FRAMING

At times THERMALUX Heating Panels must be installed in positions that do not conform with the structure framing. When such installations are necessary, supplementary framing will be required to firmly support the THERMALUX Panels. It is desirable, in most instances, to install this framing prior to panel erection. Good construction practice should be followed when installing supplementary framing.

WIRING RECESS CONSTRUCTION

Wiring recesses must be installed in the locations indicated by the System Design. Because of the methods used in constructing the recesses, it is desirable to install them prior to erecting the THERMALUX Panels. In fact, the panels themselves form at least one side of the recess while the Finishing Panels form the bottom of the recess.

The System Design will designate the wire sizes to be accommodated in the recess. A good design will have a well balanced electrical system requiring the use of #10 and #12 wire only. These wire sizes require a recess depth of only 1/4" if wires are not required to crossover, and a 1/2" deep recess if wires must crossover. A crossover will be required if more than two THERMALUX Panels are wired through the same recess. All recesses should be 3" to 6" wide. Nails used in constructing a recess should be of the insulated type.

Wiring recesses may be constructed in a variety of ways. Several typical wiring recess construction methods are described and illustrated here but other, more applicable constructions, may be devised to suit design requirements. Heating Panels and Filler Panels, identified in the illustrations, are shown for reference only, indicating where they will be positioned when they are installed.

The most important requirement in wiring recess construction is that wiring be completely surrounded by non-flammable, non-conductive gypsum.

WIRING RECESS CONSTRUCTION FOR HEATING PANELS PERPENDICULAR TO JOISTS

1/2" Deep Wiring Recess Construction (Figure 6-7)

Locate, from the System Design, the pair of joists between which the wiring recess must be constructed. Nail 2" x 4" blocking 24" on centers between the joists for the length of the recess. The bottom of the blocking must be 1/2" above the lower face of the joists.

Cut a piece of 1/2" gypsum board 6" wider than the proposed wiring recess width and the length of the recess.

Align the centerline of the gypsum board with the headers and nail in place. This forms the top of the wiring recess, with the gypsum now at the same level as the joists, ready for Heating or Filler Panels to be installed. These panels will then form the sides of the wiring recess and give it a 1/2" depth.

1/2" Deep Wiring Recess Construction (Figure 6-8)

Locate, from the System Design, the pair of joists between which the wiring recess must be constructed. Nail 2" x 2" wood strips along facing sides of the joists for the length of the recess. The bottom of the strips must be 1/2" above the lower face of the joists.

Cut a piece of 1/2" gypsum board the width of the space formed by the joists and the length of the proposed recess.

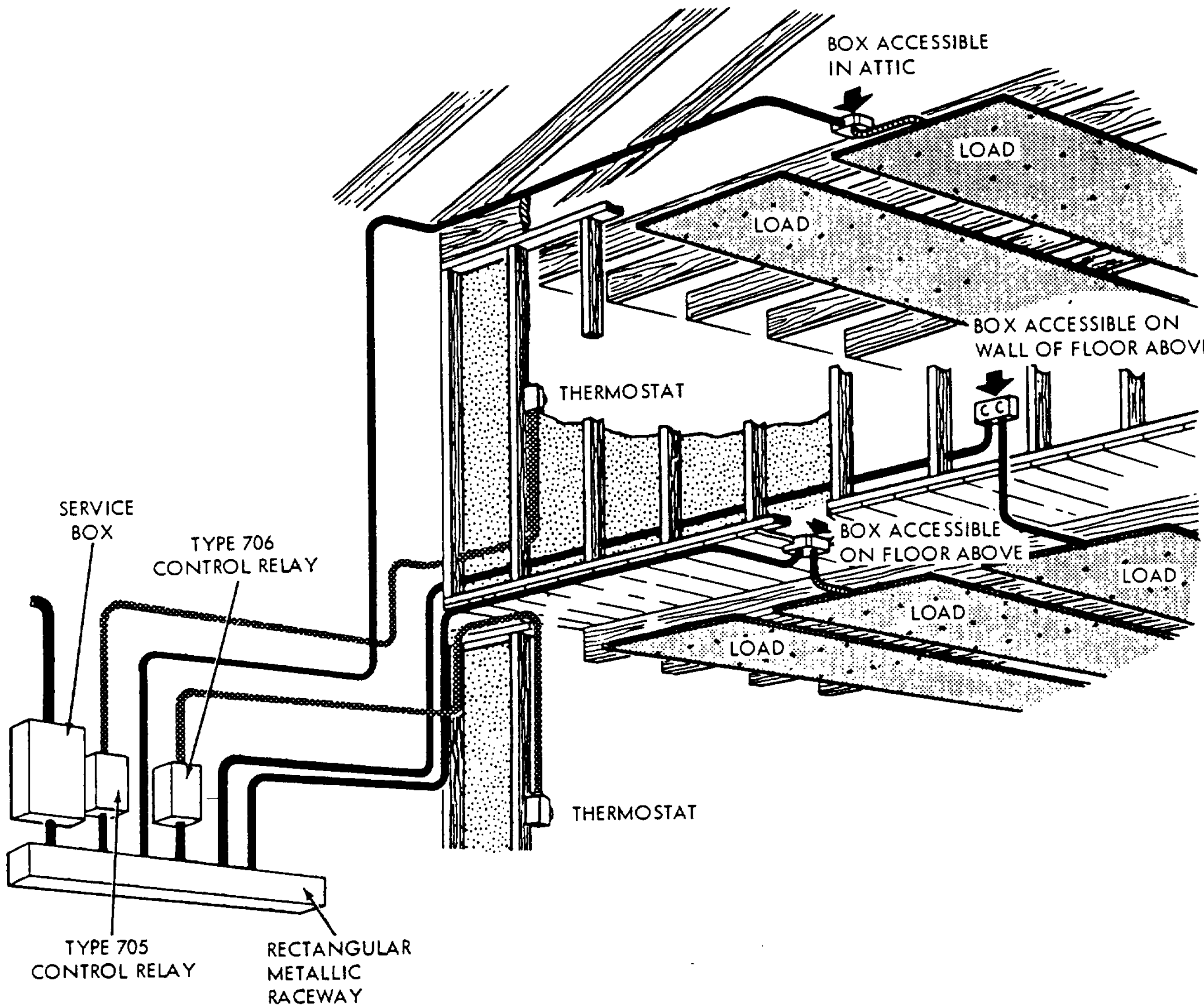

Figure 6-6. Typical Attic, Wall, and Floor Junction Box Installations

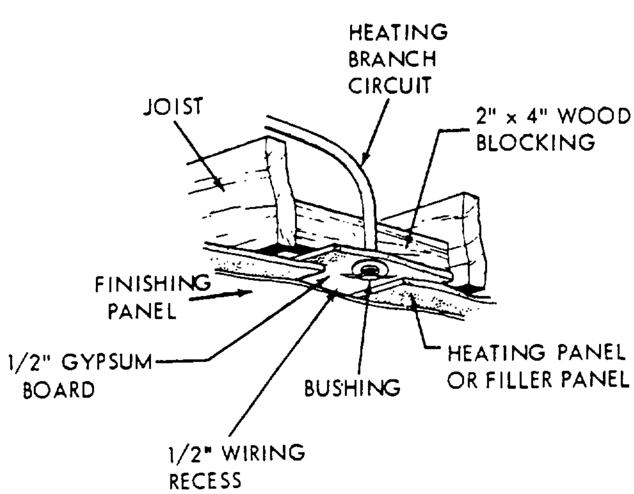

Figure 6-7. Wiring Recess Construction
(1/2" Depth)

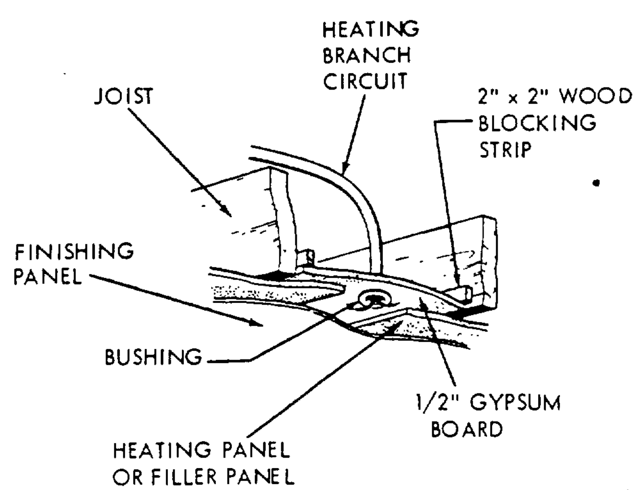

Figure 6-8. Wiring Recess Construction
(1/2" Depth)

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Position the gypsum board against the 2" x 2" strips and nail in place. This forms the top of the wiring recess, with the gypsum board now at the same level as the joists, ready for Heating or Filler Panels to be installed. These panels will then form the sides of the wiring recess and give it a 1/2" depth.

1/2" Deep Wiring Recess Construction (Figure 6-9)

This method of wiring recess construction is used after Heating and Filler Panels have been installed. However, this method is only practical where there are open joists on the floor above, such as an attic. Adequate space must also be available for this type installation as a length of 1/2" gypsum board, equal to the length of the proposed wiring recess and 6" to 8" wider than the proposed wiring recess width, must be handled.

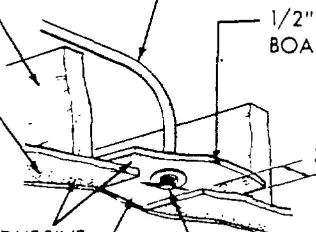

Figure 6-9. Wiring Recess Construction (1/2" Depth)

To use this method, cut a section of 1/2" gypsum board, as mentioned above, equal to the length of the proposed wiring recess and 6" to 8" wider than the proposed wiring recess width. Apply THERMALUX Adhesive, 3" to 4" wide, on one side of the gypsum board over its entire length, parallel to both edges. Apply THERMALUX Adhesive, in a strip 3" to 4" wide, to the top side of the installed Heating and/or Filler Panels, along the wiring recess opening left by these panels.

When the THERMALUX Adhesive becomes non-tacky (20 to 30 minutes after application), position the 1/2" gypsum panel on the Heating and/or Filler Panels and over the wiring recess opening. This 1/2" gypsum board has now become the top of the wiring recess and the Heating and/or Filler Panels form the sides, giving it a depth of 1/2".

1/4" Deep Wiring Recess Construction (Figure 6-10)

To construct a 1/4" deep wiring recess, the method for a 1/2" deep recess applies except that the bottom

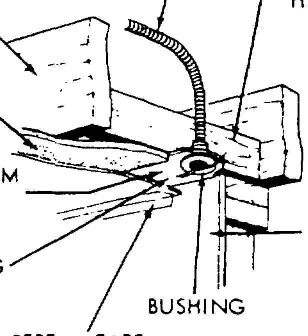

Figure 6-10. Wiring Recess Construction (1/4" Depth)

edge of the headers must be flush with the bottom edge of the joists. Also, the top of the recess is cut from a 1/4" gypsum board and to the exact length and width of the recess. This piece is then nailed to the headers in the specified location and forms the top of the recess. Heating Panels, when installed, will abut the top board of the wiring recess, forming sides 1/4" deep.

WIRING RECESS CONSTRUCTION FOR PANELS PARALLEL TO JOISTS

1/2" Deep Wiring Recess Construction (Figure 6-11)

Locate, from the System Design, the exact position of the proposed wiring recess. Mark the wiring recess location on the underside of the ceiling joists. Cut 2" x 2" (or larger) wood blocking strips approximately 4" longer than the wiring recess width. Nail the 2" x 2" blocking to the sides of each joist, parallel to and 1/2" from the bottom edge the joist, and centered above the area to be occupied by the wiring recess.

Cut pieces of 1/2" gypsum board approximately 4" wider than the proposed wiring recess width and of a length equal to the spacing between joists. Nail these boards to the underside of the 2" x 2" blocking. These boards now become the top of the wiring recess. However, the flammable joists are still exposed in the recess.

The exposed joists are covered by 1/4" gypsum boards cut to the exact width of the wiring recess and approximately 6" long. Center these across the joists, between the scribe marks, and nail them to the joists. This completes the top of the wiring recess. When the Heating or Filler Panels are installed, abut them against the 1/4" gypsum board and overlapping the 1/2" gypsum board. These will form the 1/2" sides of the wiring recess. Note that in the joist areas, the wiring recess will only be 1/4" deep, necessitating required wiring crossovers to

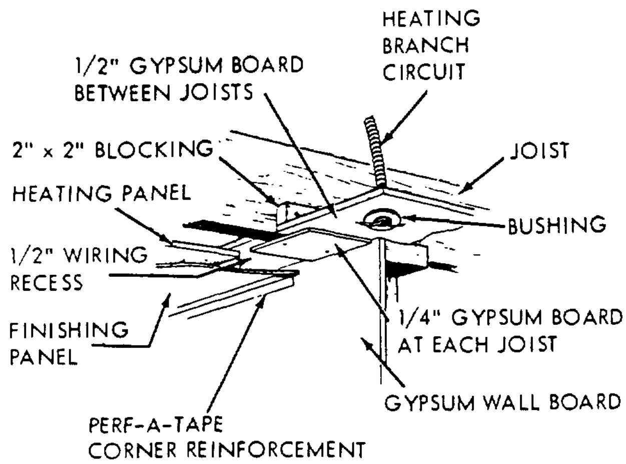

Figure 6-11. Wiring Recess Construction (1/2" Depth)

take place in the 1/2" deep areas. This type of wiring recess can be constructed adjacent to or away from a partition.

1/2" Deep Wiring Recess Construction (Figure 6-12)

Locate, from the System Design, the exact position of the proposed wiring recess. Mark the wiring recess location on the underside of the ceiling joists. Cut 1" x 6" or 1" x 8" boards (depending on the width of the proposed wiring recesses) to a length equal to the spacing between joists. Cut 1/4" or 1/2" gypsum boards (optional) to the same length and approximately 2" wider than the 1" x 6" or 1" x 8" boards. Nail the gypsum boards to the wood boards, allowing a 1" overhang on each side.

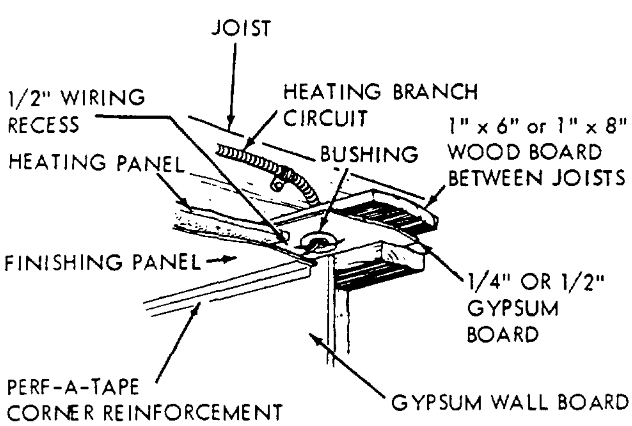

Figure 6-12. Wiring Recess Construction (1/2" Depth)

Position these boards between the joists centered on the wiring recess location, with the face of the gypsum board flush with lower edge of the joists and nail to the wall plate. These boards now become the top of the wiring recess. However, the flammable joists are still exposed and must be covered with a strip of 1/4" gypsum board as described in Figure 6-11. Since the wiring recess will be only 1/4" deep at joist locations, any wiring crossovers must be made in the 1/2" deep recess between joists.

1/4" Deep Wiring Recess Construction (Figure 6-13)

Locate, from the System Design, the exact position of the proposed wiring recess. Mark exact width of the wiring recess on the underside of the joists.

Cut a piece of 1/4" gypsum board the exact length and width of the proposed wiring recess. Position on joists and nail in place.

When installing Heating Panels, they must abut the 1/4" gypsum board, forming the 1/4" deep sides of the wiring recess.

Only two Heating Panels can be serviced by this type wiring recess since the 1/4" depth will not permit cable crossovers.

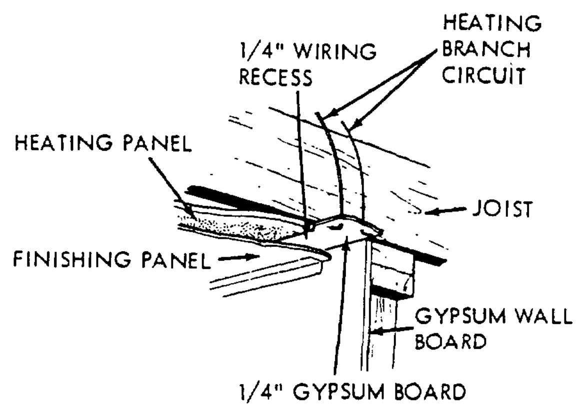

Figure 6-13. Wiring Recess Construction (1/4" Depth)

Wiring Recess Construction when Abutting a Wall

When a wiring recess is constructed adjacent to a wall or partition (such as illustrated in Figures 6-10, 6-11, 6-12 and 6-13), provision must be made so that the gypsum board on the sidewalls will completely isolate the combustible wood framing from the wiring. This is readily accomplished by temporarily nailing scrap pieces of 1/2" gypsum (or other thickness equal to wall board thickness), to the wall studs and abutted against the ceiling joists before constructing the wiring recess. Following recess installation, remove the scrap pieces of gypsum. When installing gypsum board on side walls, insert the panels into the opening and abut the joists.

Wiring Recess Closing Blocks

After the top of the wiring recess has been installed, the ends also must be closed with gypsum board, to seal the recess from combustible material. Usually the Filler Panel installed in the ceiling will provide these closures. However, it is sometimes necessary to use separate strips of gypsum board for this purpose. Install according to the following method. Cut a strip of scrap gypsum board the thickness of the recess, at least 1" wide, and as long as the recess is wide; nail the gypsum strip to the framing at each end of the recess to provide a safe clearance between recess and any framing. This strip is not necessary, as mentioned above, when the recess ends against Heating or Filler Panels.

Wiring Recess Configuration

The wiring recess should be designed to run in a straight line, for its full length, without turns or angles which complicate support blocking and conductor fastening. Still, the recess must accommodate the heating panel layout. Therefore, "L"-shaped, "U"-shaped, and other simple continuous recess designs are frequently employed without difficulty. A "U"-shaped recess is often used in hallways to connect single heating panels on each side of a central light fixture as shown in Figure 6-14. Here, the Filler Panel is "step-shaped" providing closure of the wiring recess at the end of heating element.

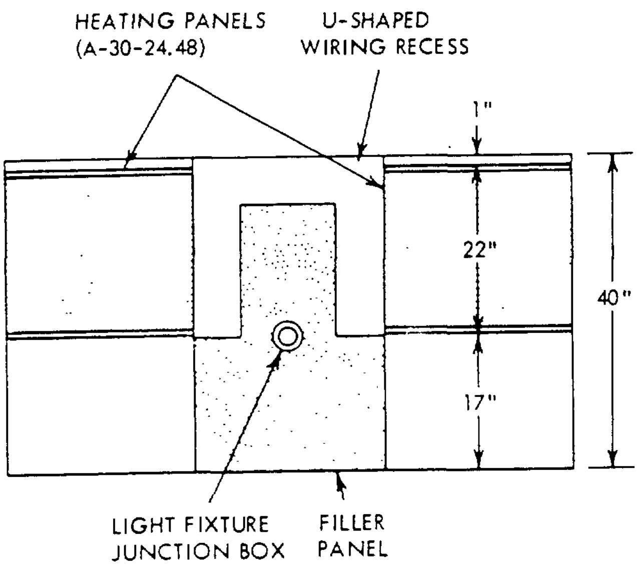

Figure 6-14. Irregular Wiring Recess Construction

HEATING PANEL INSTALLATION

Two types of Heating Panels are available, the A-60-48.48 and the A-30-24.48. Panel construction of both types is shown in Figure 4-1. Heating Panel installation is as simple as regular gypsum board. The only precautions necessary, when installing Heating Panel, are in cutting and nailing.

Nailing

Always use THERMALUX Insulated Nails when installing Heating Panels. If standard nails were used, they would be electrically "hot" from contacting the electrical element.

The type A-60-48.48 panel has 1/2" electrodes running the entire length of the panel 1" in from, and parallel to, each edge. The electrode area is the only area through which nails must not be driven.

The type A-30-24.48 has one electrode running the entire length of the panel 1" in from, and parallel to, one edge. The second electrode is then 22" from, and parallel to, the first electrode. Again, the electrode area is the only area through which nails must not be driven.

Cutting Heating Panels to Length

Normally, the System Design will not require that Heating Panels be cut to length. However, both types of Heating Panels can be cut to length. It is essential, however, that the cut be made completely across the panel, perpendicular to the electrodes, as shown in Figure 6-15.

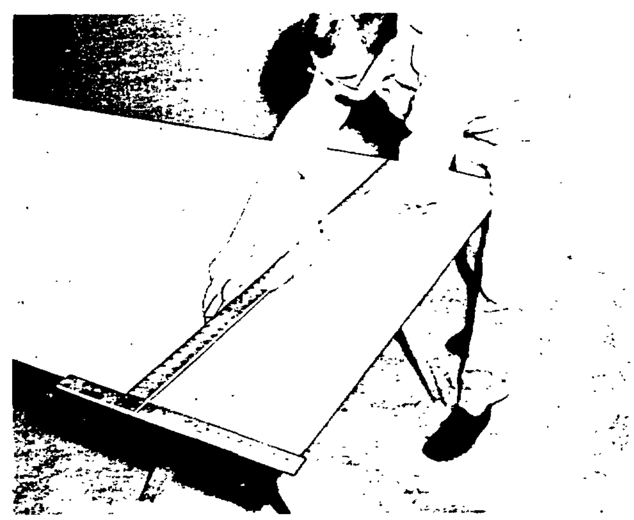

Figure 6-15. Cutting Heating Panel by Scoring through Electrodes and Heating Element

To cut a Heating Panel, simply score it on the element side, using a sharp knife and a straight edge (Figure 6-15). The score must cut through the heating element, electrodes and paper on the gypsum panel. Snap the panel at the score mark by exerting a slight downward pressure as shown in Figure 6-16. Smooth and square the cut edge with a rasp or sandpaper.

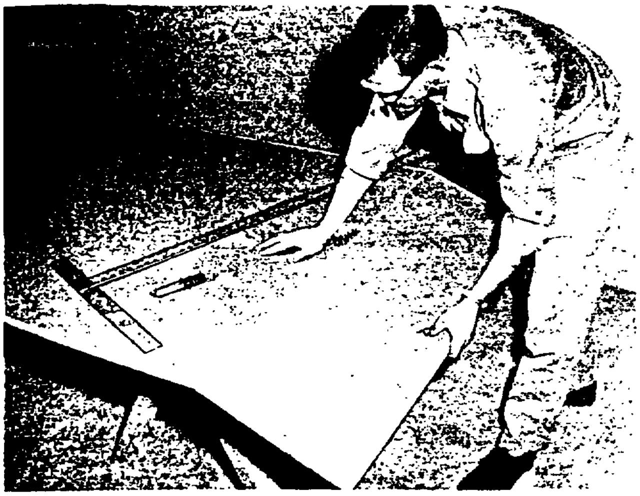

Figure 6-16. Snapping Heating Panel on Scored Mark

Cutting Heating Panels to an Irregular Length

Heating Panels may be cut to an irregular length when necessary to fit an unusual structural condition. However, this should be avoided whenever possible since heating area is lost and additional work is entailed. A System Design will seldom require this be done. If such a cut is necessary, mark the shape of the cut on the panel as shown in Figure 6-17.

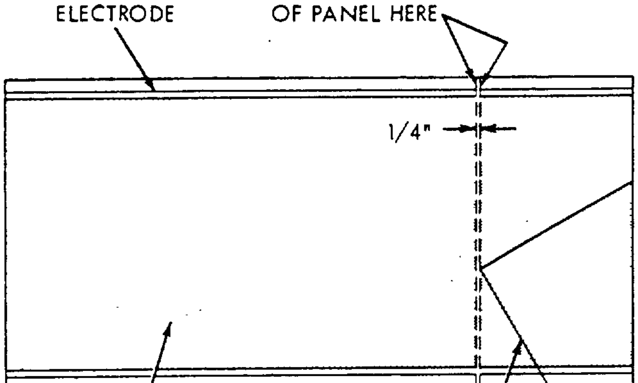

Figure 6-17. Cutting Heating Panel with Irregular Shaped End to Length

Score the Heating Panel, on the element side, straight across as shown in Figures 6-15 and 6-17. The score must be made at the point where the deepest irregularity of the end cut occurs and to a depth which insures severing the heating element and electrodes. The panel must be scored again with about 1/4" between cuts. Then the heating element and electrodes must be removed from the 1/4" area so that electrical continuity of the panel is broken. The irregularly shaped end may now be cut.

Cutting Heating Panels to Width

Only panel type A-30-24.48 can be cut to width. This panel is constructed with a 22" heating element, leaving a 24" trim width, as shown in Figure 4-1. This trim area, which is not covered with heating elements is used to reduce panel width. However, the panel must not be trimmed narrower than 24" as that would separate the electrodes, creating an open circuit.

Accommodating Light Fixture Junction Boxes and Other Devices in Heating Panel Areas

Normally, good System Design will locate light fixtures in a Filler Panel area, with the required distance of 7" from the adjacent Heating Panel edge or 8" from the end as shown in Figure 6-18. It is not always possible to position Filler Panel for light fixtures so then they have to be accommodated in Heating Panel areas.

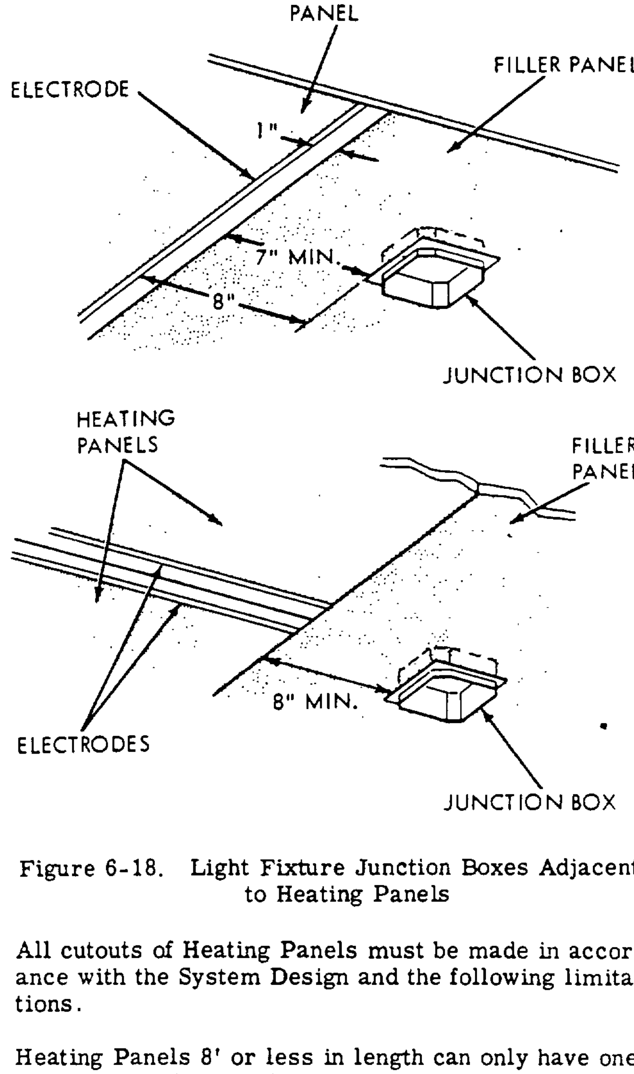

Figure 6-18. Light Fixture Junction Boxes Adjacent to Heating Panels

All cutouts of Heating Panels must be made in accordance with the System Design and the following limitations.

Heating Panels 8' or less in length can only have one cutout. Panels 8' or longer in length will accommodate two cutouts. Edges of cutouts must be at least

6" from panel ends, 2" from electrodes. If two cutouts are made in the same panel, they must be at least 24" apart. All edges of cutouts must be at least 8" from the light fixture junction box. Edges of the Heating Panel must be at least 2" from metal pipes or ducts.

The shape of the cutouts may be circular or square. However, corners of square cutouts must have a radius 2" or larger. Pertinent cutout dimensions are illustrated in Figure 6-19, as are the panel areas in which heat loss will occur because of the cutouts.

Heating Panel-to-Wall Isolation

Where ends of Heating Panels are extended to a wall, two methods of isolation may be used. The first method, which takes place during installation, is to temporarily nail a strip of 1/2" scrap gypsum board across the studs, abutted against the ceiling joists, at the Heating Panel wall junction. When installing the Heating Panel, butt the ends snugly against the 1/2" scrap board, then remove the scrap board. When 1/2" gypsum wall board is subsequently installed, slip it into the 1/2" opening and butt it firmly against the ceiling joists. This method is illustrated in Figure 6-21.

An alternate method is to remove 2" of heating element and electrodes from the end of the Heating Panel prior to installation.

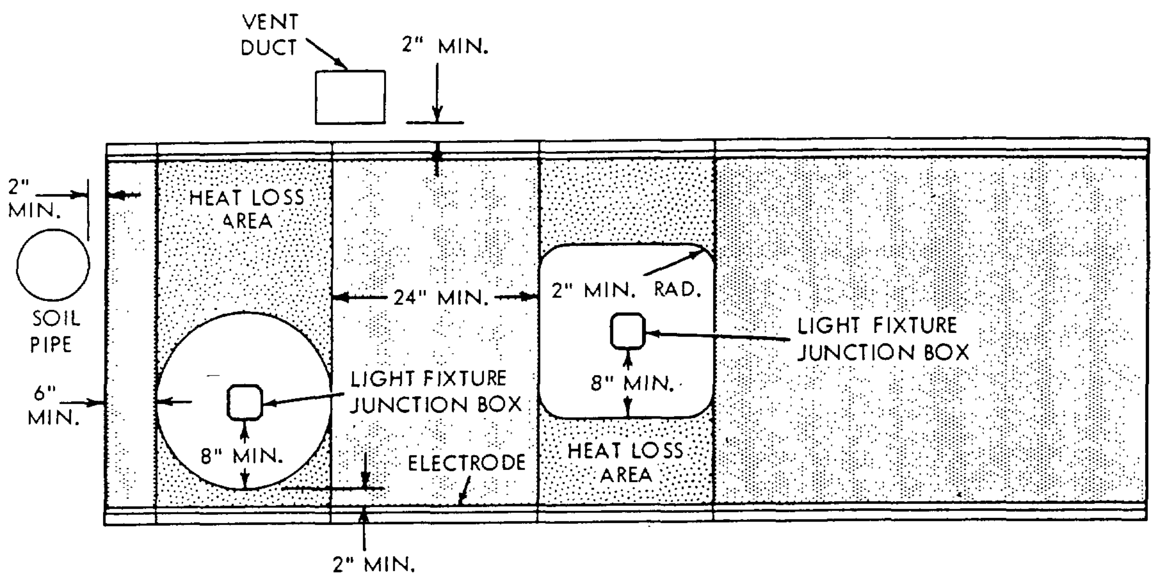

Figure 6-19. Typical Cutouts Made in a Heating Panel

Cross-bracing must be installed behind a Heating Panel cutout to provide nailing accommodations for the Heating Panel and the Filler Panel plug which must be fitted into the cutout. The method for installing cross-bracing is illustrated in Figure 6-20.

Heating Panel Isolation

Particular attention must be given to ascertain that all panel heating elements and electrodes are isolated from metal and/or combustible materials. A study of the System Design will indicate where Heating Panels will terminate. Only panel ends must be considered since panel edges have 1" wide areas beyond the electrodes which do not contain heating element.

Panel ends abutting wiring recesses, of course, need not be considered. Panels abutting Filler Panels present no problem since Filler Panels are non-conductive and non-flammable.

Heating Panel External Corner Isolation

Heating Panels installed with ends adjacent to stairwells, hatchways, skylights, and soffits usually become part of external corners. In such instances isolation takes place during installation. The gypsum board installed in the vertical plane, as shown in Figure 6-22, must be at least 1/2" thick and cover edges of both the Heating Panel and Finishing Panel. PERF-A-BEAD* corner reinforcement is used to enclose the joint.

*T. M. Reg. U. S. Pat. Off.

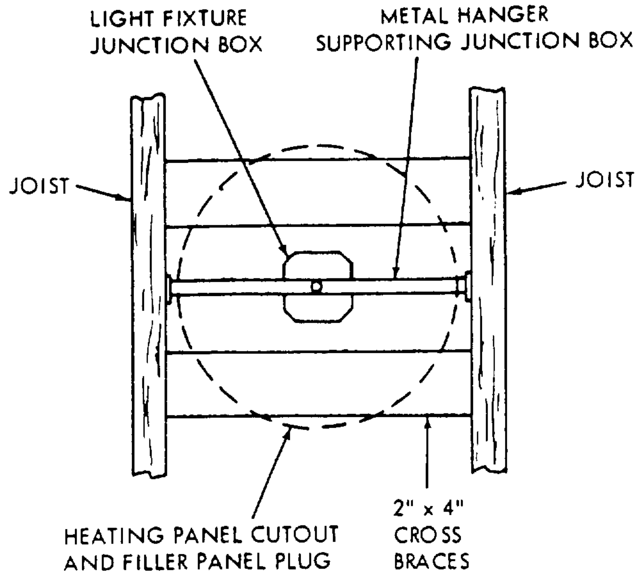

Figure 6-20. Typical Cross-Bracing for a Heating Panel Cutout

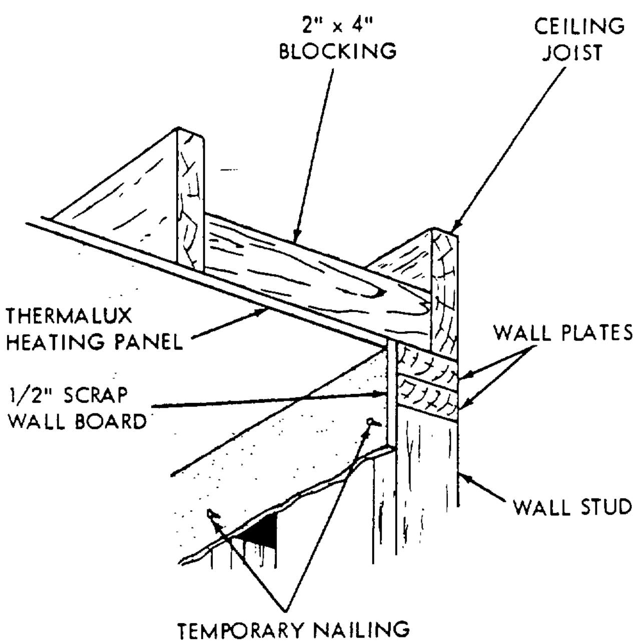

Figure 6-21. Isolating Heating Panel which Abuts a Wall

Heating Panel Erection

Actual installation of the Heating Panels is simple once the electrical wiring, supplementary structure framing, wiring recesses, necessary insulation, and panel cutting have been accomplished.

Inspect each Heating Panel before installation to be sure no cracks or gouges exist in the heating element. Damage to electrodes could cause large "dead areas"

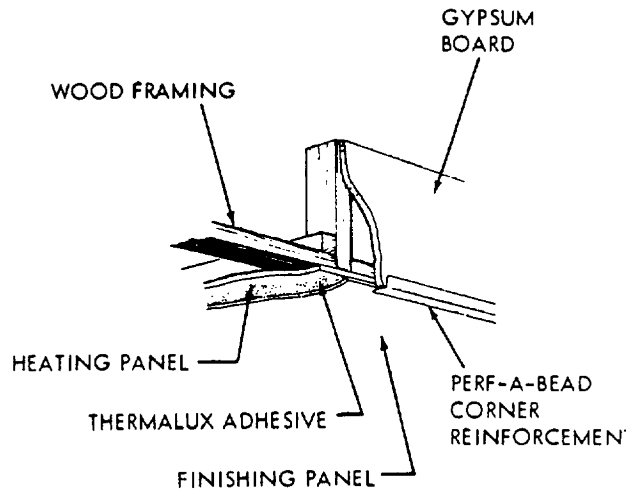

Figure 6-22. Isolating Heating Panel which Becomes Part of an External Corner

in the Heating Panel. Damage to the heating element could cause "arcing" or possible "dead areas" in the panel.

When nailing Heating Panels in position, be sure to observe the precautions outlined earlier in this chapter under "Nailing". Nails should be spaced 10" c-to-c and follow each joist and supplementary frame covered by the panel as shown in Figure 6-23.

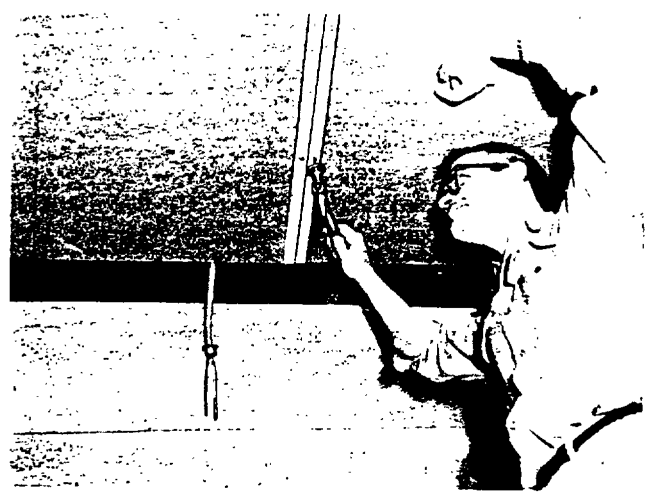

Figure 6-23. Installing Heating Panels

Filler Panel Erection

Filler Panels require no special installation instructions. Standard practice, as used when installing any gypsum board, is the only requirement. It is recommended that Insulated Nails be used 10" c-to-c, as with Heating Panels.

Remember that Filler Panel must be used in the Heating Panel junction box cutouts. The simplest way to cut a correct size piece is to use the piece which was cut out of the Heating Panel as a template as shown in Figure 6-24. When cutting the Filler Panel to the shape of the template, cut on an angle as shown in Figure 6-24. Install the Filler Panel in the Heating Panel with the smaller diameter up, the larger diameter down, for an easy, yet snug fit.

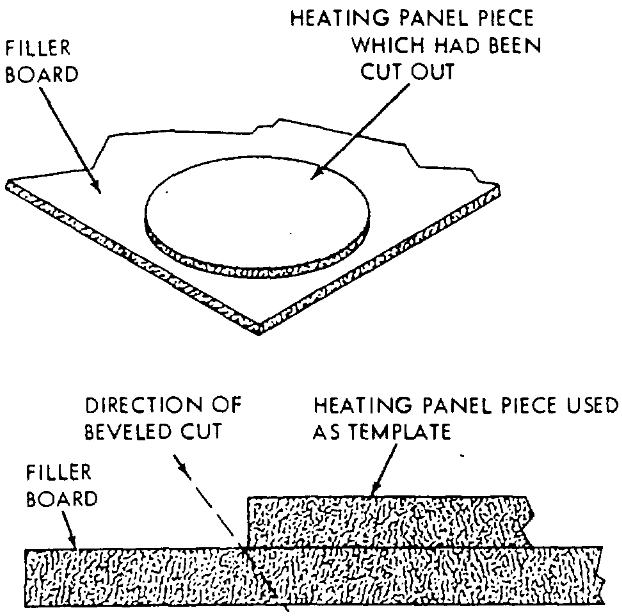

Figure 6-24. Cutting Filler Panel Plugs for Heating Panel

FEEDER WIRING INSTALLATION

The National Electrical Code, as well as local code, must be adhered to when completing the THERMALUX System wiring. In the "Electrical Installation" section of this chapter, system wiring was completed from power source through branch circuits to junction boxes located in close proximity to wiring recesses. Wiring must now be completed from the junction boxes, into the wiring recesses, to the heating panels.

Entry into the wiring recess is accomplished through a THERMALUX Bushing, a standard bushed end fitting, or simply through drilled holes in the top board of the wiring recess. (Local code will determine whether the entry must be bushed.) Figure 6-25 illustrates the methods of entry into the wiring recess.

Refer to the System Design to determine wire size and type of raceway to be used. This, and local code, will determine whether a hole be drilled in the wiring recess to accommodate a THERMALUX Bushing, bushed end fitting, or individual UF cables. Usual entry into the wiring recess is accomplished by using a hole saw of the appropriate size, as shown in Figure 6-26.

The THERMALUX Bushing will accommodate all raceway systems, such as electrical metallic tubing,

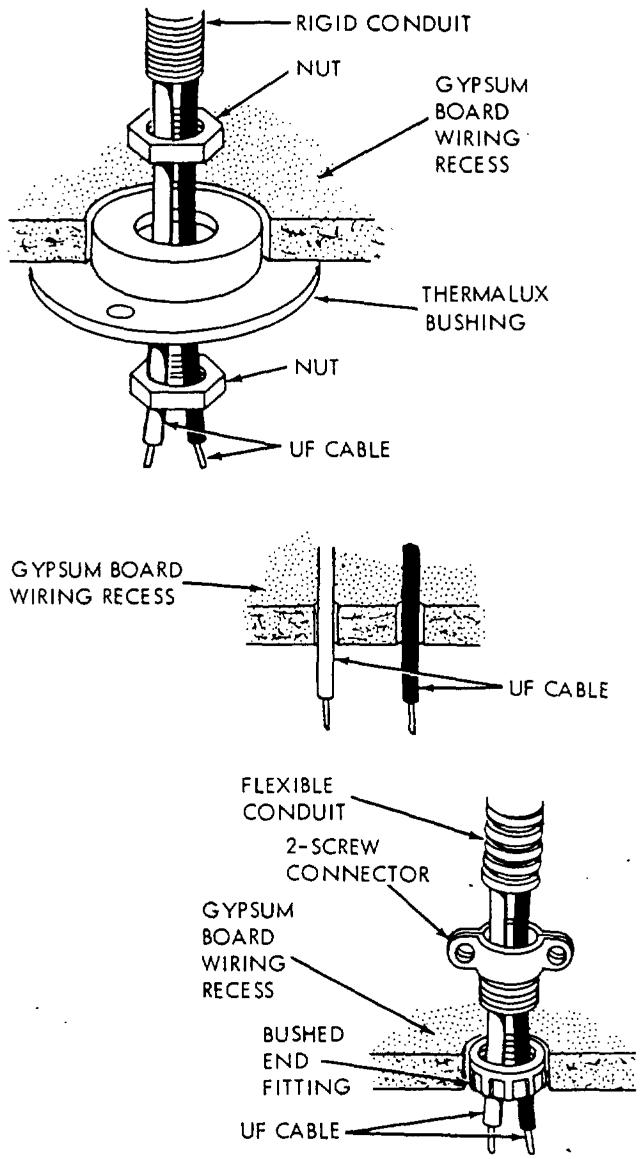

Figure 6-25. Wiring Recess Entry Methods

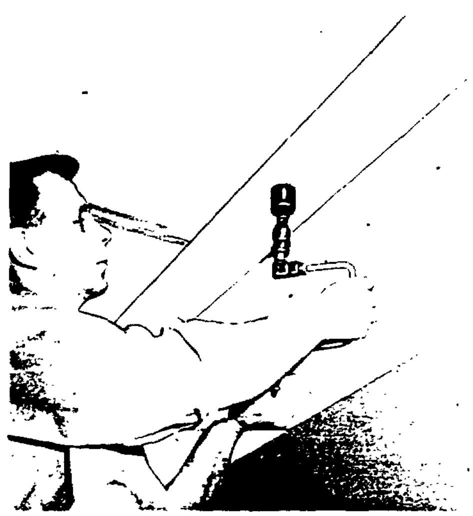

Figure 6-26. Drilling Wiring Recess for THERMALUX Bushing

rigid conduit, armored cable, flexible conduit, and non-metallic sheathed cable, when used with appropriate connectors. Ordinary UF cable may also enter the wiring recess through a THERMALUX Bushing. Bushed end fittings also accommodate all types of raceway systems. Therefore, the following installation instructions are applicable to both types of bushing entrys. The only special requirement for a bushed end fitting is that it be installed flush, and not protrude into the wiring recess, as shown in Figure 6-25. The following instructions also apply to direct entry of UF cable alone, as illustrated in Figure 6-25, or UF cable, sheathed in flexible non-metallic tubing, entering the wiring recess through a single drilled hole.

Appropriate Type UF conductors and raceways, as dictated by the System Design, are connected at the junction box. The raceway is connected to the THERMALUX Bushing which, in turn, is attached to the wiring recess with pan head sheet metal screws, as illustrated in Figure 6-27. Run the UF cable to the electrodes of the nearest Heating Panel, cut to length, and strip the conductor ends.

Figure 6-27. Attachment Of THERMALUX Bushing

An electrode connector must now be attached to each of the two conductors on each heating panel. The following technique gets the best connection and is also the easiest and quickest method:

1. Have all component parts and tools at the job when it begins: a sharp knife, channel locks, STA-KON WT-111 or WT-119 terminal pliers, THERMALUX connectors.

   Check the original heating panel design. If actual installation differs from the heating panel layout as designed, be sure wire sizes used are ample to carry the load as hooked up.

2. Fasten electrode connectors to the heating panels as shown in the following installation pictures:

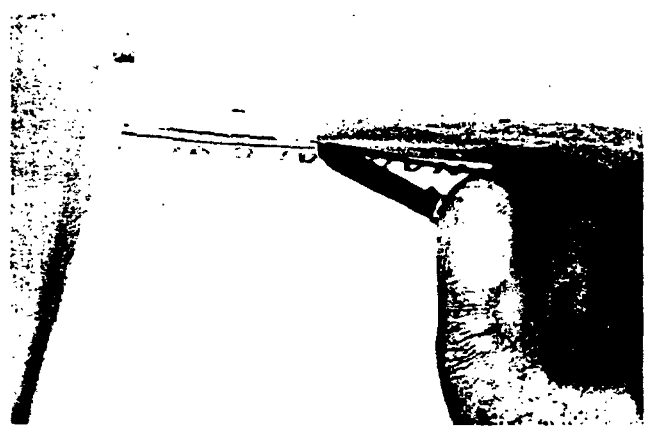

Figure 6-28. Slitting Face Paper To Free Electrode Strip

Figure 6-28 Make 1/8-inch deep cut through face paper into the gypsum core. Cut parallel to the outside edge of the electrode strip, about three inches, starting at end of board.

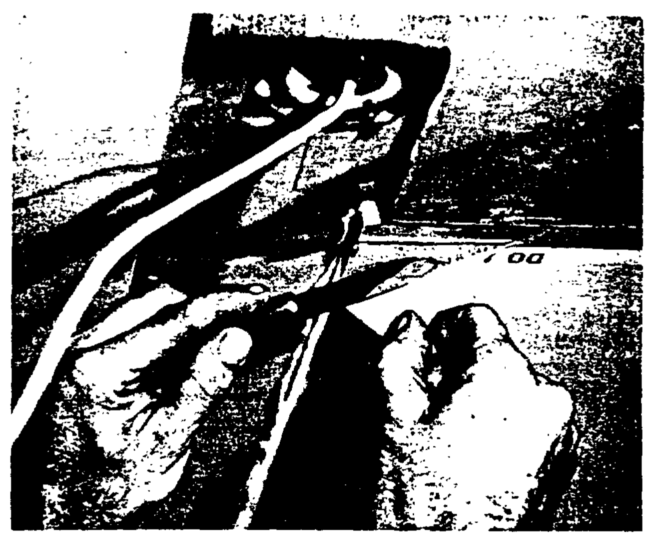

Figure 6-29. Peeling Back Paper Containing Electrode Strip

Figure 6-29 Using knife, lift corner of face paper containing the electrode strip (location identified by red printed stripe) and face paper encasing it from the core of the board. Lifting element and electrode between plies of paper prevents ripping the electrode strip from the element or tearing the element from the board. Peel corner back far enough to fit the electrode connector on the electrode without tearing the element.

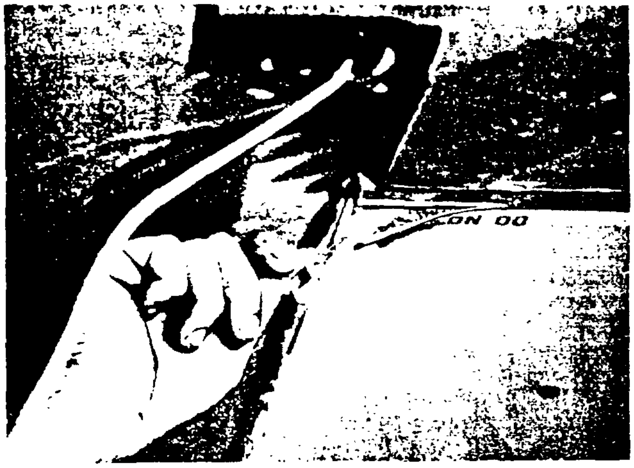

Figure 6-30. Attaching Electrode Connector Clip To Electrode Strip In Heating Panel

Figure 6-30 V-base of electrode connector is being fitted over the heating element at the electrode strip.

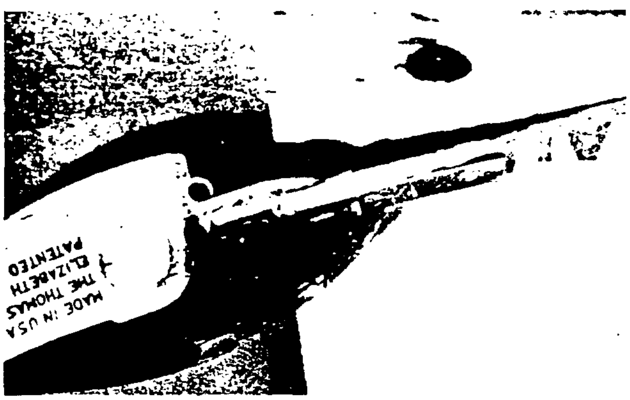

Figure 6-31. Pressing Electrode Connector Clip Points Through Electrode Strip For Positive Contact

Figure 6-31 STA-KON WT-111 pliers being used to squeeze the V-base of the electrode connector together, forcing the three prongs to pierce the electrode strip, making an electrical connection.

Figure 6-32. Bending Over Points For Permanent Hold

Figure 6-32 Connector points, having pierced the electrode, come out through holes on opposite side of connector and are bent over with the round side of pliers to lock the connector onto the heating panel. Additional contact is made by 8 short contact points on inside of the connector.

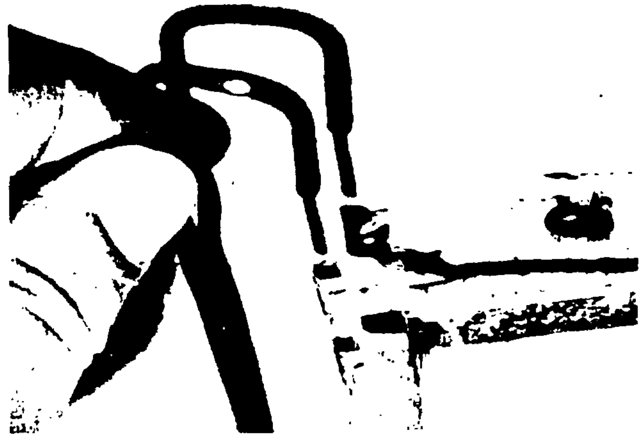

Figure 6-33. Inserting Feeder Conductor Into Electrode Connector

Figure 6-33 Insert proper size conductor into the barrel of THERMALUX connector. Bend conductors at right angles to allow complete flexibility when making connections.

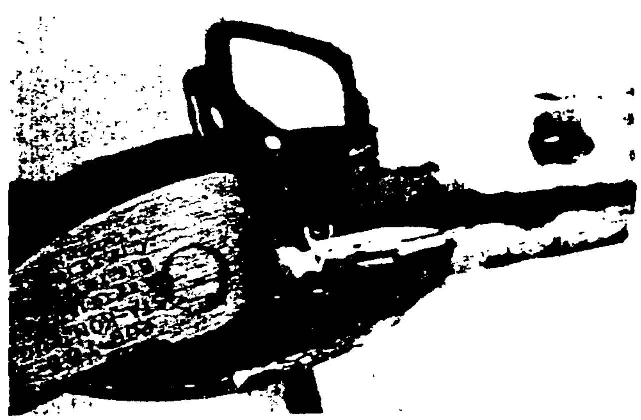

Figure 6-34. Clamping Conductor Into Clip For Positive And Permanent Contact.

Figure 6-34 Place the lug located next to cutting jaws of STA-KON WT-111 against the small flap on the electrode connector and squeeze. The lug indents the electrode connector sufficiently to make a tight connection. Connectors must be tight to prevent arcing or burnout due to a loose connection.

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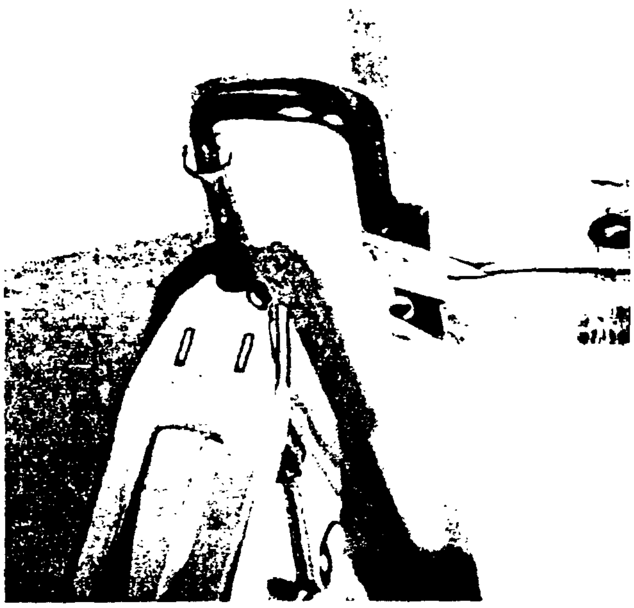

Figure 6-35. Stapling Conductor To Wiring Recess

Figure 6-35 Staple conductors into the wiring recess.

Feeder conductors must be installed between the initially wired Heating Panel and adjacent panels being serviced by the same wiring recess. Simply cut appropriate lengths of Type UF conductor and attach Electrode Connectors to both conductors and heating elements as mentioned above. Make connections in accordance with Figure 6-36 and staple conductors to the top of the wiring recess.

Note that adjacent electrodes of side-by-side Heating Panels are at the same electrical potential. That means that adjacent panels are always connected in reverse polarity. Regardless of the number of panels serviced from a single branch circuit, all must be connected in this manner for reasons of safety. Since Heating Panels do not have a specific electrode "polarity", the same results can be obtained by reversing all panel connections.

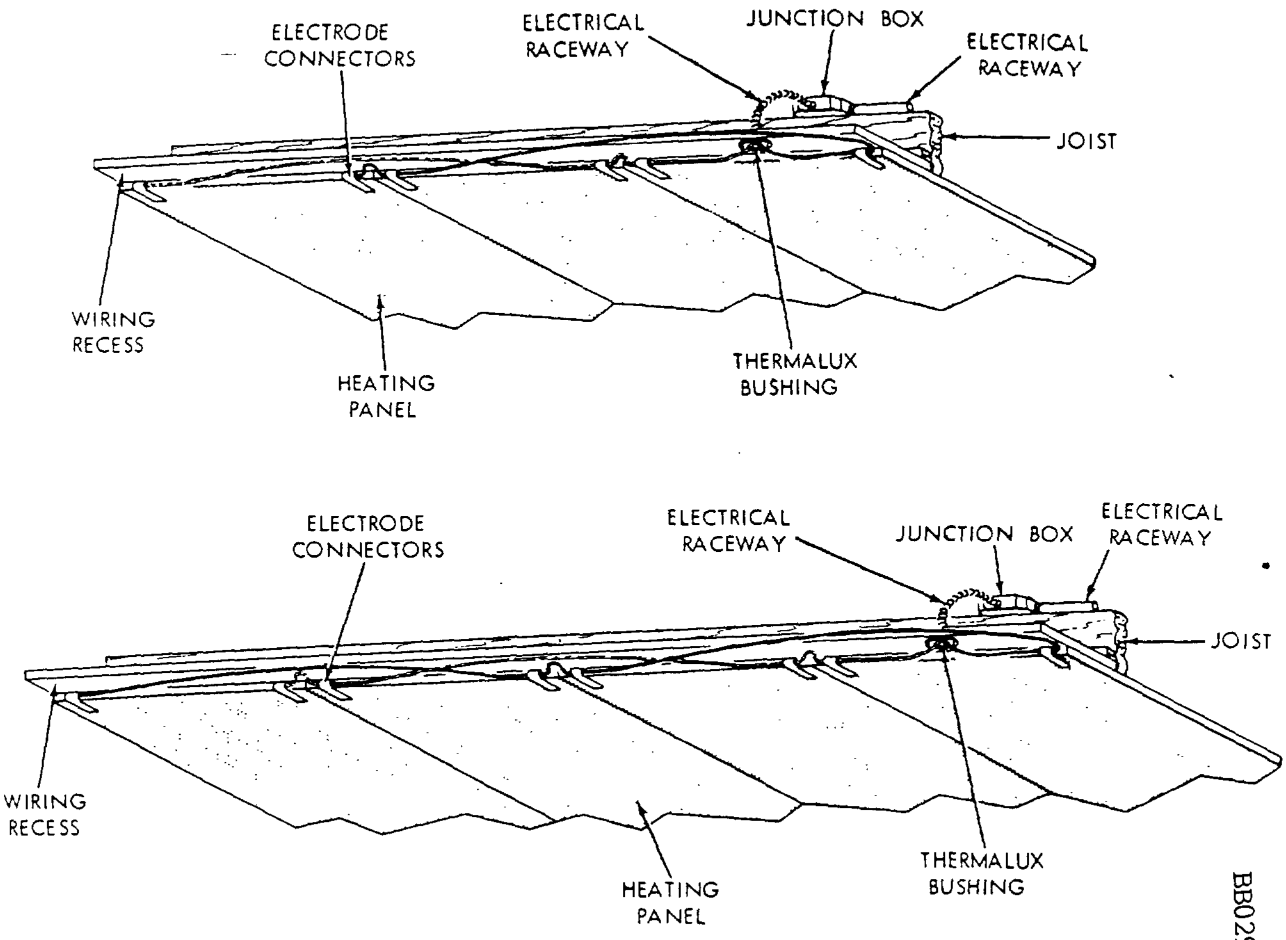

Figure 6-36. Typical Heating Panel Feeder Conductor Connections

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HEATING SYSTEM TESTING AND INSPECTION

Branch Circuit Resistance Tests

A volt-ohmmeter is used to make branch circuit resistance tests before power is applied to the THERMALUX System. Check the resistance between each black or red (hot) branch circuit conductor and its associated white (neutral) conductor as shown in Figure 6-37. (Note that two tests are required for a Type 706 control relay servicing two branch circuits, whether from a 2-wire or 3-wire system.) The measured resistance in ohms for each test, as explained in Chapter 4 of this Handbook, should equal 960 divided by the active square-foot area of the Heating Panel load on the circuit.

$$R = \frac{960}{\text{Sq. Ft. Heating Panel on Circuit}}$$

Resistance-test tolerance is subject to instrument accuracy but should be within 10% of the calculation. A very low reading (less than 85% of the calculated resistance) indicates a short circuit. A high reading (more than 115% of the calculated resistance) indicates a damaged heating panel or a poor electrical connection. A reading in excess of 250,000 ohms indicates an open branch circuit conductor or open THERMALUX feeder cable.

Continuous Operating Test

A 24-hour continuous operating test is required before the Heating Panels and recesses may be enclosed. Connect each pair of thermostat conductors together to permit continuous operation.

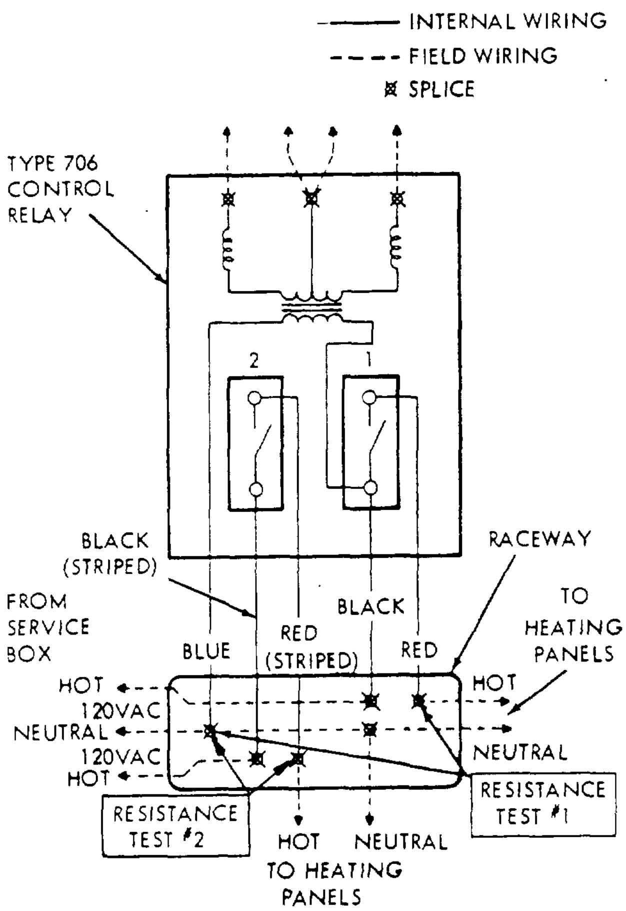
Check the load-current in each branch circuit conductor of the heating system at least three times during the 24-hour test period. Record the readings for the local inspector. Load-current readings can best be made by means of a clamp-on ammeter. The branch circuit conductors in the rectangular raceway, illustrated in Figure 6-1, are easily accessible for these measurements.

$$I = 0.125 \times \text{Sq. Ft. of Heating Panel on Circuit.}$$

A significant change in load current of any branch circuit during the continuous operating test indicates an open or a short circuit.

To locate an open or shorted heating panel, disconnect the ground side of each panel, one at a time, and measure the resistance of the panel while it is disconnected.

To locate an open or shorted wire, disconnect both ends of each wire, one at a time, and measure the



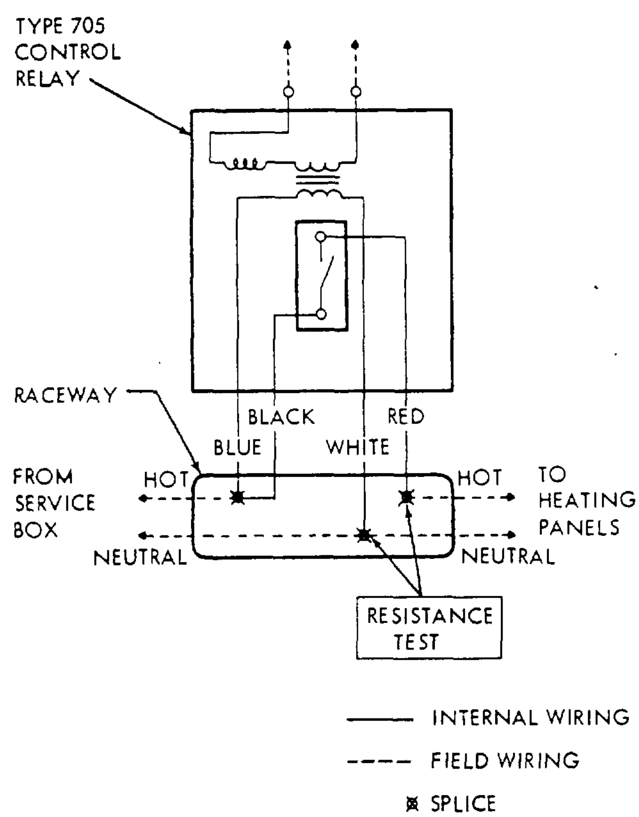


Figure 6-37. Testing Branch Circuit Resistance

resistance of each wire while it is disconnected. Replace damaged heating panels or wiring.

Inspection

Inspection is required after the 24-hour test has been completed. Make a thorough inspection of the entire THERMALUX System to be sure all code requirements have been met prior to the local inspectors arrival.

The inspector may require that thermostats and humidistat (if used) be installed prior to his inspection of the structures complete electrical circuitry, lighting, power, and THERMALUX Heating System. All circuitry must be in compliance with local electrical code requirements. If the inspector requires thermostats to be installed, they, of course, must be removed after inspection to permit remaining work such as wallboard and Finishing Panel erection, to be completed in the structure.

Insulation Resistance Tests

A volt-ohmmeter is used to make an insulation resistance test after the THERMALUX System installation is complete. Turn off THERMALUX System power at the service box and disconnect all THERMALUX System neutral conductors in the service box to eliminate system ground returns. Measure the resistance between each THERMALUX System branch circuit conductor and ground. This can be conveniently accomplished at the control relay while manually holding the relay closed. Do not touch exposed electrical connections as body resistance will upset readings.

Branch-circuit conductors no larger than #12 must show a minimum insulation resistance of 1,000,000 ohms. A minimum insulation resistance of 250,000 ohms is required for #10 conductors to comply with the requirements of Article 110-19(a) of the National Electrical Code. Reconnect the neutral conductors in the service box after insulation resistance tests have been completed.

Final Inspection

A final inspection may be required after all work has been completed in the structure. This is the option of the local inspector.

EXHAUST FAN AND HUMIDISTAT INSTALLATION

Although not a part of a THERMALUX System, an exhaust fan, automatically controlled by a humidistat, may be a requirement of the System Design. Installation at this stage of system completion, prior to erecting wall panels and Finishing Panel is, of course, desirable.

The wiring for an exhaust fan and humidistat is installed as part of the general lighting and power wiring. A typical humidistat installation is shown in Figure 6-38.

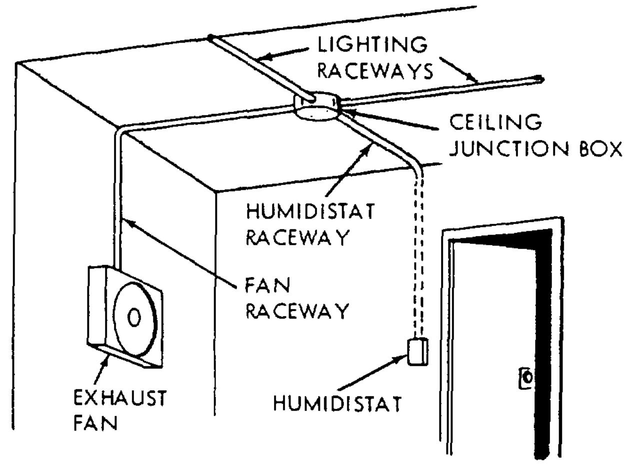


Figure 6-38. Typical Exhaust Fan/Humidistat Installation

The exhaust fan can be wired to the junction box supplying power for the lighting circuit, and the humidistat can be wired to the same junction box. Since the humidistat functions as an automatic switch, it can be paralleled by a manual switch to permit manual control of the exhaust fan.

FINISH PANEL INSTALLATION

Prior to installing THERMALUX Finish Panels, walls must be installed. Make certain that, in installations where wallboard is used to isolate Heating Panels and wiring recesses, the wallboard is inserted into the area between panels and wall studs and is tightly abutted against ceiling joists.

Finish Panels are installed perpendicular to Heating and Filler Panels with Finish Panel joints staggered to provide a uniform surface. Using the System Design and structure plans as a guide, precut Finish Panels as necessary.

Proper Lamination Methods

Pre-plan work and secure proper tools. Best adhesive application results are obtained with a 3" diameter, 12" or 18" wide long-handled roller. Use medium-napped Pronel or lamb's wool roller cover with core that is not affected by organic solvents (Phenolic core works fine). Use adhesive pan with cover. Figure 6-39 shows how one contractor has prepared for lamination.

THERMALUX Adhesive and Solvent are highly flammable and toxic. Keep away from heat and flame. No smoking. Ventilate the job. Inform all trades on the job of these precautions to prevent accidents. Remove empty or partially empty cans from the job.

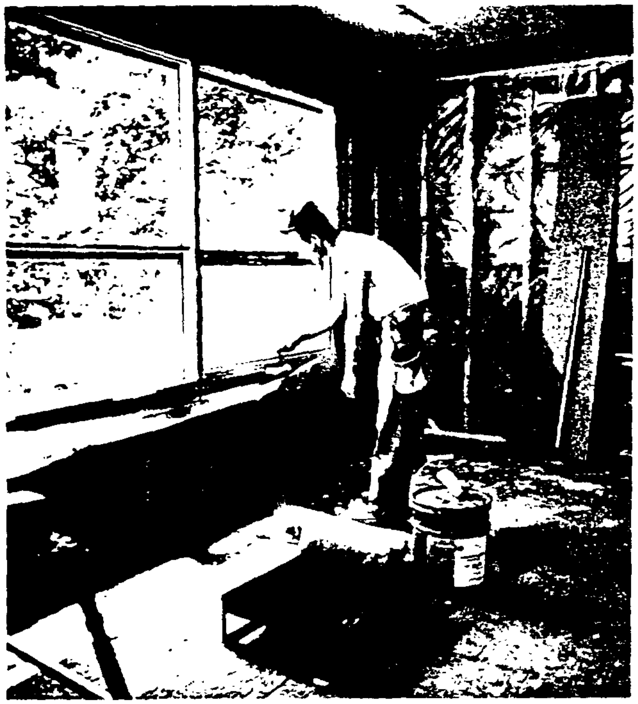


Figure 6-39. Providing For Plenty Of Ventilation Before Working With THERMALUX Adhesive or THERMALUX Solvent

THERMALUX Adhesive is specially formulated to tolerate heat of the panels. There can be no substitute of adhesives if job is to be satisfactory. Do not thin adhesive. THERMALUX Solvent is to be used only for clean-up, never for thinning adhesive. If adhesive in pan thickens, add more from can to regain working consistency.

Energize and operate THERMALUX system for 24 hours. Then shut it off for one-half hour before applying adhesive to heating panels for face layer lamination. If building is properly enclosed, ceiling, face panels and adhesive will be above the 50°F minimum temperature necessary for a satisfactory job.

Cut and fit all finish board before applying THERMALUX adhesive. Apply adhesive to back of THERMALUX finish panels, first (Figure 6-40), then coat heating panels and filler board previously erected on the ceiling (Figure 6-41). Coat only that area which can be laminated in 15 to 20 minutes: i.e., 3 to 5 panels. Stand finish panels on edge around the room to dry adhesive.

Uniform adhesive application is important to get even drying. One gallon laminates about 150 sq. ft. of finished ceiling area. Stretching coverage beyond this invites bond failure.

(Let roller sit submerged in adhesive when not in use to prevent hardening of roller cover. Roller covers with dried adhesive on them should not be used.)

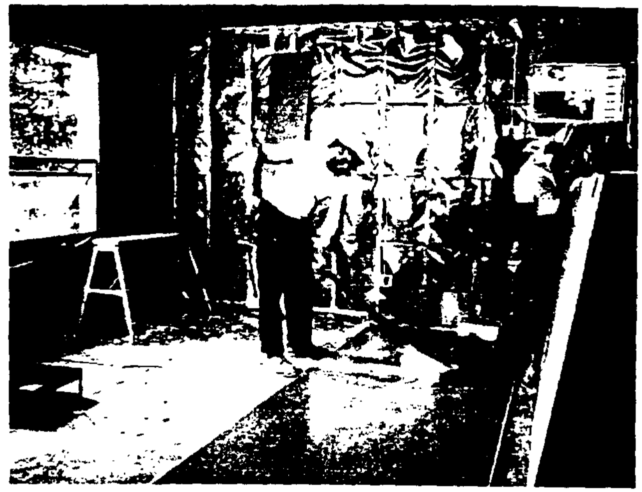


Figure 6-40. Rolling THERMALUX Adhesive Onto Back Of Special THERMALUX Finish Panels

Adhesive Drying Time Important

Allow adhesive on face panels and ceiling to dry for approximately 15 minutes before attempting lamination. Proper laminating conditions exist when finish panel adhesive is sticky, rather than wet, to the touch (Figure 6-42). Adhesive should not transfer to the fingers, yet still be quite sticky. Check several areas of panel but avoid roller lap marks where there is greater adhesive build-up. Condition of finish panels is the key. Laminate panels in the order in which they were coated, checking each to be sure adhesive has reached proper consistency.

High humidity and low temperature conditions will add to the 15-minute approximate time required for proper adhesive condition; high temperatures and low humidity will reduce the time.

Figure 6-41. Rolling Adhesive Onto Installed Heating Panels

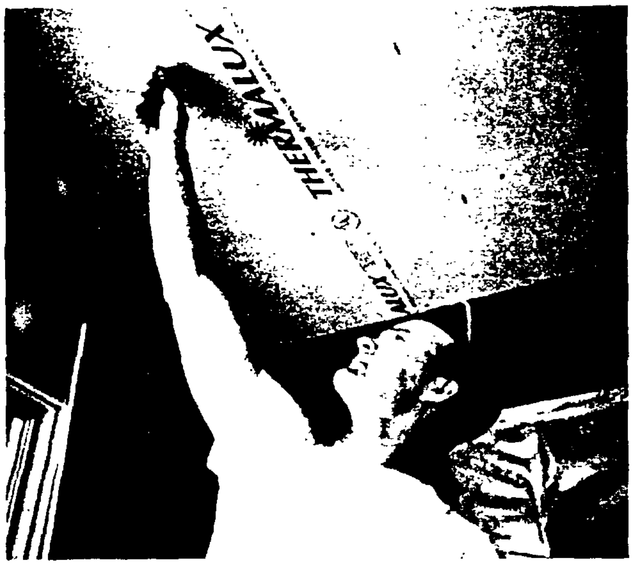


Figure 6-42. Testing dryness of adhesive to be certain it is sticky, but not wet, when finish panels are adhered. Similar test on adhesive-coated finish panels governs time that lamination takes place.

Adhesion

Finish panels should be installed perpendicular to heating panels whenever possible. If room layout requires parallel lamination, finish panel joints should fall between heating panel joints. Adhesive bond is instant and panels cannot be shifted after contact. Position edge or end of finish panel against abutting wall or adjacent panel (Figure 6-43) and "hinge" the panel into full contact by working toward the free edges (Figure 6-44). To avoid poor bond or sag, panels must be applied flat without trapped bubbles or bulges, and should not be forced into place.

Figure 6-43. Laminating A Panel Beginning At One Edge, From Which It Is "Hinged" Into Place. With Contact Adhesive, Panel Cannot Be Moved Once The Two Surfaces Have Touched.

Figure 6-44. Smoothing Panel Into Preliminary Lamination

Impact immediately with a 2-lb. half hard rubber mallet with 2-1/2 in. diameter flat face. Strike with mallet head flat to avoid indentations, and do not use wooden blocks. Impact directly under joists a minimum of once per lineal foot. Then impact between joists once per square foot (Figure 6-45). Do not impact over wiring recess or closer than six inches from that recess. Impacting must be done within five minutes of lamination.

Rolling the entire ceiling with a long-handled roller is strongly recommended as follow-up procedure (Figure 6-46). It improves contact between layers.

Figure 6-45. Impacting Face Panels For Positive Lamination

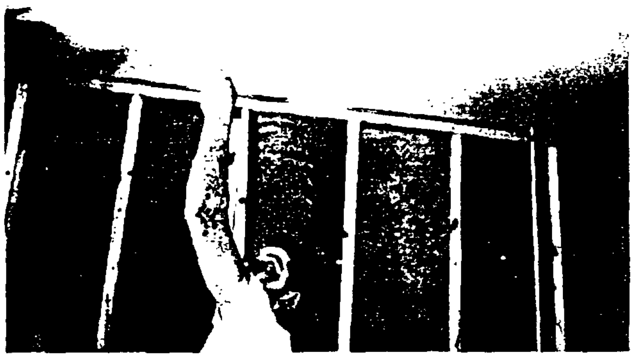


Figure 6-46. Pressure Rolling To Further Assure Complete Lamination

SPECIAL PRECAUTIONS TO TAKE WHEN LAMINATING IN COLDER WEATHER – ANYTHING BELOW 50°.

1. House must be completely closed in and insulated. The ceiling must operate continuously for a 24-hour period to warm the building and dry out panels.

2. A salamander can be used to warm the building and materials, providing it does not deposit soot on heating or finish panels. Before applying the adhesive, cut salamander off, open windows to get a good cross draft and apply the adhesive. Once you have finished applying the adhesive, close windows and continue the operation. Heat can be turned on immediately after lamination to provide construction heat and proper temperatures for applying the THERMALUX Joint Compound.

FINISHING THE JOB

Prepare ceiling for finishing by carefully trimming damaged edges and ends of Finish Panels. When removing damaged edges, handle knife carefully to avoid cutting into heating element or electrode strip. In Figure 6-47, the knife is held in such a way that it cannot cut into the heating panels.

Because this is a heated ceiling, THERMALUX PERF-A-TAPE ready-mix joint compound must be used for satisfactory results.

De-energize ceiling one-half hour before joint treatment begins. Follow normal taping procedures (Figures 6-48, 6-49, 6-50). Wait at least two hours after joint treatment before again turning on heat, and then do so gradually, setting thermostat first at 60°F and raising it 5° per day. The penalty of ignoring this practice can be joint deformation which appears later.

De-energize ceiling one-half hour before painting, and do not paint while heating system is operating. If the ceiling has not been heating, raise its temperature and air temperature to at least 50°F before painting. After normal drying time for each coat of paint, ceiling temperature may be set as desired for comfort.

Spray-on simulated acoustic finishes can be used for decoration but all materials on the market for this purpose reduce heat flow from the ceiling and thus increase the temperature of the heating element. According to scientific test results, 1/8-inch of simulated acoustic material: (1) raised temperature of face, back and within core of panel 5% above identical panel without simulated acoustic finish; (2) had 9% greater KWH power consumption; (3) had 23% longer heat-up time from 58° to 72°F; and (4) doubled the thermostat cycle.

Painting the THERMALUX Ceiling

Normal paint procedures are employed with latex base paints recommended. TEXOLITE* primer-sealer followed by GRAND PRIZE* paint provides the most durable and washable of ceiling decorations.

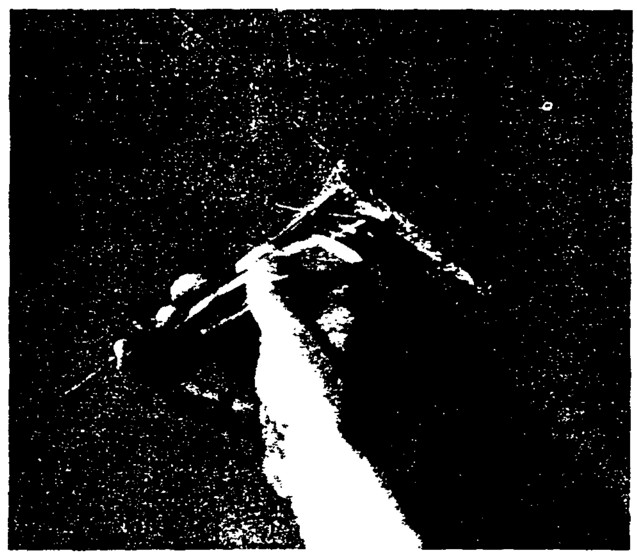


Figure 6-47. Incising A Damaged Finish Panel Edge. Extreme Care Must Be Exercised To Avoid Cutting Through Finish Panel And Into Heating Element.

Since methods and conditions of application and use are beyond the control of the United States Gypsum Company, its warranties of FITNESS and MERCHANTABILITY as well as any other warranties, expressed or implied, made in connection with the sale of this product, SHALL NOT BE EFFECTIVE OR ACTIONABLE UNLESS the product is applied according to United States Gypsum Company's directions and specifications.

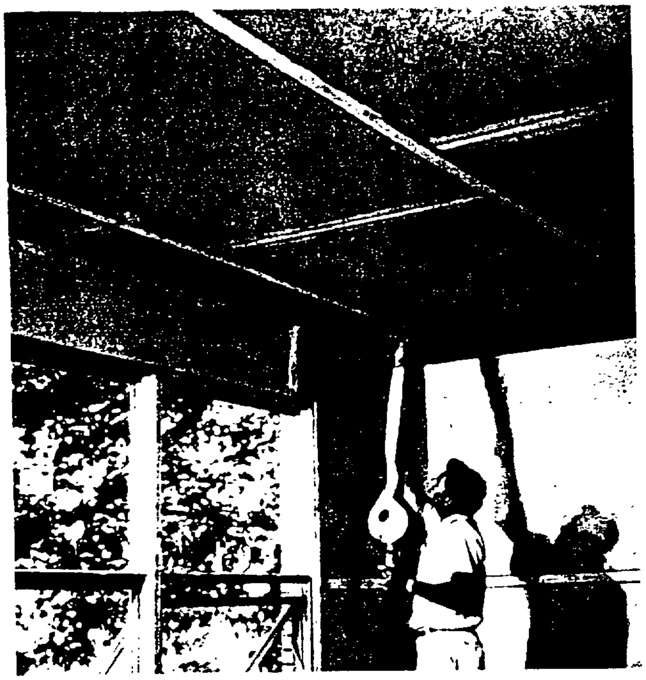


Figure 6-48. Joint Taping Finish Panel In Normal Manner With Materials Recommended

Figure 6-50. Topping Joint In Finish Panel

Figure 6-49. Finishing Corner

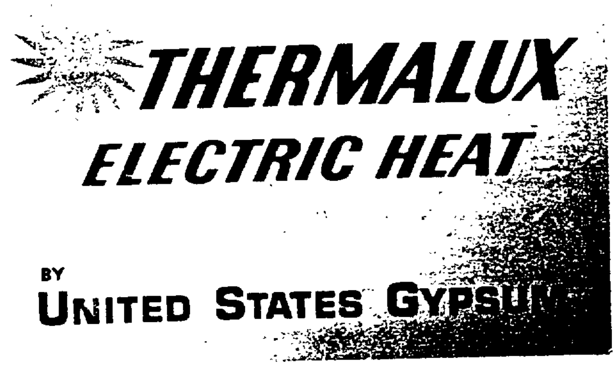


Figure 6-51. The Greatest Name In Electric Heat

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REFERENCE DATA

Table 7-1. Climatic Data — U. S. Cities*

Location	Total Yearly Degree Days	Outside Design Temp. °F.
ALABAMA		
Anniston	2820	12
Birmingham	2780	12
Mobile	1529	22
Montgomery	1954	18
ARIZONA		
Flagstaff	7525	-4
Phoenix	1492	36
Yuma	951	38
ARKANSAS		
Bentonville	4036	-1
Fort Smith	3188	6
Little Rock	2982	8
CALIFORNIA		
Eureka	4632	32
Fresno	2532	32
Independence	3834	12
Los Angeles	1451	41
Needles	1495	
Point Reyes	4474	
Red Bluff	2546	
Sacramento	2600	30
San Diego	1574	43
San Francisco	3069	37
San Jose	2410	38
COLORADO		
Denver	5673	-12
Durango	7143	-6
Grand Junction	5796	-3
Leadville	10678	-9
Pueblo	5709	-14
CONNECTICUT		
Hartford	6139	-2
New Haven	6026	0
D.C.		
Washington	4258	10
FLORIDA		
Apalachicola	1307	
Jacksonville	1113	28
Key West	77	53

Table 7-1. Climatic Data — U. S. Cities* (Cont)

Location	Total Yearly Degree Days	Outside Design Temp. °F.
Miami	173	
Pensacola	1453	24
Tampa	674	36
GEORGIA		
Atlanta	2811	11
Augusta	2138	20
Macon	2049	20
Savannah	1710	24
Thomasville	1513	
IDAHO		
Boise	5890	-10
Lewiston	5483	-12
Pocatello	6976	-17
ILLINOIS		
Cairo	3756	0
Chicago	6310	-11
Peoria	6087	-13
Springfield	5225	
INDIANA		
Evansville	4360	-4
Fort Wayne	6287	-7
Indianapolis	5134	-8
Royal Center	6239	
Terre Haute	5366	-6
IOWA		
Charles City	7504	-21
Davenport	6091	-12
Des Moines	6274	-13
Dubuque	7271	-15
Keokuk	5663	-13
Sioux City	7012	-16
KANSAS		
Concordia	5323	-11
Dodge City	5058	-9
Iola	4616	-7
Topeka	4919	-8
Wichita	4571	-6
KENTUCKY		
Lexington	4979	-2
Louisville	4279	-2

Table 7-1. Climatic Data — U. S. Cities* (Cont)

Location	Total Yearly Degree Days	Outside Design Temp. °F.
LOUISIANA		
New Orleans	1175	26
Shreveport	2117	14
MAINE		
Eastport	8246	-9
Greenville	9439	
Portland	7681	-9
MARYLAND		
Baltimore	4203	8
MASSACHUSETTS		
Boston	5791	0
Fitchburg	6743	
Nantucket	6102	
MICHIGAN		
Alpena	8073	-10
Detroit	6404	-4
Escanaba	8657	-18
Grand Rapids	6474	-4
Houghton	9030	-18
Lansing	6982	-8
Ludington	7458	-7
Marquette	8529	-16
Sault Ste. Marie	9475	-19
MINNESOTA		
Duluth	9574	-27
Minneapolis	7853	-23
Moorhead	9327	-29
St. Paul	7804	-23
MISSISSIPPI		
Corinth	3087	6
Meridian	2333	14
Vicksburg	2000	15
MISSOURI		
Columbia	5113	-9
Hannibal	5393	-12
Kansas City	4888	-8
St. Louis	4469	-5
Springfield	4693	-5
MONTANA		
Billings	7106	-31
Havre	8213	-39
Helena	8126	-39
Kalispell	8055	-31
Miles City	7850	-35

Table 7-1. Climatic Data — U. S. Cities* (Cont)

Location	Total Yearly Degree Days	Outside Design Temp. °F.
Missoula	7873	
NEBRASKA		
Drexel	6611	
Lincoln	5865	-15
North Platte	6546	-15
Omaha	6160	-17
Valentine	7075	-21
NEVADA		
Reno	6036	3
Winnemuca	6369	-9
Tonopah	5813	
NEW HAMPSHIRE		
Concord	7612	-11
NEW JERSEY		
Atlantic City	4741	8
Cape May	4870	
Newark	5252	
Sandy Hook	5369	
Trenton	5068	2
NEW MEXICO		
Albuquerque	4389	8
Roswell	3424	4
Santa Fe	6123	3
NEW YORK		
Albany	6319	-9
Binghamton	6556	-7
Buffalo	6838	-5
Canton	8305	-22
Ithaca	6914	-4
New York	5050	5
Oswego	6975	-7
Rochester	6863	-4
Syracuse	6520	-10
NORTH CAROLINA		
Asheville	4072	5
Charlotte	3205	14
Hatteras	2392	21
Manteo	3109	
Raleigh	3075	14
Wilmington	2323	20
NORTH DAKOTA		
Bismarck	9033	-31
Devils Lake	9940	-32
Grand Forks	9871	-31
Williston	9068	-35

Table 7-1. Climatic Data — U. S. Cities* (Cont)

Location	Total Yearly Degree Days	Outside Design Temp. °F.
OHIO		
Cincinnati	4532	-3
Cleveland	5717	-5
Columbus	5277	-3
Dayton	5597	-4
Sandusky	5859	-4
Toledo	6394	-5
OKLAHOMA		
Broken Arrow	3826	
Oklahoma City	3519	-1
OREGON		
Baker	7087	-14
Medford	4547	
Portland	4143	10
Roseburg	4122	19
PENNSYLVANIA		
Erie	6116	-3
Harrisburg	5258	4
Philadelphia	4523	6
Pittsburgh	5048	-3
Reading	5060	3
Scranton	6047	-2
RHODE ISLAND		
Block Island	5843	7
Narragansett Pier	6397	
Providence	5607	1
SOUTH CAROLINA		
Charleston	1769	22
Columbia	2284	19
Due West	2890	
Greenville	3060	
SOUTH DAKOTA		
Huron	7902	-21
Pierre	7283	-22
Rapid City	7535	-22
TENNESSEE		
Chattanooga	3384	8
Knoxville	3590	5
Memphis	3006	6
Nashville	3513	3
TEXAS		
Abilene	2657	7
Amarillo	4345	-2
Austin	1713	
Brownsville	617	
Corpus Christ	1011	23

Table 7-1. Climatic Data — U. S. Cities* (Cont)

Location	Total Yearly Degree Days	Outside Design Temp. °F.
Dallas	2272	8
Del Rio	1407	
El Paso	2641	20
Fort Worth	2361	8
Galveston	1211	23
Houston	1276	19
Palestine	1980	11
Port Arthur	1340	20
San Antonio	1579	19
Taylor	1909	12
UTAH		
Modena	6598	
Salt Lake City	5463	-1
VERMONT		
Burlington	7865	-17
Northfield	8718	-19
VIRGINIA		
Cape Henry	3307	17
Lynchburg	4153	11
Norfolk	3119	15
Richmond	3720	11
Wytheville	5103	3
WASHINGTON		
North Head L.H. Reservation	5211	
Seattle	4438	15
Spokane	6852	-16
Tacoma	4866	15
Tatoosh Island	5724	18
Walla Walla	4848	-12
Yakima	5845	
WEST VIRGINIA		
Elkins	5773	-4
Parkersburg	4750	-1
WISCONSIN		
Green Bay	8259	-20
La Crosse	7650	-20
Madison	7300	-19
Milwaukee	6944	-17
Wausau	8494	
WYOMING		
Cheyenne	7562	-19
Lander	8303	-30
Yellowstone Park	9605	-34

*Extracted from 1963 and 1964 ASHRAE Guide and Data books.

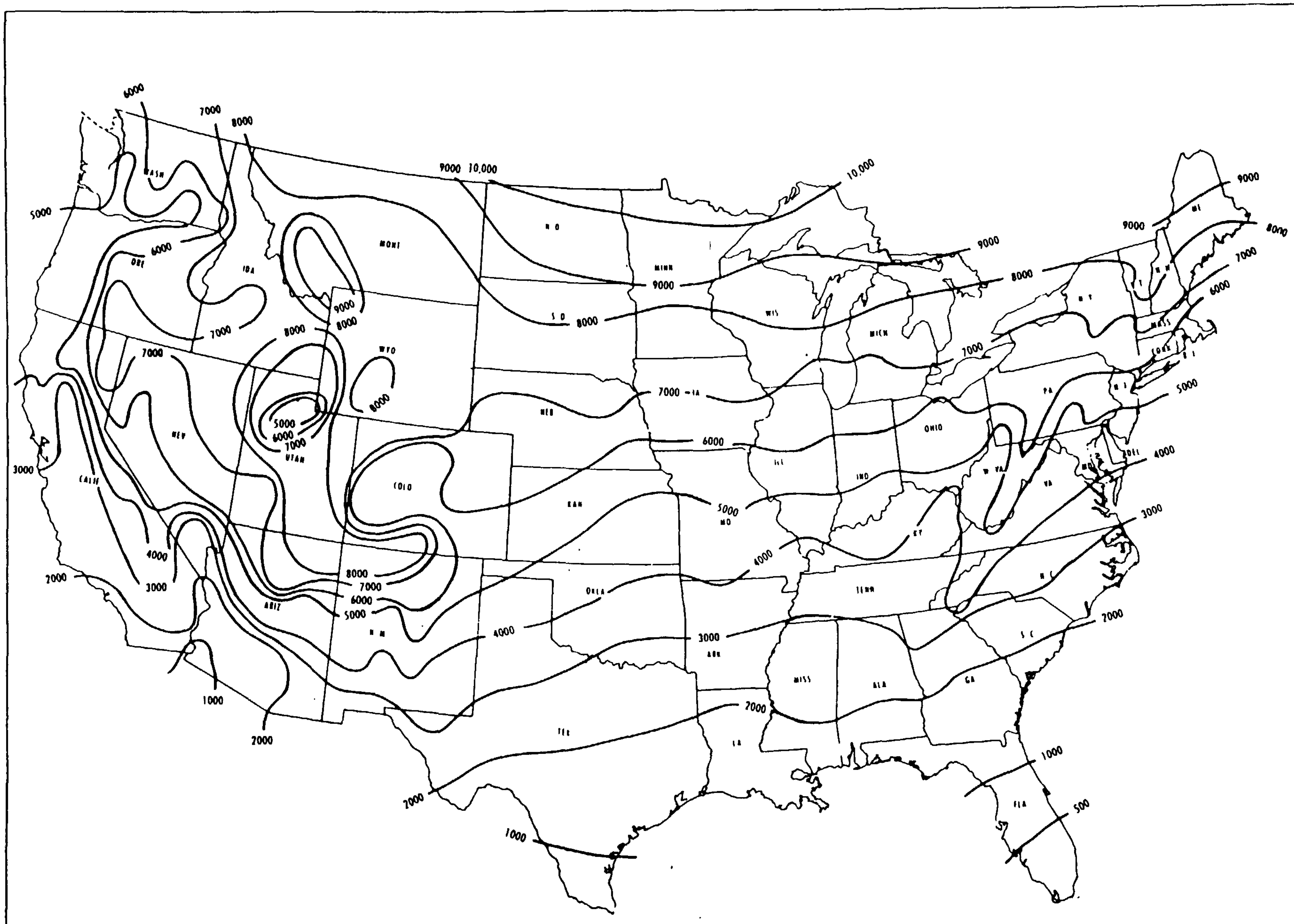

Figure 7-1. Normal Number of Degree-Days per Year

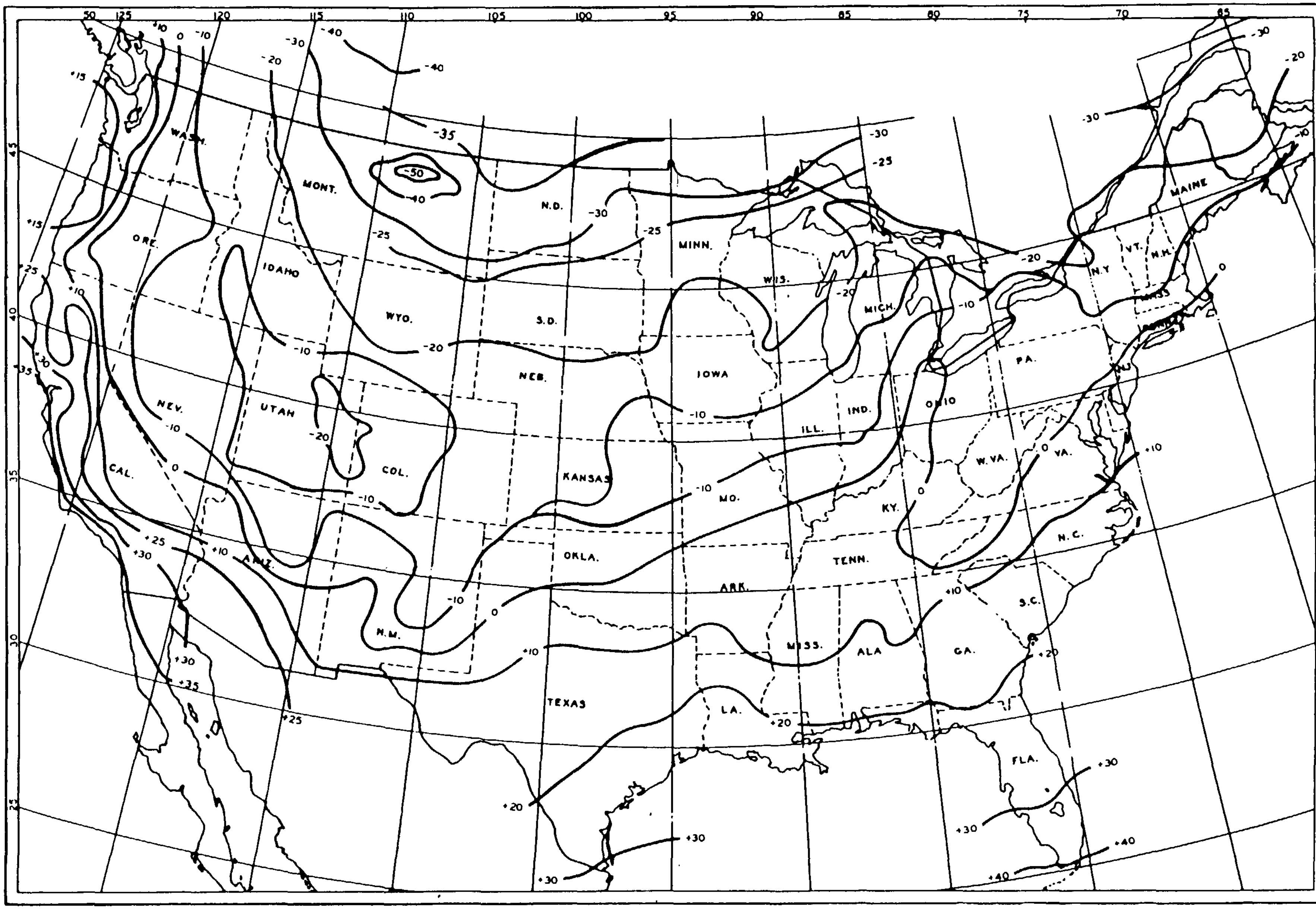

Figure 7-2. Isotherms of Winter Outdoor Design Temperatures

USING TABLE 7-2

Notice that the resistance R of any material is shown in either of two columns, the first headed 1/k, the second 1/C. The first is for a 1" thickness of a homogeneous material. Multiply this figure by 2 to find the R for a 2" thickness of the material, by 3 for a 3" thickness, and so on. Where the R value is given in the second column, it is the resistance of the specific thickness of the material shown. To find the R of a thickness not shown in the table, multiply the R given for a specific thickness by the ratio of the thickness not shown to the thickness shown. For example, the R of 1/2" impregnated sheathing is 1.32. To find the R of 3/4" impregnated sheathing, multiply 1.32 by the ratio of 3/4 to 1/2.

$$R = \frac{3/4}{1/2} \times 1.32 = 1.5 \times 1.32 = 1.98$$

Table 7-2. Thermal Properties of Building Materials*

Material	Description			For Heat Loss in Watts: Conductivity (k)	For Heat Loss in Watts: Conductance (C)	For Heat Loss in Watts: Resistance (R) Per inch thickness (1/k)	For Heat Loss in Watts: Resistance (R) For thickness listed (1/C)	For Heat Loss in BTUH: Conductivity (k)	For Heat Loss in BTUH: Conductance (C)	For Heat Loss in BTUH: Resistance (R) Per inch thickness (1/k)	For Heat Loss in BTUH: Resistance (R) For thickness listed (1/C)
				Note 1	Note 2	Note 1	Note 2	Note 3	Note 4	Note 3	Note 4
AIR SPACES	Position	Heat Flow	Thickness								
	Horizontal	Up	3/4-4 in.	-	0.3457	-	2.901	-	1.18	-	0.85
	Horizontal	Down	3/4 in.	-	0.2871	-	3.481	-	0.98	-	1.02
	Horizontal	Down	1-1/2 in.	-	0.2549	-	3.925	-	0.87	-	1.15
	Horizontal	Down	4 in.	-	0.2373	-	4.198	-	0.81	-	1.23
	Horizontal	Down	8 in.	-	0.2344	-	4.266	-	0.80	-	1.25
	Sloping (45°)	Up	3/4-4 in.	-	0.3252	-	3.072	-	1.11	-	0.90
	Vertical	Horizontal	3/4-4 in.	-	0.3018	-	3.311	-	1.03	-	0.97
AIR SURFACES (Still Air)	Position	Heat Flow									
	Horizontal	Up		-	0.4776	-	2.082	-	1.63	-	0.61
	Sloping (45°)	Up		-	0.4688	-	2.116	-	1.60	-	0.62
	Vertical	Horizontal		-	0.4278	-	2.321	-	1.46	-	0.68
	Sloping (45°)	Down		-	0.3868	-	2.594	-	1.32	-	0.76
	Horizontal	Down		-	0.3164	-	3.140	-	1.08	-	0.92
(15 mph Wind)	Any position - any direction			-	1.7580	-	0.580	-	6.00	-	0.17
BUILDING BOARD	Asbestos-cement board			1.1720	-	0.853	-	4.00	-	0.25	-
Boards, Panels, Sheathing, Etc.	Asbestos-cement board ..		1/8 in.	-	9.6690	-	1.126	-	33.00	-	0.33
	Gypsum or plaster board..		3/8 in.	-	0.9083	-	1.092	-	3.10	-	0.32
	Gypsum or plaster board..		1/2 in.	0.2344	0.6593	-	1.536	-	2.25	-	0.45
	Plywood.................			-	-	4.266	-	0.80	-	1.25	-
	Plywood...........		1/4 in.	-	0.9376	-	1.058	-	3.20	-	0.31
	Plywood...........		3/8 in.	-	0.6212	-	1.604	-	2.12	-	0.47
	Plywood...........		1/2 in.	-	0.4688	-	2.150	-	1.60	-	0.63
	Plywood...........		5/8 in.	-	0.3897	-	2.662	-	1.33	-	0.78
	Plywood...........		3/4 in.	-	0.3135	-	3.208	-	1.07	-	0.94
	Sheathing (impreg. or coated).....			0.1113	-	8.976	-	0.38	-	2.63	-

Table 7-2. Thermal Properties of Building Materials* (Cont)

Material	Description	For Heat Loss in Watts (k)	(C)	(1/k)	(1/C)	For Heat Loss in BTUH (k)	(C)	(1/k)	(1/C)
	Sheathing (impreg. or coated). . . . . 1/2 in.	-	0.2227	-	4.505	-	0.76	-	1.32
	Sheathing (impreg. or coated). . . . . 25/32 in.	-	0.1436	-	7.031	-	0.49	-	2.06
	Wood fiber board, laminated	0.1612	-	6.212	-	0.55	-	1.82	-
	or homogeneous	0.1231	-	8.123	-	0.42	-	2.38	-
	Wood fiber—hardboard type	0.4102	-	2.457	-	1.40	-	0.72	-
	Wood fiber—hardboard type 1/4 in.	-	1.6408	-	0.614	-	5.60	-	0.18
BUILDING PAPER	Vapor—permeable felt	-	4.8931	-	0.205	-	16.70	-	0.06
	Vapor—seal, 2 layers of mopped 15 lb felt	-	2.4466	-	0.410	-	8.35	-	0.12
	Vapor—seal, plastic film	-	-	-	-	-	-	-	Negl.
FLOORING MATERIALS	Carpet and fibrous pad	-	0.1406	-	7.099	-	0.48	-	2.08
	Carpet and rubber pad	-	0.2373	-	4.198	-	0.81	-	1.23
	Cork tile . . . . 1/8 in.	-	1.0548	-	0.956	-	3.60	-	0.28
	Terrazzo . . . . 1 in.	-	3.6625	-	0.273	-	12.50	-	0.08
	Tile—asphalt, linoleum, vinyl, rubber	-	5.8600	-	0.171	-	20.00	-	0.05
	Wood subfloor . . . . . . 25/32 in.	-	0.2989	-	3.345	-	1.02	-	0.98
	Wood, hardwood finish . . . 3/4 in.	-	0.4307	-	2.321	-	1.47	-	0.68
INSULATING MATERIALS	Cotton fiber	0.0762	-	13.140	-	0.26	-	3.85	-
Blanket and Batt	Mineral wool, fibrous form, processed from rock, slag, or glass	0.0791	-	12.628	-	0.27	-	3.70	-
	Wood fiber	0.0733	-	13.652	-	0.25	-	4.00	-
Board and Slabs	Cellular glass	0.1172	-	8.533	-	0.40	-	2.50	-
	. . . .	0.1143	-	8.737	-	0.39	-	2.56	-
	. . . .	0.1084	-	9.215	-	0.37	-	2.70	-
	. . . .	0.1026	-	9.761	-	0.35	-	2.86	-
	. . . .	0.0967	-	10.239	-	0.33	-	3.00	-
	. . . .	0.0938	-	10.649	-	0.32	-	3.12	-
	Corkboard	0.0820	-	12.184	-	0.28	-	3.57	-
	. . . .	0.0791	-	12.628	-	0.27	-	3.70	-
	. . . .	0.0762	-	13.106	-	0.26	-	3.84	-
	. . . .	0.0733	-	13.652	-	0.25	-	4.00	-
	. . . .	0.0703	-	14.232	-	0.24	-	4.17	-
	. . . .	0.0674	-	14.847	-	0.23	-	4.35	-
	. . . .	0.0908	-	10.990	-	0.31	-	3.22	-
	. . . .	0.0879	-	11.365	-	0.30	-	3.33	-
	. . . .	0.0850	-	11.775	-	0.29	-	3.45	-
	. . . .	0.0820	-	12.184	-	0.28	-	3.57	-

Table 7-2. Thermal Properties of Building Materials* (Cont)

Material	Description	For Heat Loss in Watts (k)	(C)	(1/k)	(1/C)	For Heat Loss in BTUH (k)	(C)	(1/k)	(1/C)
		0.0791	-	12.628	-	0.27	-	3.70	-
		0.0762	-	13.106	-	0.26	-	3.84	-
	Glass fiber	0.0733	-	13.652	-	0.25	-	4.00	-
		0.0615	-	16.246	-	0.21	-	4.76	-
		0.0498	-	20.068	-	0.17	-	5.88	-
	Expanded rubber	0.0615	-	15.529	-	0.21	-	4.55	-
	Hog hair (with asphalt binder)	0.0967	-	10.239	-	0.33	-	3.00	-
	Expanded polystyrene	0.0850	-	11.775	-	0.29	-	3.45	-
		0.0820	-	12.184	-	0.28	-	3.57	-
		0.0733	-	13.652	-	0.25	-	4.00	-
		0.0674	-	14.847	-	0.23	-	4.35	-
		0.0586	-	17.065	-	0.20	-	5.00	-
	Mineral wool with resin binder	0.0850	-	11.775	-	0.29	-	3.45	-
		0.0820	-	12.184	-	0.28	-	3.57	-
		0.0791	-	12.628	-	0.27	-	3.70	-
		0.0733	-	13.652	-	0.25	-	4.00	-
		0.0703	-	14.232	-	0.24	-	4.17	-
		0.0674	-	14.847	-	0.23	-	4.35	-
	Mineral wool with asphalt binder	0.0908	-	10.990	-	0.31	-	3.22	-
		0.0879	-	11.365	-	0.30	-	3.33	-
		0.0850	-	11.775	-	0.29	-	3.45	-
		0.0791	-	12.628	-	0.27	-	3.70	-
	Wood or cane fiberboard								
	Acoustical tile 1/2 in.	-	0.2461	-	4.061	-	0.84	-	1.19
	Acoustical tile 3/4 in.	-	0.1641	-	6.075	-	0.56	-	1.78
	Interior finish (plank, tile)	0.1026	-	9.761	-	0.35	-	2.86	-
	Interior finish (plank, tile) 1/2 in.	-	0.2051	-	4.881	-	0.70	-	1.43
	Insulating Roof Deck								
	Approximately 1-1/2 in.	-	0.0703	-	14.232	-	0.24	-	4.17
	Approximately 2 in.	-	0.0527	-	18.976	-	0.18	-	5.56
	Approximately 3 in.	-	0.0352	-	28.430	-	0.12	-	8.33
	Wood shredded (cemented in preformed slabs)	0.1612	-	6.212	-	0.55	-	1.82	-
Loose Fill	Macerated paper or pulp products	0.0820	-	12.184	-	0.28	-	3.57	-
	Mineral wool (glass, slag, or rock)	0.0879	-	11.365	-	0.30	-	3.33	-
		0.0879	-	11.365	-	0.30	-	3.33	-
		0.0791	-	12.628	-	0.27	-	3.70	-
		0.0733	-	13.652	-	0.25	-	4.00	-
		0.0674	-	14.847	-	0.23	-	4.35	-
		0.0586	-	17.065	-	0.20	-	5.00	-

Table 7-2. Thermal Properties of Building Materials* (Cont)

Material	Description	For Heat Loss in Watts				For Heat Loss in BTUH			
		(k)	(C)	(1/k)	(1/C)	(k)	(C)	(1/k)	(1/C)
	. . . .	0.0527	-	18.976	-	0.18	-	5.56	-
	Sawdust or shavings	0.1319	-	7.577	-	0.45	-	2.22	-
	Silica aerogel	0.0498	-	20.068	-	0.17	-	5.88	-
	. . . .	0.0469	-	21.331	-	0.16	-	6.25	-
	. . . .	0.0440	-	23.072	-	0.15	-	6.76	-
	. . . .	0.0440	-	23.072	-	0.15	-	6.76	-
	. . . .	0.0410	-	24.369	-	0.14	-	7.14	-
	. . . .	0.0381	-	26.246	-	0.13	-	7.69	-
	Vermiculite (expanded)	0.1406	-	7.099	-	0.48	-	2.08	-
	. . . .	0.1406	-	7.099	-	0.48	-	2.08	-
	. . . .	0.1348	-	7.440	-	0.46	-	2.18	-
	. . . .	0.1289	-	7.748	-	0.44	-	2.27	-
	. . . .	0.1231	-	8.123	-	0.42	-	2.38	-
	. . . .	0.1172	-	8.533	-	0.40	-	2.50	-
	. . . .	0.1113	-	8.976	-	0.38	-	2.63	-
	Wood fiber: redwood, hemlock, or fir	0.0879	-	11.365	-	0.30	-	3.33	-
	Wood fiber: redwood bark	0.0908	-	10.990	-	0.31	-	3.22	-
	. . . . . .	0.0820	-	12.184	-	0.28	-	3.57	-
	. . . . . .	0.0762	-	13.106	-	0.26	-	3.84	-
	. . . . . .	0.0733	-	13.652	-	0.25	-	4.00	-
	. . . . . .	0.0674	-	14.847	-	0.23	-	4.35	-
	. . . . . .	0.0352	-	16.246	-	0.12	-	4.76	-
	. . . . . .	0.0586	-	17.065	-	0.20	-	5.00	-
Roof Insulation	Preformed, for use above deck								
	Approximately . . . . . . 1/2 in.	-	0.2110	-	4.744	-	0.72	-	1.39
	Approximately . . . . 1 in.	-	0.1055	-	9.488	-	0.36	-	2.78
	Approximately . . . . . 1-1/2 in.	-	0.0703	-	14.232	-	0.24	-	4.17
	Approximately . . . . 2 in.	-	0.0557	-	17.952	-	0.19	-	5.26
	Approximately . . . . . 2-1/2 in.	-	0.0440	-	22.765	-	0.15	-	6.67
	Approximately . . . . 3 in.	-	0.0352	-	28.430	-	0.12	-	8.33
	Cellular glass	0.1143	-	8.737	-	0.39	-	2.56	-
MASONRY MATERIALS Concretes	Cement mortar	1.4650	-	0.683	-	5.00	-	0.20	-
	Gypsum-fiber concrete 87-1/2% gypsum, 12-1/2% wood chips . . .	0.4864	-	2.048	-	1.66	-	0.60	-
	Lightweight aggregates including . .	1.5236	-	0.648	-	5.20	-	0.19	-
	expanded shale, clay or slate; . . .	1.0548	-	0.956	-	3.60	-	0.28	-
	expanded slags; cinders;	0.7325	-	1.365	-	2.50	-	0.40	-
	pumice; perlite; vermiculite;	0.4981	-	2.014	-	1.70	-	0.59	-
	also cellular concretes	0.3370	-	2.935	-	1.15	-	0.86	-
	. . . .	0.2637	-	3.788	-	0.90	-	1.11	-
	. . . .	0.2051	-	4.881	-	0.70	-	1.43	-

Table 7-2. Thermal Properties of Building Materials* (Cont)

Material	Description	For Heat Loss in Watts (k)	(C)	(1/k)	(1/C)	For Heat Loss in BTUH (k)	(C)	(1/k)	(1/C)
	Sand and gravel or stone aggregate (oven dried)	2.6370	-	0.375	-	9.00	-	0.11	-
	Sand and gravel or stone aggregate (not dried)	3.5160	-	0.273	-	12.00	-	0.08	-
	Stucco	1.4650	-	0.683	-	5.00	-	0.20	-
MASONRY UNITS	Brick, common	1.4650	-	0.683	-	5.00	-	0.20	-
	Brick, face	2.6370	-	0.375	-	9.00	-	0.11	-
	Clay tile, hollow:								
	1 cell deep . . . 3 in.	-	0.3663	-	2.730	-	1.25	-	0.80
	1 cell deep . . . 4 in.	-	0.2637	-	3.788	-	0.90	-	1.11
	2 cells deep . . . 6 in.	-	0.1934	-	5.188	-	0.66	-	1.52
	2 cells deep . . . 8 in.	-	0.1582	-	6.314	-	0.54	-	1.85
	2 cells deep . . . 10 in.	-	0.1319	-	7.577	-	0.45	-	2.22
	3 cells deep . . . 12 in.	-	0.1172	-	8.533	-	0.40	-	2.50
	Concrete blocks, three oval core:								
	Sand and gravel aggregate . 4 in.	-	0.4102	-	2.423	-	1.40	-	0.71
	. . . . 8 in.	-	0.2637	-	3.788	-	0.90	-	1.11
	. . . . 12 in.	-	0.2285	-	4.369	-	0.78	-	1.28
	Cinder aggregate . . . 3 in.	-	0.3399	-	2.935	-	1.16	-	0.86
	. . . 4 in.	-	0.2637	-	3.788	-	0.90	-	1.11
	. . . 8 in.	-	0.1699	-	5.870	-	0.58	-	1.72
	. . . 12 in.	-	0.1553	-	6.451	-	0.53	-	1.89
	Lightweight aggregate . . . . 3 in.	-	0.2315	-	4.335	-	0.79	-	1.27
	(expanded shale, clay, ... 4 in.	-	0.1963	-	5.120	-	0.67	-	1.50
	slate or slag; pumice). . . . 8 in.	-	0.1465	-	6.826	-	0.50	-	2.00
	. . . . 12 in.	-	0.1289	-	7.748	-	0.44	-	2.27
	Concrete blocks, rectangular core:								
	Sand and gravel aggregate								
	2 core, 8 in. 36 lb	-	0.2813	-	3.550	-	0.96	-	1.04
	Same with filled cores	-	0.1524	-	6.587	-	0.52	-	1.93
	Lightweight aggregate (expanded shale, clay, slate or slag, pumice):								
	3 core, 6 in., 19 lb	-	0.1787	-	5.631	-	0.61	-	1.65
	Same with filled cores	-	0.0967	-	10.205	-	0.33	-	2.99
	2 core, 8 in., 24 lb	-	0.1348	-	7.440	-	0.46	-	2.18
	Same with filled cores	-	0.0586	-	17.167	-	0.20	-	5.03
	3 core, 12 in., 38 lb	-	0.1172	-	8.464	-	0.40	-	2.48
	Same with filled cores	-	0.0498	-	19.864	-	0.17	-	5.82
	Stone, lime or sand	3.6625	-	0.273	-	12.50	-	0.08	-
	Gypsum partition tile:								
	3 x 12 x 30 in. solid	-	0.2315	-	4.300	-	0.79	-	1.26
	3 x 12 x 30 in. 4-cell	-	0.2168	-	4.608	-	0.74	-	1.35

Table 7-2. Thermal Properties of Building Materials* (Cont)

Material	Description	For Heat Loss in Watts				For Heat Loss in BTUH			
		(k)	(C)	(1/k)	(1/C)	(k)	(C)	(1/k)	(1/C)
	4 x 12 x 30 in. 3-cell	-	0.1758	-	5.700	-	0.60	-	1.67
METALS	Aluminum	414.8880	-	0.002	-	1416.00	-	0.0007	-
	Brass (70-30)	210.9600	-	0.003	-	720.00	-	0.0010	-
	Cast-Iron	98.4480	-	0.010	-	336.00	-	0.0030	-
	Copper	773.5200	-	0.001	-	2640.00	-	0.0004	-
	Glass	1.0557-2.1114	-	-	-	3.60-7.20	-	-	-
	Lead	70.3200	-	0.014	-	240.00	-	0.0040	-
	Nickel	119.5440	-	0.007	-	408.00	-	0.0020	-
	Soil	0.7038-0.3519	-	-	-	2.40-12.00	-	-	-
	Steel. mild	91.4160	-	0.010	-	312.00	-	0.0030	-
	Water	1.1954	-	0.853	-	4.08	-	0.2500	-
PLASTERING MATERIALS	Cement plaster, sand aggregate . .	1.4650	-	0.683	-	5.00	-	0.2000	-
	Sand aggregate . . . . . . 1/2 in.	-	2.9300	-	0.341	-	10.00	-	0.10
	Sand aggregate . . . . . . 3/4 in.	-	1.9514	-	0.512	-	6.66	-	0.15
	Gypsum plaster:								
	Lightweight aggregate. . . 1/2 in.	-	0.9142	-	1.092	-	3.12	-	0.32
	Lightweight aggregate. . . 5/8 in.	-	0.7823	-	1.331	-	2.67	-	0.39
	Lightweight agg. on metal lath. . . . . 3/4 in.	-	0.6241	-	1.604	-	2.13	-	0.47
	Perlite aggregate	0.4395	-	2.287	-	1.50	-	0.6700	-
	Sand aggregate	1.6408	-	0.614	-	5.60	-	0.1800	-
	Sand aggregate . . . . . . 1/2 in.	-	3.2523	-	0.307	-	11.10	-	0.09
	Sand aggregate . . . . . . 5/8 in.	-	2.6663	-	0.375	-	9.10	-	0.11
	Sand aggregate on metal lath. . . . . 3/4 in.	-	2.2561	-	0.341	-	7.70	-	0.10
	Sand aggregate on wood lath.	-	0.7325	-	1.365	-	2.50	-	0.40
	Vermiculate aggregate	0.4981	-	2.014	-	1.70	-	0.5900	-
ROOFING	Asbestos-cement shingles	-	1.3947	-	0.717	-	4.76	-	0.21
	Asphalt roll roofing	-	1.9045	-	0.512	-	6.50	-	0.15
	Asphalt shingles	-	0.6651	-	1.502	-	2.27	-	0.44
	Built-up roofing . . . . . . 3/8 in.	-	0.8790	-	1.126	-	3.00	-	0.33
	Slate . . . . 1/2 in.	-	5.8600	-	0.171	-	20.00	-	0.05
	Wood shingles	-	0.3106	-	3.208	-	1.06	-	0.94
SIDING MATERIALS (On Flat Surface)	Shingles:								
	Asbestos-cement	-	1.3947	-	0.717	-	4.76	-	0.21
	Wood, 16 in., 7-1/2 in. exposure	-	0.3370	-	2.969	-	1.15	-	0.87
	Wood, double, 16-in., 12-in. exposure	-	0.2461	-	4.061	-	0.84	-	1.19

Table 7-2. Thermal Properties of Building Materials* (Cont)

Material	Description	For Heat Loss in Watts				For Heat Loss in BTUH			
		(k)	(C)	(1/k)	(1/C)	(k)	(C)	(1/k)	(1/C)
	Wood, plus insul. backer board . . . . 5/16 in.	-	0.2080	-	4.778	-	0.71	-	1.40
	Siding:								
	Asbestos-cement, 1/4 in., lapped	-	1.3947	-	0.717	-	4.76	-	0.21
	Asphalt roll siding	-	1.9045	-	0.512	-	6.50	-	0.15
	Asphalt insulating siding (1/2 in. bd.)	-	0.2022	-	4.983	-	0.69	-	1.46
	Wood, drop, 1 x 8 in.	-	0.3721	-	2.696	-	1.27	-	0.79
	Wood, bevel, 1/2 x 8 in., lapped	-	0.3604	-	2.765	-	1.23	-	0.81
	Wood bevel, 3/4 x 10 in., lapped	-	0.2784	-	3.584	-	0.95	-	1.05
	Wood, plywood, 3/8 in., lapped	-	0.4659	-	2.014	-	1.59	-	0.59
	Structural glass	-	2.9300	-	0.341	-	10.00	-	0.10
WOODS	Maple, oak, and similar hardwoods	0.3223	-	3.106	-	1.10	-	0.91	-
	Fir, pine, and similar softwoods	0.2344	-	4.266	-	0.80	-	1.25	-
	Fir, pine, and similar softwoods . . . . 25/32 in.	-	0.2989	-	3.345	-	1.02	-	0.98
	. . . . 1-5/8 in.	-	0.1436	-	6.928	-	0.49	-	2.03
	. . . . 2-5/8 in.	-	0.0879	-	11.195	-	0.30	-	3.28
	. . . . 3-5/8 in.	-	0.0645	-	15.529	-	0.22	-	4.55

*Extracted from 1963 ASHRAE Guide and Data book.

NOTES:

1. Data in terms of $\frac{\text{Watt In.}}{\text{Hr. Sq. Ft. }^{o}\text{F}}$
2. Data in terms of $\frac{\text{Hr. Sq. Ft. }^{o}\text{F}}{\text{Watt}}$
3. Data in terms of $\frac{\text{Btu In.}}{\text{Hr. Sq. Ft. }^{o}\text{F}}$
4. Data in terms of $\frac{\text{Hr. Sq. Ft. }^{o}\text{F}}{\text{Btu}}$

Table 7-3. Electrical Characteristics of THERMALUX Heating Panel

ACTIVE WIDTH (feet)	LENGTH (feet)	R (ohms)	I (amperes)	P (watts)
2	2	240.00	0.50	60
2	3	160.00	0.75	90
2	4	120.00	1.00	120
2	5	96.00	1.25	150
2	6	80.00	1.50	180
2	7	68.50	1.75	210
2	8	60.00	2.00	240
2	9	53.30	2.25	270
2	10*	48.00	2.50	300
2	11	43.60	2.75	330
2	12*	40.00	3.00	360
4	4	60.00	2.00	240
4	5	48.00	2.50	300
4	6	40.00	3.00	360
4	7	34.30	3.50	420
4	8	30.00	4.00	480
4	9	26.65	4.50	540
4	10*	24.00	5.00	600
4	11	21.80	5.50	660
4	12*	20.00	6.00	720

* Indicates standard length.

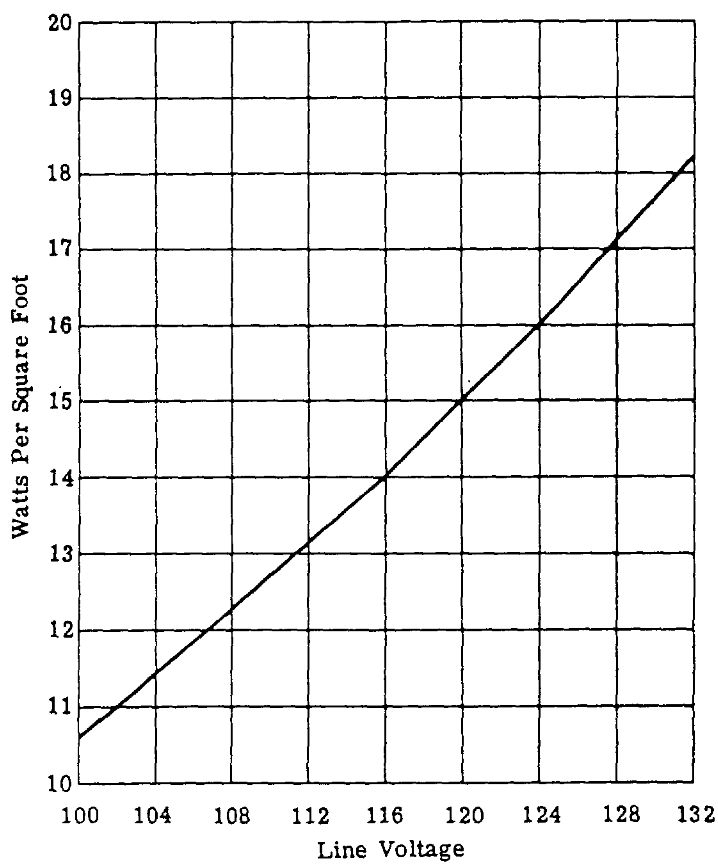

Figure 7-3. Heat Output of Panels Versus Voltage Input

BB029 0582

Table 7-4. Heat Loss Calculation Formulas

$K_{watts} = 0.293\ K_{Btuh}$

$K_{Btuh} = 3.413\ C_{watts}$

$C_{watts} = 0.293\ C_{Btuh}$

$C_{Btuh} = 3.413\ C_{watts}$

$R_{ohms} = 1/U$

$R_{watts} = 1/W$

$R = X/k$

$R = 1/C$

$R_{Btuh} = 0.293\ R_{watts}$

$R_{watts} = 3.413\ R_{Btuh}$

$R_T = R_1 + R_2 + R_3 + \ldots R_N$

$W = 1/R_T$ (R_T in watts)

$U = 3.413\ W$

$W = 0.293\ U$

$U = 1/R_T$ (R_T in Btuh)

$TD = T_{inside} - T_{outside}$

$HL = W \times A \times TD$

$HL_{trans} = W \times A \times TD$ (HL in watts)

$HL_{infil} = 0.0053 \times V \times CH \times TD$ (HL in watts)

$HL_{trans} = U \times A \times TD$ (HL in Btu)

$HL_{infil} = 0.018 \times V \times CH \times TD$ (HL in Btu)

$HL_{total} = HL_{trans} + HL_{infil}$

$HL_{Btu} = 3.413\ HL_{watts}$

$HL_{watts} = 0.293\ HL_{Btu}$

$$DD = 65 - \frac{T_{high} + T_{low}}{2}$$

Table 7-5. Electrical Formulas

$E = IR$

$E = PI$

$I = E/R$

$I = P/E$

$R = E/I$

$P = EI$

$P = I^2R$

$P = E^2/R$

THERMALUX $R_{install}$ = 960 ohms/sq. ft. of heating panel

THERMALUX $I_{install}$ = 0.125 amps x sq. ft. of heating panel

THERMALUX $I_{install}$ = Area of Heating Panel/8

THERMALUX $P_{install}$ = 15 watts x sq. ft. of heating panel

R in parallel $1/R_T = 1/R_1 + 1/R_2 + 1/R_3 + \ldots 1/R_N$

R in series $R_T = R_1 + R_2 + R_3 + \ldots R_N$

$KWH = \dfrac{HL \times DD}{TD \times 185}$ (FHA formula)

$KWH = \dfrac{HL \times DD \times C}{TD}$ (NEMA formula)

HEATING COST = KWH x Rate

Table 7-6. Room Air Changes Per Hour

Type of Room	Air Changes Per Hour	
	Without Storm Sash on Windows and Doors	With Storm Sash on Windows and Doors
1 side exposed	1	1/2
2 sides exposed	1-1/2	3/4
3 sides exposed	2	1
4 sides exposed	2	1
Entrance Hall	2 to 3	1 to 1-1/2

Table 7-7. W of Horizontal Glass Sheets
(watts per square foot per ^oF)

Air Space	One Sheet	Two Sheets	
	None	1/4"	1/2" or more
Outdoor exposure	0.41	0.20	0.19
Indoor exposure	0.28	0.17	0.16

Table 7-8. W of Vertical Glass Sheets
(watts per square foot per ^oF)

Air Space	One Sheet	Two Sheets	
	None	1/4"	1/2" or more
Outdoor exposure	0.33	0.18	0.16
Indoor exposure	0.22	0.15	0.13

Table 7-9. All Weather Comfort Standards

Building Section	U	R_{Btu}	W	R_{Watts}
Ceilings*	0.05	20.0	0.0147	68.0
Walls	0.07	14.3	0.0223	45.6
Floors over vented crawl spaces	0.07	14.3	0.0223	45.6

Table 7-10. W of Wall Sections of Hollow Glass Block
(watts per square foot per ^oF)

Size of Block	Outside Wall Section	Inside Wall Section
5-3/4"x5-3/4"x3-7/8" thk	0.18	0.14
7-3/4"x7-3/4"x3-7/8" thk	0.17	0.13
11-3/4"x11-3/4"x3-7/8" thk	0.15	0.12

Table 7-11. Floor Slab Heat Loss
(watts per lineal ft. of exposed slab edge)

Outside Design Temperature	24" Insulation (Horizontal + Vertical)		No Insulation
	2" thick	1" thick	
-20^o to -30^o	15	17	22
-10^o to -20^o	13	15	19
0 to -10^o	11	13	18

Table 7-12. Heating Branch Circuit Capacities

Branch Circuit Conductor		Maximum Installed Area of Heating Panel	
Size	Max. Load-Amps (20% Derated)	2-Wire Circuit	3-Wire Circuit
#14	12	96	192
#12	16	128	256
#10	24	192	384

Table 7-13. W of Solid Wood Doors
(watts per square foot per ^oF)

Nominal Thickness	Actual Thickness	Exposed Door	With Glass Storm Door
1"	25/32"	0.19	0.11
1-1/4"	1-1/16"	0.16	0.10
1-1/2"	1-5/16"	0.14	0.09
1-3/4"	1-3/8"	0.14	0.09
2"	1-5/8"	0.13	0.08
2-1/2"	2-1/8"	0.11	0.08
3"	2-5/8"	0.09	0.07

Table 7-14. Correction Factors for Window Framing

Type of Window		Factor		
Sash	% Glass	Single Glass	Double Glass	Window with Storm Sash
None	100	1.0	1.00	--
Wood	80	0.9	0.95	0.9
Wood	60	0.8	0.85	0.8
Steel	80	1.0	1.20	1.0
Aluminum	80	1.1	1.30	1.1