ENGINEERING NEWS

HOFFMAN SPECIALTY CO.
INDIANAPOLIS 7, IND.

PANEL HEATING

Panel Heating has come well to the front during the past few years. The Hoffman Hot Water Controlled Heat Series 90 is well adapted for use on such systems. In fact it is now being used for controlling many such installations, and with a marked degree of success.

You are, of course, familiar with the Hoffman Hot Water Controlled Heat Series 90, but nevertheless it may not be amiss to go through the various parts in a general way, before discussing their application to panel heating.

The system consists of five major parts, namely--

1 - The Hoffman Temperature Controller, of which there are four basic models, C-93, C-98, C-97 and C-99.

2 - The Hoffman Circulating Pipe, which bypasses the boiler.

3 - The Hoffman Control Valve, of which there are two types. The heat motor operated valve (D-2) is used on smaller systems, that is up to and including 2". For sizes of 2-1/2" and larger, a motor operated valve is used.

4 - The Hoffman Union with Orifice is a calibrated orifice, and balances the circuits through the boiler and the Hoffman circulating pipe. It is so sized that two times as much water flows through the boiler as flows through the circulating pipe, when the control valve is wide open. The size of the orifice depends only on the resistance of flow through the control valve, and since every control valve has a definite orifice to go with it, it need not be specified separately.

5 - The Hoffman Circulator comes in all sizes from 1" to 3" inclusive. Except for special cases, they are furnished in the same size as the control valve. On systems larger than 3" a larger pump than the one which we regularly handle must be used. At times an Economy pump will fit into the picture, or one of the larger types of B&G circulators, such as the belt driven model, or the Universal Pump.

SERIES 90 APPLIED TO PANEL HEATING:

All of the standard parts are used when the Series 90 is applied to panel heating.

Temperature Controller: The brains of the Series 90 system is of course the Temperature Controller. It is the function of the Hoffman Temperature Controller to supply water to the heating system at the temperature demanded by the outdoor temperature existing at the moment. In order, however, to set it properly so that it may perform this function in a satisfactory manner, it is necessary that the designer of the panel heating system tell us what water temperature he desires at several outdoor temperatures. As a rule, the water temperature of panel heating systems is expressed as a mean temperature - that is the average between the supply and return. We must, therefore also know for what temperature drop (difference between supply and return) the system was designed when operating at the lowest outdoor temperature (design temperature). The following is the information necessary:-

1 - Room air temperature.

2 - Design temperature (lowest outdoor).

3 - Mean water temperature at design temperature.

4 - Mean water temperature at outdoor temperature of +40F or some other definite but relatively high temperature.

5 - Maximum temperature drop for which the system was designed.

From this information the controller can be set at the factory and we can guarantee that it will supply the correct water temperature for any outdoor temperature, provided of course the information transmitted to us was correct.

Sometimes a designer will calculate a system based on a published empirical formula and cannot give the information in the above shape. In that case, the following information is necessary so we can make a fairly accurate calculation of the water temperature for different outdoor temperatures:

1 - Describe the panel. Does the system consist of a floor, a ceiling or a wall type panel? In case it is a combination of several, describe each panel separately.

2 - Size and spacing of the pipe in each panel.

3 - The calculated output of each panel in Btu per sq.ft. per hour.

4 - The design temperature (lowest outdoor temperature).

5 - The room air temperature to be maintained.

6 - Maximum temperature drop between supply and return.

In addition to the information necessary to set the Hoffman Temperature Controller, we must also have the mechanical specifications for this instrument. There are four basic models of the controller, namely-- C-93, C-98, C-97 and C-99.

The C-93 and C-98 are used when the system employs a heat motor operated valve, and this should never be used on installations over 2". The two controllers differ from each other inasmuch as the C-93 is built to handle 115V a.c., whereas the C-98 is built to handle 220V a.c.

The C-97 and C-99 are again similar but are designed to function with a motor operated valve, and this is used on all installations of 2-1/2" and larger. They differ from each other only inasmuch as the C-97 is built for 115V a.c., and the C-99 is for 220V a.c.

There are six variations of each of these four basic models. These variations consist only in difference of construction and length of the capillary tubing leading from the controller to the water bulb and the outdoor bulb. There are six such variations as shown on the attached table, viz.,

Both capillaries plain, 25 ft. each.

Both capillaries plain, 50 ft. each.

Both capillaries plain, one leading to the outdoor bulb 50 feet in length and the one leading to the water bulb 25 feet in length.

The other three variations use these same lengths, but the capillaries are surrounded by a protecting armor.

Some engineers and architects specify that the capillary tubing must be protected. It is not good practice to remove the bellows, capillary and the bulb assembly from the control box and pull it through a conduit, therefore we suggest that where a protection is specified, that one of our models having armored capillary be used.

You will note from the table*that the "model parts list" designates which of these various capillary assemblies is to be used in the controller. Our standard assemblies are C-93-A2, C-98-B2, C-97-C2 and C-99-D2. In other words, the plain capillary, 25 ft. long, to each bulb is our standard equipment and should be specified whenever possible.

When you order a 115V controller for a smaller size (not over 2") and desire to have a perfectly standard instrument with 25 ft. plain capillary to each bulb, please specify a Model C-93-A2. If your customer desires to have, for example, an instrument equipped with 50 ft. of armored capillary to the outdoor bulb,

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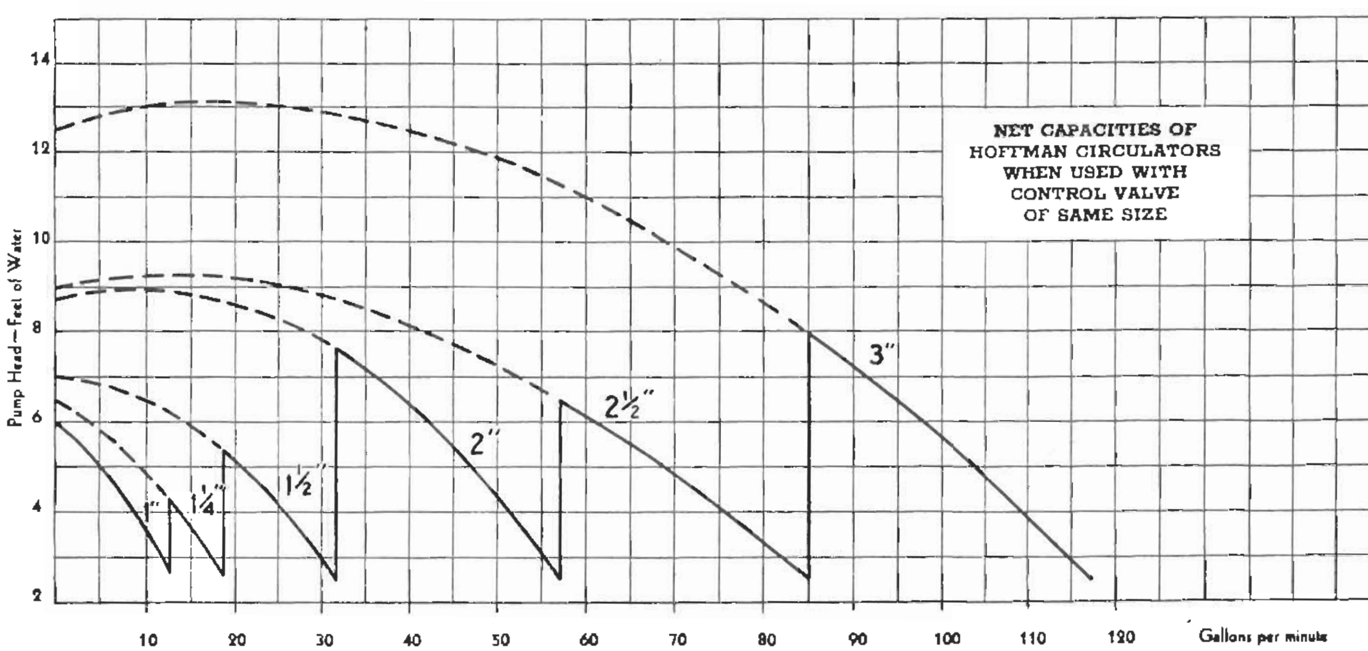
* see page 6.

and 25 ft. armored capillary to the water bulb for a 1-1/2" valve, the controller to operate on 220V a.c., then specify a Model C-98-B9.

<u>Control Valve:</u> In addition to specifying the model of the temperature controller, you must of course specify the size of the Control Valve. The size of the valve is usually specified by the designer of the heating system, and is the same size as his return piping into the boiler. The union and orifice need not be specified, since it is included with the Control Valve.

<u>Circulator:</u> Ordinarily the size of the circulator is also the same as the return piping, and therefore the same size as the valve. In Panel Heating, however, the resistance of all the piping including that of the panel coils may be so high that this same size circulator will not be large enough. In addition to that, a panel heating system is frequently designed for only a 10° temperature drop between supply and return. This, in itself, means that the circulator must handle twice the amount of water as in an ordinary radiator system designed for the usual 20° drop. You should point this out to your customer, and have him tell you how much water he is going to pump and against what resistance. To aid you in the selection of the proper circulator size, I am attaching a chart showing the capacity of our various size circulators.



On this chart, the resistance of our control valve has already been subtracted, and that, therefore, need cause you no worries. You will note that on the chart, part of the lines are solid, and part of them are dotted. The solid curves show the usual range in an ordinary radiator system for which each size circulator is used. In a Panel Heating System, however, you may use the dotted portion of the various curves. For example - for delivering 70 gpm a 2-1/2" circulator would usually be used in an ordinary radiator system, and this size would deliver this quantity of water against practically a 5 ft. head. Substituting, however, a 3" circulator we find from the chart that this size circulator delivers 70 gpm against practically a 10 ft. head. If your customer cannot give you information regarding the quantity of water and the resistance against which it must be pumped, you can calculate it from the data given on Chapter 15 of the ASH&VE Guide 1945. It is of course necessary that you have a piping layout of the job and know the temperature drop between supply and return, and the total Btu output of the system under maximum conditions. If you need any help in working this out, I shall be glad to have you get in touch with me.

I fully realize that this dissertation may not be as clear as it should be. If there are any points which are not clear to you, I shall be very glad indeed to have you drop me a line, and I will see if I can help you. Also, if you have any information on new systems, new uses for our temperature controller, or anything which you think would be of Engineering value, pass it along.

Ferdinand Jehle
Ferdinand Jehle.
Director of Engineering.

HOFFMAN TEMPERATURE CONTROLLER.
Basic Models and Their Variations

Basic Model	Model Parts List	Voltage	Capillary	Switch	Valve and Transformer.
C-93	A-2	115 a.c.	Outside 25 ft. Water 25 ft.	Single Pole Single Throw A-87	Heat Motor D-2 Bell Ringing Transformer B-4 Use only on sizes up to and including 2".
C-93	A-3	115 a.c.	Outside 50 ft. Water 50 ft.		
C-93	A-6	115 a.c.	Outside 25 ft.armored Water 25 ft.armored		
C-93	A-7	115 a.c.	Outside 50 ft.armored Water 50 ft.armored		
C-93	A-9	115 a.c.	Outside 50 ft.armored Water 25 ft.armored		
C-93	A-10	115 a.c.	Outside 50 ft. Water 25 ft.		
C-98	B-2	220 a.c.	Outside 25 ft. Water 25 ft.	Single Pole Single Throw A-87	Heat Motor D-2 Bell Ringing Transformer. **B-19** Use only on sizes up to and including 2".
C-98	B-3	220 a.c.	Outside 50 ft. Water 50 ft.		
C-98	B-6	220 a.c.	Outside 25 ft.armored Water 25 ft.armored		
C-98	B-7	220 a.c.	Outside 50 ft.armored Water 50 ft.armored		
C-98	B-9	220 a.c.	Outside 50 ft.armored Water 25 ft.armored		
C-98	B-10	220 a.c.	Outside 50 ft. Water 25 ft.		
C-97	C-2	115 a.c.	Outside 25 ft. Water 25 ft.	Single Pole Double Throw A-167	Reversing Motor Power Transformer (fused). Use on sizes 2-1/2" and larger.
C-97	C-3	115 a.c.	Outside 50 ft. Water 50 ft.		
C-97	C-6	115 a.c.	Outside 25 ft.armored Water 25 ft.armored		
C-97	C-7	115 a.c.	Outside 50 ft.armored Water 50 ft.armored		
C-97	C-9	115 a.c.	Outside 50 ft.armored Water 25 ft.armored		
C-97	C-10	115 a.c.	Outside 50 ft. Water 25 ft.		
C-99	D-2	220 a.c.	Outside 25 ft. Water 25 ft.	Single Pole Double Throw A-167	Reversing Motor Power Transformer (fused). Use on size 2-1/2" and larger.
C-99	D-3	220 a.c.	Outside 50 ft. Water 50 ft.		
C-99	D-6	220 a.c.	Outside 25 ft.armored Water 25 ft.armored		
C-99	D-7	220 a.c.	Outside 50 ft.armored Water 50 ft.armored		
C-99	D-9	220 a.c.	Outside 50 ft.armored Water 25 ft.armored		
C-99	D-10	220 a.c.	Outside 50 ft. Water 25 ft.		

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INDIANAPOLIS 7, IND.

CALCULATIONS FOR PANEL HEATING

The business of the Hoffman Specialty Company is the manufacturing of heating specialties, which includes hot water heating control apparatus useful in controlling panel heating. The company does not design heating installations. You may, however, be called upon to give advice or may want to design one yourself, so I am passing on to you these few notes which I trust may be helpful.

Panel Heating is new and many engineers have their own ideas on how such a system should be calculated and designed. Although what I shall outline here is based upon published information, some will disagree with me. All I can say is "make the best of it".

The ASH&VE now differentiates between Panel Heating and Radiant Heating. By Radiant Heating they mean "high temperature radiant heat". In this system a high temperature panel is used, which radiates heat directly to the object or person to be heated, and in this case the surrounding air temperature is not heated. Such installations are used mainly for more or less temporary purposes, as for example a hospital bed in the outdoors; or may be a school room in the open air.

Panel Heating involves both radiation and convection. Panels may in fact be considered as huge radiators working at comparatively low temperatures. It is this kind of heating in which you will be principally interested and with which this bulletin will deal. In order to make the calculation as simple as is possible, I am sacrificing some technical accuracy.

HEAT LOSS CALCULATIONS:

Calculate the heat loss of the house the same as you would for any other heating system. Any method which you have used and which has proved successful in figuring an ordinary steam system or hot water system is quite all right. You may use Chapter 2 in Mr. Gillett's Notes on Heating, or follow the instructions given in Chapter 6 in the ASH&VE Guide, 1945. The two are practically identical. In these calculations, it is safe to assume the room temperature as 70F. In case the owner desires a higher room temperature or it is found that a lower room temperature is livable due to the radiant effect of the panel system, an adjustment of water temperature can always be made.

PANEL LOCATION:

A heating panel can either be put into the floor, the ceiling or the walls. Structural reasons should decide the best location. The ceiling panel has some advantages, particularly since it can be run at a higher output than a floor or a wall panel. A floor panel, on the other hand, is probably the cheapest construction, and the ceiling the most expensive. At times it may be necessary to combine several of these panels. It is not always possible to get a sufficient amount of heat output from a floor panel, and in that case this must be augmented by a panel in the wall or one in the ceiling, or a certain amount of standing radiation has at times been used in connection with the panels.

CALCULATION OF PANEL SIZE:

After the heat loss has been calculated, it should be divided by the largest size panel available in the room to be heated, and that will give the output per square foot of panel. The output of the panel depends of course on its surface temperature, and the relation of this temperature to the air temperature and the temperature of the surrounding walls. A floor panel should never be run over 85F surface temperature. A wall panel may be run as high as 100F maximum, while the permissible ceiling temperatures vary between 105F and 130F, depending on the ceiling height. For ordinary dwellings, it is wise to hold the ceiling panel temperature to 115F.

CHART 1 shows the output of floor, wall and ceiling panels for different surface temperatures. This output includes that given off by radiation, convection and conduction. In making the calculations, the room air temperature was assumed to be 70F while the average temperature of all walls to which the panel must radiate was assumed at 68F. Since the maximum floor panel temperature is 85F, we see from CHART 1 that the maximum output of a floor panel is about 30 Btu per square foot. A wall, if it is not to run over 100F maximum, can emit 59 Btu per square foot, whereas a ceiling panel run at the maximum of 115F can put out 76 Btu per square foot. Not all of this output, however, is useful. In the case of a floor panel, a certain amount of heat will travel downwards and that is lost if the panel is directly on the ground. In the ceiling, of course, the loss will extend upwards, which may or may not go into an occupied room. In the case of an exterior wall, there will be a certain loss to the outside, whereas an interior wall will be from room to room, and therefore can be recovered.

This loss, during heating up in a floor panel, may reach 30%. Since, however, this heating up process occurs only about once a year, I believe if an average loss of 15% were taken, it would be sufficient. The loss in an upstairs ceiling and an exterior wall may safely be assumed as 20%.

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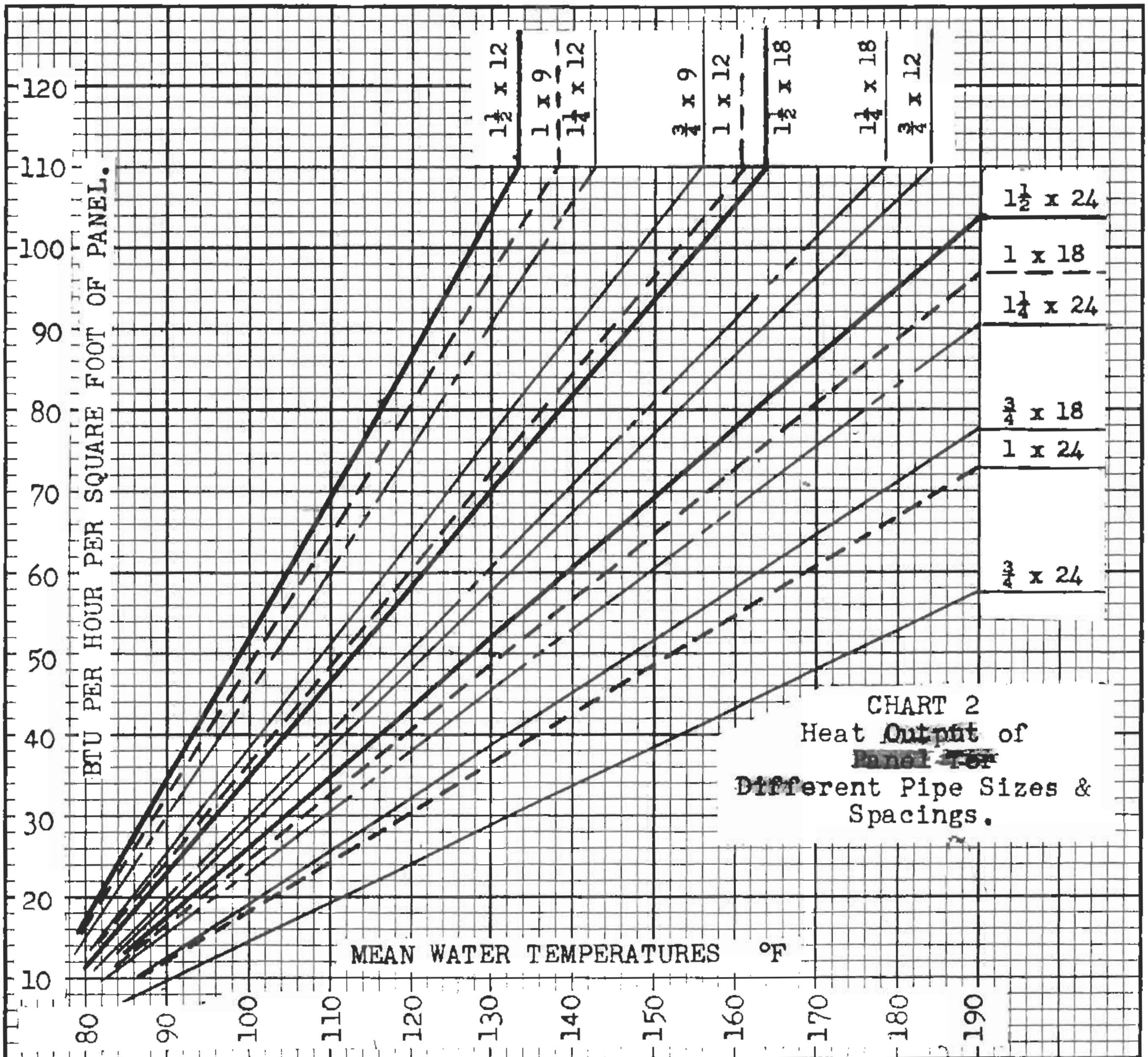

CHART 2
Heat Output of
Panel for
Different Pipe Sizes &
Spacings.

total area of 300 square feet. 7000 divided by 300 is equal to 23.3 Btu per square foot per hour. This represents only the heat to be actually supplied to the room, and does not represent the entire output including the loss of the floor panel. It is therefore only 85% of what the panel must actually put out. The entire output of the panel equals 23.3 divided by .85 which equals 27.4 Btu per hour per square foot.

If the floor is covered or there are heavy draperies on the wall, an additional allowance must be made. Published information seems to indicate that if the floor is covered with a thin pad and a carpet, water temperatures should be increased 40F. This might be expressed as a 50% reduction in output. Linoleum does not have as much effect, but nevertheless, a 20F increase in water temperature is recommended. Heavy draperies might affect wall panels about as much as carpeting does on a floor. Floor cover-

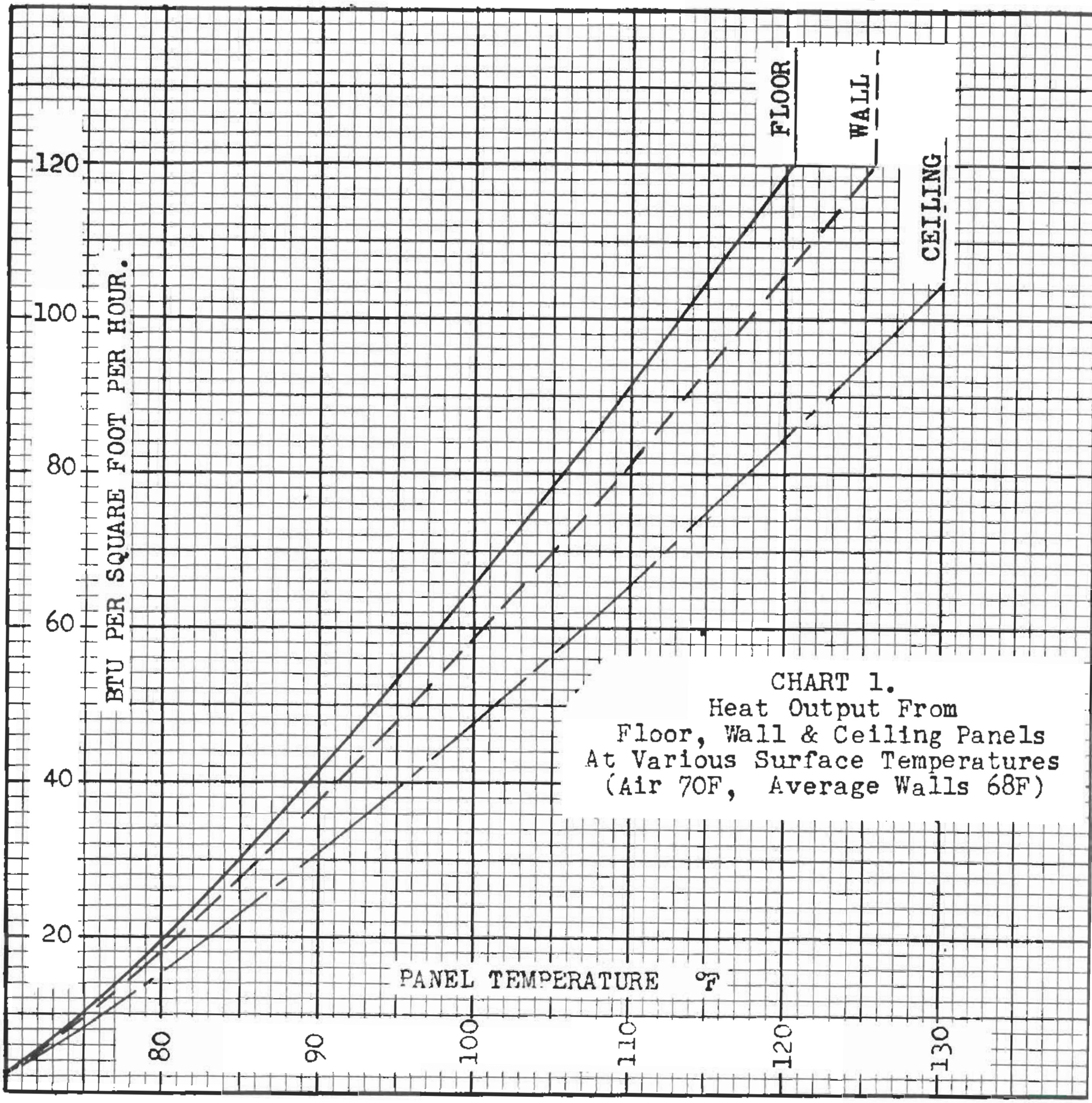

CHART 1.
Heat Output From
Floor, Wall & Ceiling Panels
At Various Surface Temperatures
(Air 70F, Average Walls 68F)

Having decided on the output per square foot per hour of the panel, CHART 2 can be consulted. This gives the output of panels of various constructions, that is, made of various size iron pipe, spaced at various distances and supplied with water at various mean temperatures. From that a selection can be made based on the cheapest and otherwise most desirable pipe size and spacing. Ordinarily the installations so far made, do not seem to go below 3/4" nor above 1-1/2".

Bear in mind that CHART 2 shows the entire output and includes the losses mentioned above. For a floor panel your calculated heat loss should be taken as 85%, and for an exterior wall and an upstair ceiling as 80%. Supposing that you figured a total loss of 7000 Btu per hour for a certain room and that this heat will have to be supplied by a floor panel **having a** ings, etc. should be taken into consideration when the system is first designed, otherwise the other panels in the house may present considerable difficulty when in operation if the temperature of the covered floor panel is stepped up. The exact effect of all of these things still seems open to some argument. Time and experience will straighten this out, and in the meantime the best estimate possible should be made and the system provided with suitable adjustments.

CHART 2 is for iron pipe, although I see no reason why it could not be applied to copper tubing for the same actual size. It should not be used however for panels constructed out of very small copper tubing. I hope that the various copper companies will shortly publish some information on the use of this kind of tubing. As soon as this is available, I shall pass it along to you. Please note that CHART 2 is based on mean water temperatures which is the average of the supply and the return water temperatures.

In making the selection of proper pipe size and spacing, we must also bear in mind the water temperature which must be supplied with these sizes. If the water temperature for maximum conditions is taken at a low temperature, control becomes difficult. If assumed too high, the general results may be somewhat erratic. Supposing we are talking of a floor panel whose total output must be 30 Btu per hour per square foot of area. We will find from CHART 2 that this might be made of 3/4" pipe, spaced on 9" centers, and this would call for a maximum water temperature of approximately 94F. Supposing further, that your design temperature is -10F and your room temperature 70F (a temperature difference of 80F) then when there is a temperature difference of 40F, namely 30F outside temperature, the panel must supply one-half that amount of heat, or 15 Btu per square foot per hour. CHART 2 tells us that at this output a water temperature of 82F will be required. In other words, a difference of 12F water temperature must take care of an outdoor temperature difference of 40F. That would call for pretty much of a micrometer form of control.

Supposing we had selected 3/4" pipe, spaced 24" apart. Consulting CHART 2, we see that that would call for a mean water temperature of 133F. At half-output, that is an outdoor temperature of 30F, this would call for a mean water temperature of 102F, that is a difference of 30F. The control would therefore be two and one-half times as accurate as when the control would be used on the first example. I would suggest that you design your floor panels so that a mean water temperature of say between 120 and 140F for maximum output is used. For ceiling and wall temperatures, a higher mean water temperature is permissible, provided of course the installation does not consist of a mixture of floor and these other panels.

USE OF SEVERAL PANELS IN HOUSE:

If several panels in different rooms are necessary to produce the heating of the entire house, then find out which one must have the highest output per square foot, regardless of whether it be floor, ceiling or wall, and that one will determine the water temperature which must be used for the entire system. Since our control can furnish only one water temperature, all the other panels must be designed for using the same water temperature.

Supposing the dining room is the hardest room to heat. That then will determine what water temperature to use. All the other rooms will have to use this same temperature, and must, therefore, be designed to give a lesser output per square foot than the dining room panel, by the proper selection of pipe sizes and spacing from CHART 2.

While it is at times necessary to combine a small wall or ceiling panel with a floor panel because none of the surfaces would in themselves present area enough for supplying the required amount of heat, yet it is not good practice, for the present at least, to combine panels of these various locations in a single system. It would not, for example, be well to put a floor panel in the living room, a ceiling panel in the dining room and wall panels in the bedrooms. An exception to this general rule might be where downstairs rooms are equipped with ceiling panels and the bedrooms, just above, equipped with floor panels. In case it is necessary to combine various kinds of panels, then bear in mind that the one which requires the highest mean water temperature determines the water temperature for all the others.

COMBINING PANEL AND STANDING RADIATION:

As pointed out previously in this dissertation, at times it may be necessary to combine some standing radiation with a panel. Particularly is this true in such rooms as vestibules, and the like, where a sufficient panel area is not obtainable. Care must be exercised in an installation of this type, however, that the standing radiation be made of the proper size to give the correct output per square foot per hour with the water temperature available. To aid you in the proper selection of a radiator size, CHART 3 is included. This shows the heat emission of standing radiation for different mean water temperatures. It is plotted from information contained on page 243 of the 1945 ASH&VE Guide.

Suppose that you use 130F mean water temperature for the floor panels in the house, then the radiator must be fed with exactly the same water temperature. Consulting CHART 3, we find that for the mean water temperature of 130F, standing radiation will emit 77 Btu per square foot per hour, and the radiator must be made of sufficient size so its output will take care of the deficiency which it must supply.

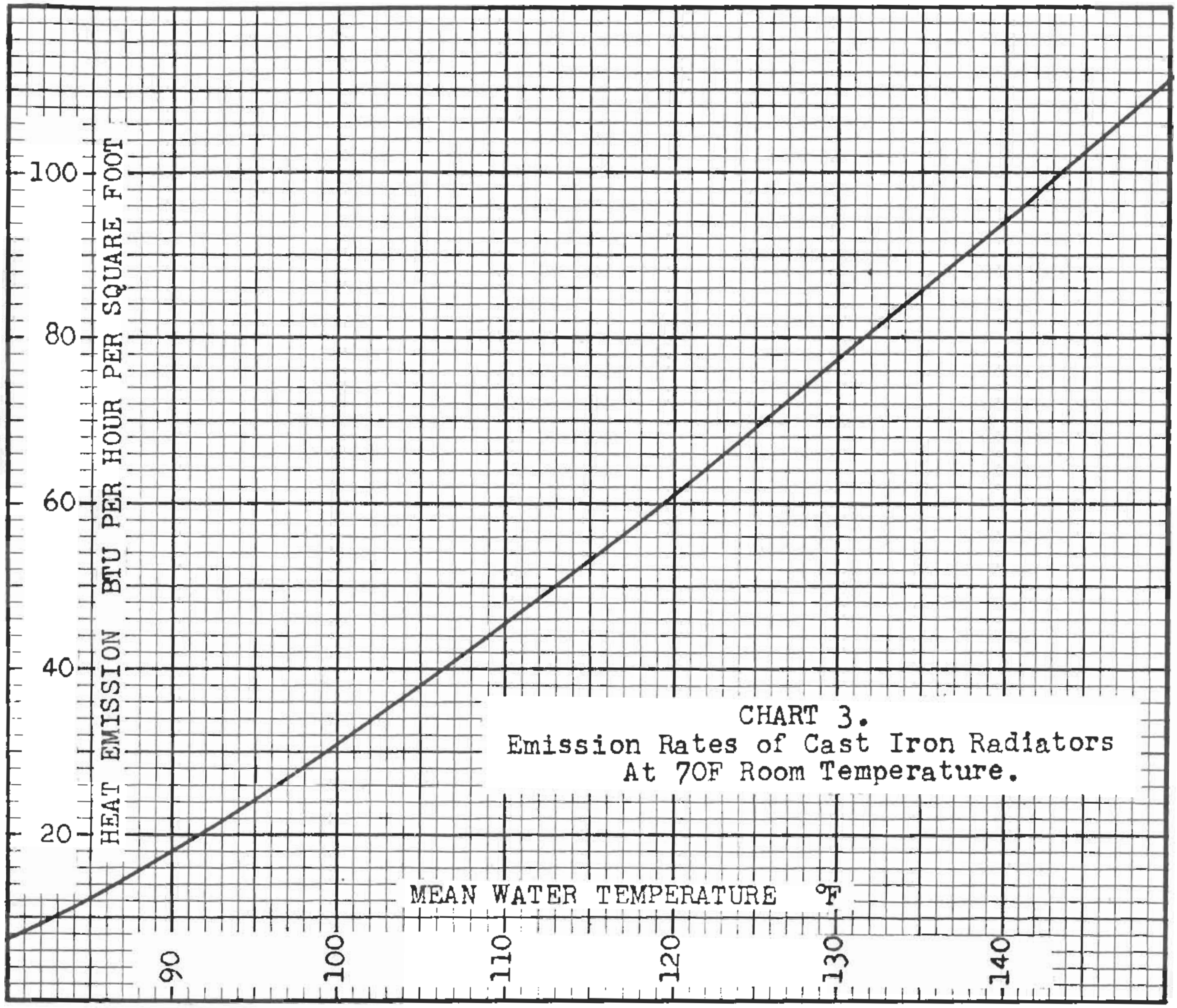

CHART 3.
Emission Rates of Cast Iron Radiators
At 70F Room Temperature.

MEAN WATER TEMPERATURE AND TEMPERATURE DROP:

I have used the term "mean water temperature" throughout this discussion. By that is meant, of course, the average between supply temperature and return temperature. In an ordinary heating system, the temperature drop (the difference between supply and return temperature) is usually set at 20F. In the case of panel heating, however, a 10° drop is usually used. The reason for this is that in the case of a long panel and a 20F drop, one end would be at a considerably lower temperature than the other, and the output per square foot at the low end would naturally be less than at the high end.

CIRCULATOR SIZE:

Bulletin No. 1, covers the determination of the circulator size and I would suggest that you refer to that when you calculate systems of this description. Bear in mind that pipe friction in a panel heating system may be greater than in an ordinary heating system, and the fact that only a 10° drop is allowed means that the circulator must pump twice the amount of water than in an ordinary radiator forced hot water system.

STRUCTURAL SUGGESTIONS:

It is difficult at this time to go very thoroughly into the subject of the construction of the panels. If continuous coils are used they can be bent on the job. Connections between different lengths of pipes and their headers are usually made by welding. You will probably find that most of the contractors who have installed panel heating will have some particular method which they have learned and naturally prefer to use. It is important, however, that the panel, when it is in place on a floor or ceiling, should be level so as not to provide spaces in which air might gather. This brings up the point of air venting. By all means an air vent should be placed at every high point, or at least one on each panel, so that the system may be freed from air. Usually these vents take the form of some manually operated cock or valve.

We have developed an automatic vent for hot water lines which will be useful for this purpose. It is known as our #79 Air Vent for Hot Water Lines, and we hope that before long we can be in production on it.

One thing in the layout and construction of the system is of very great importance. Each panel should be provided with a separate return, run either to the basement or to the Utility Room so that square headed cocks can be put in each panel and the water flow adjusted and thereby the output of each panel regulated. If it can be done, it would not be bad to also run a separate supply to each panel, likewise from some centrally located place like the Utility Room or the basement.

In compiling the information contained in this bulletin, I have made frequent use of the excellent work done by Dr.F.E.Giesecke, and which appeared in the Journal for Heating Piping & Air Conditioning, December 1940, as well as of the articles which appeared in the Plumbing & Heating Business. I also referred to the excellent work published by the A.M.Byers Company.

Ferdinand Jehle
Director of Engineering.

ENGINEERING NEWS
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STRUCTURAL DETAILS OF HEATING PANELS

So far two Engineering News bulletins have been issued on panel heating. No. 1 had only to do with the application of our series 90 control for this type heating. No. 2 contained the fundamental calculations for panel heating. Included in No. 2 were several paragraphs under the general heading of "Structural Suggestions". It is this phase of the subject which I want to dwell on at a little greater length in this bulletin, but I should again like to point out that the Hoffman Specialty Company is not engaged in designing complete systems, but in furnishing controls. After all the calculations have been made, there still remains the important task of designing the piping so that it will meet the structural requirements.

A panel heating system is a "tailor-made" system. It must be "tailored" to certain physical dimensions and it must be "tailored" for the proper heat output under the installation conditions. It is therefore possible to give only the fundamentals and general outlines of design. Many illustrations could be given of installations in buildings, but these would again serve only as suggestions for new installations.

1. VARIOUS ARRANGEMENTS OF PANEL PIPING:

There are several ways of arranging the heating pipes in the panel. All of them possess certain advantages and certain disadvantages over the others.

Sinuous Coil:

In this system the entire panel area is covered by one continuous coil bent so that it passes back and forth. This is sometimes referred to as a continuous coil, a sinuous coil, or a serpentine coil. The hot water is supplied at one end of this coil and passes to the return piping at the other end. There is only one path for the water. The chief advantage of a structure of this kind is that it is relatively cheap. There are the fewest welds to make, but of course a great number of bends.

The disadvantage of this kind of a structure is that as relatively small piping is used, the frictional resistance offered to the water flowing through it is high, and a pump capable of working against a greater head pressure is necessary. Although this has not been generally discussed in the literature, high water velocity usually also results with this kind of construction, and if this reaches too high a figure (over 4 ft. per second), it may become noisy.

The temperature drop too is of rather great importance. If the temperature drop is high through the coil, then one end of the coil will operate at a lower temperature and, therefore, at less Btu output than the other end. It is well for this reason to design a system of this description on only a 10° drop; that is, a 10° difference between supply and return temperature. Figure 1 is a sketch of a coil of sinuous design.

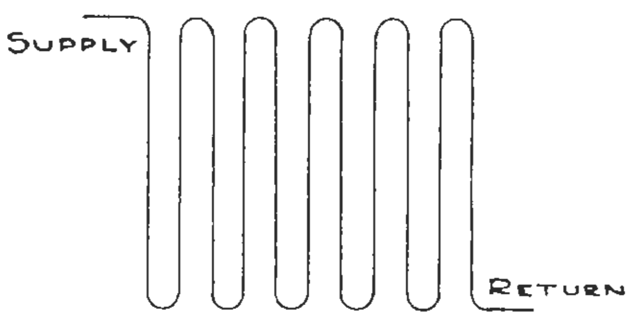


FIG. 1

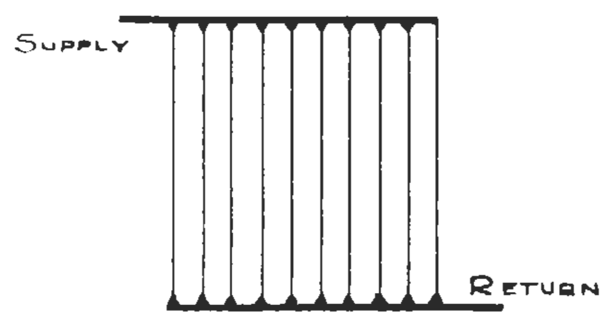


FIG 2

<u>Parallel, Grid, or Header Type Coils:</u>

In this type of construction a supply pipe is run down one side of the room and a return on the other, and the panel piping consists of a series of rather short pipes, each one connected to the supply and the return. The advantage of this construction lies chiefly in the fact that it offers a very low frictional resistance to the water flow and the pump size need not be so large. Velocities are also lower and it might therefore make for quietness.

With the proper selection of the location of supply and return, it is possible to utilize a higher temperature drop in the water without the disadvantage of giving the two ends of the panel too great a difference in heat output. The disadvantage of this construction of a panel lies in its greater cost and the greater chance for getting leakage. There are many more welded joints, which bring up the cost and also increase the chance for leakage.

Figure 2 shows the usual design of a header type coil, while Figure 3 is a modification suggested by Mr. Bradfield, and made out of copper. You will note that both supply and return are in the center of the room and temperature drop is not so important, since the average temperature of any one of the coils is constant.

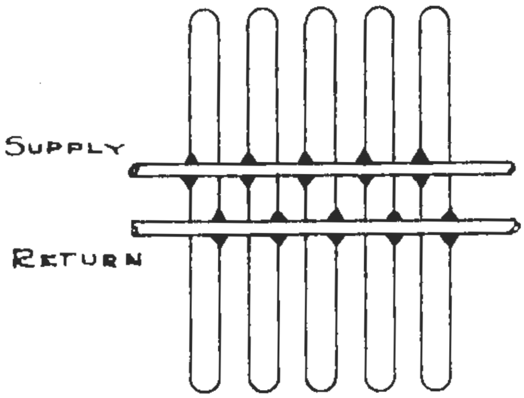
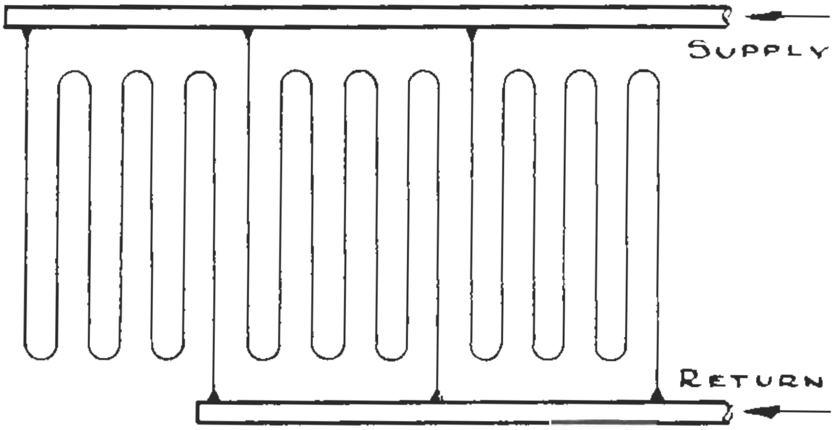


FIG 3

Combination Sinuous and Parallel Coils:

Where a panel is extremely large, a combination of both the above described constructions is usually used. The panel might be divided say into three parts, each covered by a sinuous coil and the three coils connected together in parallel.



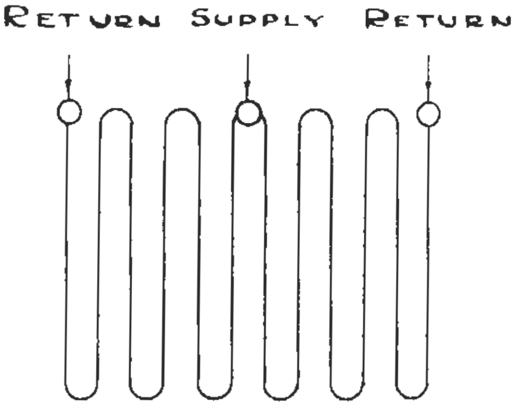


FIG 4

FIG 5

The following sketches indicate four of the many ways this could be done. Figure 4 shows three sinous coils in parallel. The supply runs down one side of the room and the return down the other. This could easily be used in a large room. Figure 5 shows a sinuous coil with a return on each end and a supply in the middle. In reality these are two sinuous coils in parallel. Figure 6 shows a little different arrangement. A return runs down each side of the room and a supply main down the center. Several sinuous coils can be put between the supply and either return.

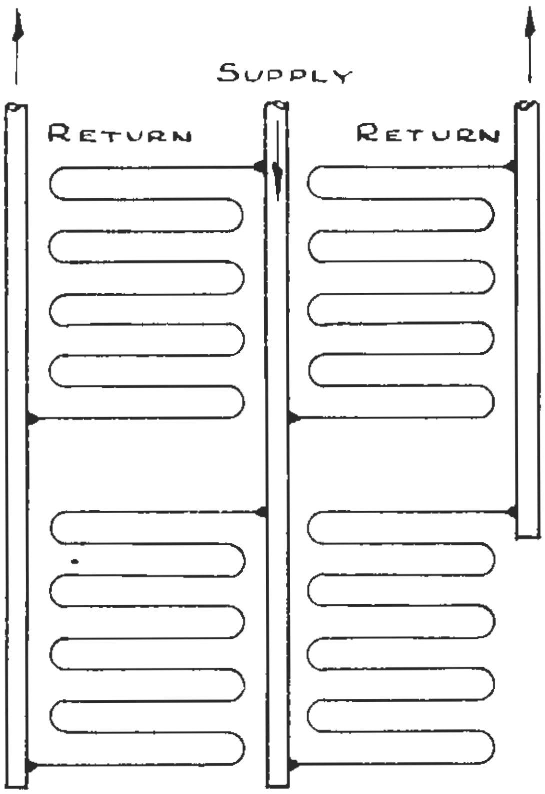


Fig 6

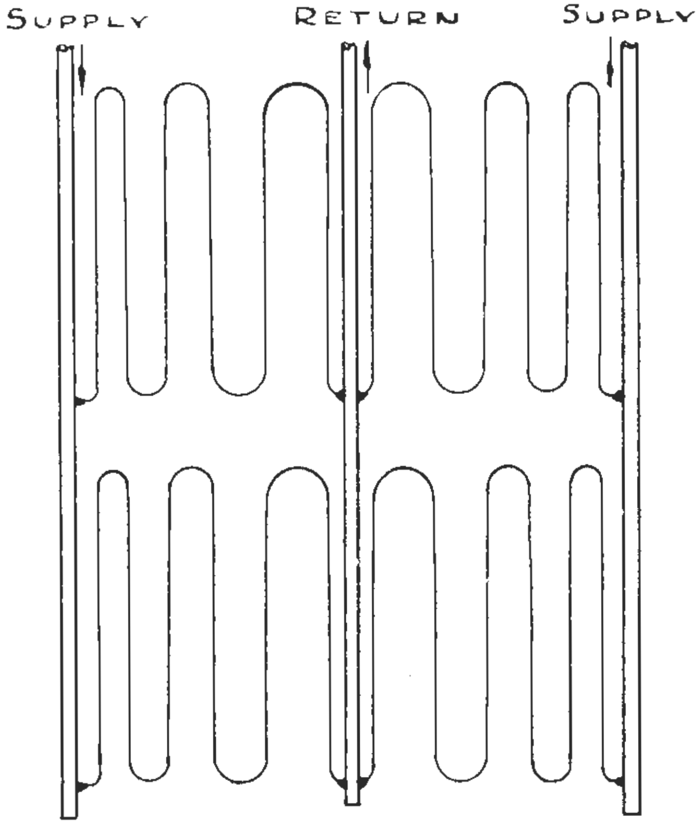


Fig 7

Figure 7 shows a method of running the coils which might be very useful for a floor or ceiling coil in a room with two exposures. It shows a supply running down each of the exposed sides, and a return in the middle. You will note that the sinuous coil is so arranged that the temperature of the water decreases toward the center of the room. This leaves the higher temperature water and, therefore, the somewhat higher panel temperature along the edges or the exposed sides of the room. It means a higher average panel output but leaves the higher temperature at the place where it is least likely to produce discomfort, and this may be of particular importance in a floor panel. It is possible to space the coils closer together on the supply end as shown, and thus exaggerate this effect. In such an arrangement it is possible to use a somewhat higher temperature drop.

2. COIL BENDING:

It can be seen at a glance, in any system except the parallel system, that pipe bending is one of the major problems in installing a panel heating system. A. M. Byers Company has published the following information:

Pipe Size	*Minimum Diameter of Bend Center to Center
1/2"	2.8"
3/4"	3.5"
1"	4.3"
1-1/4"	5.5"
1-1/2"	7.0"
2"	11.0"

*These are for cold bending on the job.

You will note that the center-to-center distance, which can be produced by cold bending, is in every case less than the center-to-center spacing called for in Chart 2 of Engineering News No. 2. These bends can be made on the job cold with the proper tools.

3. AIR VENTING:

In a complicated system of piping, such as a panel coil, it is very important to provide means for freeing the system of air while filling, and to also provide means of ridding the system of air during operation; or in other words, avoiding air pockets. It is at times advantageous to install the expansion tank where it will also serve as an air accumulator at the highest point, say in the attic. Frequently the attic of a modern home is not easily accessible and in that case a vent pipe should be run from the expansion tank to the basement, or utility room, and provided with a valve so that the air can be eliminated from this point.

The vent pipe above mentioned should be attached to approximately the middle of the expansion tank. Standard expansion tanks do not come with a tapping at this point. Both the tappings with which they come equipped are on the bottom. It is, therefore, necessary to do a little more "tailoring". Figure 8 shows a method which is frequently used for similar purposes. A tube extending into the tank is, of course, subjected to rusting and a brass or copper tube would be desirable. Figure 9 shows another possible method of accomplishing this; namely, by welding a small flange to the center of one of the heads of the tank. This should not present any particular difficulty because a welder will have to be on the job anyway.

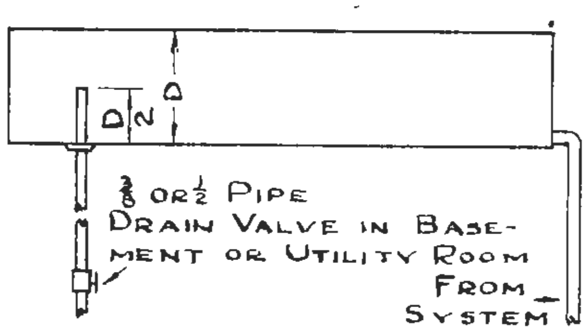


FIG 8

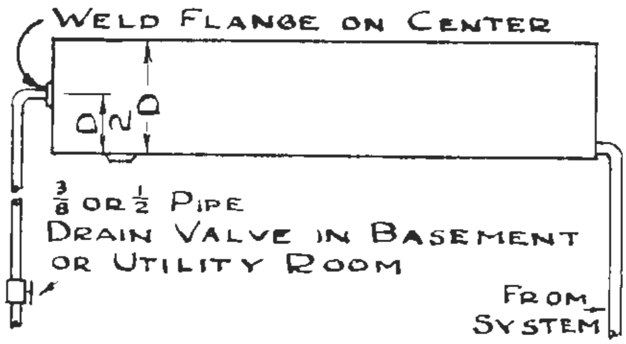


FIG 9

It should be borne in mind, however, that when the system is again deaerated, water will flow from the air drain for the first few seconds if the installation is made as suggested. At points where there is danger of the accumulation of air in the piping, a Hoffman #79 Air Vent should be placed. It is well, however, to connect the outlet of the #79 to a drain, unless the installation is in the basement, where a certain amount of condensation of water vapor will not hurt.

4. <u>DRAINAGE OF THE SYSTEM</u>:

As in any other hot water heating system, provision must be made so that the entire system can be drained of water to prevent freezing, in case the house remains unoccupied for some length of time in the winter. This means that not only the supply and return piping must be properly sloped and free of pockets, but all of the panel coils must be so arranged that they will drain. Sometimes compressed air is used to blow a system free of water and if this is contemplated, provision should be made for the attachment of an air hose at the proper points. Even this, however, will not guarantee absolute freedom of water if there are any pockets in the piping.

In the laying of the coil, the different types require different attention. A sinuous coil should be laid absolutely level in the direction of the coils, but sloping slightly toward the return. If the sinuous coil would be laid with the axis of the separate pipes inclined, the unit could not drain. The header type coil, it would seem, were less susceptible to slight slopes. It should be laid with a definite, although not very great slope from the supply header towards the return header. In the case of panels using combinations of these two constructions, each type requires separate consideration. Each sinuous portion of the combination must be leveled in the direction of the separate pipe coils but sloping from supply towards return. This becomes an easier problem if the combination is constructed similar to that shown in Figure 7; that is, with the coil pipes parallel to the supply and return header.

Anti-freeze solutions have been used in some installations, but the proper kind are quite expensive and at the present at least, rather difficult to obtain.

P28R103

5. PANEL CONSTRUCTION:

After the nature of the coil has been decided upon, that is, sinuous, header, or any combination of the two, the details embodying it in the panel must be considered. Such structural details, of course, depend first of all upon whether the coil is to be installed in the floor, the ceiling, or the walls.

In order to insure that the coil can be sloped as desired, it is well to fasten it to three structural members, such as shown in Figure 10. This structural member may be a piece of pipe, an angle, or a channel of sufficient size. A 2" light angle or channel, I believe, is the most desirable, although a piece of pipe is probably the most convenient and, if made of a pipe size the same as the coils, usually possesses sufficient stiffness. The coil should be fastened to the supporting members either with strips or spot-welded. The entire panel construction can then be laid on the slab and carefully leveled or given just enough slope for drainage.

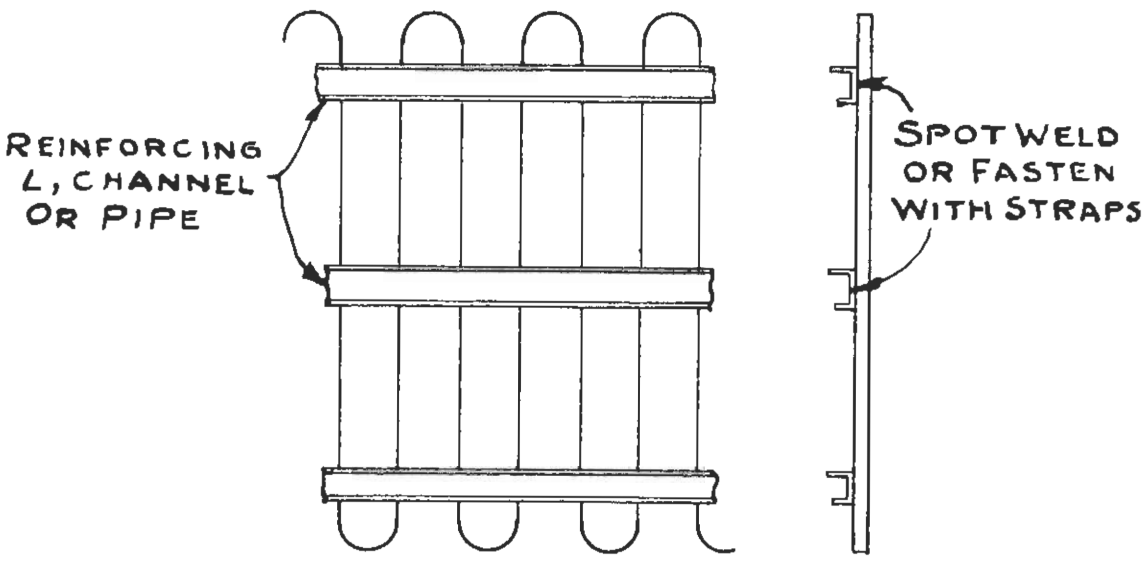


FIG. 10

Heating Panel in Floor:

The floor panel construction has been most frequently used, especially where the house has no basement and the first floor is a concrete slab.

Coils in Concrete Slab: In a construction of this kind, the pipes of the panel can either be placed in the slab itself, or on a sand or gravel fill immediately below the slab. If the former construction is used, the pipes should be placed towards the bottom of the slab, and the top of the pipes should be at least a pipe diameter below the surface.

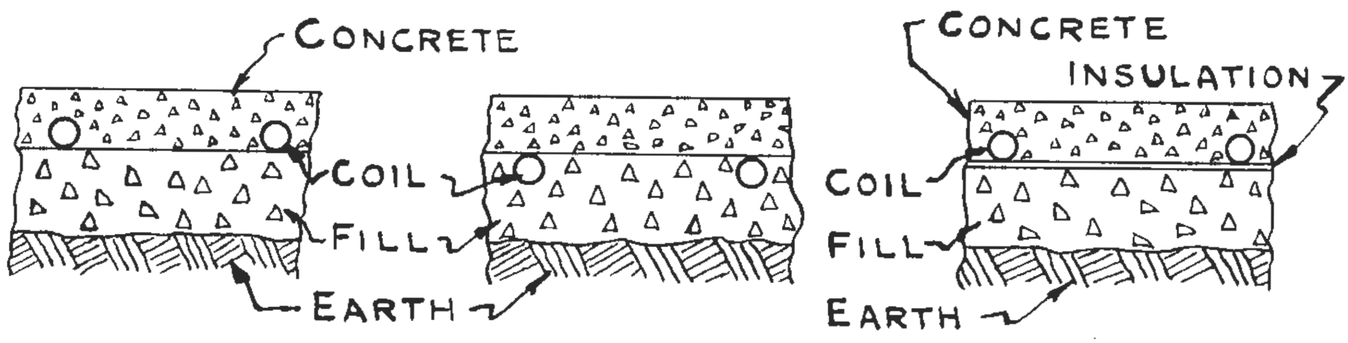


FIG.11 FIG.12 FIG.13

Figure 11 shows a construction with the coil laid upon the sand, gravel or limestone fill and the cement poured over it. Figure 12 shows the coil imbedded in the fill, that is either sand, gravel,or limestone, and then the slab poured. Figure 13 shows an installation in which a layer of roofing paper is placed on the fill (sand, gravel, or limestone), the pipe coils are placed on the roofing paper, and the cement slab then poured in the usual manner.

Other variations involving the use of different kinds of insulation can be used. It should be pointed out, however, that cinders should never be used where they come in contact with pipe. Cinders contain a certain amount of sulphur which may form sulphurous acid and corrode the pipes very badly.

Installation Under Wooden Floor with Basement or on Second Floor: This refers to the installation of floor heating coils under a wooden floor, either in a second story room or in a first floor room over a basement. The coil structure is placed directly on the joists, the coil piping running at right angles to the joists. Sleepers or stringers are then nailed at suitable intervals to support the floor. These stringers must of necessity be thicker than the coil structure, and I would suggest that they be of such thickness that approximately 1/2" of space remains between coil and floor. The reinforcing members (see Figure 10) should be so spaced that they fall between the joists. A sheet of insulating board is then fastened to the bottom of the joist and additional insulation is placed in the space between this insulating board and the coil. Aluminum foil may successfully be used for this purpose. Figure 14 shows a constructions of this description.

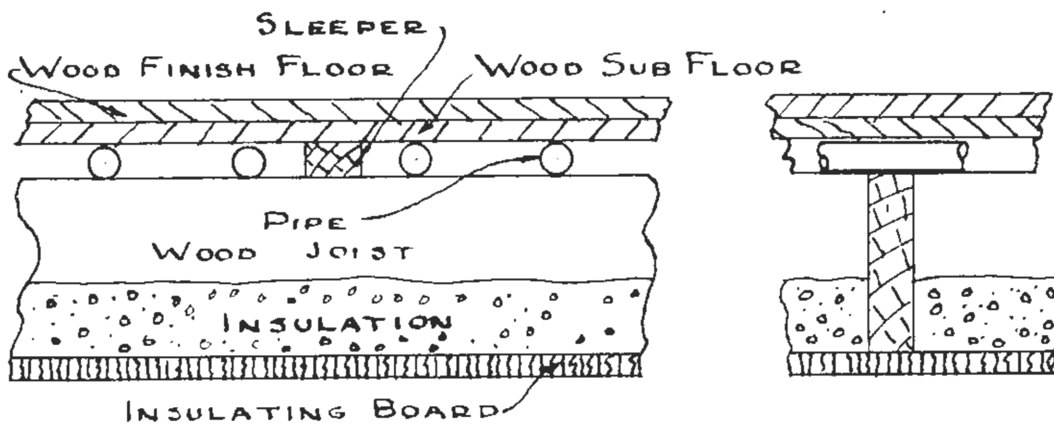


FIG 14

If the installation of a floor heating panel is planned when the house is designed, it would be possible to notch the joists instead of using sleepers. Needless to say, allowances must be made for these notches so that the joists will have sufficient strength to support the required loading. In this case the coils are run in the space between the joists and notches are made only for cross-overs The use of sleeper or stringers seem to be the preferred construction.

There are, no doubt, other forms of construction which may occur to you and which may serve the purpose equally well as those mentioned.

Not many installations of coils under a wooden floor have been made, and the question has been raised in the published literature as to the possible warpage of floors which the heat may cause. It would certainly be advisable to use well dried lumber for the flooring. It has also been suggested that the flooring be laid out for a few days before nailing down.

Heating Panel in Ceiling:

There are several constructions used for ceiling panels:

Under Concrete Floor: If the room above has a concrete slab for a floor, then of course the heating coil can be installed on the bottom of the concrete form, and when the concrete is poured, part of the pipe will be surrounded by concrete. This is very similar to a concrete floor construction. The plaster coats are then applied to the pipes.

Under Wooden Floor: If the building has the more standard residential construction, that is a wood floor for the second story, the coil can be fastened to the bottom of the second floor joists. The metal lath is then nailed to the joists covering the entire lower surface of the pipes. The plaster coats are applied in the usual way. Insulation is placed on top of the coils, that is between upstairs floor and coil. Such a construction is shown in Figure 15

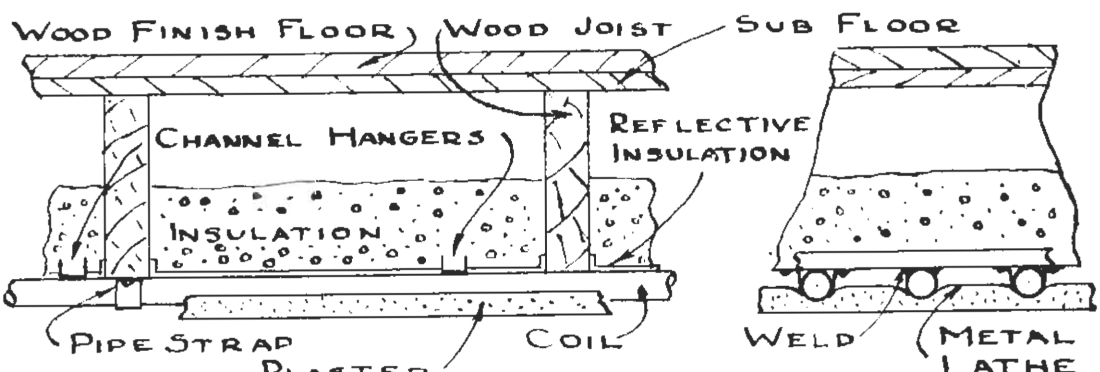


Fig 15

As in the case of the floor coils, the ceiling coils too should be fastened to a rigid support, such as angle, channel, or pipe, similar to that shown in Figure 10, and then the entire assembly raised to the ceiling and fastened in place. Careful positioning to obtain proper drainage is necessary.

Heating Panel in Walls:

Judging by the literature, less is known about heating panels in the walls than about those in ceilings and floors. After Prof. Hutchinson completes his work at Purdue in the experimental house, which has panels located in all of these locations (floor, ceiling and walls) much more can be said on this subject.

The chief use of a wall panel seems to be to augment the heat output of a floor panel. Figure 16 shows a suitable construction. The coil structure is fastened to the studding and the space between the coil and the sheathing is filled with insulating material. Metal lath may be placed over the coils and the plastering applied as usual. If the panel is to cover only a portion of the wall, then of course the rest of the studding must be furred out so there will be no offset in the wall.

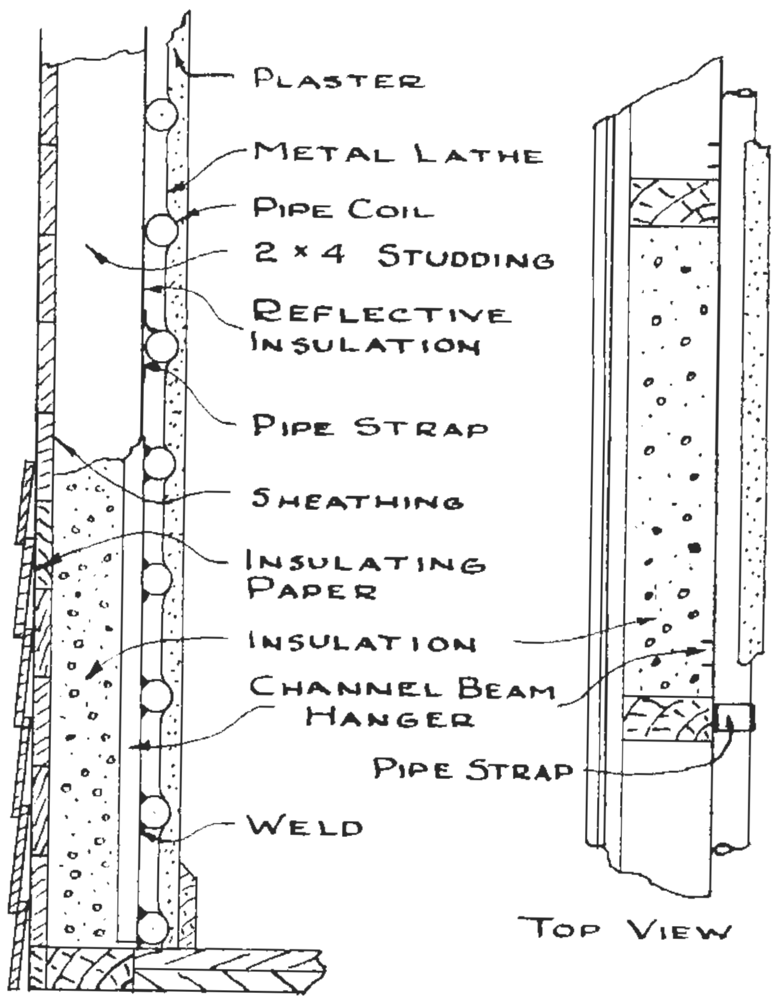


FIG 16

Figure 17 is a diagrammatic sketch of an installation if a sinuous coil is used; and Figure 18 if a header coil is used. In a sinuous coil the individual coils should run horizontal or drainage is not possible. A header type construction can be used either way, but the preferable construction is to run the headers in a horizontal plane. In either case an air vent, our #79, should be installed. This is particularly important since the coil structure is in a vertical plane. In the return a square-head cock should be placed so that the amount of water flowing through the coil can be regulated.

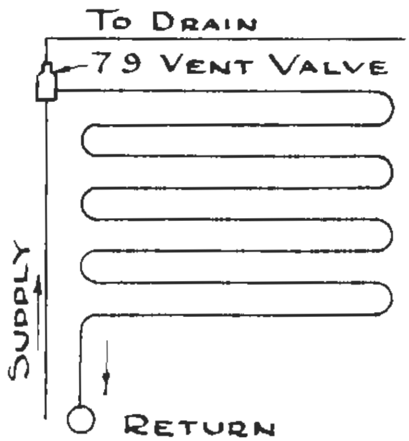


Fig 17

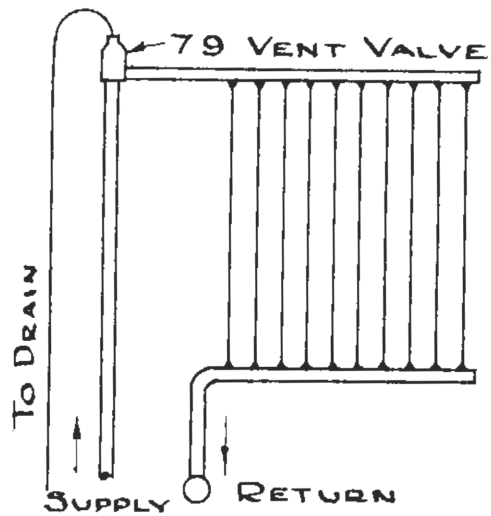


Fig 18

6. <u>LOCATION OF SQUARE-HEAD COCKS FOR ADJUSTING HEAT OUTPUT OF DIFFERENT PANELS</u>:

It would be very difficult, indeed, to figure the panels with such accuracy that each room would be provided with exactly the correct amount of heat. Some form of adjustment is therefore necessary and the method usually used in an ordinary hot water system, namely, placing square-head cocks in the return lines, can be effectively used. Just why the cocks should be placed in the return line I do not know, and I see no reason why they cannot be put into the supply piping, if that is more convenient.

It would be well to locate all the cocks in the basement or the utility room. This is not always possible and it is at times necessary that they be located close to the panel. In that case a location must be picked which can be reached without too much difficulty. If the installation is in a single-story house with ceiling panels, they may be placed so they will be accessible from the attic. At times the head room in a modern attic is so small that such an installation is not possible. In that case they should be placed so they can be reached by removing a plate from the ceiling. Naturally, such a plate should be put in a closet, or behind a built-in bookcase, or in some other inconspicuous place.

Globe, gate or needle valves should not be used for this purpose. Square-head cocks are more leak-proof and tampering with them is less likely to occur.

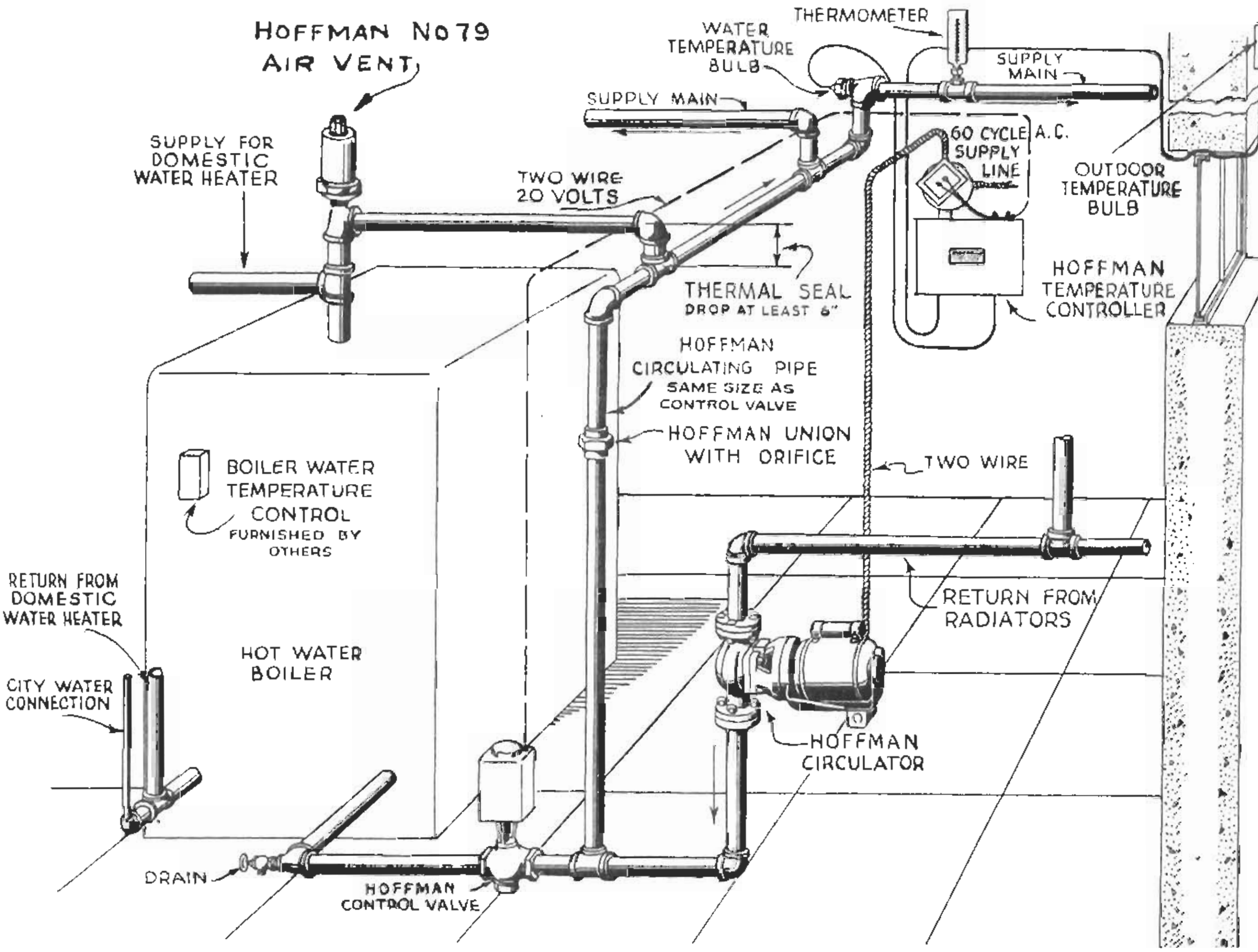


FIG 19

7. <u>BOILER AND PIPING:</u>

The boiler and piping are in the main no different from the boiler and piping for any hot water installation using our system. I thought it wise, however, to include a sketch to refresh your memory. It appears as Figure 19. You will note that where we ordinarily put the expansion tank, I have indicated one of our 79's. This presupposes that an expansion tank is used in the attic. In certain installations, it might be advantageous to use an expansion tank at this point instead of at the high point. Your judgment will have to guide you in this matter.

8. TESTING THE SYSTEM:

After all the piping is in place and just before it is covered, a test should be made of the system. This test should consist of subjecting the piping system (not the boiler) to a hydrostatic pressure of at least 125 pounds per square inch for a period of eight hours. If there are any leaks or imperfections appearing, these shall be remedied and the test repeated. It is well to have the owner or his representative present during such final test period.

9. CONTROLS:

The Heating and Ventilating, Air Conditioning Guide, 1945, published by The American Society of Heating and Ventilating Engineers makes this statement on Page 772:

> * "The heat emitted by hot water pipes imbedded in the plaster of the ceiling and walls or in the concrete base of a floor, can be effectively controlled by an instrument designed to modulate the temperature of the water circulating in the system according to the outside conditions. Metal panels which can be installed in the ceiling or side walls, may be either controlled by an instrument responsive to outside weather conditions or by a specially designed instrument responsive to both air temperature and radiation. Any purely on or off control system is not recommended for panel heating."

If this paragraph said - ". . . . . to modulate the temperature of water continuously circulating in the system", then it would accurately describe our system of control. Undoubtedly they do mean continuous circulation, since the last sentence does not recommend an on and off system for controlling panel heating.

In this same description of control for panel heating, the Guide also mentions a control instrument in the room in connection with the outdoor control. This room instrument is so constructed that it is affected by the radiant energy. I feel that such an inside instrument in addition to the outdoor control is not necessary if the panel is properly designed. My belief is borne out by the fact that we have many installations controlled by the outdoor temperature only, which have given great success. These installations are not in any one particular location, but scattered throughout the country, and I believe represent the true cross-section of how such installations may be expected to perform.

The first Engineering News described the application of our controls to panel heating and it specified the information which we should have in order to set a control properly at the factory. The series 90 temperature controller controls the

- - - -

*Underscoring by me

supply water temperature with respect to the outdoor temperature, and it must be known what water temperature the designer wants at two outdoor temperatures. If the designer does not know this, then if he will give us the information descriptive of the panel, which is asked for on Page 2 of Engineering News No. 1, the temperatures can be calculated.

10. GENERAL NOTES:

I fully realize that many more constructions are possible than I have shown. The information which formed the basis of this dissertation on coil construction, has been gleaned from the published literature, with the possible exception of Figure 7.

All of the sketches and their descriptions are based on the use of iron pipes, as was Engineering News No. 2, for the simple reason that there has been published much more information on the use of this kind of piping than there has on copper. It does not mean that we are siding with the iron pipe industry. During the last few months there has appeared in Heating and Ventilating, some excellent material by Mr. Vanderweil of the Chase Brass and Copper Company. After more of this type of panel construction has appeared in the literature and I have had time to digest it, I shall issue another bulletin.

Ferdinand Jehle

Ferdinand Jehle
Director of Engineering

No. 4

July 20, 1946

ENGINEERING NEWS

HOFFMAN SPECIALTY CO.
INDIANAPOLIS 7, IND.

CALCULATIONS FOR PANEL HEATING
Supplementing those given in Engineering News No. 2

In Engineering News No. 2, Figure 1, I showed the output of floor, wall and ceiling panels. I pointed out that the maximum permissible temperature of a floor panel was 85°F, of a wall panel 100°F, and of a ceiling panel from 105°F to 130°F, depending on the height, but ordinarily a ceiling panel should not be run over 115°F. The maximum outputs of these various panels according to these figures, therefore, are floor 30 Btu's per sq.ft. per hour, wall 59 Btu's per sq.ft. per hour, and ceiling 76 Btu's per sq.ft. per hour. It was also pointed out that these outputs were based on an air temperature of 70°F and an average wall temperature (MRT) of 68°F.

The above results were based upon what seemed to me average conditions. One sees, however, in the published literature, outputs which exceed the figures above given by a considerable amount, and under certain conditions a reasonable increase is possible. It is the object of this News Letter to acquaint you with the conditions under which the outputs of these various panels may be increased over the amounts originally given you. If the mean surface temperature (MRT) of the unheated surfaces, is lower than 68°F, the output of a panel will be increased. Figures 1, 2 and 3 show the output of floor, wall and ceiling panels respectively, at different panel temperatures for different average surface temperatures (MRT).

The problem now is to get the correct inside surface temperature of all the surfaces, such as walls, glass, floors, in fact all except the panel itself. Any interior wall can be assumed to be the same as the air temperature, usually 70°F. The temperature of the exposed surfaces, which includes the exterior wall and glass, depends on the outdoor temperature, the inside air temperature, and the over-all coefficient of heat transmission. The over-all coefficient of heat transmission is usually known as the "U" factor and is readily available for different floor, wall and ceiling constructions in the ASH&VE Guide. The inside air temperature may be taken to be 70°F.

The chart in Figure 4 enables you to find the inside surface temperature of the exposed walls, ceiling, floor and glass, if the outdoor temperature and the over-all coefficient of heat transmission are known. Naturally, one is only interested in outdoor design temperature and not any other outdoor temperature. The chart in Figure 4 is based on an inside air temperature of 70°F.

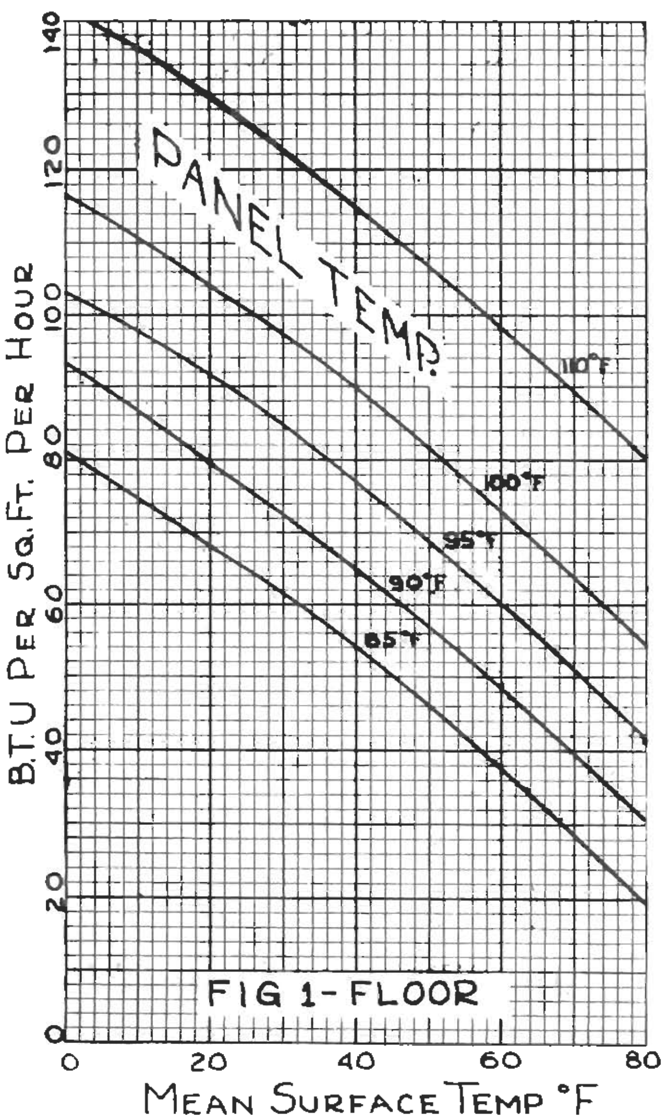


FIG 1 - FLOOR

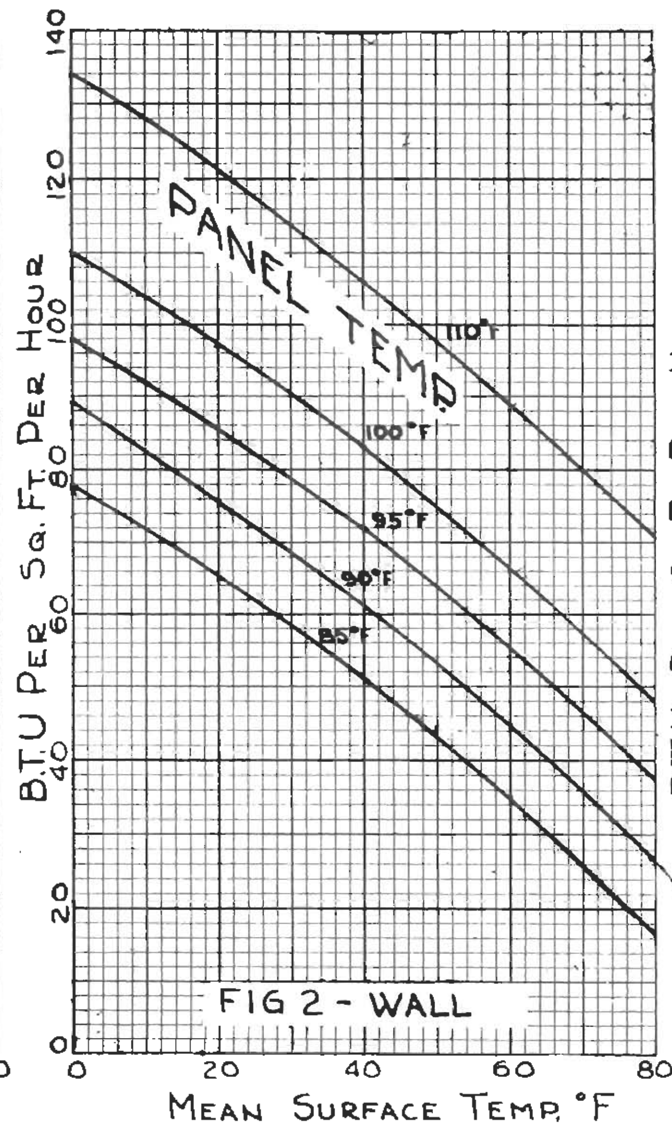


FIG 2 - WALL

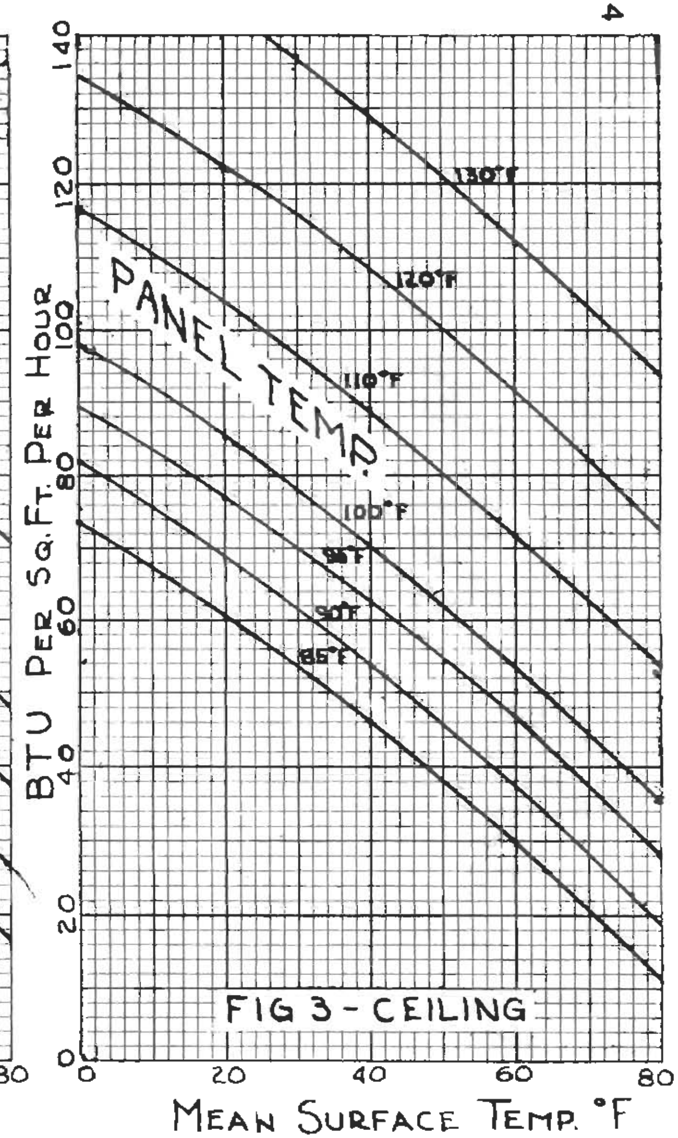


FIG 3 - CEILING

HEAT OUTPUT BY CONVECTION, CONDUCTION & RADIATION OF VARIOUS TYPES OF PANELS

It is true that the temperature, read either from chart in this News Letter or from a similar chart in the ASH&VE Guide, is not absolutely correct, but it should enable you to calculate a panel which is sufficiently close to meet requirements, so that it can be adjusted with the usual cocks placed in the circuits for this purpose.

Many articles have been published which aim to solve this problem with much greater accuracy than is here outlined. I doubt, however, whether all of the information necessary to make these calculations is easily obtained or is accurate enough to warrant these more tedious methods. So that you may become more familiar with the use of these charts, I shall use them in an example.

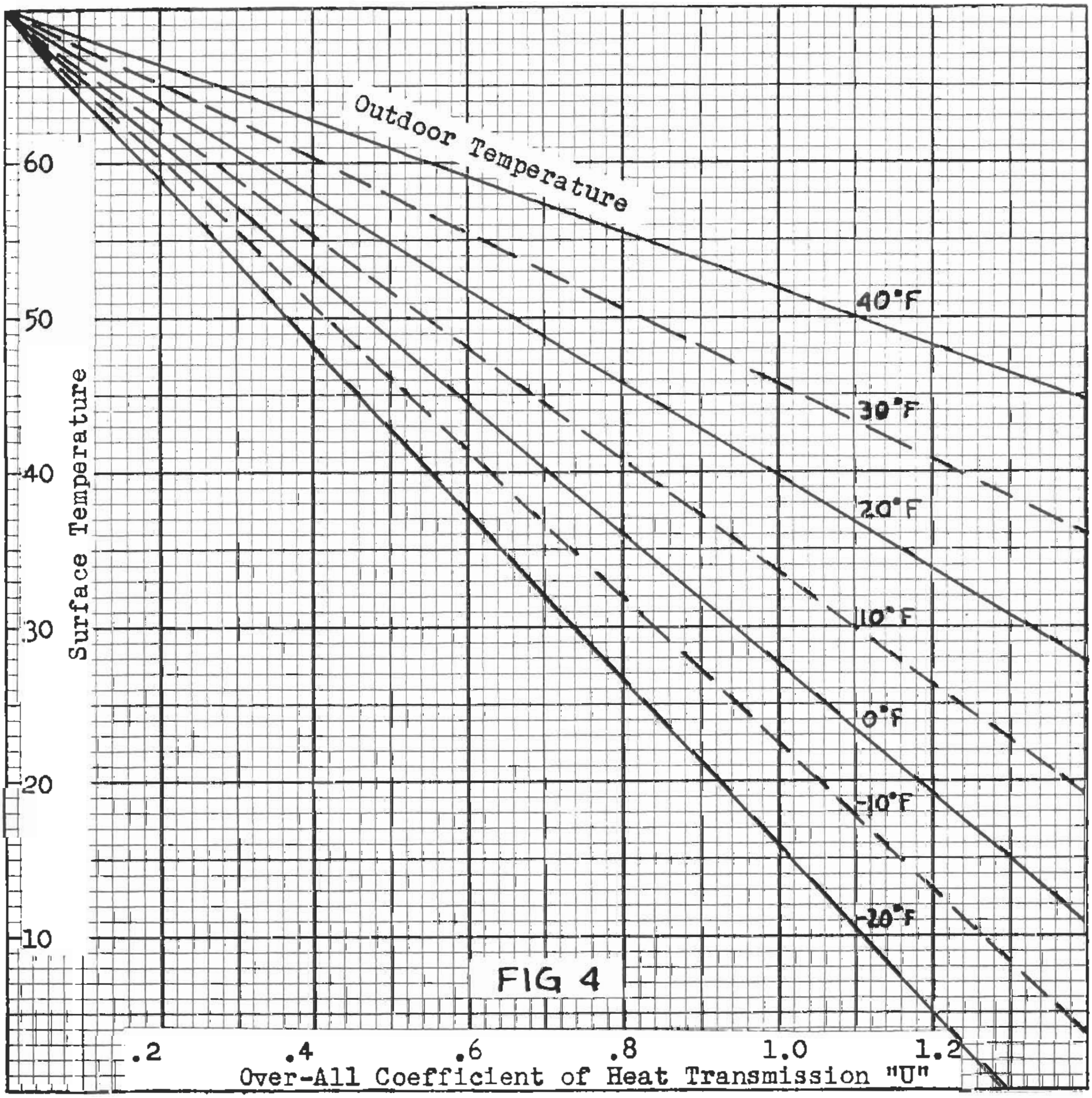


FIG 4

EXAMPLE

Figure 5 is a schematic sketch of a room to be heated by ceiling panel. You will note it is 24' x 25' and has an 8' ceiling. Two of the walls are interior walls and two of them exterior. The exterior walls have a total of 90 sq. ft. of glass. Summing up, the known data are these:

Panel location	Ceiling
Ceiling height	8 ft.
Outside design temperature	Minus 10°F
Inside air temperature . .	70°F
Air changes	1 per hour
Floor construction . . .	Concrete slab directly on the ground (no basement)
Glass	Single thickness
Outside walls	Frame with plaster, no insulation

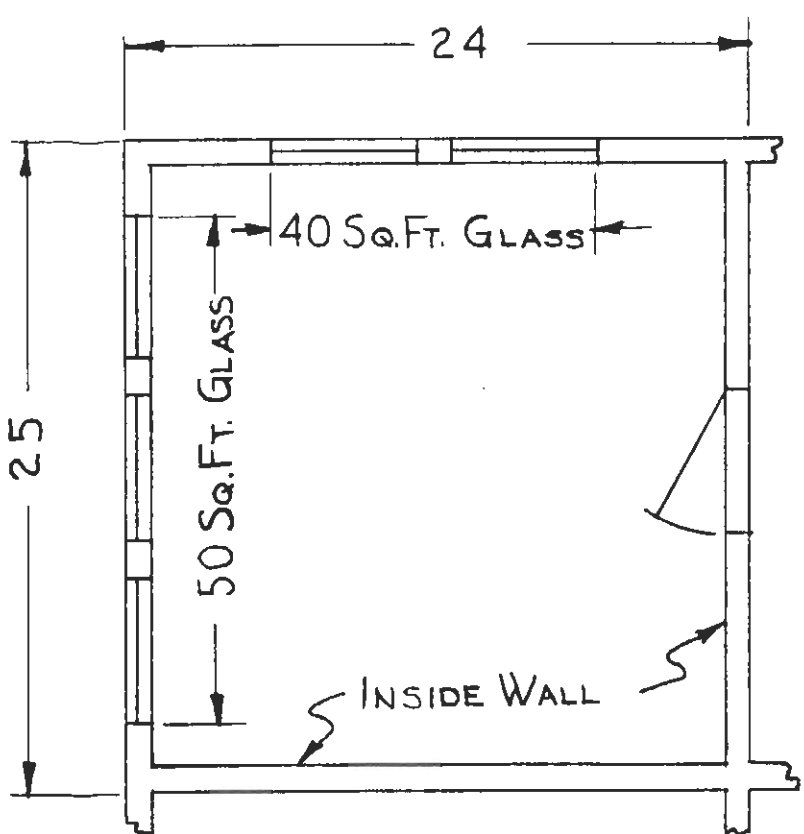


FIG 5

Heat loss coefficients of over-all heat transmission (U) are as follows:

Floor (U_f) 0.10

Glass (U_g) 1.13

Outside walls (U_w) 0.33

A wall with rather high heat loss was picked because it better illustrates our problem.

Heat Loss Calculations:

The heat loss is determined as follows:

Heat loss from floor	= 25 x 24 x 80 x 0.10	= 4800 Btu per hr
Heat loss from glass	= 90 x 80 x 1.13	= 8136 " " "
Heat loss from outside walls	= (49 x 8 - 90) x 80 x 0.33	= 7973 " " "
Heat loss from air changes	= 1 x 4800 x 0.075 x 0.241 x 80	= 6940 " " "
Total heat loss		27849 " " "

We shall take the entire ceiling area for the heating panel. The area of the ceiling panel is 600 sq. ft. and, therefore, output per sq. ft.

$$= \frac{27849}{600} = 46.4$$

Mean Wall Temperatures:

We must now turn to the chart in Figure 4. From this we can determine the inside temperatures of the walls, floor, and glass in our room. We will use only the line marked minus 10, because that is our outdoor design temperature. The following table gives the surface temperatures as read from the chart:

Floor:

U_f . . . . = 0.10

Therefore surface temperature = 65.0

Outside Wall:

U_w . . . . = 0.33

Therefore surface temperature = 54.0

Glass:

U_g . . . . = 1.13

Therefore surface temperature = 16.5

Inside Wall:

U_i . . . . = 0

Therefore surface temperature = 70.

In figuring the average surface temperature (MRT), we must know the area of the surface for each temperature. Various parts of our room have the following areas:

Outside wall area (less glass)	= 49 x 8 - 90	= 302 sq. ft.
Glass area		= 90 " "
Floor area	= 24 x 25	= 600 " "
Inside wall	=(24 + 25) x 8	= 392 " "

The average mean surface temperature (MRT) is found by multiplying the area of each surface by its temperature and dividing the sum of these products by the sum of the areas:

Outside walls	= 302 x 54.0	= 16308
Glass	= 90 x 16.5	= 1485
Floor	= 600 x 65.0	= 39000
Inside walls	= 392 x 70.0	= 27440
Total	1384(surface)	84233

Mean surface temperature (MRT) . . . $= \frac{84233}{1384}$

$= 60.8$ (say 61)

Consulting Figure 3, we find that a ceiling panel having an output of 46.4 Btu per sq. ft.,and operating in a room in which the average surface temperature of the unheated walls (MRT) is 61°F, must be run at a surface temperature of approximately 95°F. Consulting Chart 1 in Engineering News No. 2, we find it would take a ceiling panel of 100°F to give the same output, because in that case the MRT was taken at 68°F.

The only things that remain to be figured now are the coils and spacing for the panel. In Engineering News No. 2 on Page 3, I pointed out that part of the heat of the panel represents a loss to the other side, and I suggest that for our purpose we can assume an upstairs' ceiling as having a 20% loss. The 46.4 Btu per sq. ft. which we arrived at represents, of course, the useful output and therefore only 80%. A calculation shows that

$$\text{Total output of ceiling panel} = \frac{46.4}{80}$$

$$= 58.0 \text{ Btu per hour.}$$

Consulting chart 2, Engineering News No. 2, we find quite a variety of combinations of pipe sizes, spacing, and water temperatures which would give us that result. We do not want to pick too low a water temperature, as control then becomes difficult, and I would suggest that in this we figure on using a water temperature in the neighborhood of 130°F. We find that 3/4" pipe, spaced on 12" centers, would call for 130°F water and that should give us the desired results.

I hope the above information will be useful but I should like to leave this word of caution with you - don't increase the output of the panels beyond that shown on the charts, or the occupants will not be comfortable.

Ferdinand Jehle
Director of Engineering