HANDBOOK

SECOND EDITION

BELL & GOSSETT COMPANY

THE

HANDBOOK

SECOND EDITION

A complete manual of instruction covering the design and installation of modern forced hot water space heating systems and service water heating systems.

BELL & GOSSETT COMPANY
Morton Grove, Illinois

No. 99988

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PLEASE READ CAREFULLY!

A little preliminary study of the arrangement of this book will thereafter enable you to turn quickly to the information for which you are looking.

In compiling this Handbook, the Bell & Gossett Company has been guided by two objectives: First, to accumulate under one cover all practical design and installation data on space and service water heating systems. Second, to present this information in a manner easily understood and arranged for quick reference.

The B & G Handbook is divided into sections covering the various design procedures. Cross indexing of every subject (see Index in back of book) makes it easy to obtain the information sought.

SECTION I. **Principles of Indirect Water Heating** — This section includes descriptions and applications of various types of water heaters, complete with selection data and diagrams illustrating the best installation practices.

SECTION II. **Principles of Forced Hot Water Heating** — Consists of complete instructions for the proper designing and installation of Forced Hot Water Heating Systems, including Radiant Panel installations. Design procedure for baseboard systems is not included in this Handbook but will be issued in the very near future.

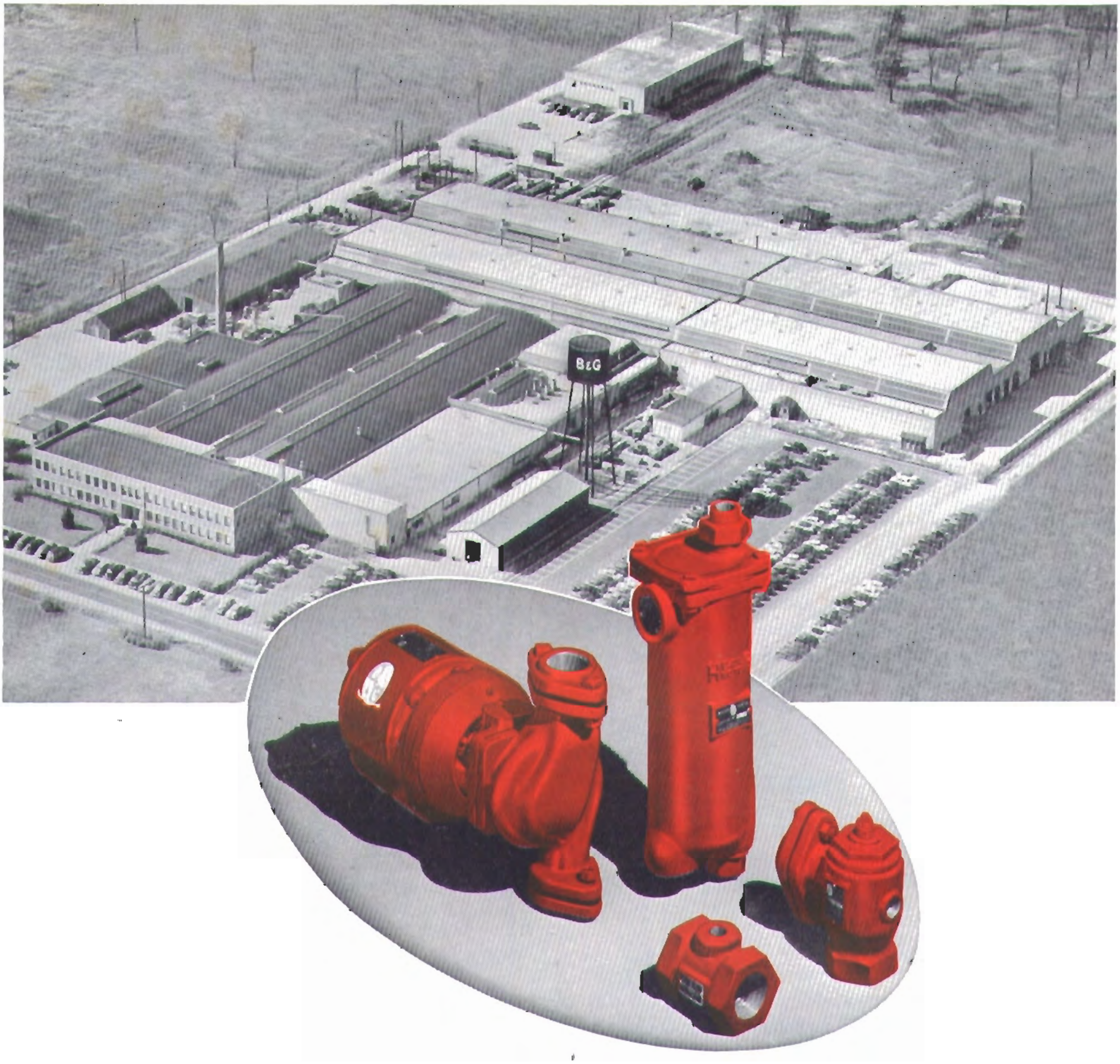
SECTION III. **Heat Loss Determination** — How to calculate building heat loss is covered in this section, together with a complete set of Heat Transmission Tables.

SECTION IV. **Electrical Controls** — This section presents a simplified outline of Electrical Control methods. Numerous wiring diagrams cover the problems of control usually encountered.

SECTION V. **B & G *Hydro-Flo* Products** — The B & G equipment required for Forced Hot Water Heating Systems and Service Water Heating is described here, with recommendation as to use. Includes many typical installation diagrams.

Capacity and dimensional data is not given, as it should be recognized that continual effort to improve product causes changes in product characteristics. Therefore, complete current information on B & G *Hydro-Flo* Products is provided in catalogs available upon request. Be sure you have a complete file.

SECTION VI. **Supplementary Data** — Includes tables of various kinds of information frequently required and sometimes hard to find elsewhere.



INTRODUCTION

The need for a single authoritative source of information on the design and installation of Forced Hot Water Systems for space heating and Service Water Heating Systems is the reason for this Handbook. It is dedicated to the Boiler, Radiator and Automatic Control industries, and to our many friends in the heating and building industries.

This Handbook presents a simplified outline of instruction, easy to understand and based on accepted and proved engineering practices.

All specialties required for the systems described herein are provided by the B & G line of *Hydro-Flo* Hot Water Heating Equipment. Full product information is given in various B & G Catalogs which will be sent to you upon request.

BELL & GOSSETT
COMPANY
Morton Grove, Illinois

SECTION I

PRINCIPLES OF INDIRECT DOMESTIC WATER HEATING

Domestic water heaters are divided into two classes:

(1) Those which heat the water by direct application of heat, such as gas water heaters and small boilers.

(2) Those which transfer heat from water or steam in the heating boiler to the domestic water.

This latter type is known either as an Indirect Heater or a Submerged Heater.

The indirect method of heating water has many advantages, particularly with automatically fired systems. It permits furnishing year around hot water in ample quantities at low cost, since it eliminates the extra firing of a separate water heater. Besides, heating boilers almost always have a higher efficiency rating, so that the same amount of fuel burned in the heating boiler produces service hot water for less. Indirect Heaters are adaptable to either steam, vapor or hot water heating boilers of any size or type.

OPERATION OF THE INDIRECT HEATER

Indirect Heaters consist of an arrangement of coiled or straight copper tubes for transferring heat from boiler water or steam to the domestic water. There are two types of Indirect Heaters—internal submerged and external submerged. The internal type is screwed into or bolted on to the boiler; the external type is self-contained- that is, the copper tubes are encased in a steel or cast iron jacket.

When external type heaters are connected with suitable piping to the boiler, hot water circulates through the heater casing, transferring its heat to the domestic water flowing through the copper tubing. Boiler water and domestic water are thus in separate circuits and never mix.

Where a constant steam pressure is maintained, as in a factory for processing work or in a hospital for sterilizing, the Heater can be installed externally above the water line and steam used as the heating medium. For steam pressures above 15 lbs., use special steam regulating valves as illustrated on page 17.

On a low pressure steam boiler, domestic water can be heated more economically with the heater connected below the water line.

HOW YEAR AROUND HOT WATER IS OBTAINED

Indirect Water Heaters will supply hot water in summer as well as winter, from either steam or hot water boilers fired with any fuel.

On automatically fired steam or vapor heating boilers it is necessary to install a suitable electrical Hot Water Control below the water line to avoid getting boiler temperatures above the steaming point during times when heat is not required in the radiators. This control, when set to maintain boiler water below the steaming point, and when a properly sized heater is installed, will deliver abundant hot water at all times.

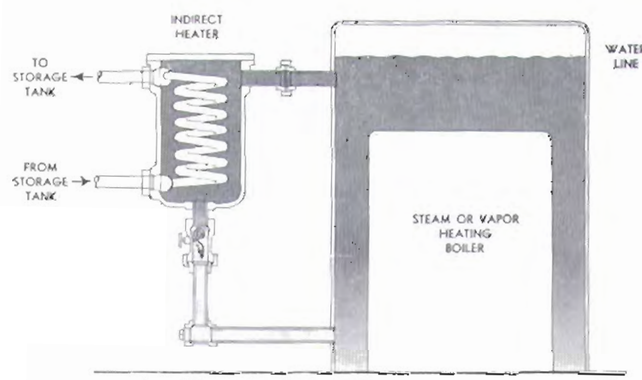


Fig. 1. This illustrates the principle of the Indirect Water Heater. Hot water from the boiler circulates through the Heater jacket, transferring heat to the Domestic Water flowing thru the copper tubes.

For hand-fired coal burning steam or vapor boilers, during summer operation, only a small fire is required along one side of the boiler. Pack the rest of the grate a few inches deep with ashes. Experiment with the size of fire required to maintain the boiler water temperature between 180° and 200°. Once a day break up the red hot coals and push them over to the side of the boiler. For most economical operation never allow the fire to get into the center of the boiler. When adding fresh coal, do not completely cover the red coals but leave some exposed to burn the coal gases.

Garbage can be burned by drying it first on that part of the grate packed with ashes, then pulling it over on the fire.

On a forced circulation hot water boiler, the temperature of the boiler water is similarly kept within certain limits. Circulation to the radiators is prevented by a B & G Flo-Control Valve, installed in the supply main, which remains closed, except when the room thermostat calls for heat and the Booster Pump is running.

Even gravity hot water systems can have the benefits

OPERATION OF THE INDIRECT HEATER (continued)

of indirect water heating. In this system, a Motorized Valve is installed in the supply main to prevent circulation to radiators in summer. The Valve is electrically controlled to open only when the room thermostat calls for heat, thus permitting the use of an indirect heater to furnish a year around supply of hot water. Or, a gravity system can be brought completely up-to-date from both a comfort and economy standpoint by installing a B & G Indirect Heater, B & G Booster and B & G Flo-Control Valve. This equipment converts it into a forced circulation system and is usually the preferred method.

Wiring diagrams for all types of domestic water heating systems are explained in detail in Electrical Control Section.

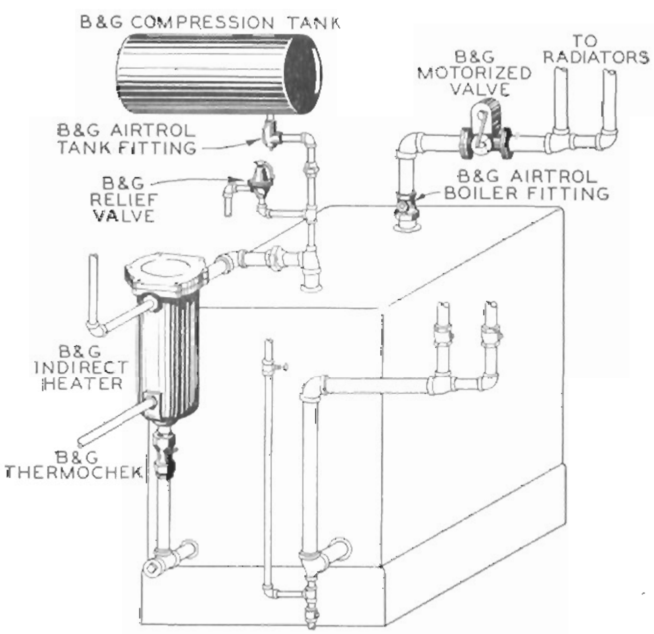


Fig. 2. Gravity hot water system with Motorized Valve to permit summer operation of Indirect Heater (Patent No. 1,533,630).

ECONOMY OF OPERATION

During the winter, the heating boiler is in constant use. Only a small fraction of the heat generated is used in heating the domestic water. When a storage tank is used, on coal-fired boilers, hot water is accumulated during banked firing period at night and during the day when steam pressure in the boiler is down.

In summer a similar economy is achieved. Remember that a large boiler is usually much more efficient than a small one. Once brought up to the proper temperature for domestic water heating, it can be maintained at that degree on very little fuel. A few operations daily of the automatic firing device are sufficient; or if the boiler is hand fired, rubbish and garbage, plus a little fuel will keep plenty of hot water on hand.

Continuous use of the heating boiler is like regular exercise to an athlete—it prevents costly deterioration which occurs when the boiler is idle for long periods. Internal circulation of the boiler is also improved by the use of an Indirect Heater, increasing efficiency and reducing fuel cost.

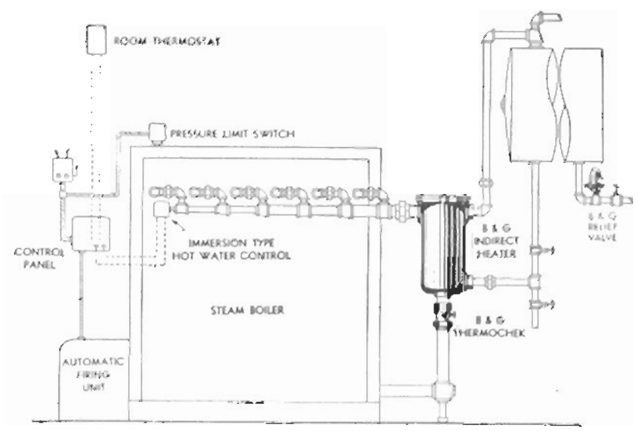


Fig. 3. Indirect Heater on steam boiler, showing electrical control system for automatic firing.

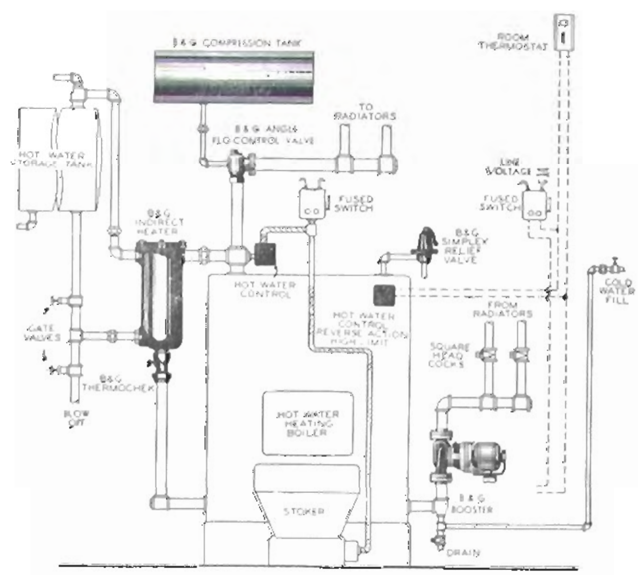


Fig. 4. Indirect Heater on a forced circulation, automatically fired hot water heating system with necessary electrical controls.

TANK AND TANKLESS HEATERS

Indirect Water Heaters are available for use with or without storage tanks.

Storage tank types require fewer square feet of copper heating surface to accomplish any given water heating job, because hot water is stored in the tank against periods of peak demand. They are made in submerged, built-in and external models.

The Tankless Heater, on the other hand, must have a large heating surface area, so that it can provide hot

OPERATION OF THE INDIRECT HEATER (continued)

water instantly and in sufficient volume to handle peak load demands. There are several factors which must be taken into consideration when selecting a Tankless Heater, such as Pressure Drop, Volume of Water and Boiler Load. These factors are discussed hereafter.

Heaters of this type are generally used in installations where the "draw" of water is heavy or constant, as in apartments, restaurants, garages, hotels, etc. They are also employed where limited boiler room space prohibits the installation of a storage tank or where it would be necessary to use expensive non-ferrous tanks. Tankless Heaters are not recommended for territories with extremely hard water.

Tankless Heaters can be supplied for installation within the boiler itself or for external application.

ADDITIONAL BOILER LOAD

Obviously, in heating domestic water, some tax is placed on the capacity of the boiler.

In territories with a design temperature of 0° or colder and where the building is used exclusively for living purposes, if the boiler is sized in accordance with the recommendation of the Heating, Piping and Air Conditioning Contractors Association, the allowance made for pick-up load will take care of whatever tax the heater places on the boiler. Where a boiler is maintained at the constant temperature required for indirect water heating the pick-up load is reduced sufficiently to take care of the domestic water heating.

In territories with design temperature above 0° or where large volumes of hot water are to be used, it may be desirable to allow for water heater tax as follows:

(1) Installations using a hot water storage tank:

½ sq. ft. of 240 BTU radiation for each HOURLY gallon of heater capacity when raising water from 40 to 140 degrees.

(2) Tankless Heater installations:

For buildings where domestic water demand is intermittent, 1½ sq. ft. of 240 BTU radiation for each gallon per hour rating of the heater, raising water from 40° to 140°, is sufficient.

For installations designed to provide a constant supply of hot water (as for restaurants, wash racks and industrials) it is good practice to calculate the BTU requirements for heating the building, then add 3⅓ sq. ft. of 240 BTU radiation for each gallon of water to be heated per hour from 40° to 140°.

(3) When boiler is used only for heating domestic water with an indirect heater, figure 3⅓ sq. ft. of 240 BTU radiation capacity for each HOURLY gallon of Heater capacity for raising water from 40 to 140 degrees.

PRESSURE DROP
and its effect on heater capacities

Whenever work of any kind is done, resistance is encountered and power consumed. Moving any material through ducts or channels creates friction which resists the movement of the material. In moving water through pipes, there must be a difference in pressure between inlet and outlet, or there will be no flow. Thus the pressure of water at the outlet must be lower than the pressure at the inlet. This difference is known as the Pressure Drop of the system.

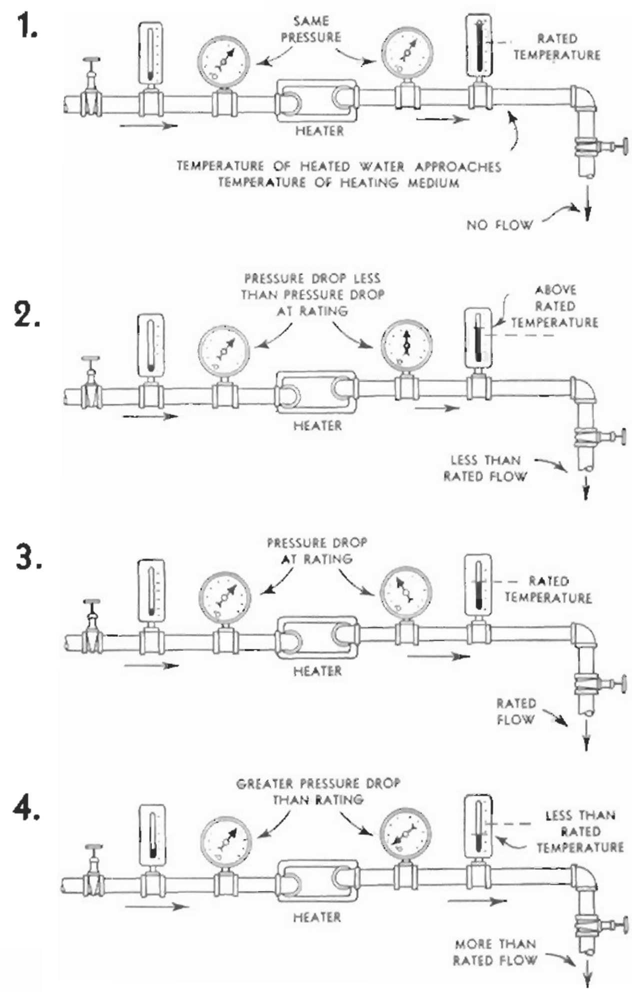


Fig. 5. These diagrams illustrate the effect on water flow produced under various conditions of pressure drop.

Water flowing under pressure moves more easily through large piping than through small. The smaller the pipe, the greater the friction and lesser amount of water at the outlet. All water heating installations must take into consideration this resistance—especially in using Tankless Heaters.

OPERATION OF THE INDIRECT HEATER (continued)

If the pressure drop through the heater is low in comparison with the available city pressure, water will flow through the heater faster than it should. The rate of heat transfer will increase but not fast enough to heat the larger volume of water to the required temperature. Hence, the final temperature of the water will be lower than the heater rating.

Conversely, if the pressure drop of the heater is high compared to the available city pressure, the flow through the heater will be slower and the final temperature higher than rating, because there is less water to heat.

Where large volumes of water are required, the cross-sectional tubing area through the tankless heater must be large enough so that available pressure will be sufficient to carry water to the highest fixtures. Consequently, in territories where water pressures are low, heaters must be larger in area than where high water pressures are available.

HOW TO SELECT AN INDIRECT WATER HEATER AND STORAGE TANK

WATER DEMAND CALCULATIONS

The quantity of hot water required for a building is a variable quantity depending on the type of structure—industrial, institutional or dwelling unit—number of people occupying the building—type or class of people and living habits peculiar to the territory, time of day, season of the year. Further, the quantity of water required varies depending on whether the cost of supplying hot water is assumed by the occupant or is provided on a no-charge basis by the building.

Estimates of the hot water demand for a building are based on the number of *water demand units*, i.e. number and kinds of fixtures, number and kinds of labor saving devices such as automatic dish washers and clothes washers. A second and important consideration is the probable simultaneous use of these water facilities.

In any consideration, however, the domestic water supply system, including piping, water heaters and storage tanks must be of ample capacity to meet the peak demand for hot water.

The Domestic Hot Water Demand Chart (on page 5) is an aid in determining the domestic water requirements for a given number of *Water Demand Units* for either a storage or tankless type system in residential, commercial and industrial installations.

TABLE E

A *Water Demand Unit* is defined as a dwelling unit having two bedrooms, a single bath with either shower or tub fixture, lavatory, standard kitchen sink and laundry tubs in the basement.

DWELLING UNITS

For each additional bedroom add ½ *Water Demand Unit*. If the additional bedroom has a separate bath, add one unit.

For Automatic Type Clothes Washers, add one *Water Demand Unit*. For automatic type dish washers, add one *Water Demand Unit*.

INDUSTRIAL & COMMERCIAL BUILDINGS

Restaurant—

For each two hundred (200) people fed during peak meal, capacity required equals fifteen (15) *Water Demand Units*.

Drug Store—

For 20 feet of soda fountain, capacity required equals twelve (12) *Water Demand Units*.

Barber Shop—

For each chair, capacity required equals three (3) *Water Demand Units*.

Beauty Shop—

For each operator, capacity required equals four (4) *Water Demand Units*.

Country Club—

For each shower, capacity required equals five (5) *Water Demand Units*. Figure restaurant and living quarters as noted above.

Office Building—

For each doctor, dentist, or other single office, capacity equals one (1) *Water Demand Unit*.

Factory Building—

For each shower, required capacity equals five (5) *Water Demand Units*. Each two (2) hot water fixtures should be figured as one (1) *Water Demand Unit*. For each multiple-fixture lavatory add one *Water Demand Unit*.

Hospitals, laundries, and other similar institutions are special engineering applications. It is recommended that a Bell & Gossett Co. representative be consulted in preparing hot water demand estimates for these types of installations.

HOW TO SELECT AN INDIRECT WATER HEATER (continued)

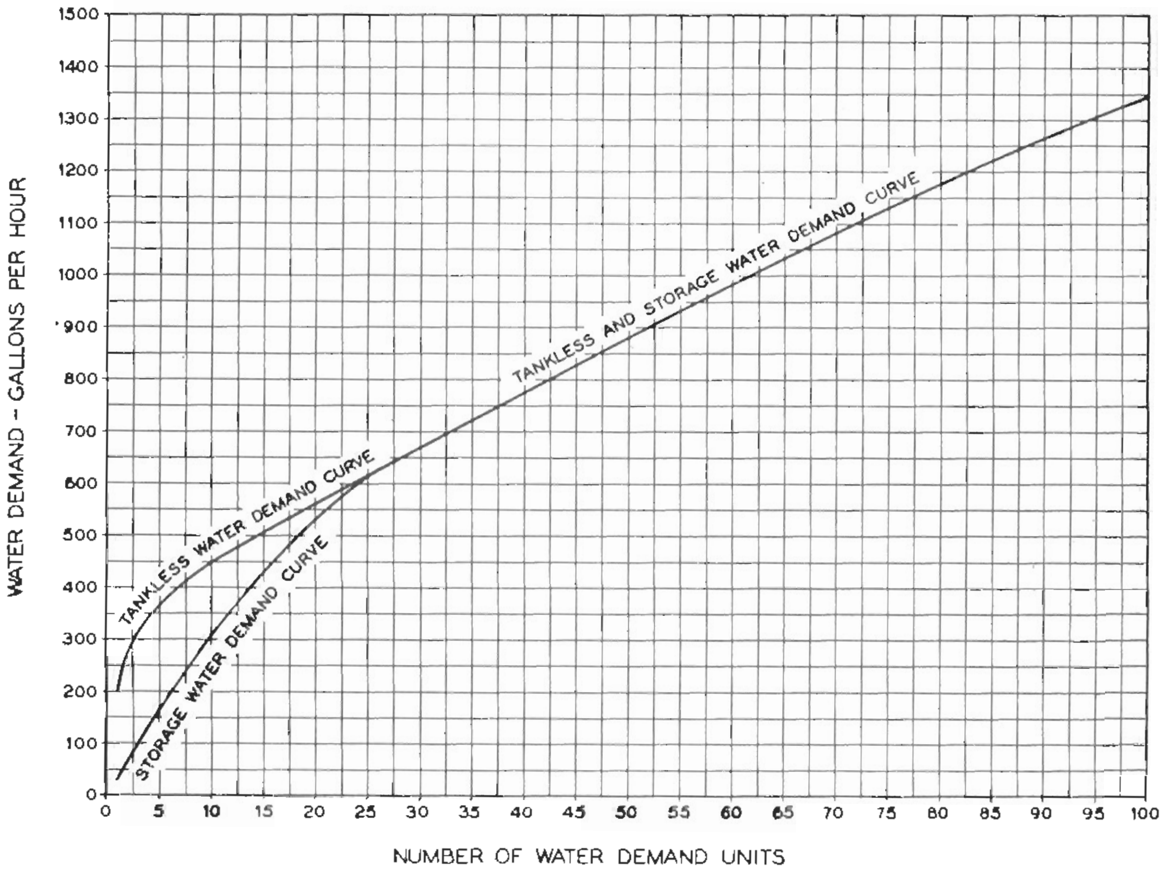
WATER DEMAND CHART

The hot water requirement for a given number of *Water Demand Units* is identical whether it be provided by a storage or instantaneous type hot water supply system.

heater recovery capacities for storage type installations in small residences and small apartment buildings totaling 25 *Water Demand Units or less.* In storage tank systems it is possible to draw water at rates identical to those of instantaneous systems until the capacity of the

CHART 11

DOMESTIC HOT WATER DEMAND CHART



The curves plotted on the Hot Water Demand Chart (above) indicate the estimated water demand rate in gallons per hour required for any specific number of *Water Demand Units.*

Further, this water demand rate in gallons per hour is also the required heat exchanger *recovery capacity* in gallons per hour.

The upper curve labeled "Tankless Water Heater Demand Curve" is to be used in estimating water heater recovery capacities for instantaneous or tankless type systems.

In constructing this curve, the minimum tankless water heater recovery capacity considered adequate for an ordinary single dwelling or one *Water Demand Unit,* is 3 GPM or 180 GPH.

The lower curve of Chart 11, labeled "Storage Water Heater Demand Curve" is to be used in estimating water

tank is exhausted or at smaller water flow rates over a much longer period of time.

WATER STORAGE TANK REQUIREMENTS

Adequate water supply for a single *Water Demand Unit* usually can be accomplished by a tank with a minimum storage of 30 gallons.

In buildings where the water demand is fairly uniform, smaller storage tank capacities are required than for office and industrial buildings where the demand is uniform but over a much shorter period of time.

The minimum recommended water storage for small dwelling units, office buildings and industrial plants where the water demand occurs over a short period is 30 gallons per *Water Demand Unit.* Larger dwelling units can consider storage tanks sized on the basis of less than 30 gallons per dwelling unit, however, in any

HOW TO SELECT AN INDIRECT WATER HEATER (continued)

specific calculation, nothing less than 15 gallons per dwelling unit is considered advisable.

Usually it is desirable to consider a large storage tank capacity in order that both the water heater and the load on the boiler be as small as possible.

A good rule when estimating storage tank capacities is that only 75% is actually available, for when the tank is drawn down to this point, the remaining volume has been cooled by the incoming cold water and cannot be considered as available hot water.

STORAGE TANK SELECTIONS

The following table shows minimum recommended storage tank capacities for a specific number of *Water Demand Units:*

TABLE F

Number of Water Demand Units	Storage Capacity
0 — 10	30 gals. for each water demand unit
11 — 25	25 " " " " " "
26 — 50	20 " " " " " "
over 50	15 " " " " " "

DURATION OF PEAK DRAW PERIODS

The *Peak Draw Period* need not be considered when calculating Water Heater sizes for an instantaneous system, as the unit is selected to meet the required recovery capacity whenever it may occur.

For a storage type system, however, a much smaller Water Heater can be selected if the tank recovery calculations take into consideration the duration of the peak draw period.

For small dwelling units and apartment buildings, the water demand rates are usually considered fairly uniform over a two to three hour period. Generally, the maximum demand for water occurs during the morning from 6:00 a.m. to 9:00 a.m. and again in the evening from 5:00 p.m. to 8:00 p.m. On this basis the Water Heater can be sized to provide for tank recovery over a 3-hour period.

In industrial plants and similar institutions where the maximum demand occurs over a short period of time, say at lunch time, for a period of fifteen minutes, and in the evening at quitting time for a period of fifteen to twenty minutes, the demand rate and the hourly recovery capacity of the Water Heater must be carefully calculated.

In the case of a storage type installation, this is no particular problem, for even though the water demand lasts from fifteen to twenty minutes, a suitably sized storage tank will provide the necessary water volume and the Water Heater can, during the period between draws, again bring the tank up to temperature. However, in the case of tankless operation, care must be used in estimating the hourly draw, for the hourly draw is the figure used in estimating the Heater recovery capacity.

If, in an industrial plant an estimated 300 gallons is required for a fifteen minute period, the tankless Water Heater must be sized on an hourly rating of *1200 GPH.*

EXAMPLES

A few examples of water demand estimates and Water Heater recovery are outlined in the following specific problems, using the general equations below:

STORAGE SYSTEM—FOR A 3 HOUR PEAK DRAW PERIOD

$$\text{Water Demand in gals/hr.} - \left(\frac{\text{Tank Capacity} \times .75}{3}\right) = \text{Heater Hourly Recovery Capacity}$$

TANKLESS SYSTEM

Water Demand in gals/hr. = **Heater Hourly Recovery Capacity**

Example #1

Problem—10 Dwelling Unit Apartment

Each apartment having one bedroom, single bath with ordinary kitchen and laundry facilities.

Storage tank capacity 30 gallons per dwelling unit.

Three-hour peak draw period.

Permissible Tank Recovery Period 3 hours.

Estimate the heater recovery capacity required for either a tankless or storage type system.

Water Heater Recovery Capacity Required—Storage System

In Chart 11 the estimated hourly draw is shown to be 300 gallons per hour.

Storage Tank Capacity 30 × 10 Dwelling Units = 300 gallons

Required Water Heater hourly recovery in gallons per hour is therefore:

$$\text{300 gals. (Water Demand Rate)} - \left(\frac{\text{300 (Tank Capacity)} \times .75}{3}\right)$$

= 225 GPH (Heater Hourly Recovery Capacity)

Since B & G Heaters are rated on a 3 hour basis select a unit, therefore, that will deliver a rating of:

225 × 3 = 675 gallons/3 hrs.

HOW TO SELECT AN INDIRECT WATER HEATER (continued)

Now if 15 gallons storage per dwelling unit was considered as adequate storage for the above example, the required Heater Recovery Capacity would be as shown by the following calculation:

Storage Tank Capacity 15 × 10 150 gallons

Required water heater hourly recovery in gallons is—

$$300 - \left(\frac{150 \times .75}{3}\right) = 263 \text{ GPH (Heater Hourly Recovery Capacity)}$$

263 × 3 = 789 gallons/3 hrs. (required Heater Rating)

TANKLESS SYSTEM

Water Demand Rate/hr. = Heater Hourly Recovery Capacity

450 gal./hr. (from "Tankless Water Heater Demand" curve in Chart 11) = Heater Hourly Recovery Capacity

Example #2

Problem—Industrial Building

Hot water facilities include the following fixtures:

12 shower fixtures — 6 washing fixtures

Thirty gallon storage per *Water Demand Unit*

Peak water draw period; twenty minutes

Three hour tank recovery period permissible in case of the storage system.

Estimate the heater recovery capacity for either a tankless or storage type system.

STORAGE SYSTEM

12 shower fixtures = 12 × 5 = 60 Water Demand Units

6 hot water fixtures = 3 × 1 = 3 Water Demand Units

Total = 63 Water Demand Units

Water Storage required 63 × 30 = 1890 gallons

In Chart 11 the water demand is shown to be 1000 gallons/hr. However, conditions of the problem state we will draw 1000 gallons in twenty minutes. By providing a storage tank of sufficient size, in this case 1890 gallons, we can draw 1000 gallons in twenty minutes and meet the demand conditions.

Required Water Heater Recovery Capacity is:

$$1000 - \left(\frac{1890 \times .75}{3}\right) = 528 \text{ GPH (Heater Hourly Recovery Capacity)}$$

528 × 3 = 1584 gallons/3 hr. (Required Heater Rating)

TANKLESS SYSTEM

1000 gallons required in twenty minutes (1/3 of an hour)

or

Required Heater Recovery Capacity = 1000 × 3 = 3000 gallons/hr. (Required Heater Rating)

Table G below may be used as a quick method of determining the size of water heater required from the number of *Water Demand Units.*

TABLE G

Required Water Heater Capacities in gallons per hour—100° Rise with Boiler Water at 180° F. for Tankless and Storage Type Water Heaters. In the case of storage type Heaters, multiply the capacities by 3 to arrive at the 3 hour rating on which Water Heater Capacities are based.

No. of Water Demand Units	Tankless Heater	Storage Type Heater			
	Storage in gallons Per Water Demand Unit				
	0	15	20	25	30
1	180	26.3	25	23.7	22.5
2	290	52.5	50	47.5	45
3	320	78.8	75	71.3	67.5
4	350	112.5	105	97.5	90
5	370	131.3	125	118.8	112.5
6	390	157.5	150	142.5	135
7	410	183.8	175	166.3	157.5
8	425	210	200	190	180
9	440	236.3	225	213.8	202.5
10	450	262.5	250	237.5	225
15	510	363.8	345	325.8	307.5
20	565	455	430	405	380
25	620	516.3	485	453.8	422.5
30	670	557.5	520	482.5	445
40	770	620	570	420	470
50	870	688	625	563	500
60	975	750	675	600	525
70	1075	817.8	730	642.8	555
80	1180	880	780	680	580
90	1280	942.5	830	717.5	605
100	1380	1005	880	755	630

HOW TO INSTALL INDIRECT WATER HEATERS

Detailed diagrams for the installing of B & G Indirect Heaters are shown on following pages. While only one type of B & G Indirect Heater is indicated in the diagrams, any of the many B & G Heaters should be connected in a similar manner. Read the following instructions carefully—they are most important to the successful operation of a domestic water heating system.

POSITION OF HEATER

On steam boilers, install the heater as close to the waterline as possible. Every inch below this point loses several degrees in temperature. High position of the heater is most important in producing summer hot water at lowest cost.

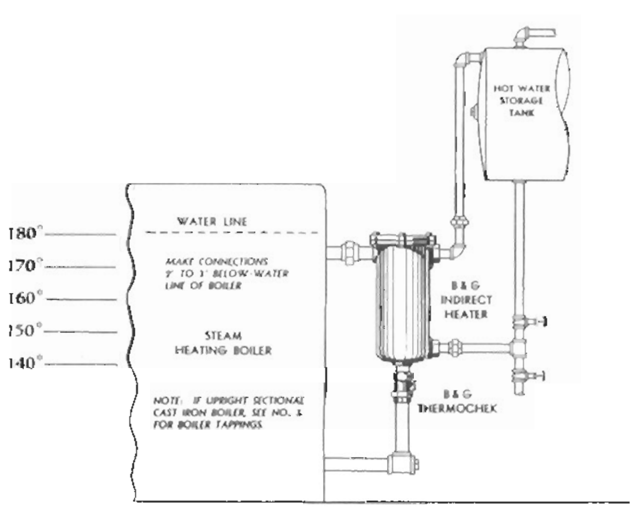


Fig. 6. Illustration shows correct position of external type Indirect Heater connected to a steam boiler.

Hot water boilers, likewise, should have the heater installed at the top of the boiler so as to induce active circulation of boiler water. Either a B & G Motorized Valve or a B & G Booster Pump with a B & G Flo-Control Valve must be installed to prevent circulation of boiler water to radiators when heat is not required.

If height of boiler and basement ceiling make it impossible to locate heater and tank as outlined, the boiler water can be circulated with a B & G Booster Pump, and the heater lowered to give the tank the necessary height as previously described.

PUMPING BOILER WATER THROUGH HEATER

When selecting a B & G Booster Pump for circulating the boiler water, its capacity should equal 4 gallons of boiler water per minute for every gallon per minute being heated by the water heater. A pump also permits reducing the size of the piping connections between the boiler and heater. Usually connections the same size as those of the pump will be found sufficient. The pump can be automatically operated with an electrical Hot Water Control in center of hot water tank.

POSITION OF TANK

Install tanks as high as the basement ceiling will permit. The greater the height above the heater, the faster the circulation and the recovery of tank temperature.

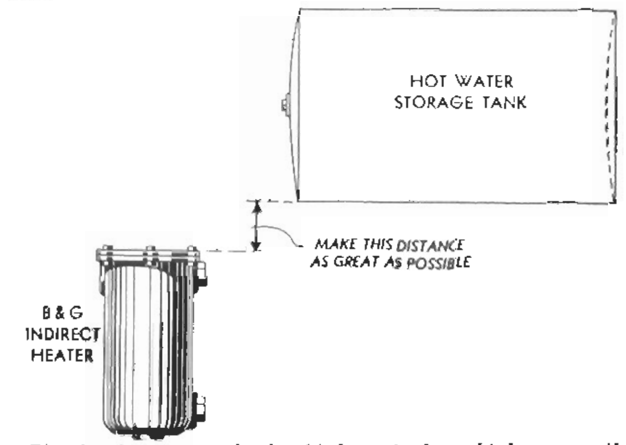


Fig. 7. Storage tank should be raised as high as possible above the Heater. This assures maximum gravity circulation between Heater and tank.

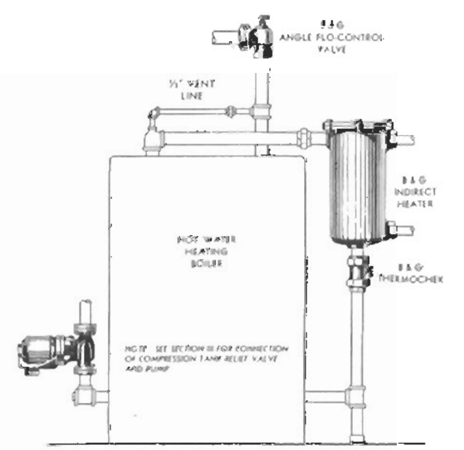


Fig. 8. On forced hot water heating systems, install the Heater above the boiler as indicated.

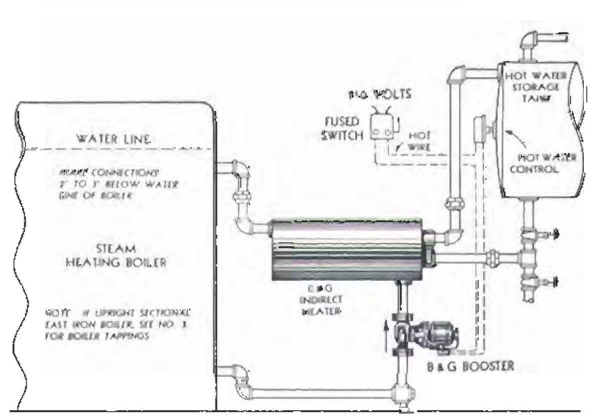


Fig. 9. Where Heater and tank must be kept low, install a B & G Booster as indicated.

HOW TO INSTALL INDIRECT WATER HEATERS (continued)

BOILER TAPPINGS

All sections of an upright cast iron sectional steam boiler should be tapped if summer hot water is desired. This obviously does not apply to steel boilers or to round boilers and square sectional boilers with large top nipple port which permit free circulation from section to section and require only a single connection below the water line.

Where a large single connection is required and the boiler must be tapped for it, it may be found easier and better to make two or more tappings on the same level and connect into a header. The total cross sectional area of the tappings should equal the cross sectional area of the opening in the heater.

Boilers with split sections must be tapped at each section on both sides, with connections brought to a header.

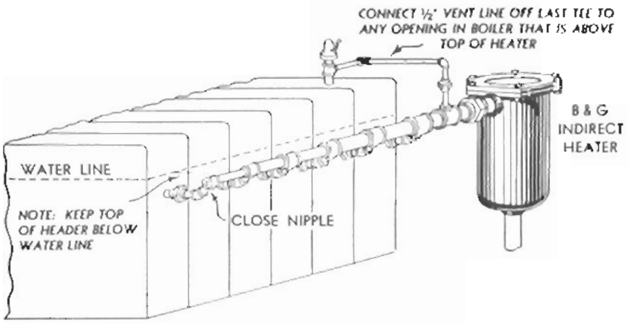


Fig. 10. This is the ideal header connection to the boiler as it assures hottest possible water to the heater.

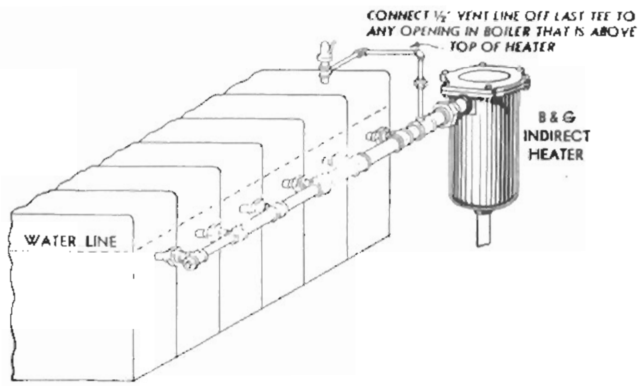


Fig. 11. A second choice of header connections to the boiler.

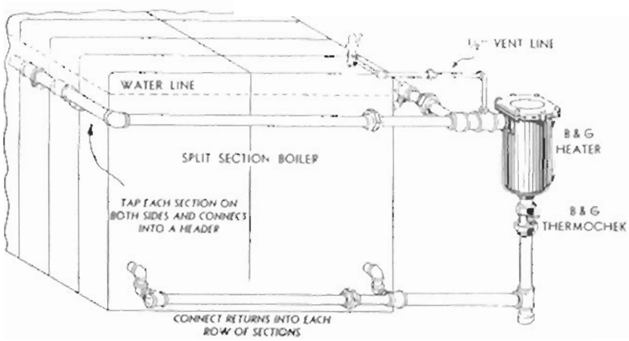


Fig. 12. Boilers with split sections must be tapped at each section on both sides.

TABLE H — SHOWING SIZE OF TAPPINGS IN EACH SECTION OF CAST IRON BOILER

Header Size	Number of Sections in Boiler																
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1" Header	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"
1¼" Header	¾"	¾"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"
1½" Header	1"	¾"	¾"	¾"	¾"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"	½"
2" Header	1"	1"	1"	1"	¾"	¾"	¾"	¾"	¾"	½"	½"	½"	½"	½"	½"	½"	½"
2½" Header	1¼"	1¼"	1¼"	1"	1"	1"	1"	1"	¾"	¾"	¾"	¾"	¾"	¾"	¾"	¾"	½"
3" Header	*	*	*	1¼"	1¼"	1¼"	1¼"	1"	1"	1"	1"	1"	1"	1"	¾"	¾"	¾"
4" Header	*	*	*	*	1½"	1½"	1½"	1¼"	1¼"	1¼"	1¼"	1¼"	1¼"	1¼"	1¼"	1"	1"

HOW TO INSTALL INDIRECT WATER HEATERS (continued)

BOILER CONNECTIONS

Boiler connections to the Heater, where a single boiler tapping is used, should be the same size as the Heater tappings. Where all sections are tapped and a header employed, follow the pipe and tapping sizes indicated in Table H on page 9.

All piping between heater, boiler and storage tank should be as short as possible, with a minimum of elbows.

Use valves and plugged tees at all points in piping where sediment is apt to collect. Gate valves should be placed in vertical pipe lines wherever possible. In hard water territories, tees with brass plugs instead of elbows should be installed, so that piping can be easily cleaned.

No job is correctly installed unless provision is made to drain all piping, as a safeguard against freezing during time building is unoccupied.

Air pockets are deadly enemies of a good water heating installation. Pitch boiler connections so that high point vents into boiler. Domestic water connections between heater and tank should pitch up to storage tank or to hot water fixture outlet connection which will draw any air accumulation along with fixture water.

TANK CONNECTIONS

As explained previously the storage tank should be located entirely above the top of the water heater which usually means that it must be installed horizontally. If the tank is located on the floor above the heater, a vertical tank will give excellent results and can be connected as illustrated in Figure 15.

HOT WATER CONNECTIONS

With a vertical tank on the same floor as the water heater, much of the tank will be below the top of the heater which results in sluggish circulation through the lower part of the tank and reduces the output of the heater. Some small residences have used vertical tanks quite successfully, due to their limited demand for hot water. These same jobs, however, when installed where a family uses a normal amount of hot water, are found to lack capacity. Therefore, we suggest a high horizontal tank unless located as shown in Figure 16 or unless a Booster pump is used for circulating the tank water.

A vertical range boiler tank is usually without sufficient openings to connect it in the regular manner if installed horizontally. By using bent copper tubes soldered or brazed into nipples it can be connected as illustrated in Figure 20.

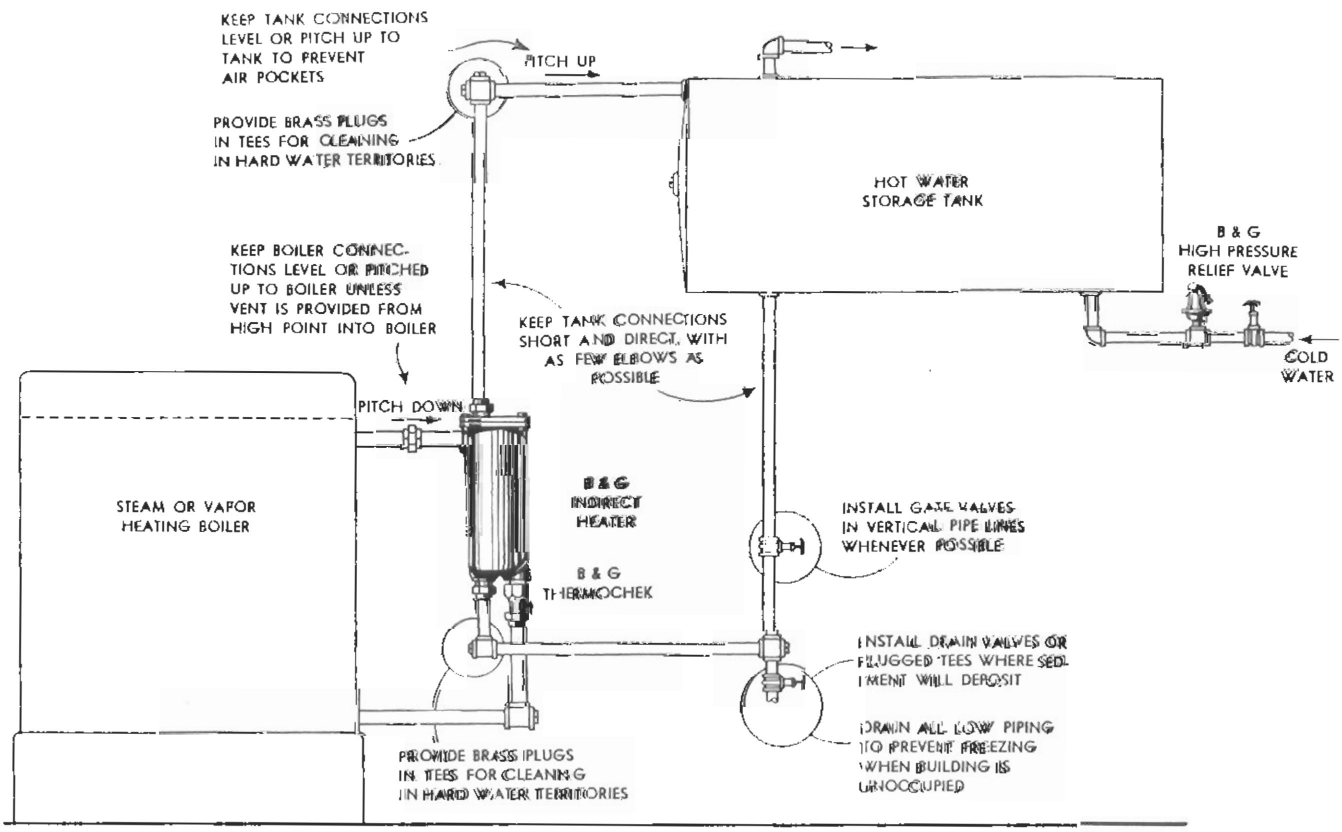


Fig. 14. Illustration shows an installation properly equipped with valves, plugged tees and crosses, etc., and with pipes pitching in the right direction.

HOW TO INSTALL INDIRECT WATER HEATERS (continued)

In piping a horizontal tank, it is good practice to connect the cold water supply line at one end of the tank and make all the other hot water connections, including those to the heater, at the other end of the tank. This eliminates the possibility of the cold water short circuiting through to the hot water line.

In Figures 16 to 19 are illustrated connections commonly used for heater connections to storage tank. Note that each is marked as to preference.

In Figure 16, the first choice, the hot water connection from heater to tank is located near the top of the tank and is recommended especially on installations where the hot water demand is great. This opening, being separated from the hot water connection to the fixtures, eliminates the mixing of any cooler water from the heater with that drawn to the fixtures.

Fig. 17, second choice, uses a tee on top of the tank for both the heater and hot water connections. It is recommended that the opening into the tank be equal to the total cross sectional area of the other two lines connecting into the tee. This will lessen the possibility of pulling water through the coil of the heater during the peak water demand.

If the space above the tank is limited, the connection can be made as illustrated in Figure 18. For this connection be sure to use an eccentric coupling as illustrated to remove all air from heater line.

Fig. 19, third choice, is a center tank opening which can be used but is not as efficient as the 1st and 2nd choice unless a bent tube the full size of heater opening is used inside the tank, extending to within 1" of the top.

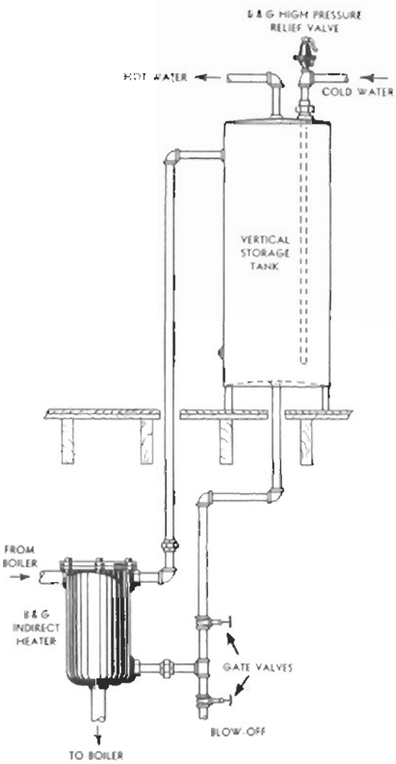


Fig. 15. Diagram shows proper use of vertical storage tank.

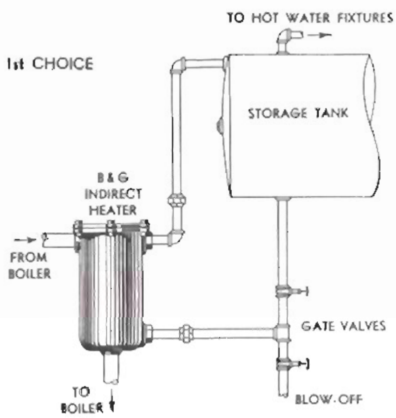


Fig. 16. The hot water connection from heater to tank is separated from the outlet to the fixtures, preventing any mixing of cooler water.

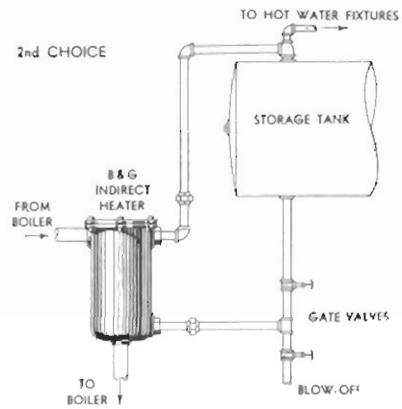


Fig. 17. Be sure that the opening into the tank is equal to the total cross sectional area of the other two lines connecting into the tee.

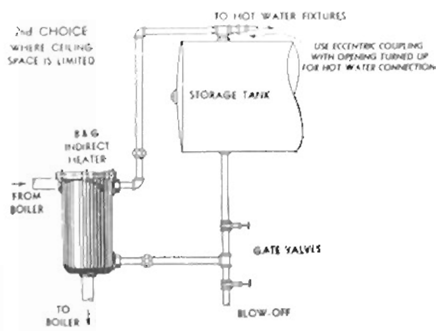


Fig. 18. Recommended where ceiling space is limited. The eccentric coupling at the hot water outlet assures removal of air from heater line.

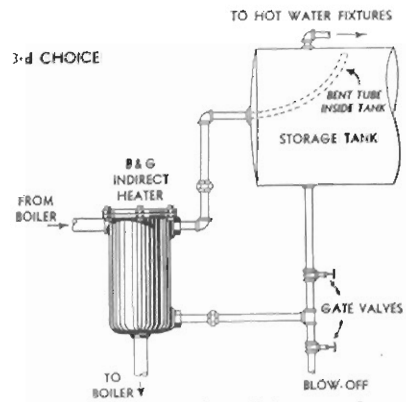


Fig. 19. For full efficiency a bent tube should be installed as noted in the diagram.

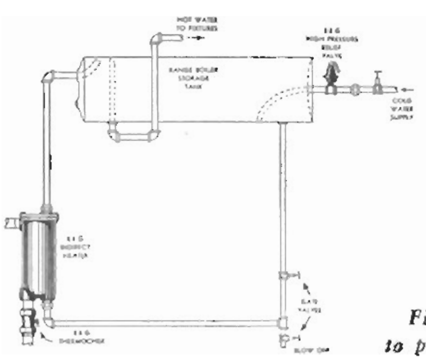


Fig. 20. Range boiler equipped with a bent copper tube to permit use in a horizontal position.

HOW TO INSTALL INDIRECT WATER HEATERS (continued)

COLD WATER CONNECTIONS

The cold water is connected at the other end of the tank using any one of the three choices listed in Figures 21, 22, 23. Either the first or second choice (Figs. 21 and 22) spread the cold water along the bottom of the tank more than does Fig. 23, the third choice, thus eliminating much tendency for the cold water to be pulled directly up to the hot water outlet. Always connect a B & G High Pressure Relief Valve in the cold water line between the tank and cold water valve. This will eliminate any possible trouble should the cold water valve be closed and a cold tank of water heated. Order Relief Valve to be set at 25 lbs. higher than maximum city water pressure.

HOT WATER CIRCULATING SYSTEMS

In many smaller residences, no hot water circulating line is provided and each time water is drawn at the fixtures, the cold water in the piping must be wasted. Figure 24 illustrates an installation of this type.

In large residences, apartment buildings, etc., hot water is circulated continuously through the piping lines by gravity or with a B & G Booster Pump. Here two general types of piping connections are used:

(1) The overhead system which has the supply main in the attic. It is used in tall buildings and the most common installation is shown in Figure 25.

(2) The up-fed system. Both the supply and return mains are in the basement as illustrated in Figure 26.

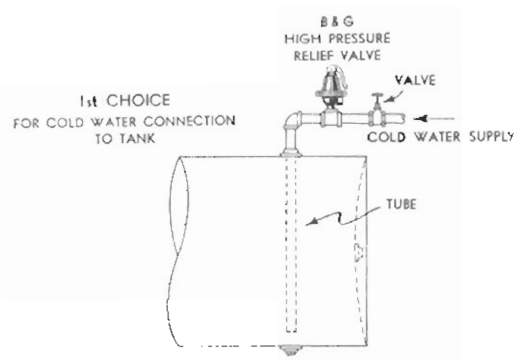


Fig. 21. First choice. With this connection, cold water tends to spread out on bottom of tank.

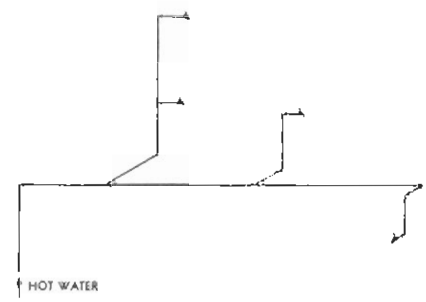


Fig. 24. Up-fed domestic water system without circulating line.

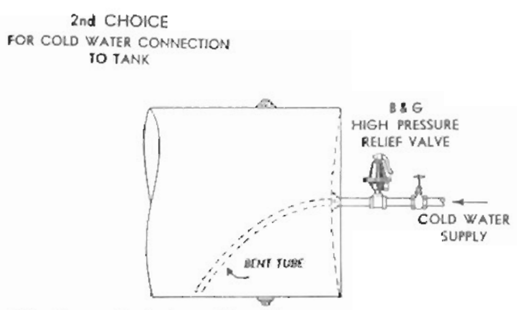


Fig. 22. Second choice. If cold water connection is made at center of tank, the bent tube will help stratify cold water at the bottom of the tank.

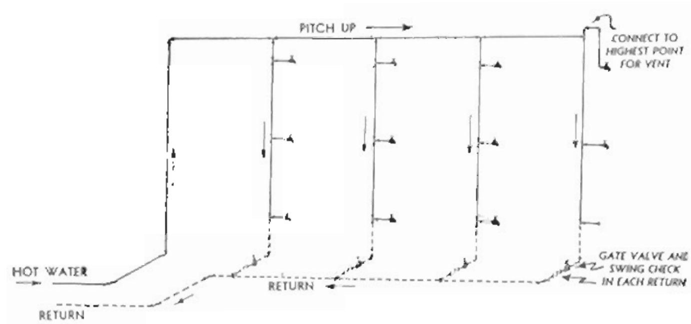


Fig. 25. Circulating domestic water system with supply main in attic.

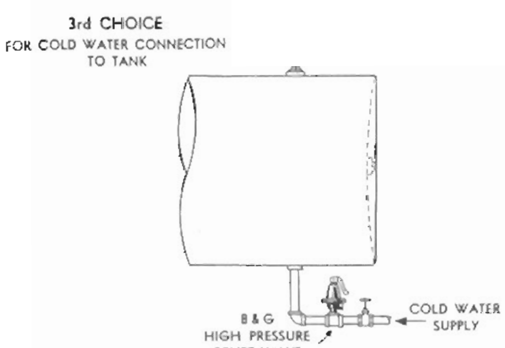


Fig. 23. Third choice. With this connection, cold water has a tendency to be pulled directly up to the hot water outlet.

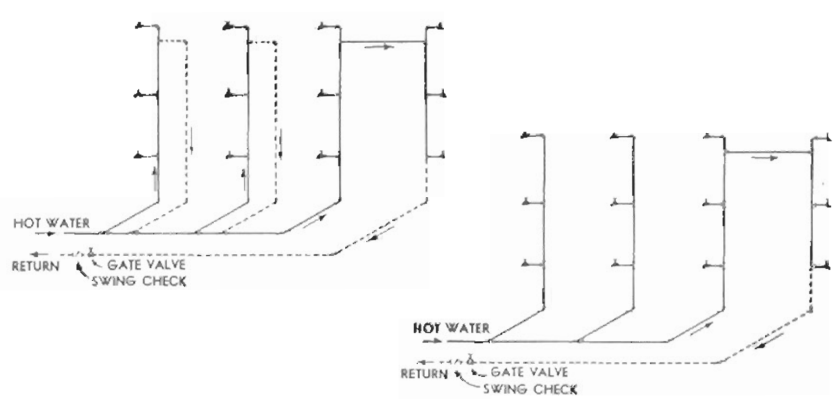


Fig. 26. Up-fed domestic water circulating system with supply and return mains in basement.

HOW TO INSTALL INDIRECT WATER HEATERS (continued)

Always connect a swing check valve in each circulation return to prevent pulling cold water through it to mix with the hot water. It is also a good plan to valve each return. By valving as illustrated in Fig. 27, mud and sediment can be flushed from the hot water return lines by closing valve "A" and opening "B".

Fig. 27 also shows a typical gravity circulation return connection. Best results are obtained by locating the connection near the heater as illustrated. Connections as shown in Fig. 28 are also satisfactory.

It is not recommended that the return be connected as illustrated in Fig. 29 as this connection has a tendency to retard gravity circulation. Usually the water in the building circulation return is hotter than that in the line connecting the bottom of the tank to the B & G Heater. The tendency of this hotter water is to rise into the storage tank in a direction opposite to that of the water being circulated by the B & G Heater. Thus one flow opposes the other, causing a retarding of circulation.

When using a B & G Booster Pump to circulate hot water through the building, it is best connected as illustrated in Fig. 30. If the tank is low, install a jet to pull the tank water along through the heater. This jet is made up of a nipple and a double tapped bushing. Due to the corrosive action of the water a *bronze body* Booster Pump should be used on all domestic water systems. To automatically operate the pump, an electrical Hot Water Control can be installed in the building return above the pump. Adjusting the control to a close differential will assure frequent operation of the pump. If the jet is used, the electrical hot water control can be installed in the tank and adjusted for a 10° to 15° differential.

Piping connection between the coil of the B & G Heater and the tank should be the same size as the heater connection, if the bottom of the storage tank is level with or above the top of the heater. If the tank is ⅓ below the top of the heater and is circulated by gravity, better results will be obtained by increasing the connections one size over the tappings in the heater. If the bottom of the tank is 10 ft. above the top of the heater, the connections between them can usually be reduced to one size smaller than the heater tappings.

BACKWASHING MUD AND SEDIMENT FROM HEATER COIL

All city water contains mud and sediment which settles in the storage tank and on the inside of heater coil. Any sediment in the coil insulates the domestic water from the heated boiler water, thus reducing the output of the heater. All installation drawings are shown with back washing valves which make it easy to periodically flush the mud from the coil, under city water pressure.

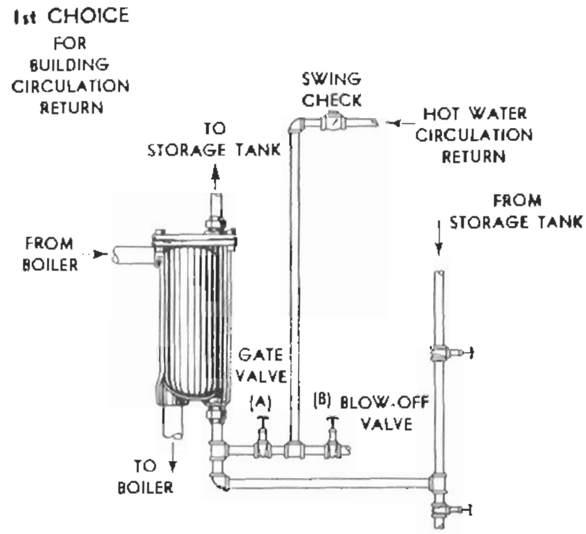


Fig. 27. First choice for building circulation return.

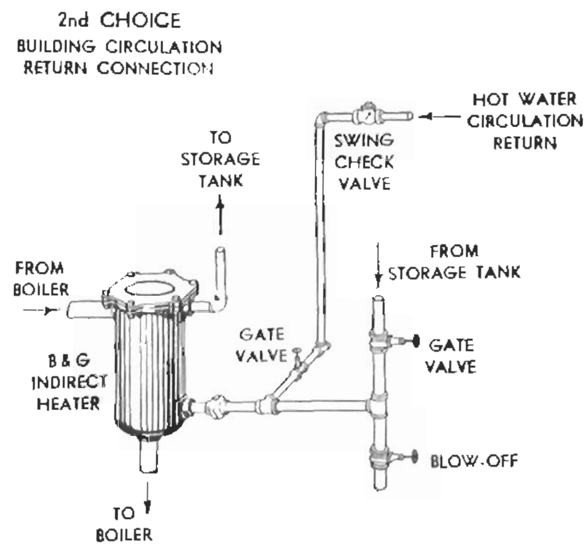


Fig. 28. Second choice for building circulation return.

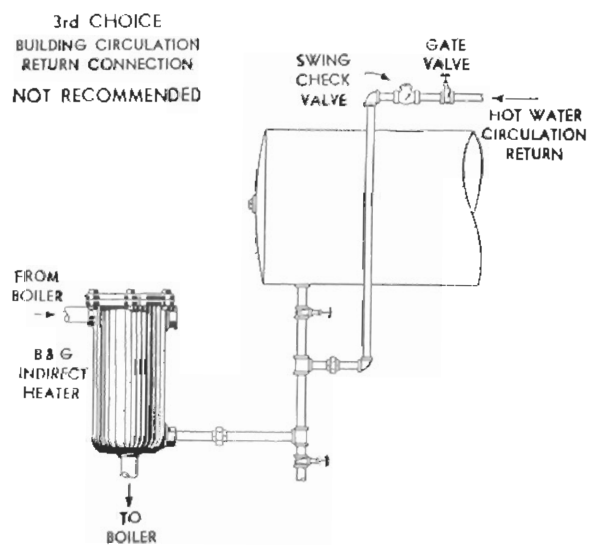


Fig. 29. Third choice. Not recommended.

HOW TO INSTALL INDIRECT WATER HEATERS (continued)

On a storage tank installation as illustrated in Figure 30, close gate valve C and open D until the water runs clear. Be sure that D is wide open and for best results this valve should be the same size as the cold water connection to the system. After backwashing the heater, the valves should be readjusted to their original position.

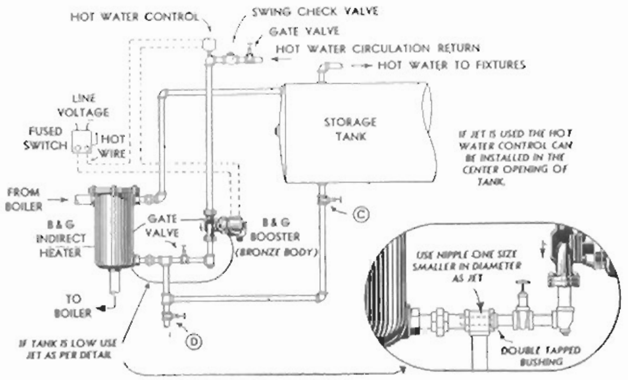


Fig. 30. B & G Booster Pump used to circulate hot service water through the building. Install jet if tank is low.

On a tankless installation the flushing valve is installed at the hot water outlet of the heater as illustrated in Figure 31. The blow-off valve should be opened and water permitted to flow through it until it runs clear. This backwashing gate valve should also be the full size of the cold water connection to the heater.

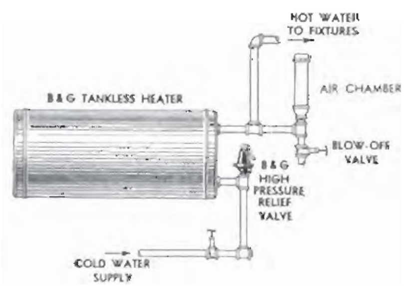


Fig. 31. This installation permits flushing of the heater by opening blow-off valve.

VALVES AND DRAINS

All installations of B & G Heaters should have the proper number and locations of valves, drains and blow-offs. Do not economize on these, as they are necessary for proper cleaning and control. Building circulation return lines should have light weight check valves with perpendicular discs. High Pressure Relief Valves should be installed on all domestic water heating systems.

WATER TEMPERATURE CONTROLS

It is poor policy to economize on electrical controls. An improperly equipped job will waste many times the cost of these controls.

When installing immersion type controls, be sure there is depth enough for the control well.

WATCH FOR LEAKY FAUCETS

Leaky faucets can run up the operating cost of a hot water installation more deceptively than any other single cause. Check them carefully.

USE OF CIRCULATORS

A *bronze bodied* B & G Booster on a sluggish hot water circulating return line will pay for itself many times over in water saved. If a storage tank on a large installation is too low for effective circulation, do not raise it, but install a Booster operated by a hot water control in the tank. It will cost less and, in addition, control storage tank temperature.

Where the storage tank is low and a *bronze bodied* Booster Pump is used only for circulating water between the tank and B & G Heater (not through the building circulating lines) it should be connected as illustrated in Fig. 32. An electrical Hot Water Control is installed in the storage tank to automatically operate the pump whenever the tank requires heat.

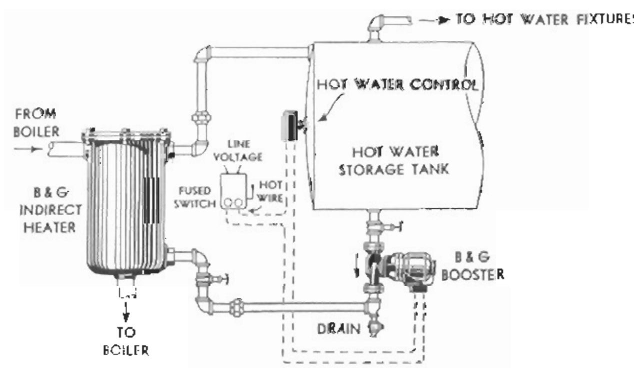


Fig. 32. B & G Booster used to circulate water from a low tank through the heater.

The B & G Booster Pump required for circulating the tank water through the heater should be of ample capacity and can be sized as follows:

(1) Determine the number of gallons of water per *minute* that the heater you have selected will deliver.

(2) Select from the Booster Capacity Chart in Section II a B & G Pump that has a delivery equal to this figure at a head of not less than 4 ft.

Where a storage tank is installed to supplement a tankless heater of insufficient capacity, the greater pressure drop through the tankless heater must be considered. In this case, a Booster must be selected which will deliver the required amount of water at a head sufficient to take care of the pressure drop through the coil of the heater. Pressure drop data on various sizes of B & G heaters are available upon request.

Usually, piping connections the full size of the pump tapping will be found of ample capacity. Install a gate

HOW TO INSTALL INDIRECT WATER HEATERS (continued)

valve on the suction side of the pump so that circulation can be throttled down if the rise in water temperature is not sufficient.

TANKLESS HEATER DOMESTIC WATER CONNECTIONS

The hot and cold water lines are connected to their respective openings in the heater. The cold water supply line should be provided with a swing check valve and connected as illustrated in Fig. 33.

The use of a B & G Watermixer tempering valve is recommended on all tankless heaters for maintaining domestic water at a uniform temperature.

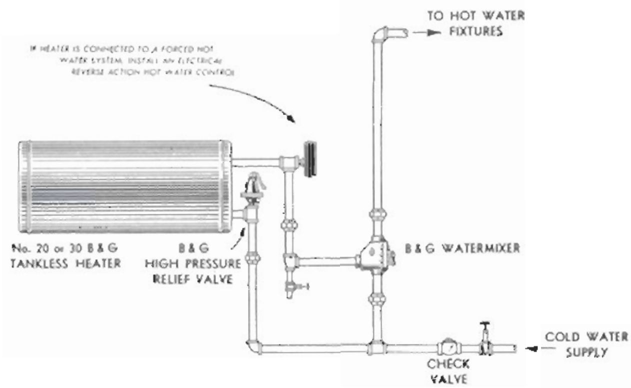


Fig. 33. Domestic hot water connections to a B & G Tankless Heater.

All restaurants require water at a temperature of at least 180° F which is much too hot for lavatory use. A B & G Watermixer can be used to temper the lavatory water but does not provide as economical a system to operate as one that heats the building water to a lower temperature and super heats only the restaurant water.

Figure 34 illustrates a typical installation using a B & G Indirect Heater for the heating of the tank and a tankless heater for the super heating of the restaurant water.

CONNECTING BUILDING HOT WATER CIRCULATING RETURNS ON TANKLESS HEATER INSTALLATIONS

Connect the circulation return from the building into the cold water inlet of the Tankless Heater. To prevent pulling cold water through this line and mixing it with the hot water at the fixtures, the return should be equipped with a vertical swing check valve. On installations with long runs or where very little gravity head is possible for circulating returns, it may be necessary to use a *bronze body* B & G Booster Pump.

HARD WATER TERRITORIES

The best heater for hard water districts is the Tank and Heater shown on page 111. With this unit the

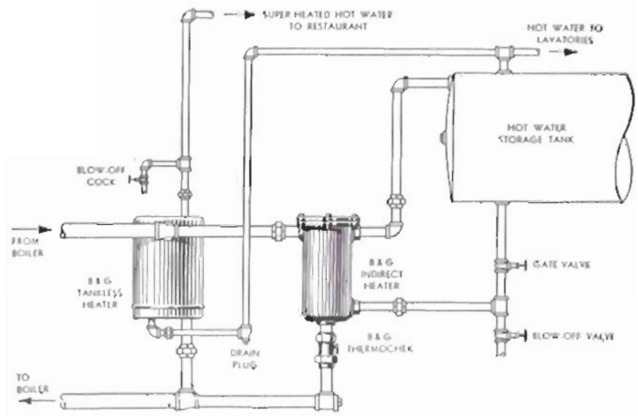


Fig. 34. An excellent installation for supplying two different temperatures of water.

boiler water is circulated through the copper coil, heating the domestic water in the tank. Any lime will, therefore, precipitate on the outside of the coil.

The lime is usually easily removed from the outside of the copper coils by draining the water from the storage tank and heating the boiler water to a temperature of 200 to 220 degrees, then spraying the coil with cold water through an opening in the tank. This sudden change in temperature causes a contraction of the copper tubes and tends to crack the lime loose.

INSULATING HEATER AND CONNECTIONS

It is recommended that the heater and all connections to the boiler and the storage tank be insulated. Uninsulated equipment is like a radiator and heats the room or space around it, thus causing frequent firing of the boiler and a higher cost of operating the system.

AIR CHAMBER FOR ELIMINATION OF TANKLESS HEATER WATER HAMMER NOISES

On some tankless heater installations a water hammer noise is created by the quick closing of faucets. It is especially noticeable on buildings supplied with domestic water at pressures above 35 pounds. There are several anti-water hammering devices on the market that absorb or cushion the hammer action, thus reducing or eliminating the noise. An air chamber made of a piece of 3 inch pipe with a cap on one end and a 3" x ½" reducer on the other as illustrated below has been used satisfactorily.

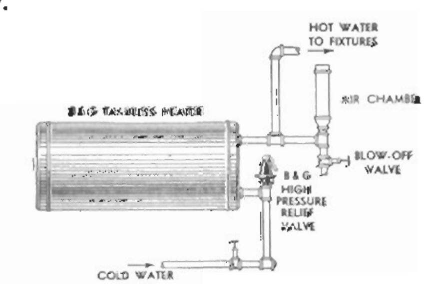


Fig. 35. This diagram shows the installation of an air chamber for reducing water hammer noise.

HOW TO INSTALL INDIRECT WATER HEATERS (continued)

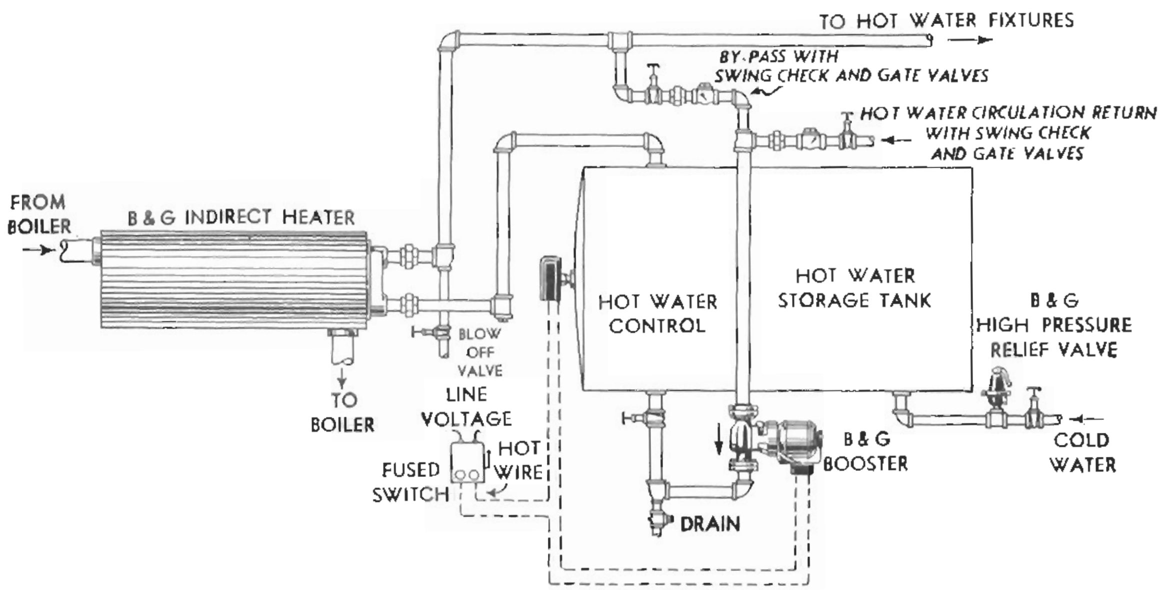


Fig. 36. This semi-tankless pumped installation permits storage of tempered water in tank.

SEMI-TANKLESS PUMPED INSTALLATIONS

Where the hot water storage tank is low or located at a distance from the heater, a connection that uses the tank for the storage of tempered water has been found very efficient. A *bronze body* Booster Pump circulates the hot water through the building and into the storage tank. Before the hot water is "drawn" to the fixtures it again passes through the heater. The piping connections include a bypass so that part of the hot water circulates directly into the tank. The Booster Pump should be automatically operated with an electrical Hot Water Control in the storage tank. Figure 36 illustrates a typical installation. Any of the B & G Horizontal Indirect Heaters, the B & G Type "WU" Heaters or B & G Unitem Submerged Heaters can be used with this connection. For this type of installation the storage tank can be smaller than normally used. For example, a storage tank of 25% less capacity than normally used should be ample.

If using a B & G Unitem Submerged Heater, select a tankless type.

HEATERS CONNECTED TO STEAM

Low Pressure—not exceeding 15 lbs. pressure

Any of the B & G Heaters can be connected to low pressure steam. The storage tank installation is illustrated in Figure 37. For controlling domestic water temperature, connect an automatic steam regulating valve in the steam line with its operating bulb in the storage tank. If the steam does not exceed 5 lbs. pressure, the regulating valve can be omitted.

A B & G Watermixer, however, should be used to automatically mix cold water with the hot water as it leaves the tank. Without this control device, the temperature will vary with the amount of water being drawn.

Under certain conditions, when no water is drawn, the water in the heater and tank may rise to the same temperature as the steam, which might scald anyone using it. The use of a B & G Watermixer will prevent this possibility.

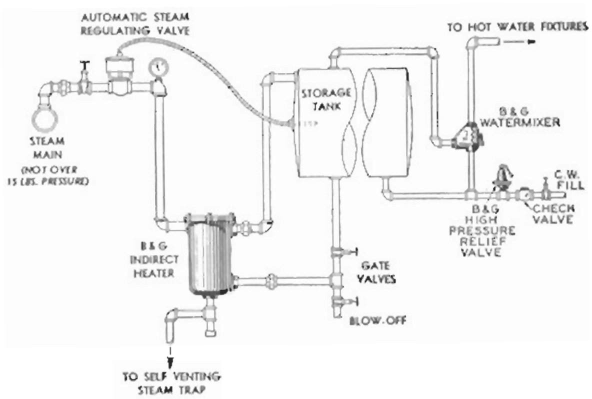


Fig. 37. Typical low pressure steam installation.

HIGH PRESSURE STEAM

The B & G type "SU" Heater, for instantaneous operation, can be used through a wide range of steam pressures. This heater, in 2 pass models, can also be used in conjunction with a storage tank. The ratings in the "SU" catalog are for instantaneous operation—capacities for storage tank operation can be obtained upon request from the factory.

The B & G Tank Heater Unit is an excellent high pressure heater and is installed directly into the storage tank, or the tank and coil can be purchased as a complete unit in tank sizes up to and including 180 gallons. It is recommended that the collar of the B & G Heater Unit be welded into the tank by the tank manufacturer.

HOW TO INSTALL INDIRECT WATER HEATERS (continued)

Do not use the regular low pressure B & G Indirect Heater on a high pressure steam installation unless pressure is reduced to below 15 lbs. with a pressure reducing valve.

Most Tankless water heater loads are intermittent and for this reason, it is suggested that not greater than 10 lbs. steam pressure be used. For a constant load, such as required for processing work in factories, higher steam pressures can be used satisfactorily.

In localities supplied with water high in lime content, it is recommended that water be passed through a good water softener to eliminate as much as possible any precipitation within the tankless heater.

For capacities of B & G low pressure heaters, see the B & G Catalog.

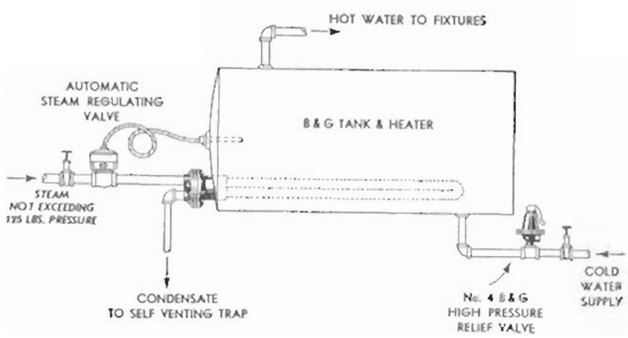


Fig. 38. B & G Tank and Heater installation, heated with high pressure steam.

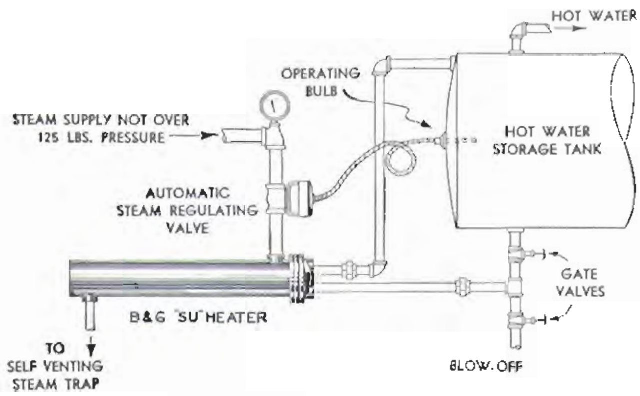


Fig. 39. B & G 2-pass Type "SU" Heater using high pressure steam.

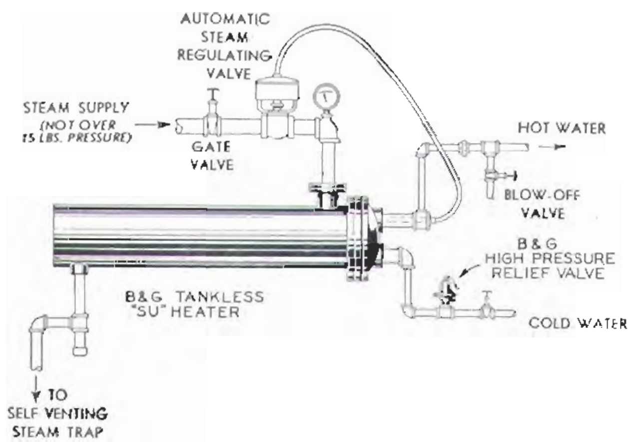


Fig. 40. B & G Type "SU" Heater using low pressure steam.

ELECTRICAL CONTROLS FOR BOILER & SERVICE WATER TEMPERATURE

There are many ways of providing electrical control circuits for control of service water temperature and boiler water temperature.

Generally, a boiler operating control is provided in the boiler to maintain a constant boiler water temperature. For summer operation the control is usually adjusted to a setting of 180° F. Winter operation may require a higher setting depending on the design of the heating system.

Controls can be installed in the storage tank to control the boiler-burner operation to maintain a pre-determined temperature in the tank.

Further, on many tankless installations, an additional control is sometimes placed in piping circuits to the fixtures to cut off the circulating pump of the heating system in the event the domestic water temperature drops below the control setting.

MECHANICAL WATER TEMPERATURE CONTROLS

The use of a tempering valve, such as the B & G Watermixer, is recommended on all tankless heaters for maintaining domestic water at a uniform temperature.

SECTION II

PRINCIPLES OF FORCED HOT WATER HEATING

Forced Circulation Hot Water Heat eliminates all the objections applying to the old style gravity flow system, yet retains the advantages of the heating medium (water) most easily subject to accurate control.

In a gravity system, circulation to the radiators is accomplished by the difference in the weight of water in the supply and return main. Water heated in the boiler increases in volume and rises, simultaneously with a downward movement of the cooler, heavier water in the return main. Circulation is thus set up.

The forced circulation system employs an electric pump to provide movement of the water. By this means, circulation is so greatly speeded up that radiators can be almost instantly supplied with hot water whenever needed, or a constant temperature can be maintained in the system to compensate for outside weather conditions.

A further advantage of the forced circulation system is that it may be equipped with modern mechanical controls which permit year around use of the heating boiler for heating the domestic water supply.

Definition of terms used

A heating system must be designed to replace the heat lost from the building through the walls and by infiltration of air through cracks around the doors and windows. The rate of heat loss is determined by these factors:

1. **Construction of building**
2. **Velocity of prevailing winds**
3. **Degree of outdoor temperature**

The method of correlating these factors to obtain the correct heat loss of the building is given in detail in Section III, "Heat Loss Determination." When the heat loss is known, the required capacity of the heating plant can then be calculated.

DEFINITION OF A BTU

The BTU (British Thermal Unit) is the accepted measurement of heat. One BTU is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. The term MBH is used to express the heat emission of 1000 BTU per hour. It is recommended that all calculations of heat output and heat loss be made by the BTU method, for the following reasons:

For many years the heating industry has been accustomed to the use of the Equivalent Square Foot (EDR) of radiation as a measure of heat loss of any given building. This Equivalent Square Foot is the surface that will emit 240 BTU per hour when maintained at an average temperature of 215°F. Since 215°F. is the temperature of steam at a pressure of 1 pound per square inch, the Equivalent Square Foot of radiation has come to be called a Square Foot of Steam Radiation. Whenever a building was to be heated by means of Hot Water, the rule was to increase the number of square feet by 60%, because the temperature of the heating medium was limited to approximately 180°.

The modern hot water heating system, equipped with a compression tank and relief valve is no longer limited to a boiler temperature of 180°. Because of the extreme flexibility of water as a heat transmitting medium, it can be circulated at any desired temperature within the working pressure of the system, without the use of critical equipment or mechanical devices dependent upon close adjustment.

Accordingly, the term "Square Foot of Radiation" has lost its meaning as a measurement of heat emitted by a hot water heating system. The amount of surface which will emit 240 BTU per hour at an average temperature of 215° (steam pressure of 1 lb.) will also emit more or less than 240 BTU per hour as the average temperature of the water is raised or lowered.

Since the modern Hot Water Heating System is generally calculated to cool the water 20° between the inlet and outlet of the radiator, and the water enters the radiator at approximately boiler temperature, the average temperature of the radiator may be taken to be 10° less than the boiler.

As an example of the use of this method, let us assume we have a building with a heat loss of 240,000 BTU per hour. Radiators may then be selected according to the following table below:

TABLE J

Emission Per Sq. Ft.	Average Rad. Temperature	Boiler Temperature	Required No. Eq. Sq. Ft.
240 BTU	215°	225°	1000
225 BTU	210°	220°	1065
200 BTU	197°	210°	1200
180 BTU	190°	200°	1330
160 BTU	175°	185°	1500
150 BTU	170°	180°	1600

DEFINITION OF TERMS USED (continued)

HIGH AND LOW TEMPERATURE WATER

Gravity flow systems commonly employ low temperature boiler water, providing a heat emission of 150—165 BTU per sq. ft. of radiation. The modern forced circulation system is generally designed for higher boiler temperatures and consequently higher BTU heat emissions.

The obvious advantage of higher temperature water is that smaller radiation can be used. (See Fig. 41) The maximum outdoor temperature for which the system is designed occurs for only a relatively short time during the heating season, so the boiler water is brought to maximum temperature for correspondingly short periods. Increasing use of automatic firing devices and the development of more accurate controls make possible the use of higher temperatures without sacrificing good design.

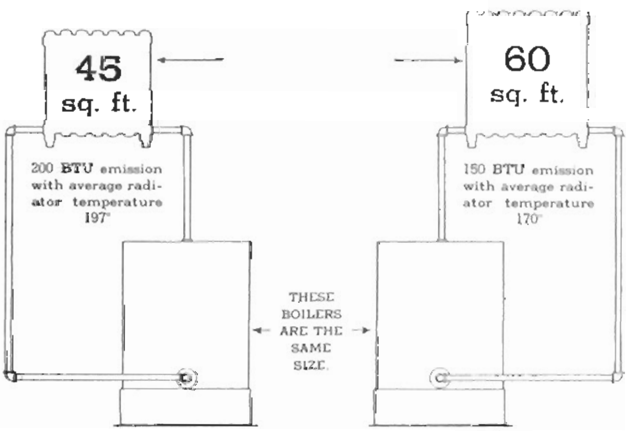


Fig. 41. Illustration above shows the material reduction in radiator size when heat emission rate is increased from 150 BTU to 200 BTU.

Because of the pump, available Pressure Heads in forced circulation systems are much greater than in gravity systems. Hence, higher velocities may be used in designing the system, with resulting smaller pipe sizes. (See Fig. 42) In other words, the BTU carrying capacity of a pipe increases as the velocity increases, which means that with forced circulation a small pipe will carry the same heating load as a larger one in a gravity system.

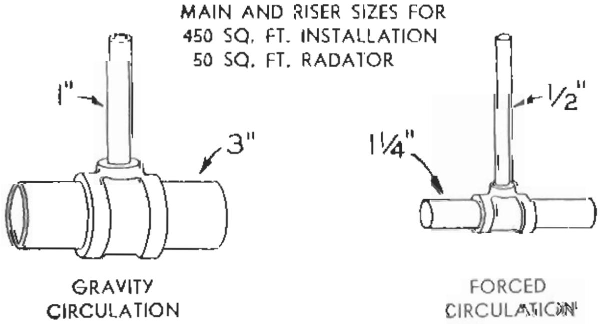


Fig. 42. Shows typical pipe size reduction in forced circulation system.

Forced hot water systems are classified as one-pipe or two-pipe designs. Two-pipe systems are further divided into *direct return* and *reverse return* layouts.

The development of the B & G Monoflo Fitting confers so many advantages that design trends are definitely to the single main Monoflo System.

PRESSURE DROP

"Pressure drop" is the term which expresses the fact that power is consumed in moving liquids through pipes, heating units, fittings, etc. Or, expressed in another way, pressure drop is the amount of pressure lost between any two points in a system. For example, if the city water pressure at the inlet of a tankless type copper coil indirect water heater is 40 lbs., and at the outlet, 35 lbs.—

40 lbs. — 35 lbs. = 5 lbs. pressure drop through the heater.

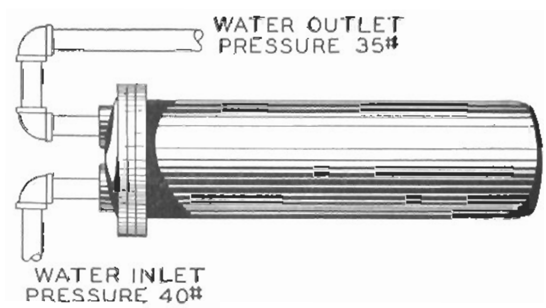


Fig. 43. Friction causes a drop in pressure when liquids move through pipes or heating units.

Pressure drop is caused by the friction created between the inner walls of the conveyor and the moving liquid. In a horizontal pipe in which there is no flow, the pressure is equal at all points. The moment flow starts, friction is set up, which increases in direct proportion to the velocity of the flow.

For all practical purposes, pressure drop may be considered to vary as the squares of the velocities.

To calculate the effect of changing velocity on pressure drop, this simple rule may be followed—

Divide the final velocity by the initial velocity and square the result. Then multiply the original pressure drop by the above result, which gives the new pressure drop. The following example shows the effect of an increased velocity—

6′ per second final velocity ÷
3′ per second initial velocity = 2
2 squared = 4
10 lbs. initial pressure drop × 4 =
40 lbs. final pressure drop.

DEFINITION OF TERMS USED (continued)

Gallons of water may be substituted for feet per second in the above formula.

Therefore, in designing both service water heating systems and hot water space heating systems, pressure drop must be taken into consideration.

In either case, enough power must be available to overcome the effects of pressure drop before the desired results can be obtained. This means that the power consumption, or pressure drop, of each component part of a system must be known and a source of sufficient power provided. In a forced hot water heating system this power is provided by the pump—in a domestic water heating system, city water pressure is the source of power.

MEASUREMENT OF PRESSURE DROP

Boilers, radiators, unit heaters, convectors, blast coils, pipe and fittings all offer resistance to the flow of water and the amount of water that flows through each is proportional to the resistance offered. Since the amount of heat delivered to the various units depends upon the amount of water passing through the units, it is easy to see that excessive friction in any one unit may prevent it from delivering its rated capacity.

In order to reduce these various units to a common factor, their relative resistances are expressed in "elbow equivalents." *A 90° elbow offers to the flow of water an amount of friction equal to a pipe of the same diameter, with a length of twenty-five times the diameter.*

Thus, a ½" elbow is equal in resistance to 12½ inches of ½" pipe, or ¾" elbow equals 18¾" of ¾" pipe. The "elbow equivalent" system of resistance measurement has been applied to the common pieces of equipment in a heating system as shown in the table below. How to use these "equivalents" is explained later under the instructions for designing one and two-pipe forced hot water systems.

The equivalents applied to the radiator are intended only for the free standing cast iron radiator, which has large waterways and low velocities. All other emission units, such as convectors, baseboards, panels, unit heaters and blast coils must be considered separately and their individual pressure drops known.

Manufacturers who publish pressure drop information on their equipment express the data either in pounds per square inch or in feet of water or milinches.

These figures are easily interchangeable as follows:

1 lb. per sq. in. = 2.3 feet of water
or
1 foot of water = .43 lbs. per sq. in.
or 12000 milinches.

HEAD PRESSURE

"Head Pressure" as used in designating the capacity of a circulating pump, is merely another way of expressing pressure drop. The maximum "Head" of a pump (usually expressed in feet of water) is actually the maximum pressure drop against which the pump can induce a flow of liquid.

Head Pressure should not be confused with Static Pressure, as they have no relationship. Static Pressure is created by the weight of water in the system and is equal to .43 lbs. per sq. in. per foot of height above the gage. For example, if the highest radiator is 20 ft. above the gage in the boiler, the Static Pressure at the gage will be:

20 × .43 = 8.6 lbs. per sq. in.

At various elevations above the gage the Static Pressure becomes correspondingly less. At 10 ft. it is 4.3 lbs. per sq. in., and at the top radiator, located 20 ft. above the boiler, there is no pressure.

Static Pressure has no effect on pump capacity. If you will consider a hot water heating system as being an upright loop of water confined in a pipe, the Static Pressure in one of the vertical pipes of the loop is identical with the pressure *at the same level* in the opposite vertical pipe.

The Static Pressure at the point where the pump is installed is therefore exactly equalized by the pressure

Table of Elbow Equivalents

1 90° Ell	1
1 45° Ell	0.7
1 90° Long Turn Ell	0.5
1 Open Return Bend	1
1 Open Gate Valve	0.5
1 Open Globe Valve	12
1 Angle Radiator Valve	2
1 B & G Flo-Control Valve	20
1 Stop Cock Open	1
1 Radiator (Cast Iron)	3
1 Convector (See Page 35)	
1 Boiler	3
1 Tee	
25% Water to Branch	16
33% Water to Branch	9
50% Water to Branch	4
100% Water to Branch	1.8

DEFINITION OF TERMS USED (continued)

at the same level in the opposite side of the loop. Hence, the capacity of the pump is limited only by the friction in the pipes. This friction value is called the Head Pressure.

The chart below shows a typical B & G Booster pump capacity curve. At the "no delivery" point on the curve, the power of the pump is exactly equalled by the friction or pressure drop opposed to it. Since a drop in pressure between two points is necessary before flow can occur, the pump delivers no water.

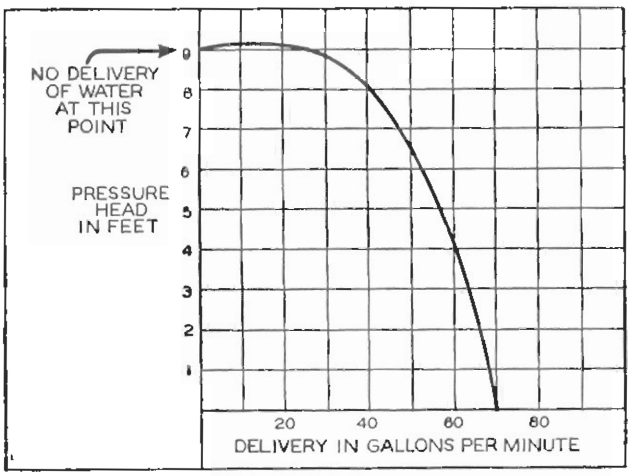


Fig. 44. Above chart shows the relationship between Head Pressure and amount of water delivered by pump. As the Head Pressure increases, the delivery decreases.

If the pressure drop is lessened by eliminating some of the friction in the system, the pump begins to deliver water. For example, at 6 ft. of Head Pressure on the chart, the pump delivers 52 gallons of water per minute. It is clear that the lower the Pressure Head (pressure drop) the greater will be the water delivery.

Pressure drop is therefore one of the major factors in designing a forced circulation hot water heating system. The friction or pressure drop in the system is directly related to the size of the piping used and is accordingly under the control of the designer.

THE MILINCH

The word "milinch" means 1/1000 of an inch, or 1/12000 of a foot. Since in hot water heating system design, pressures are measured in terms of "feet of water," 12000 milinches represents the pressure exerted by a column of water one foot high.

To illustrate—a tank has a hole in the bottom of such size that 10 gallons of water per minute will flow through it when the water stands one foot high in the tank. Under this condition, we have a pressure of 12,000 milinches (or one foot) causing a flow of 10 gallons per minute through the hole.

The above example may be applied to a hot water heating system. If in a circuit of pipe it is necessary to cause a flow of 10 gallons per minute and if it is found that a pressure equivalent to that of a water column one foot above the center line of the pipe is needed, then 12,000 milinches of Head Pressure must be supplied.

Conversely, the milinch is used to express friction values. In the above example, the fact that 12,000 milinches of Head Pressure is required to move 10 gallons per minute through the pipe, means that the pipe offers 12,000 milinches of friction or resistance. Therefore, before any flow can occur in a pipe, the Head Pressure must be equal to the friction loss through the pipe.

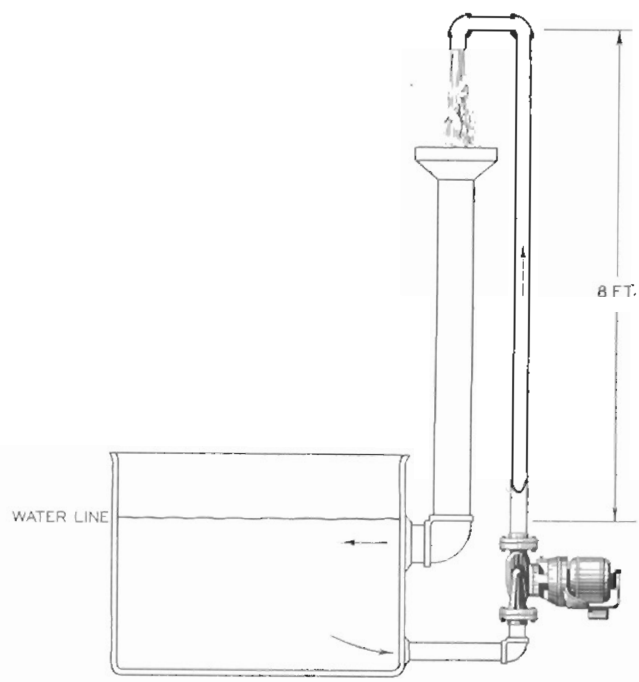


Fig. 45. A size 1¼" Booster, if connected to a tank of water, as illustrated, will pump water to a height of 8 feet. This height therefore, is the maximum Pressure Head against which the Pump can cause a flow of water.

The reason for dividing pressure measurements into such small units is because the pressure drop through the piping of a heating system is usually very low. If "feet of water" were used, then the necessary calculations would have to be made in fractions of a foot, always awkward to handle mathematically. The milinch, which in heating system design occurs in fairly large whole numbers, eliminates fractional values. In heating practice, pressure drops from 100 to 500 milinches per foot are normally used.

DEFINITION OF TERMS USED (continued)

THE SINGLE MAIN (ONE-PIPE) B & G MONOFLO SYSTEM

In this system, a single main in one or more circuits is used to circulate water. Risers are equipped with B & G Monoflo Fittings at their connections to the main, in accordance with directions given in the Monoflo System Design Tables.

Monoflo Fittings are carefully engineered devices, which introduce just the right amount of resistance to assure a proper diversion of hot water into the radiator.

Tables of diversion capacities of the Monoflo Fitting have been accurately determined and are shown on following pages for system design use.

In application, the Monoflo System is practically unlimited. It is equally well adapted to the small residence or to commercial and industrial installations requiring thousands of feet of radiation. Complete design instructions for this system begin on page 25.

THE TWO-PIPE HOT WATER SYSTEM—DIRECT AND REVERSE RETURN

There is no question but that the *reversed return* system is definitely superior to the direct return system.

As shown in the illustration of a *direct* return system, the first radiator taken off the line is the first radiator to return its load and the last radiator is last to return. Consequently, the circuits of water to radiators are of unequal length. This inherent lack of balance can obviously cause serious difficulty in obtaining a proper distribution of heat. It is a typical "short circuit" system.

In the *reverse* return system, on the contrary, the first radiator off the line is the last to return, and all radiator circuits are of equal length. The problem of proper balance is therefore greatly simplified. It is obvious that the larger the system, the more unbalanced a two-pipe system may become.

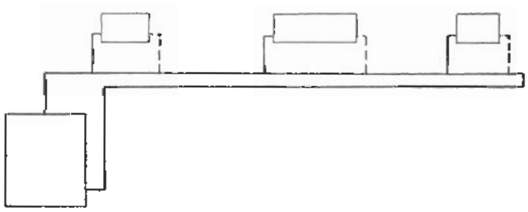


Fig. 46. Monoflo single main (one-pipe) hot water system.

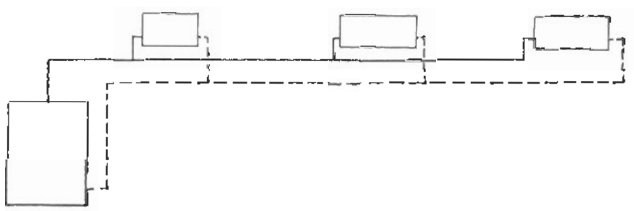


Fig. 47. Two-pipe direct return system. Note that each radiator circuit is of a different length.

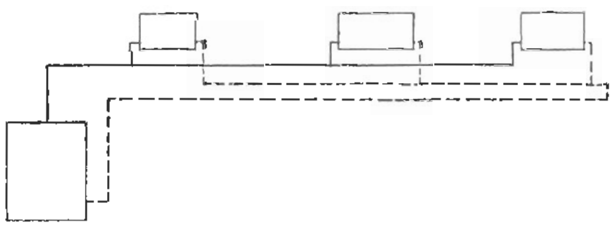
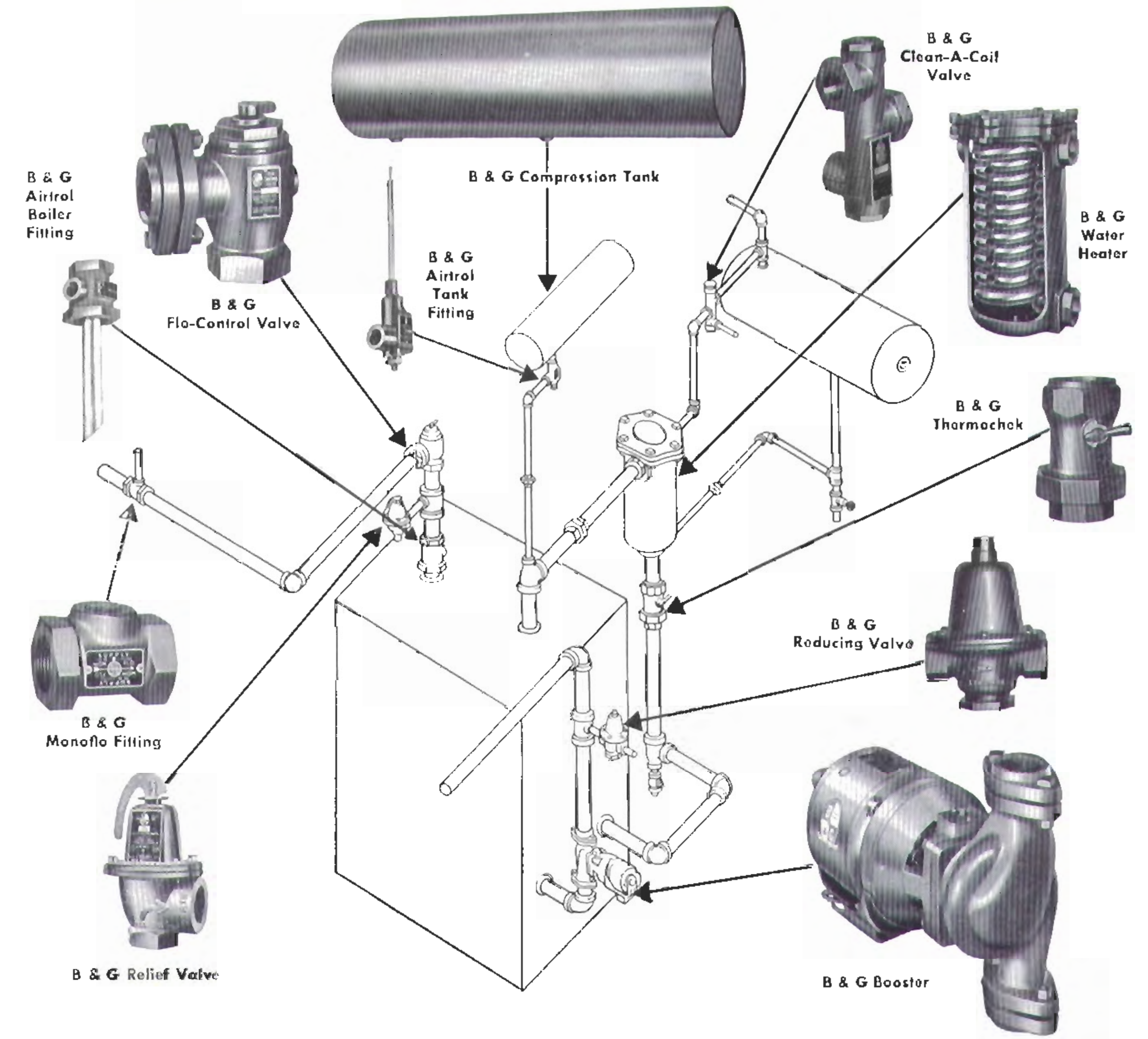


Fig. 48. Two-pipe reverse return system, showing equalized circuits.

B & G EQUIPMENT REQUIRED FOR A FORCED HOT WATER HEATING SYSTEM



The illustration above shows the B & G *Hydro-Flo* Products required for a forced hot water system. With the exception of the Monoflo Fittings, the same equipment is used on both one and two-pipe systems. Briefly, the function of each item is as follows:

B & G Booster Pump. An electrically operated centrifugal pump, connected into either the supply or return main. It is thermostatically controlled to circulate heated water through the system whenever heat is required.

B & G Flo-Control Valve. Installed in the supply main, this valve opens when the Booster is running and closes when the Booster stops. It thus prevents gravity circulation which might cause an override in room temperature.

In summer, the Flo-Control Valve shuts off circulation to the heating units, so that the heating boiler can be used to heat domestic water in a B & G Water Heater.

B & G Water Heater. The Water Heater selected for a forced circulation hot water system can be any one of the various types described in Section V, depending upon the nature of the hot water requirements.

B & G Compression Tank. Forced hot water systems operating at heat emissions higher than 150-160 BTU must be installed as closed systems so that higher pressures can be built up, thereby raising the boiling point. For this purpose, a B & G Compression Tank is installed. It provides a cushion of air against the expansion of heated water in the system.

MORE COMPLETE DESCRIPTIONS AND INSTALLATION DIAGRAMS ARE GIVEN IN SECTION V

B & G EQUIPMENT REQUIRED FOR A FORCED HOT WATER HEATING SYSTEM (continued)

B & G Relief Valve. This valve is designed to relieve the system when pressures in excess of 30 lbs. occur.

B & G Reducing Valve. Installed in the cold water fill line, this valve automatically keeps the system properly filled with water.

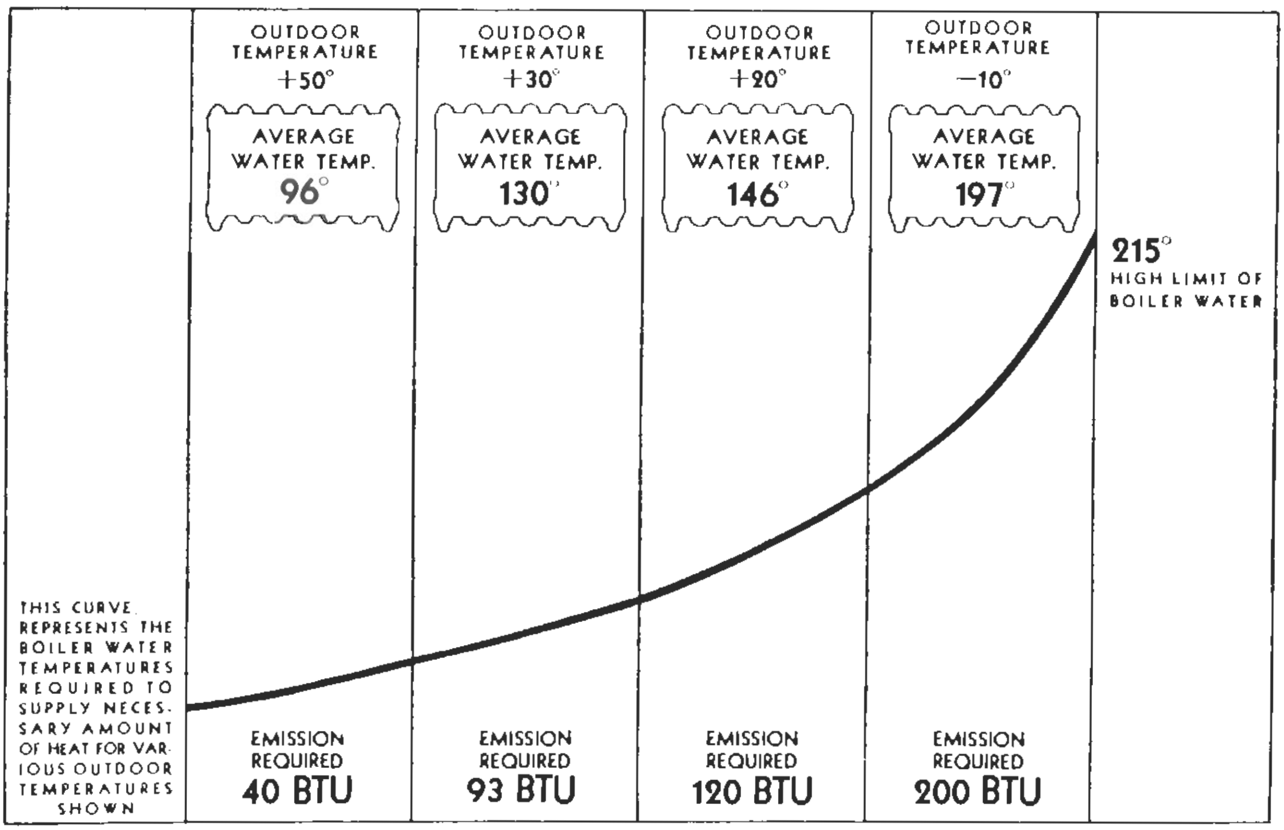
B & G Airtrol Boiler and Tank Fittings. The combined action of these units keeps the system free of air.

B & G Monoflo Fittings. These Fittings permit the use of a *single* pipe main instead of two pipes. When used to connect the risers to the single main, they assure a proper diversion of heated water into the radiators or convectors.

B & G Thermochek. This valve prevents overheating of the water in the hot water storage tank by controlling the circulation of boiler water through the Water Heater.

B & G Clean-A-Coil Valve. A unique device which helps keep the Water Heater coils free of lime and sediment. The ingenious design of the Valve causes automatic backwashing of the Heater coils every time a faucet is opened.

OPERATING CYCLE OF B & G *HYDRO-FLO* FORCED HOT WATER SYSTEM



One of the principal advantages of a forced hot water heating system is its ability to modulate the temperature of the water circulating through the heating units. The chart above shows the requirements of the heating units as the outside temperature rises or falls.

It is possible to accomplish this modulation with several types of control circuits. Simple intermittent controls provide satisfactory operation, but a more elaborate and refined type of control can be obtained with continuous circulation systems.

SUMMER-WINTER DOMESTIC HOT WATER HOOK-UP

See the Electrical Control Section for complete instructions on wiring forced hot water heating systems and Domestic water heating systems.

DESIGNING THE B & G MONOFLO HOT WATER HEATING SYSTEM

(See page 46 for two-pipe system design)

The following six steps must be taken in designing a B & G Monoflo System. Each is explained in detail hereafter. The calculations and tables are for systems employing cast iron radiators. For systems using convectors or unit heaters see design instructions on Page 35.

1. **RADIATION REQUIRED.**
2. **PIPING LAYOUT.**
3. **AMOUNT OF WATER IN GALLONS PER MINUTE NECESSARY TO CARRY THE HEATING LOAD.**
4. **SELECTION OF B & G BOOSTER.**
5. **SIZING THE PIPE.**
6. **SELECTION OF BOILER.**

On page 26 is an installation sketch of a B & G Monoflo System which will be used as an example for the design procedure.

STEP No. 1

RADIATION REQUIRED

Every designer has his own method of determining the amount of radiation required for any specified installation. Convenient, quick tables are shown in Section VI—"Supplementary Data". The more accurate BTU method of figuring heat losses and radiation (from which all condensed tables are derived) is given in Section III—"Heat Loss Determination", together with heat loss coefficients for all usual building materials.

Note Carefully

When using handy reference tables to figure hot water radiation, be sure to convert the figures in accordance with the BTU emission factor of the system you are designing.

Example:

A room requiring 60 sq. ft. of 150 BTU Radiation will need 45 sq. ft. if the heat emission rate is 200 BTU

$$150 \times 60 = 9000 \text{ BTU}$$

$$\frac{9000 \text{ BTU}}{200} = 45 \text{ sq. ft. of radiation}$$

STEP No. 2

PIPING LAYOUT

Next make a sketch of the piping layout as illustrated by the example on Page 26. This should show pipe lengths, location of the boiler and all radiators. It is used both as an installation sketch and for figuring pipe sizes.

STEP No. 3

AMOUNT OF HOT WATER IN GALLONS PER MINUTE NEEDED TO CARRY THE HEATING LOAD

Radiation load must be converted into gallons per minute, so that the correct B & G Booster can be selected for the system. First the square feet of radiation required to heat the building must be converted into its BTU equivalent.

The system used here as an example requires 600 sq. ft. of radiation, figured on a 200 BTU heat emission. **Multiplying 600 by 200 gives us 120,000 BTU as the total hourly heat loss of the building.**

To determine the number of gallons of water per minute required, the temperature difference between the inlet and outlet water of the radiators must be known. A 20° temperature drop is recommended as the most economical for the type of system described here. The calculation is then as follows:

$$\frac{120{,}000 \text{ BTU}}{20 \times 60 \times 8} = 12.5 \text{ gallons per minute}$$

Explanation:

20 = Temperature drop in degrees between radiator inlet and outlet water.

60 = Minutes in one hour.

8 = Pounds of water in one gallon at 215° F.

—or, more simply expressed, dividing the total number of BTU by 9600 (20 x 60 x 8) equals the gallons of water per minute needed to carry the radiation load. **For quick figuring, it is safe to divide by 10,000 instead of 9600.**

For designing systems on other than a 20° temperature drop see page 37.

STEP No. 4

SELECTION OF B & G BOOSTER

In step No. 3 we have established 12.5 gallons of water per minute as the amount required to carry a heating load of 120,000 BTU at a 20° temperature drop. The Capacity Chart on Page 38 will show you how to select the proper size Booster to handle this quantity of water at the least initial and operating cost.

Look first at the bottom of the Chart, where Booster delivery in gallons of water per minute is shown. Run a line straight upward from the 12.5 gallon point until it intersects the first pump capacity curve *above* 2½

DESIGNING A B & G MONOFLO HOT WATER HEATING SYSTEM (continued)

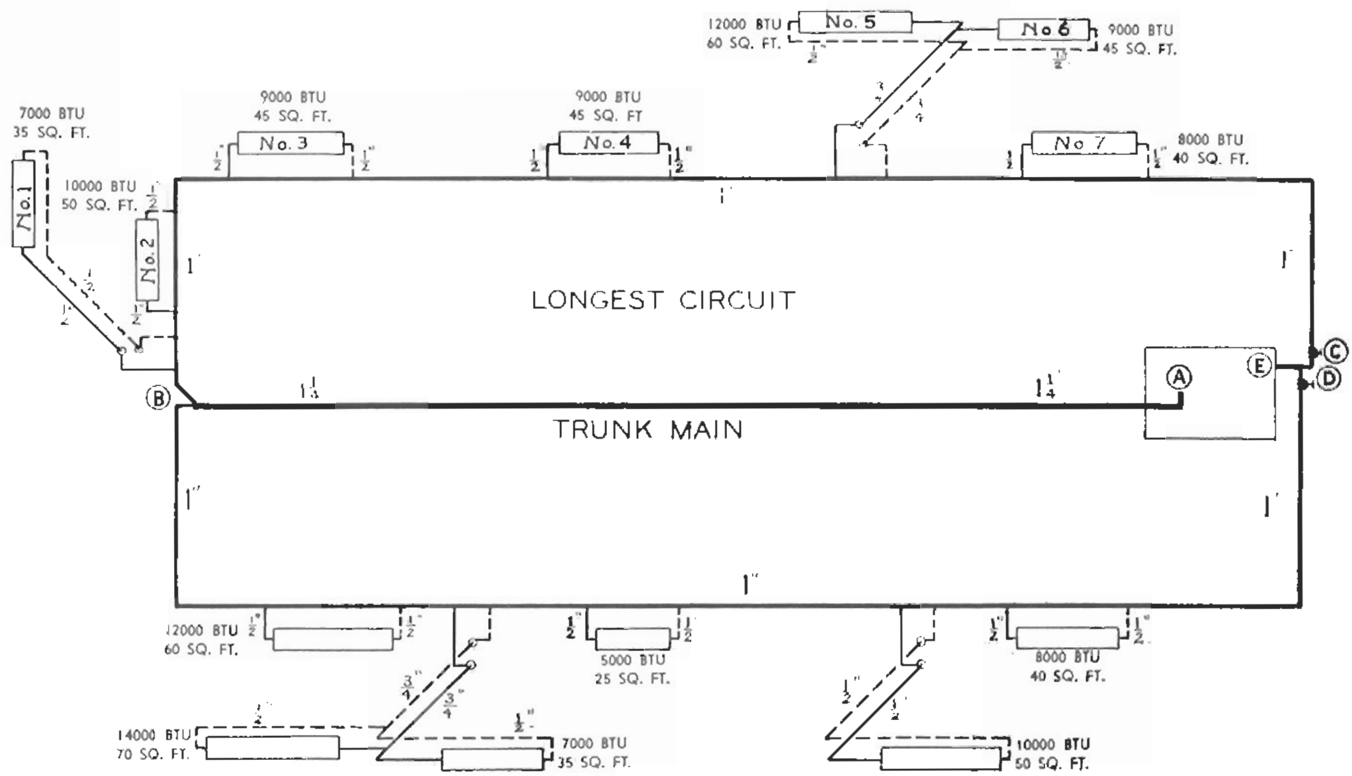


Fig. 49. Example of Monoflo forced hot water system piping layout.

Step No. 4 (continued)

feet of head pressure. This occurs at 4¾ feet of head pressure on the curve of the 1″ Booster. Hence a 1″ Booster will deliver 12.5 gallons of water per minute against a Pressure Head of 4¾ feet.

Some degree of judgment should be used in selecting a Booster. It may be more economical to go to a larger size pump with a higher Head Pressure because of the savings made in pipe sizes. In this example, a trial calculation shows that the increased cost of a 1″ Booster over that of a ¾″ is more than offset by the reduced cost of smaller piping. Good practice, however, indicates that Head Pressures should be such that pipes are sized at not greater than 500 milinches resistance per foot.

STEP No. 5

PIPE SIZING

SIZING THE MAINS

To cause a flow of water in a hot water heating system, the Pressure Head must be equalled by the Friction Head. In a gravity system, Pressure Head is produced by the difference in the weight of the water in the supply and return lines. In a forced circulation system, Pressure Head is produced by the Booster.

Since a pump increases the Pressure Head beyond that of a gravity system, sufficient equalizing resistance, or Friction Head, is introduced by making the pipes much smaller than in the ordinary gravity system.

The example sketch shows a double circuit installation carrying 600 sq. ft. of 200 BTU radiation. The longest circuit A-B-C carries 320 sq. ft. and the shorter circuit A-B-D carries 280 sq. ft.

The resistance of the piping must now be figured in order to size it correctly. As all fittings have a greater resistance to the flow of water than a straight length of pipe, this must be taken into account.

For quick figuring, it is safe practice to consider the resistance of the fittings in any circuit to be 50% of the resistance offered by the straight lengths of pipe. The sum of the lengths of straight pipe plus 50% is called the TOTAL EQUIVALENT LENGTH.

The method of determining the Total Equivalent Length by actual calculation of the resistance of various fittings in any given pipe circuit is shown in Problem 1 on page 36, but for the average smaller installation, the above rule is sufficiently accurate.

In forced hot water heating systems having more than one circuit, the Total Equivalent Length of the *longest circuit only* is considered. The longest circuit is selected because it obviously offers the greatest resistance. Therefore, if the pump head is sufficient to circulate this circuit, it will be more than adequate to circulate all other circuits.

Assume that the length of the longest circuit shown in the sketch is 90 feet. This measurement includes the trunk and longest supply main.

DESIGNING A B & G MONOFLO HOT WATER HEATING SYSTEM (continued)

Step No. 5 (continued)

Therefore:

90 ft. (straight pipe) + 45 ft. (50% of straight pipe for equivalent pipe length of fittings) = 135 ft. Total Equivalent Length

Now refer to the Pipe Sizing Table on Page 39. Table A shows Total Equivalent Pipe Lengths for Pressure Heads from 2 ft. to 100 ft. Table B gives the carrying capacities (in thousands of BTU) of various sized pipes at different Friction Heads. The Friction Heads are expressed in milinches (see page 21 for definition of milinch).

Reading to the right from 4½ ft. Head Pressure, (which is the closest and next lower Head Pressure to the required 4¾ ft.), the closest Equivalent Length to our system length of 135 ft. is found to be in the 400 milinch column and is exactly 135 ft. (Table A).

Following down this column into Table B, the figure closest (and next largest) to our calculated 120,000 BTU is 140,000. Reading to the left, a 1¼" pipe is indicated as the size required by the Trunk Main.

The supply main of the longest circuit carries 64,000 BTU (320 sq. ft. of radiation). Reading in the same column of Table B, a 1" pipe is shown to be necessary. *This same size is carried all around the circuit!*

SIZING THE RISERS

The risers of a Monoflo System should be sized from Table C on page 40, working in the same column (400 milinches) used in Table B.

Note that this table is divided into two sections—one showing the capacities of risers with a Monoflo Fitting at *both* supply and return connections—and one showing the capacities of risers with a Monoflo Fitting at one riser only. The reason for the division is this:

In any hydraulic system there must be a drop in pressure or there will be no flow. This statement applies to a hot water heating system, and to any part of it, including any particular length of pipe, any radiator or the boiler. For example, if the pressure at the supply end of a radiator is the same as the pressure at the return, no water can flow through the radiator.

Thus, the force which causes the flow through a branch is the difference in pressure at the supply and return ends of the branch. If this pressure difference is high, the flow will be large; if it is low, the flow will be small.

If one Monoflo Fitting and a common tee are used to connect a riser to the main, the pressure drop across them is considerably lower than the pressure drop across *a pair of* Monoflo Tees. Consequently, the flow of water is less and the BTU carrying capacity of any given pipe size is smaller than when two Monoflo Fittings are used.

This difference in capacity is clearly shown in the two divisions of Table C.

The decision as to whether to use one Monoflo Fitting or two is governed by the size and distance from the main of the connected radiator or radiators.

The characteristics of the heating system we are working on have caused it to be pipe-sized in the 400 milinch column. Radiator No. 1 carries 7,000 BTU and is located on the second floor. Referring to the 400 milinch column in the Pipe-Sizing Table for Risers we find that 14,000 BTU will be carried by a ½" pipe if two Monoflo Fittings are installed. This is greater than the required 7,000 BTU, so we drop down into the table showing pipe carrying capacities with *one* Monoflo Fitting. Here a 7,000 BTU Radiator on the second floor is shown to be handled by a ½" pipe.

Therefore the obvious selection is to use a ½" pipe and one Monoflo Fitting.

Radiator No. 2 requires 10,000 BTU and is on the first floor. Reference to the Table shows that this number of BTU will be carried by a ½" pipe with one Monoflo Fitting. The same pipe size applies to radiators Nos. 3, 4 and 7.

Radiators Nos. 5 and 6 on the second floor are taken off the same riser and carry a combined load of 21,000 BTU. As shown by the Table, this load can be carried by a 1" pipe and one Monoflo Fitting or a ¾" pipe with two Monoflo Fittings. Comparison will show that material cost is practically the same for either method of installation.

The schedule of radiator riser sizes and number of Monoflo Fittings for the longest circuit is shown in the table below.

Radiator No.	Riser Sizes	Fittings	Radiator No.		Riser Sizes	Fittings
1—2nd Floor	½"	1	5—2nd Floor	Taken	¾—½"	
2—1st Floor	½"	1		Off One		2
3—1st Floor	½"	1	6—2nd Floor	Riser	¾—½"	
4—1st Floor	½"	1	7—1st Floor		½"	1

MONOFLO FITTINGS FOR RADIATORS BELOW THE MAIN

Each radiator below the main must be equipped with TWO Monoflo Fittings. The added resistance provided by two Fittings is necessary because circulation to a radiator below the main is working against the natural tendency of heated water to *rise.* Table C also lists pipe capacities for down-fed radiators.

DESIGNING A B & G MONOFLO HOT WATER HEATING SYSTEM (continued)

STEP No. 6

SELECTING A BOILER

Selection of a properly sized boiler should be in accordance with the standards of the Heating, Piping and Air Conditioning Contractors' National Association, "Net BTU Load Recommendations for Heating Boilers."

NOTE! Inasmuch as the hot water ratings in some manufacturers' bulletins are based on 150 BTU per square foot heat emission, care should be taken to correct these ratings for the BTU emission of the system you are designing. It is necessary to install a water boiler of the same size and number of sections as required for steam when using a heat emission factor of 240 BTU.

MONOFLO SYSTEM INSTALLATION DETAILS

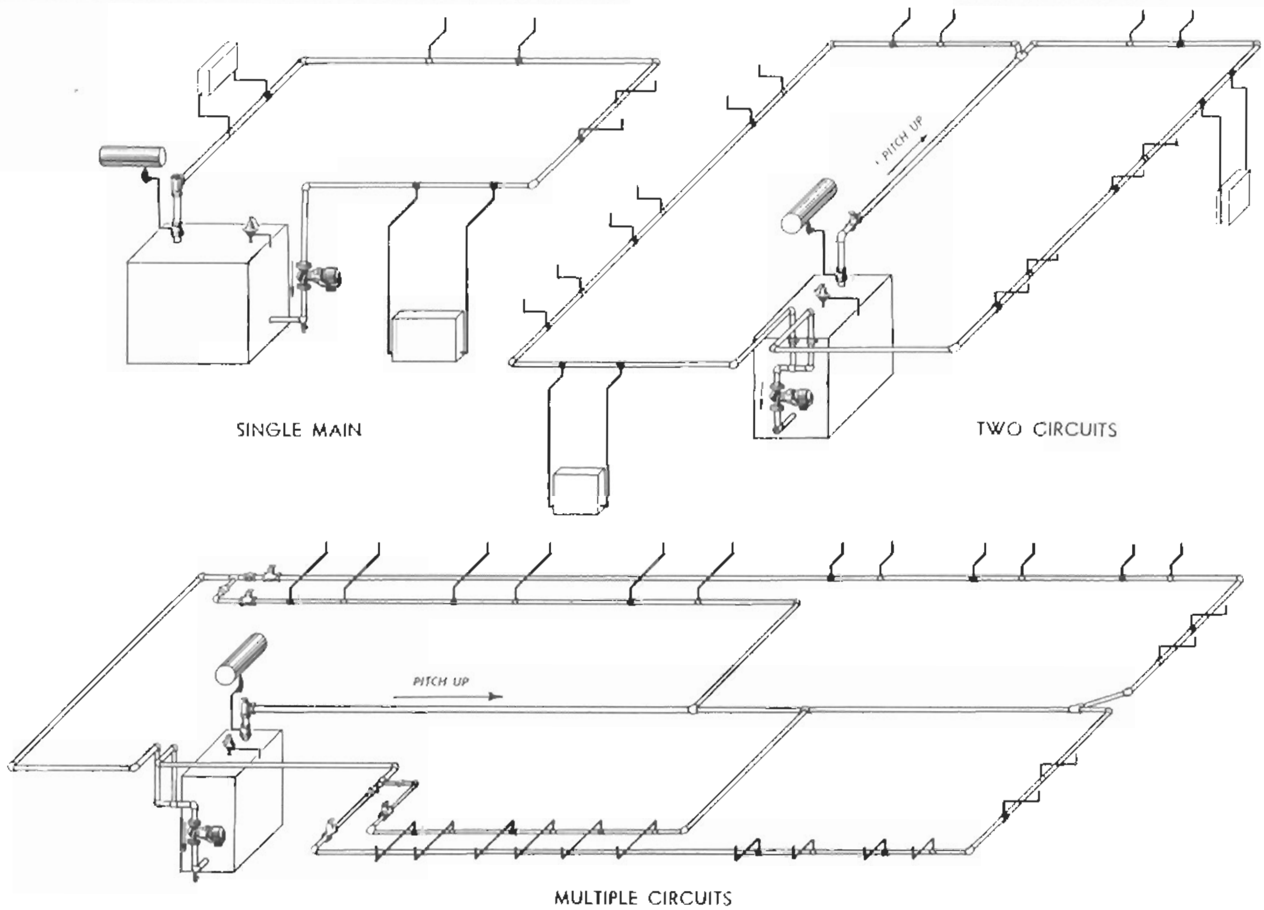


Fig. 50. Typical circuits employed in Monoflo System design.

GENERAL PLAN

This should be as simple as possible, following a pattern which will serve each radiator with a short branch, if this can be accomplished without lengthening the main unduly or creating an unreasonable number of breaks in its direction or level.

LOCATION OF BOILER

The boiler can be placed at any convenient location. It can be located in the basement, or on the ground floor, or in a detached building. The B & G Monoflo System permits the installation of all or any part of the radiation below the level of the main which eliminates the necessity of excavating for a boiler room only.

TRUNK AND SUPPLY MAINS

When the main is to be divided into two or more circuits, no radiator connections should be taken off the trunk main which feeds the supply mains. In cases where the supply mains are smaller than the trunk main, the reduction should be made by means of eccentric reducers, keeping the tops of the pipes level. See next page.

MONOFLO INSTALLATION DETAILS (continued)

Note here that one of the major differences between sizing a two-pipe and a B & G Monoflo installation is that in the latter system, the supply mains are kept at one size all through the circuit, instead of reducing them as radiators are taken off the line.

LEVELS AND GRADING OF TRUNK AND SUPPLY MAINS

Where conditions demand it, it is perfectly permissible to run one part of a circuit at a higher level than the balance of it, or one circuit at a higher level than its companion circuit, or to run one trunk main to circuits higher than those served by another trunk main. Naturally, these changes in level will add to the friction loss of the system. In determining the Equivalent Length of the longest circuit, the lengths of vertical pipe must be added to the lengths of horizontal pipe. It is also necessary that the high points be automatically vented.

SUPPLY TRUNK CONNECTIONS

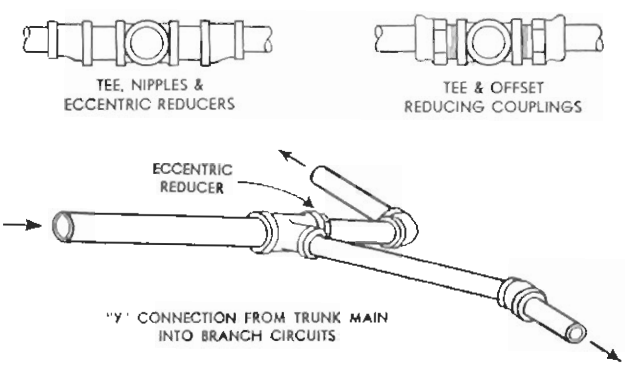


Fig. 51. Supply trunk connections for B & G Monoflo System.

In the case of divided circuits, it is frequently possible to plan the mains in such a manner that the return ends of the supply mains can be dropped directly into a pump header connected to the boiler. Otherwise a return trunk main should be employed to complete the connection to the boiler. *Do not use bull head connections on any returns!*

If most of the radiation is above the main, B & G Monoflo System mains can be carried level or graded. If graded, be sure that the mains pitch-up in the direction of water flow and are vented automatically at the high point. Mains run level must be accurately checked for level.

Where all radiation is below the main, pipes must be graded up ½" in 10 ft. in the direction of water flow, and the high points automatically vented.

PUMP CONNECTIONS

The pump should be installed in either the supply or return main as close to the boiler as possible. It is good practice to install a square head cock or gate valve on each single circuit and between the pump and

RETURN TRUNK CONNECTIONS

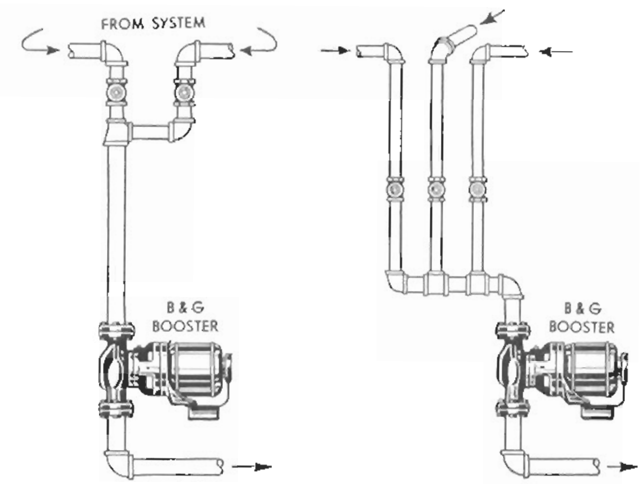


Fig. 52. Return trunk connections for Monoflo System—two or more circuits.

the boiler.

VENTING DOWN-FEED RADIATORS

To automatically vent air in branches to down-fed radiators, connections should be made as in Fig. 83, page 50.

COMPRESSION TANK

It is recommended that the B & G Monoflo System be installed as a closed system with a compression tank.

Use a regular, tested B & G Compression Tank—range boilers or galvanized water tanks are not designed for this purpose.

UNBALANCED CIRCUITS

Where one main circuit is considerably shorter than the other, smaller friction loss will obviously cause a faster circulation in the shorter circuit. To compensate for this, a square head cock or gate valve should be installed as indicated in Fig. 52, so that flow of water can be throttled down in the shorter circuit. Thermometers located in the returns ahead of the square head cocks provide an accurate check on the balance of the system.

LIMITATIONS OF PIPE SIZE

Mechanically or from the standpoint of water temperature, there is virtually no limit to the number of radiators which can be taken off a single main circuit. B & G Monoflo Fittings are carried in stock in sizes ¾" - 1" - 1¼" - 1½" - 2" - 2½" and 3" in cast iron, and ¾" to 2" in copper, because under ordinary circumstances, larger sizes are not necessary. When pipe sizing according to the B & G method, if the mains figure out to be larger than 3", they should be divided into the number of circuits necessary to keep pipe within the maximum size of Fittings. Except on very small jobs, a more flexible installation can be obtained by dividing the system into two or more circuits.

MONOFLO SYSTEM INSTALLATIONS

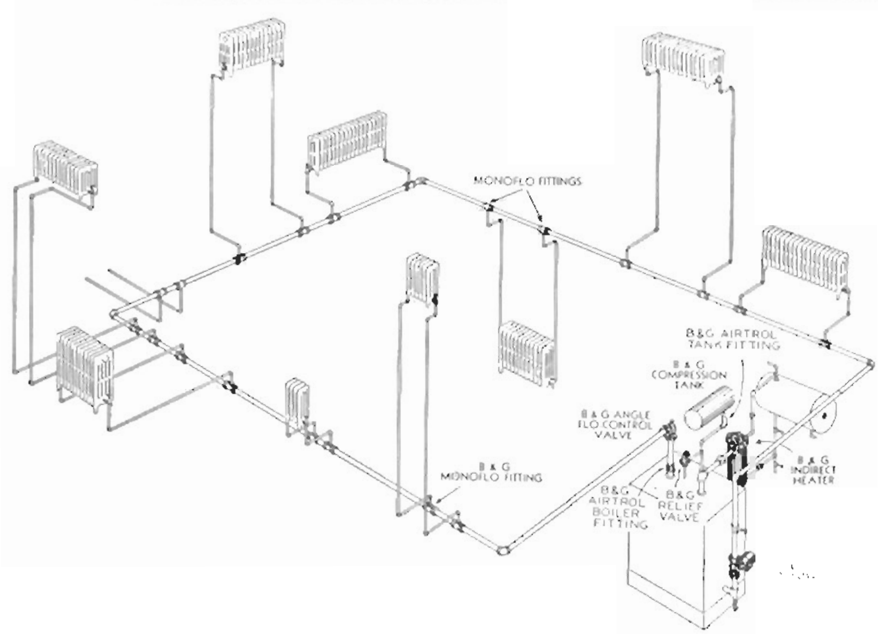


Fig. 53. Typical single circuit B & G Monoflo System with year around domestic hot water supply.

ZONING

A zoned system, particularly in large buildings, where a single control is impractical, offers a very satisfactory method of obtaining more comfortable and economical heating.

Zoning a forced hot water heating system consists of setting up a number of individual circuits, as determined by exposure, number of apartments or difference in character of occupancy.

For example, a factory building might require 70° in the office, 65° in the machine shops and only 50° in storage rooms. Establishing three zones, each separately controlled would permit each zone to be held at the desired temperature.

In apartment houses, zoning each apartment enables the occupants to enjoy the temperature they most prefer. Likewise, zoning can be employed to compensate for the greater heat loss on exposed walls, thus preventing over and underheating.

Accurate control is achieved by equipping each zone circuit with a Booster pump, Flo-Control Valve and individual temperature control, or, by using one Booster and a thermostatically controlled Motorized Valve installed in each of the various supply circuits.

Typical examples of zoning are shown below and on pages 32 and 33.

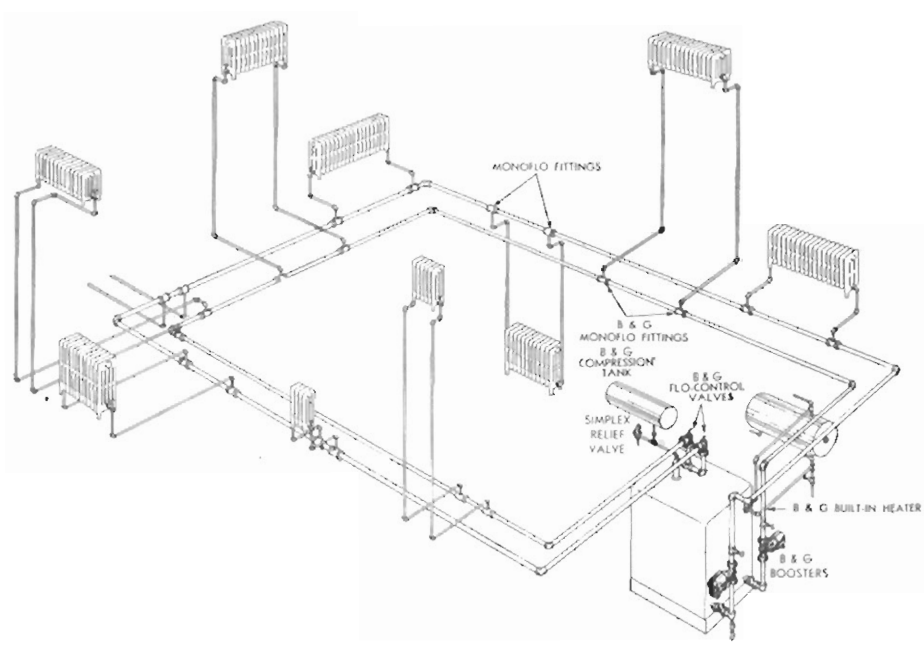


Fig. 54. Typical example of a two zone B & G Monoflo System.

MONOFLO SYSTEM INSTALLATIONS (continued)

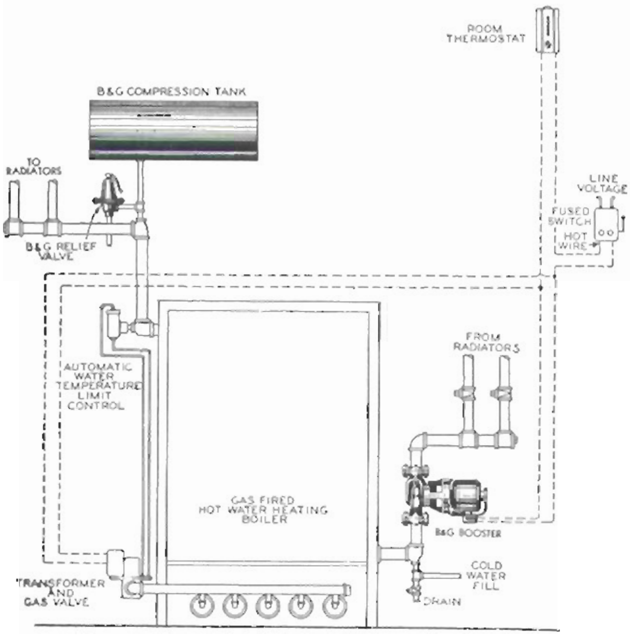


Fig. 56. Connections for gas-fired boiler—either Monoflo or two-pipe system.

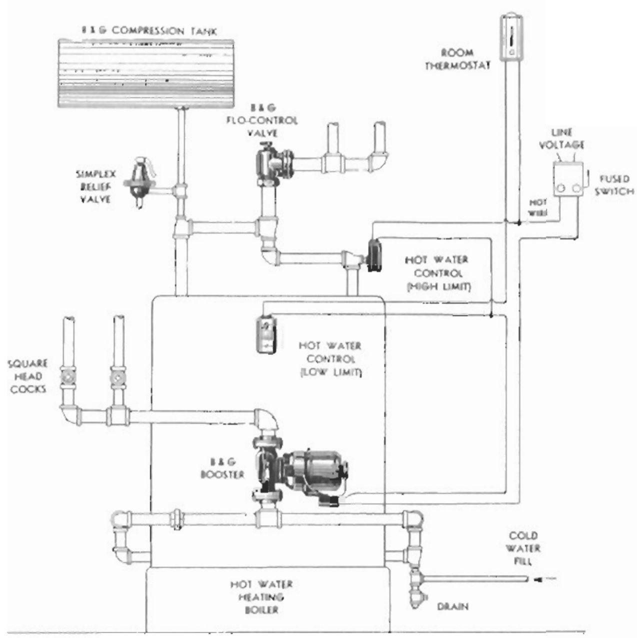


Fig. 58. Connections for round, hand-fired boiler with forced circulation.

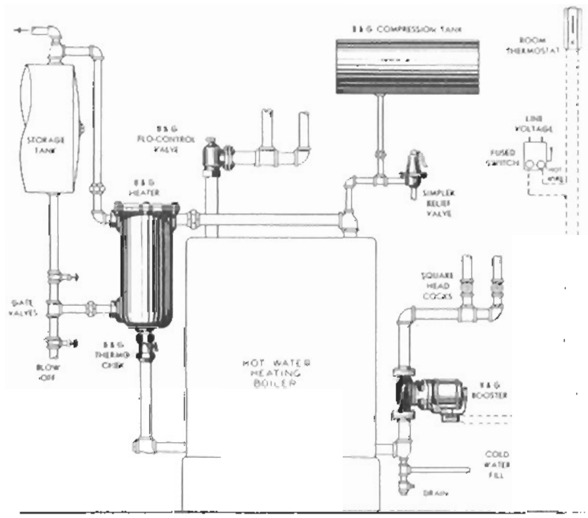


Fig. 57. Connections for round, automatically-fired boiler—either Monoflo or two-pipe system.

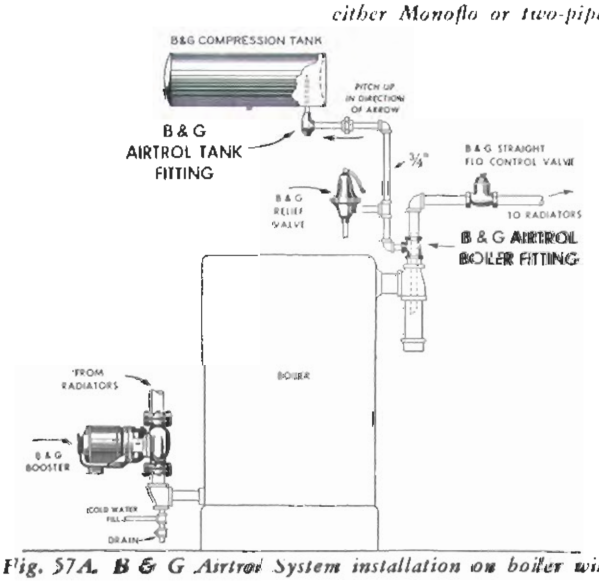


Fig. 57A. B & G Airtrol System installation on boiler with side opening.

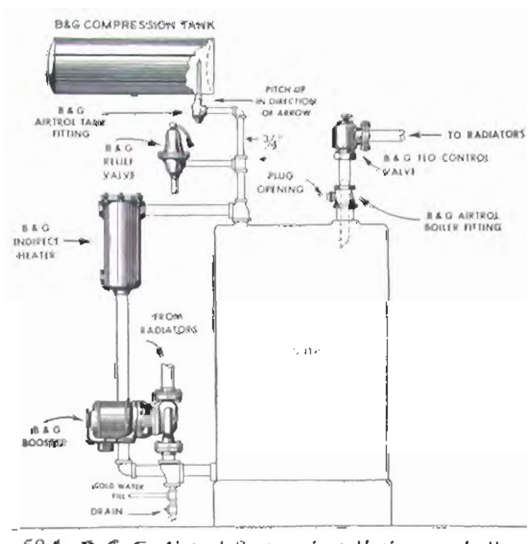


Fig. 58A. B & G Airtrol System installation on boiler, (side view) with external type water heater.

MONOFLO SYSTEM INSTALLATIONS (continued)

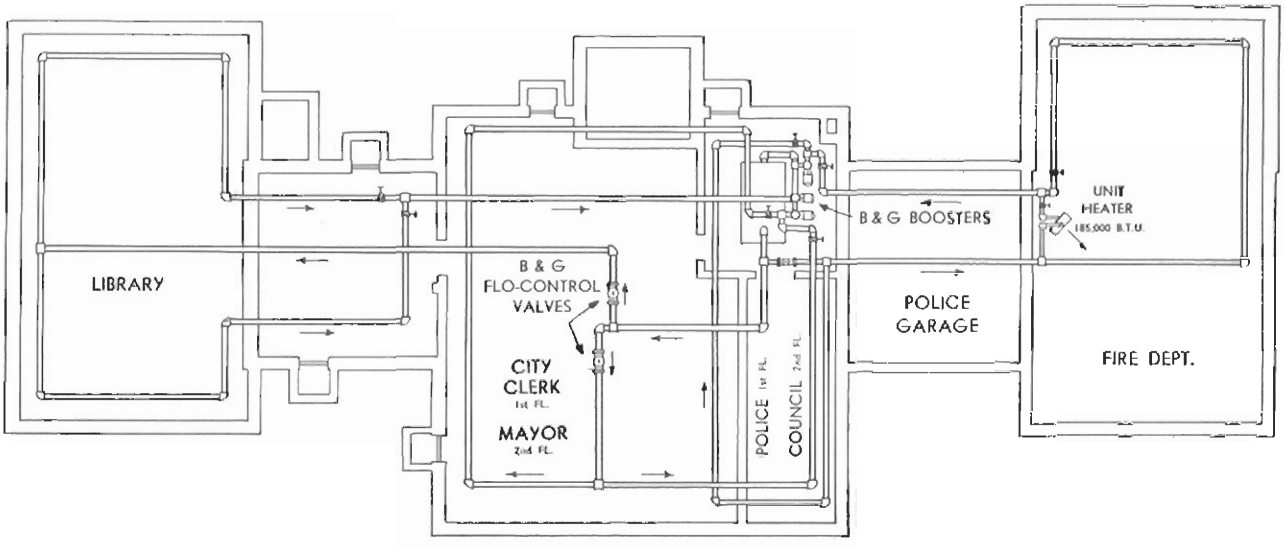


Fig. 59. This diagram is an excellent example of zoning for occupancy. The layout is for a Municipal Building, with occupancy of widely varying characteristics. Zone No. 1 heats the Police Garage and Fire Department which require continuous heat. Zone No. 2 supplies the offices of the Mayor, City Clerk and Council Rooms, having usual office hour heating requirements. Zone No. 3 supplies the Library, which has longer hours of occupancy than the offices. This particular installation is coal-fired and has shown an exceptionally low operating cost.

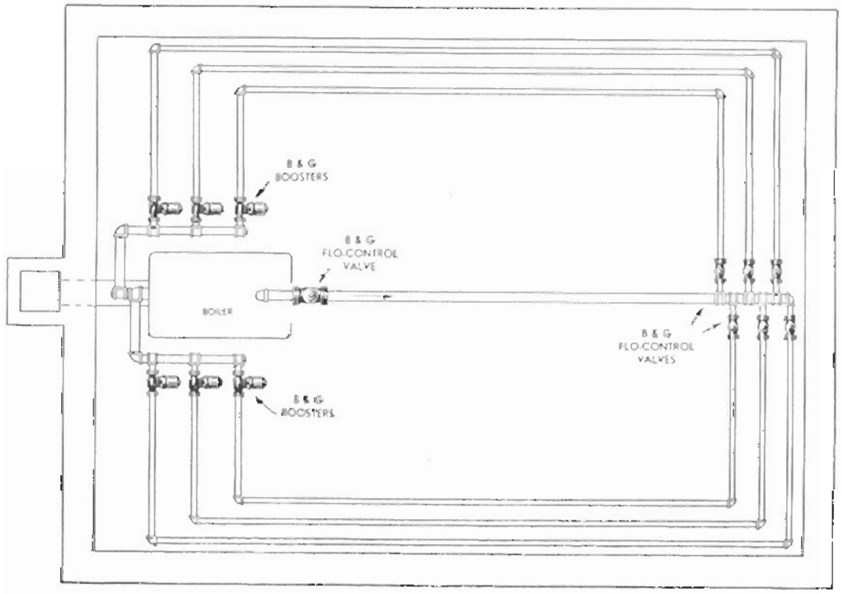


Fig. 60. This diagram shows a six zone layout for an apartment house. Each apartment is on a separate circuit, with heating controlled by a Booster and room thermostat. The occupants of each apartment may thus enjoy the temperature they prefer without affecting the comfort of other tenants.

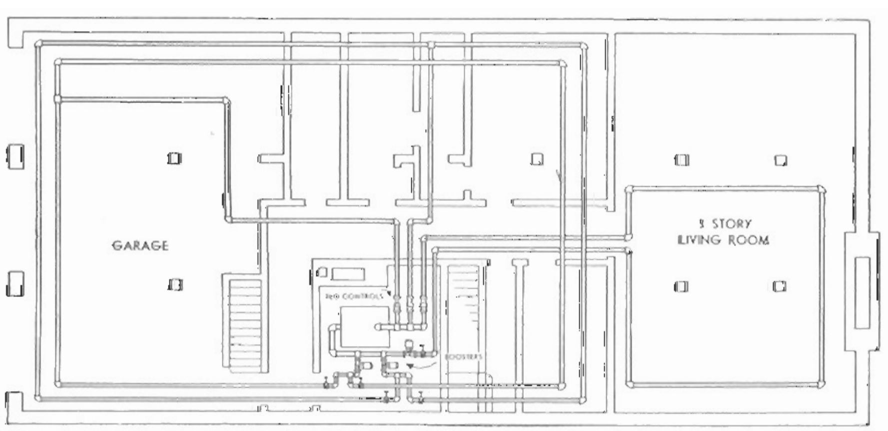


Fig. 61. A three zone Monoflo System layout for a large residence. One zone heats the garage, another supplies heat to the second floor and part of the first floor. The third zone is devoted to heating the studio living room, which is three stories high and requires 680 sq. ft. of radiation.

MONOFLO SYSTEM INSTALLATIONS (continued)

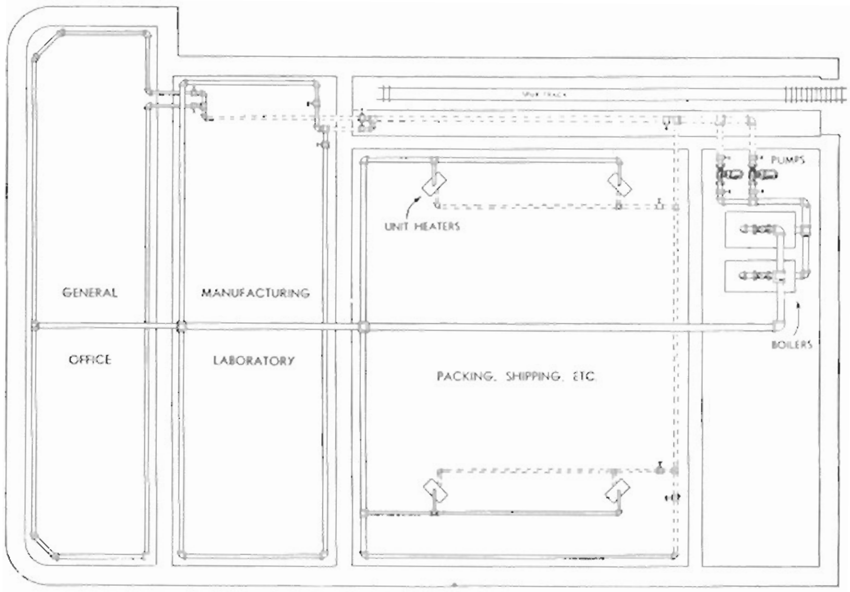


Fig. 62. A long, low factory building equipped with a zoned Monoflo System. Note the unit heaters—installed on a two-pipe reverse return circuit.

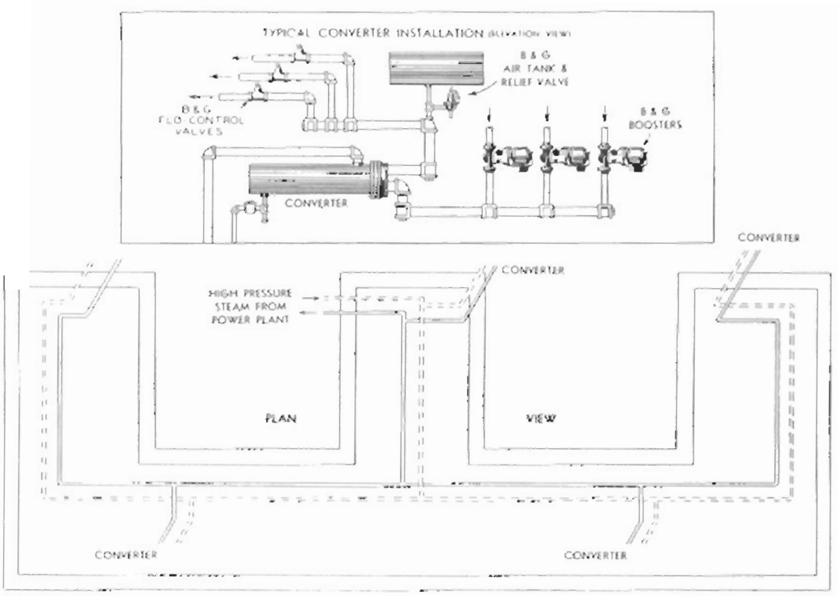


Fig. 63. An example of the use of steam convertors to supply hot water for the heating circuits. This is a hospital installation, in which steam is required for sterilizing, cooking, etc. Five convertors furnish hot water for fourteen zones, each controlled by a B & G Booster and Flo-Control Valve

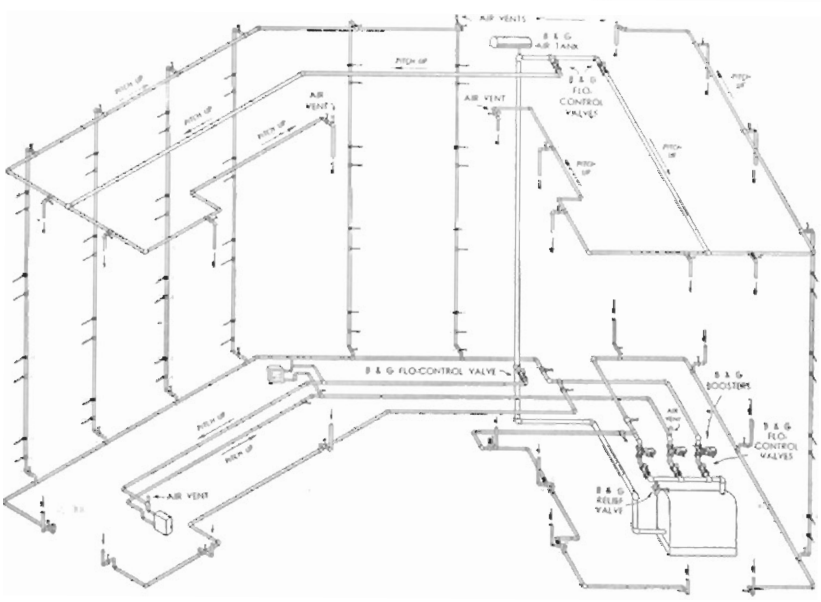


Fig. 64. A three zone, down-fed Monoflo System, supplying heat to four floors and the basement. Note that mains pitch-up with the flow of water to help air reach the venting point.

MONOFLO SYSTEM INSTALLATIONS (continued)

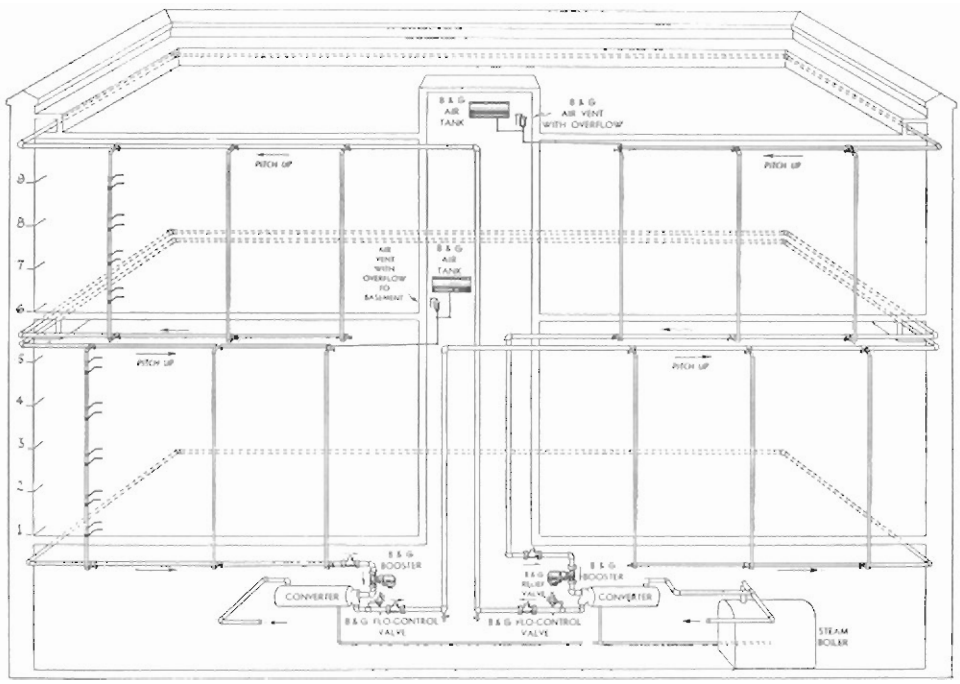


*Fig. 65. A **nine** story Monoflo System installation with hot water supplied by two **convertors** connected to a steam boiler. **Note** that mains pitch-up with the **flow** of water to help air reach the venting point*

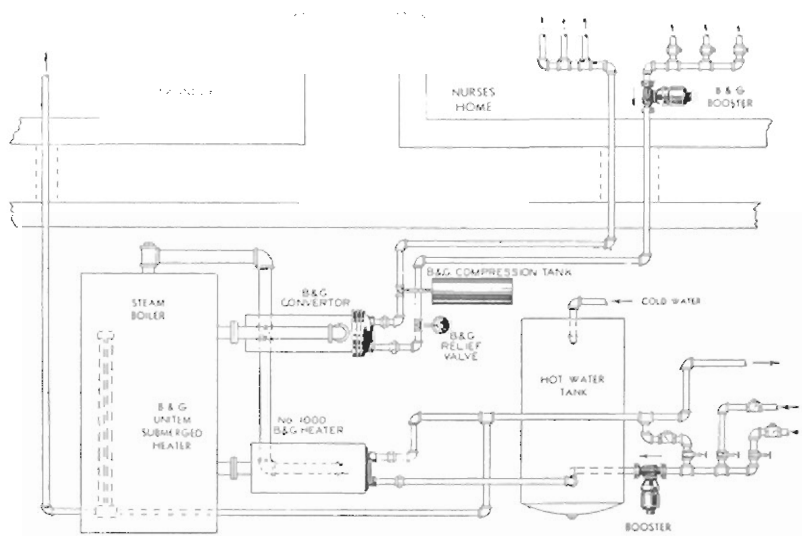


*Fig. 66. In this installation a detached **building** is **heated** by forced hot water supplied by a B & G Indirect Heater connected to a steam boiler. A **second heater supplies** hot water to a storage tank. **When** hot **water is** required in the laundry, it is **drawn from the tank** and passed through a B & G **Unitem** Heater **in** the boiler, where it is superheated.*

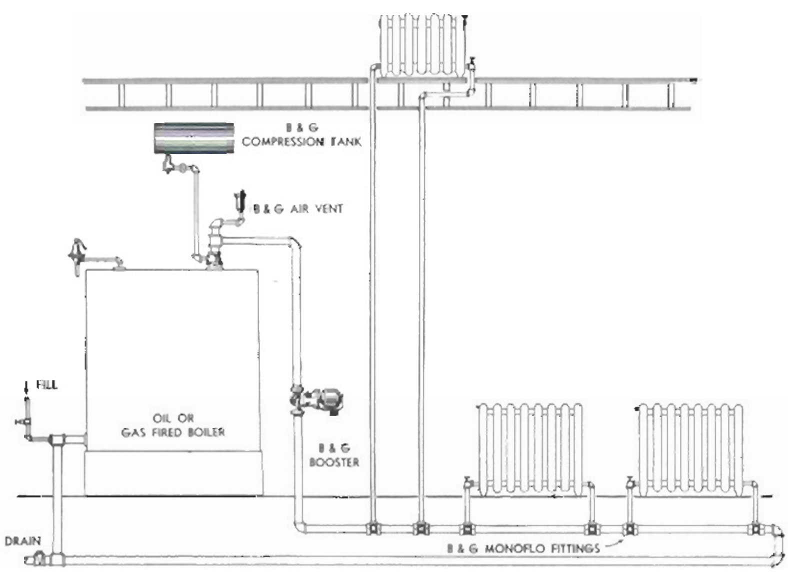


Fig. 67. An excellent installation where part of the radiation is on a level with or below the boiler.

MONOFLO SYSTEM INSTALLATIONS (continued)

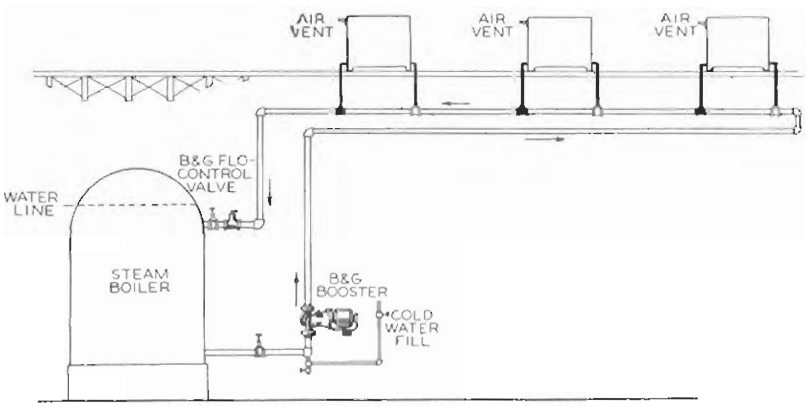


Fig. 68. In factories, warehouses and garages with a steam boiler, but where steam pressures are not required constantly, the above installation provides a very satisfactory method of heating the offices with hot water.

Radiators must not be more than 7 feet above the water line of the boiler and the top connection from boiler must be at least 6 inches below normal water line.

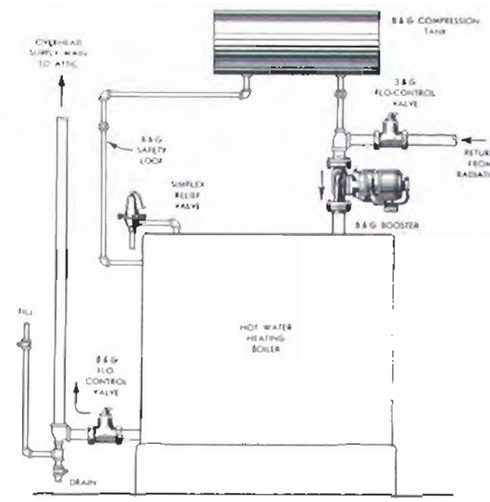


Fig. 69. This diagram shows the proper connections for an overhead main system.

PIPE SIZING CONVECTOR AND UNIT HEATER SYSTEMS

The use of copper convectors on hot water heating systems requires special consideration of the pressure drop through the units. Generally speaking, the water passages through a convector are small in comparison with the passages of a cast iron radiator and hence interpose a greater resistance.

This means that the amount of water required to deliver the rated capacity of the unit must move through the unit with a relatively high velocity. Otherwise, there will be a high temperature drop between the inlet and outlet of the unit, with a resulting low average temperature and a lower emission rate than the rated capacity.

First, obtain from the manufacturer the pressure drop of his heating units in milinches. Next, determine the pump and main size as explained on pages 25 and 26. To size the risers, use Conversion Chart 8 on page 43 in accordance with number of Monoflo Fittings used per branch.

EXAMPLE — INSTALLATION WITH TWO MONOFLO FITTINGS

Assume that a system is designed on a 20° temperature drop with a 300 milinch resistance in the main. A 10,000 BTU Convector on the second floor has a pressure drop through it of 3360 milinches. The risers, equipped with two Monoflo Fittings should be sized as follows:

Reading upward from the 300 milinch point on the Conversion Chart to the intersection with 3360 milinch loss in the heating unit indicates that the riser capacity is only 75% of the value in the standard Monoflo riser table.

The capacity of a ½" pipe with cast iron radiation is shown in the table to be 11,000 BTU. 75% of this is 8250 BTU. Since the radiator requires 10,000 BTU, it is necessary to go to a ¾" pipe.

If riser capacities are shown to be less than 25% of the standard Monoflo pipe capacity table, it is advisable to recalculate the system, using a larger pump with correspondingly higher head pressure. This will make available a higher milinch per foot pressure in the main, which may also result in a smaller main size.

Where both convectors and cast iron radiators are used, the system should be so designed that each type is on a separate circuit, so that the pipe can be sized in accordance with differing requirements.

UNIT HEATERS

Where unit heaters comprise either all or part of the heating units in the system, it is recommended that they be installed on a two-pipe circuit, rather than a Monoflo circuit. This is because the high pressure drop through the unit and the large quantities of water involved exceed the diversion capacities of standard size Monoflo Fittings. A good example of correct piping for a system employing both cast iron radiation and unit heaters is shown in Fig. 62, page 33.

METHOD OF SIZING FOR ANY CIRCUIT OF A SINGLE PIPE MAIN EQUIPPED WITH B & G MONOFLO FITTINGS AND CAST IRON RADIATORS

For sizing Convector Circuits see page 35.

NOTE! This section is intended for use by the heating engineer on large or unusual installations where extreme accuracy of design is necessary.

The force available to divert water from a single pipe main equipped with B & G Monoflo Fittings is produced by the special insert in the fittings and varies in direct proportion to the flow in the main. Chart No. 7 on page 43 shows the force available at any rate of flow through one or two Monoflo Fittings.

The procedure for pipe sizing the individual circuits of a system should be as follows:

G.P.M. Needed. Determine the gallons of water per minute needed to deliver the required amount of heat.

$$\frac{\textbf{Total BTU Heat Loss}}{\textbf{9600}} = \textbf{G.P.M.}$$

Pump Selection. Select a pump from chart on page 38 at the desired Pressure Head.

Total Equivalent Length of Main. Measure the length of the longest main circuit and add 50% to give the Total Equivalent Length.

Main Size. From Tables A and B on page 39, size the main. This will establish the size of the Monoflo Fittings needed.

Total Equivalent Length of Radiator Supply and Return Riser. The piping from the main to the radiator and back to the main should be considered as a separate circuit. Measure this length and add to it the equivalent length of the fittings, radiator valve, cast iron radiator, etc. (see page 38 for table of Elbow Equivalents).

The calculation now requires some "trial and error" methods before the correct pipe size of the radiator circuit can be determined. The diagram on this page will serve as the basis for a typical calculation.

PROBLEM NO. 1

First consider the circuit as being a ½" pipe supplying a 10,000 BTU radiator on the third floor. The Total Equivalent Length therefore is—

41' Straight Pipe + 12 Ells =

$$41' + \frac{12 \times 25 \times ½''}{12 \text{ inches}} = 53'$$

Referring to the table of BTU carrying capacities on Page 39, we find that a ½" pipe carries 11,000 BTU at a 200 milinch loss per foot. Since the Total Equivalent Length of the radiator circuit is 53' the total milinch resistance is—

53' × 200 Milinches = 10,600 Milinches

Assume that the G.P.M. required for the main circuit from which this branch is taken is 20 gallons and

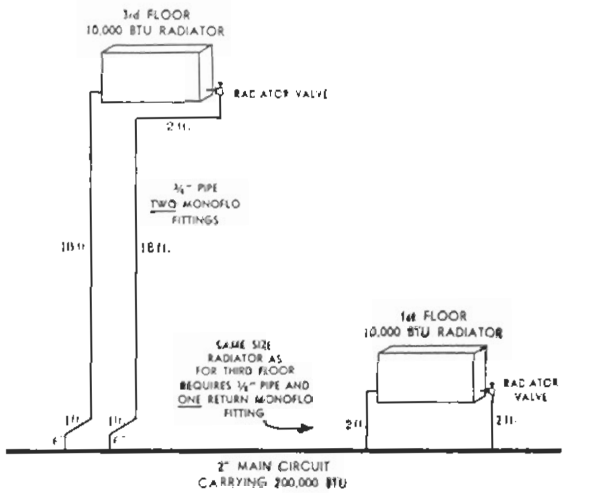


Fig. 70.

that the main size is 2". Refer now to Chart of "Pressure Drop Curves of B & G Monoflo Fittings" on page 43. Reading upward from the 20 gallon point to the intersection with the 2" curve in the lower Chart, the available force is shown at the left to be 2,000 milinches. This is obviously too low to meet the milinch resistance through the radiator circuit.

Continuing into the upper Chart, we find that two 2" Monoflo Fittings provide a force of 3,800 milinches, which is still below the resistance of 10,600 milinches in the radiator circuit.

The radiator circuit, therefore, must be recalculated as above but as a ¾" pipe. As a ¾" pipe the Total Equivalent Length of the circuit becomes 59'. Referring again to the BTU carrying capacity table, 11,300 BTU is shown to be carried in a ¾" pipe at 50 milinches per foot. Therefore, the total resistance in the radiator circuit is—

59' × 50 Milinches = 2950 Milinches

We have shown above that a force of 3,800 milinches is made available by two 2" Monoflo Fittings, which is more than ample to overcome the 2,950 milinch resistance in the radiator circuit.

If this same sized radiator were on the first floor, connected with ½" pipe and the Total Equivalent Length was 10', then —

METHOD OF SIZING FOR ANY CIRCUIT OF A SINGLE PIPE MAIN (continued)

10′ × 200 Milinches = 2000 Milinches

2000 milinches resistance would be overcome by the 2000 milinch force made available by a single 2″ Return Monoflo Fitting.

PROBLEM NO. 2

Sizing the piping circuit for convector radiators with known pressure drop

Suppose that all conditions remain as in Problem No. 1, on page 36, but instead of a cast iron radiator, we substitute a convector with a pressure drop of 1000 milinches when circulating the amount of water necessary to deliver the rated capacity of the unit.

The total equivalent length of the circuit, therefore, changes from—

41 feet + 12 ells to
41 feet + 9 ells

since we have eliminated the 3 elbow equivalents of the cast iron radiator. This makes our Total Equivalent Length—

$$41 \text{ feet} + \frac{9 \times 25 \times 3/4''}{12} = 55 \text{ feet}$$

55 feet × 50 milinches = 2750 milinches. To this 2750 we must add the milinch resistance of the convector or—

2750 + 1000 = 3750 milinches

This is the total resistance of the circuit. The previous calculation shows that the head made available by the 2 Monoflo Fittings (3800) is sufficiently large to overcome the 3750 milinch resistance in the circuit.

PROBLEM NO. 3

Now consider the problem of a convector circuit having a pressure drop considerably higher than the available head across the Monoflo Fittings.

For example, assume a convector circuit having a convector with a pressure drop of 2000 milinches at an output of 20,000 BTU. Assume the circuit is connected to a 1½″ main in which there is flowing 17.5 GPM, and that pipe sizing is being done in the 300 milinch column. First, consider the convector circuit as being ¾″ pipe supplying the required BTU to a third floor convector.

The total equivalent length, therefore, is—

$$41 \text{ feet} + \frac{9 \times 25 \times 3/4''}{12} = 55 \text{ feet}$$

From Table B, page 39, we find a ¾″ pipe will carry 20,000 BTU at a loss of 150 milinches per foot.

Therefore, the pressure drop in the circuit becomes:

55 feet × 150 milinches
+ 2000 milinches (for convector) = 10250 milinches

The available head with a flow of 17.5 GPM across a pair of 1½″ Monoflo tees is 8250 milinches. Since the total loss through the convector circuit is greater than the available head, a larger riser size is required.

Therefore, recalculate on the basis of using a set of risers one pipe size larger.

The resistance of 1″ pipe when carrying a BTU load of 20,000 is 50 milinches per foot (Table B, 50 milinch column). The total equivalent length now becomes—

$$41 \text{ feet} + \frac{9 \times 25 \times 1''}{12} = 59 \text{ feet}$$

Total resistance is:

59 feet × 50 = 2950 milinches +
2000 milinches = 4950 milinches

The total resistance of 4950 milinches is considerably less than the available head of 8250 milinches. Therefore, a 1″ riser size with a pair of Monoflo tees will amply satisfy the requirement. Since the actual losses are considerably less than the available head (8250—4950), this suggests a further calculation to check the possibility of the use of a single Monoflo Fitting.

Checking Chart 7, Page 43 for a single Monoflo Fitting shows that with a flow of 17.5 GPM in the main, a head of 3600 milinches is available. Since the loss of 4950 milinches exceeds this figure, the required riser sizes are 1″ with two Monoflo Fittings.

PIPE SIZING FOR 10° TEMPERATURE DROP

Heating systems are sometimes calculated on a 10° temperature drop, which doubles the amount of circulated water required by a 20° drop.

Assuming a total heat loss of 100,000 BTU with a 10° temperature drop, the formula for converting BTU into gallons of water is:

$$\frac{100{,}000 \text{ BTU}}{10 \times 60 \times 8} = 20.8 \text{ gallons per minute}$$

Since all Pipe Capacity Tables shown in this Handbook are based on a 20° temperature drop, the above 100,000 BTU heat loss must be *doubled* before using the tables to ascertain the necessary pipe size. When pipe sizing the system, not only must the total BTU heat loss of the building be doubled, but also the BTU heat loss of the individual main and radiator circuits. *This does not mean that the boiler and radiators are increased in size beyond that required for a 20° drop, but that the pipes will be larger to accommodate the greater amount of water necessary.*

For changing temperature drop in an installed system, see page 48.

DESIGN TABLES AND CHARTS

IN THIS SECTION ARE FOUND ALL OF THE TABLES AND CHARTS NECESSARY FOR THE DESIGN OF FORCED HOT WATER HEATING SYSTEMS, WHETHER EMPLOYING RADIATORS, CONVECTORS, BASEBOARDS, UNIT HEATERS OR RADIANT PANELS.

CHART 1

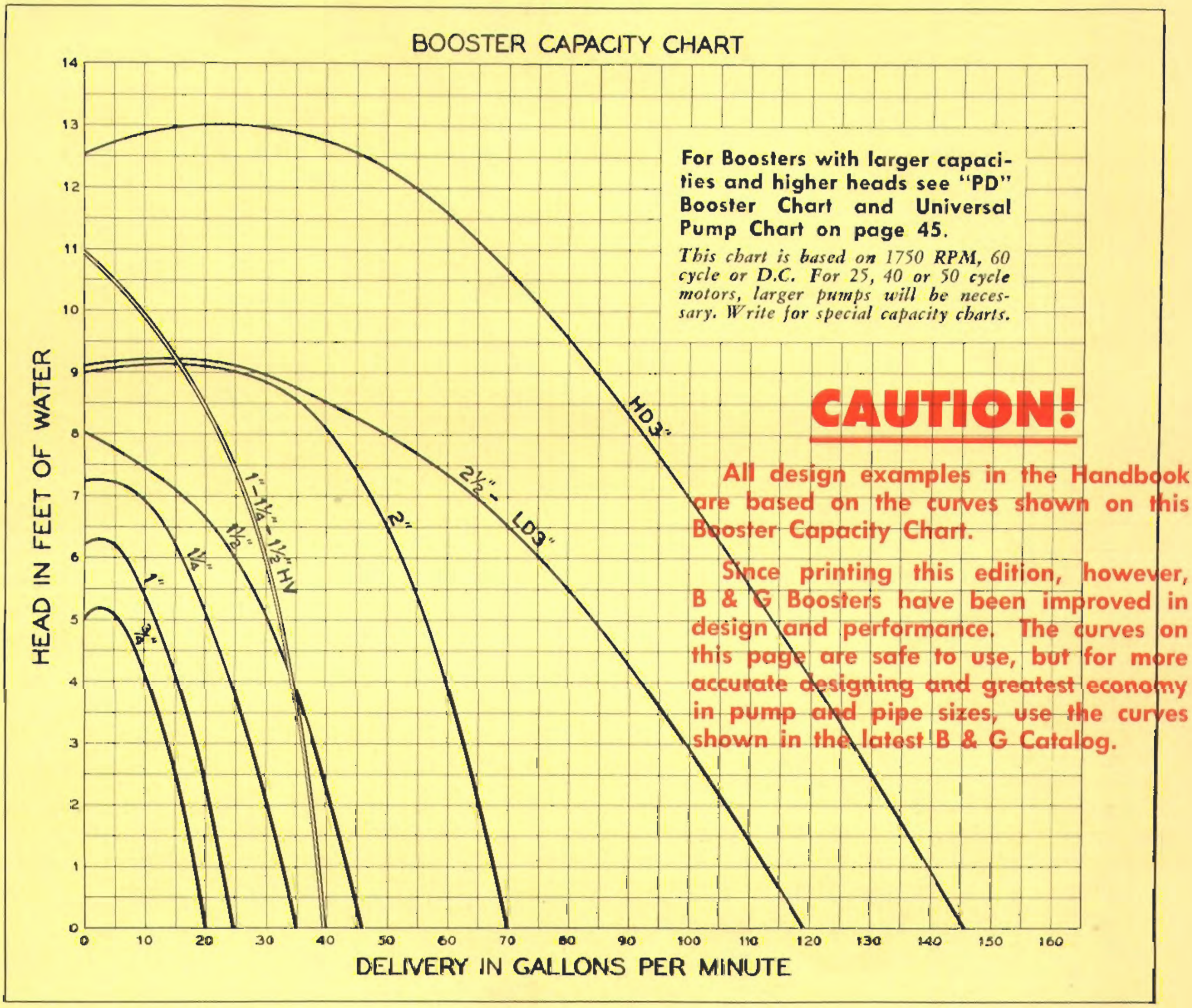


TABLE D ELBOW EQUIVALENTS

A 90° elbow offers to the flow of water an amount of friction equal to a pipe of the same diameter, with a length of 25 times the diameter.

1 90° Ell	1
1 45° Ell	0.7
1 90° Long Turn Ell	0.5
1 Open Return Bend	1
1 Open Gate Valve	0.5
1 Open Globe Valve	12
1 Angle Radiator Valve	2
1 B & G Flo-Control Valve	20
1 Stop Cock Open	1
1 Radiator (Cast Iron)	3
1 Convector (See Page 35)	
1 Boiler	3
1 Tee	
25% Water to Branch	16
33% Water to Branch	9
50% Water to Branch	4
100% Water to Branch	1.8

DESIGN TABLES AND CHARTS (continued)

PIPE SIZING TABLE—FOR THE MAINS OF ONE AND TWO PIPE FORCED HOT WATER HEATING SYSTEMS

NOTE—The figures shown in these tables apply to both steel pipe and type "L" copper tubing, as capacity differences are not sufficient to cause design errors.

TABLE A — Total Equivalent Length of Pipe in Feet

Booster Pressure Head in Feet	MILINCHES 700	600	500	400	350	300	250	200	150	100	50
2′	34	40	48	60	69	80	96	120	160	240	480
2½′	43	50	60	75	84	100	120	150	200	300	600
3′	51	60	72	90	102	120	144	180	240	360	720
3½′	60	70	84	105	120	140	168	210	280	420	840
4′	68	80	96	120	137	160	192	240	320	480	960
4½′	77	90	108	135	154	180	216	270	360	540	1080
5′	85	100	120	150	171	200	240	300	400	600	1200
5½′	94	110	132	165	188	220	264	330	440	660	1320
6′	103	120	144	180	206	240	288	360	480	720	1440
6½′	111	130	156	195	223	260	312	390	520	780	1560
7′	120	140	168	210	240	280	336	420	560	840	1680
7½′	128	150	180	225	256	300	360	450	600	900	1800
8′	137	160	192	240	274	320	384	480	640	960	1920
8½′	146	170	204	255	292	340	408	510	680	1020	2040
9′	154	180	216	270	309	360	432	540	720	1080	2160
9½′	163	190	228	285	326	380	456	570	760	1140	2280
10′	171	200	240	300	343	400	480	600	800	1200	2400
10½′	180	210	252	315	360	420	504	630	840	1260	2520
11′	188	220	264	330	376	440	528	660	880	1320	2640
11½′	197	230	276	345	395	460	552	690	920	1380	2760
12′	206	240	288	360	410	480	576	720	960	1440	2880
15′	257	300	360	450	515	600	720	900	1200	1800	3600
20′	343	400	480	600	686	800	960	1200	1600	2400	4800
25′	428	500	600	750	857	1000	1200	1500	2000	3000	6000
30′	515	600	720	900	1030	1200	1440	1800	2400	3600	7200
35′	600	700	840	1050	1200	1400	1680	2100	2800	4200	8400
40′	685	800	960	1200	1370	1600	1920	2400	3200	4800	9600
50′	857	1000	1200	1500	1725	2000	2400	3000	4000	6000	12000
60′	1028	1200	1440	1800	2060	2400	2880	3600	4800	7200	14400
70′	1200	1400	1680	2100	2400	2800	3360	4200	5600	8400	16800
80′	1370	1600	1920	2400	2740	3200	3840	4800	6400	9600	19200
90′	1540	1800	2160	2700	3090	3600	4320	5400	7200	10800	21600
100′	1715	2000	2400	3000	3430	4000	4800	6000	8000	12000	24000

TABLE B* — B.T.U. Carrying Capacity of Various Pipe Sizes in Thousands of B.T.U.'s

Nominal Pipe Size	MILINCHES 700	600	500	400	350	300	250	200	150	100	50
¼″	5.3	4.8	4.4	3.9	3.6	3.3	3.0	2.7	2.3	1.8	1.3
⅜″	12	11	10	8.7	8.1	7.5	6.8	6	5.0	4.1	2.8
½″	22	20	17	16	15	13	12	11	9.6	7.7	5.3
¾″	48	42	39	35	31	30	27	23.9	20.4	16.4	11.3
1″	90	80	71	64	59	53	48	42	37	31	20
1¼″	180	170	160	140	130	118	102	90	78	63	45
1½″	280	260	240	210	185	175	156	140	121	94	65
2″	580	500	450	410	360	322	294	261	227	182	130
2½″	905	810	750	670	610	551	523	460	385	310	210
3″	1700	1500	1400	1300	1150	1000	900	800	680	550	390
3½″	2500	2300	2100	1850	1650	1500	1350	1190	1020	825	580
4″	3500	3200	2900	2600	2300	2100	1950	1700	1350	1140	800
6″	11000	10000	9000	8000	7000	6900	6000	5400	4500	3800	2500
8″	23000	21000	19000	17000	15000	13500	13000	11000	9500	7500	5000
10″	—	40000	36000	32000	29000	27000	23000	21000	18000	14000	9500
12″	—	—	—	—	—	—	40000	35000	30000	22000	16000

*Based on 20° temperature drop

DESIGN TABLES AND CHARTS (continued)

PIPE SIZING TABLE — FOR RISERS OF MONOFLO SYSTEMS

NOTE—The figures shown in these tables apply to both steel pipe and type "L" copper tubing, as capacity differences are not sufficient to cause design errors.

TABLE C*

CAPACITY OF RISERS WITH TWO FITTINGS (IN THOUSANDS OF BTU)

Pipe Size	MILINCHES 600	500	400	350	300	250	200	150	100
	Upfeed Risers—First Floor (See Note #1)								
½"	23	22	19	18	17	16	14	12	10
¾"	43	41	37	33	30	28	26	22	20
1 "	80	73	64	60	55	50	45	39	32
1¼"	180	140	120	110	100	93	80	74	62
	Upfeed Risers—Second Floor (See Note #2)								
½"	16	15	14	13	11	10	10	8	7
¾"	31	28	25	24	22	21	18	15	13
1 "	58	52	45	43	37	33	32	28	25
1¼"	122	108	92	90	79	72	68	59	50
	Upfeed Risers—Third Floor (See Note #2)								
½"	14	12	11	10	9	8	8	7	6
¾"	26	24	23	21	19	18	16	14	12
1 "	47	43	38	36	34	31	29	28	25
1¼"	99	91	81	77	70	66	59	56	46
	Downfeed Risers (See Note #3)								
½"	16	15	14	12	11	9	8	FOR LESS THAN 200 MILINCH RESISTANCE, BASE CALCULATIONS ON PUMP WITH HIGHER HEAD PRESSURE.	
¾"	33	30	26	24	20	18	14		
1 "	58	52	43	41	34	29	25		
1¼"	117	106	86	83	69	59	49		

CAPACITY OF RISERS WITH ONE FITTING (IN THOUSANDS OF BTU)

Pipe Size	MILINCHES 600	500	400	350	300	250	200	150	100
	Upfeed Risers—First Floor (See Note #1)								
½"	16.5	15	13	12	11	10.6	10	9.2	8
¾"	29	27	25	24	21	19	18	17	15
1 "	50	48	44	41	37	35	33	31	28
1¼"	95	88	78	76	69	62	55.6	48	40
	Upfeed Risers—Second Floor (See Note #2)								
½"	11	10	9	8	7	7	6	6	4
¾"	20	19	17	16	14	13	12	11	11
1 "	34	32	29	28	25	24	22	21	18
1¼"	70	68	59	57	51	49	45	43	36
	Upfeed Risers—Third Floor (See Note #2)								
½"	9	8	7	7	6	6	6	5	4
¾"	18	16	14	14	12	12	11	10	9
1 "	31	29	28	27	24	22	21	20	18
1¼"	63	60	56	52	48	45	43	41	36

*Based on 20° temperature drop

READ THESE NOTES CAREFULLY BEFORE SIZING RISERS

NOTE 1. 1st FLOOR UPFEED RISERS—Capacities shown in the table are based upon horizontal branches not more than 3 feet long, with stubs 18" long, or a total of 9 feet of pipe. 6 elbows, one valve and one union ell, and one C.I. radiator are added for the equivalent length.

For each additional 10 equivalent feet of pipe, move 2 milinch columns to the right.

NOTE 2. 2nd and 3rd FLOOR UPFEED RISERS—Capacities shown are based upon horizontal branches not more than 3 feet long, with risers 10 feet high and 20 feet high respectively. 8 elbows, one valve and one union ell, and C.I. radiator are added for the equivalent length.

For each additional 10 equivalent feet of pipe, move 2 milinch columns to the right.

NOTE 3. DOWNFEED RISERS—Capacities shown are based on a drop of seven feet to the *center of the radiator*, with not over 3 feet total in horizontal branches, 6 elbows, one valve and one union ell and one C.I. radiator.

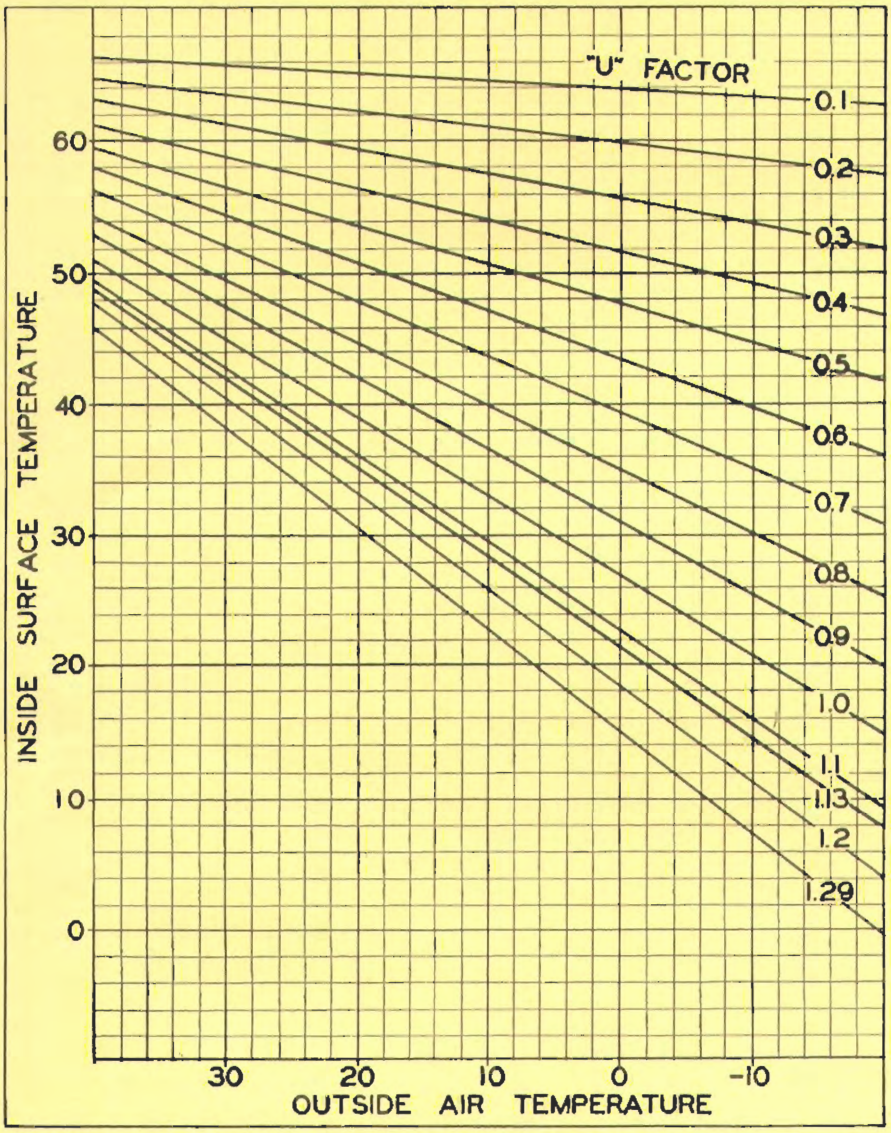
For every additional 2 feet of vertical drop, move one column to the right in milinch table.

All downfeed risers must have a Monoflo Fitting installed in both supply and return lines.

DESIGN TABLES AND CHARTS (continued)

DESIGN CHARTS FOR RADIANT PANEL SYSTEMS

CHART 2 CHART FOR DETERMINING INSIDE SURFACE TEMPERATURES OF OUTSIDE WALLS



NOTES ON PIPE SIZES

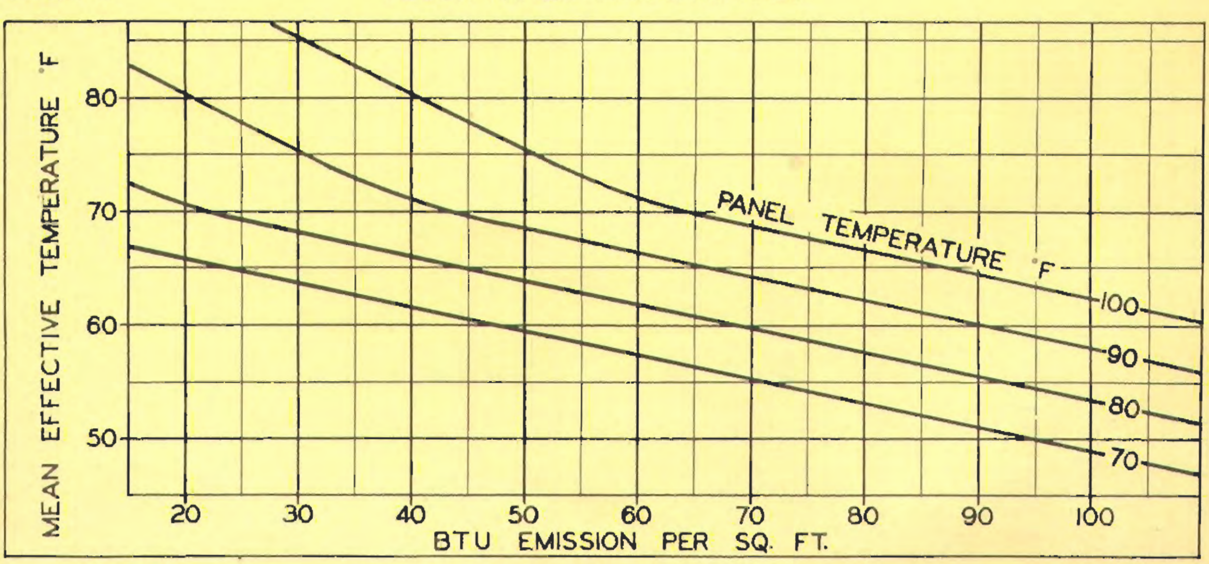
Chart 5 — Floor Coils

These spacings are based on 3/4" pipe buried 3" in a 6" concrete slab poured on 4" of gravel fill and with 3/4" wood floor covering. Other pipe diameters, varying depth of bury and other floor coverings affect the pipe spacing. However, a higher or lower water temperature will compensate for variation of conditions within reasonable limits. Accordingly, the spacings as shown are safe for pipe diameters from 1/2" to 1 1/4" and for depth of bury from 2" to 6" and for ordinary floor covering.

Chart 6 — Ceiling Coils

These spacings are based on 5/8" copper tubing imbedded 1/4" from surface and with 3 1/2" of insulation in back of plaster. Other tube diameters affect the spacing. However, within reasonable limits, varying conditions can be compensated for by changing the water temperature. Accordingly, it is safe to use these spacings for tube diameters from 3/8" to 1".

CHART 3 FLOOR PANEL TEMPERATURES



DESIGN TABLES AND CHARTS (continued)

DESIGN CHARTS FOR RADIANT PANEL SYSTEMS

CHART 4

CEILING PANEL TEMPERATURES

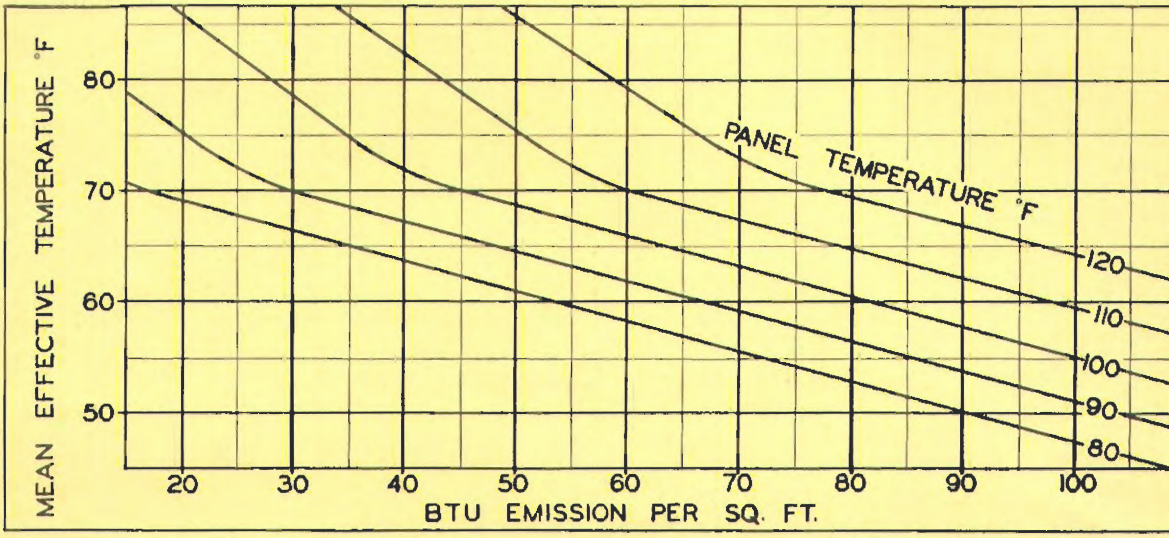


CHART 5

PIPE OR TUBE SPACING FOR FLOOR COILS EMBEDDED IN CONCRETE

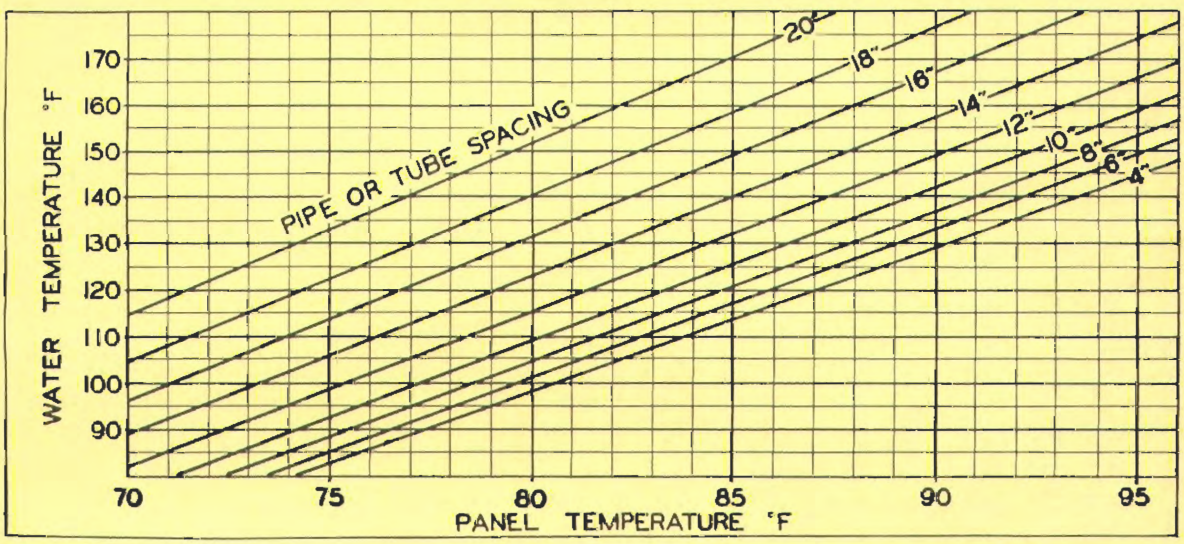
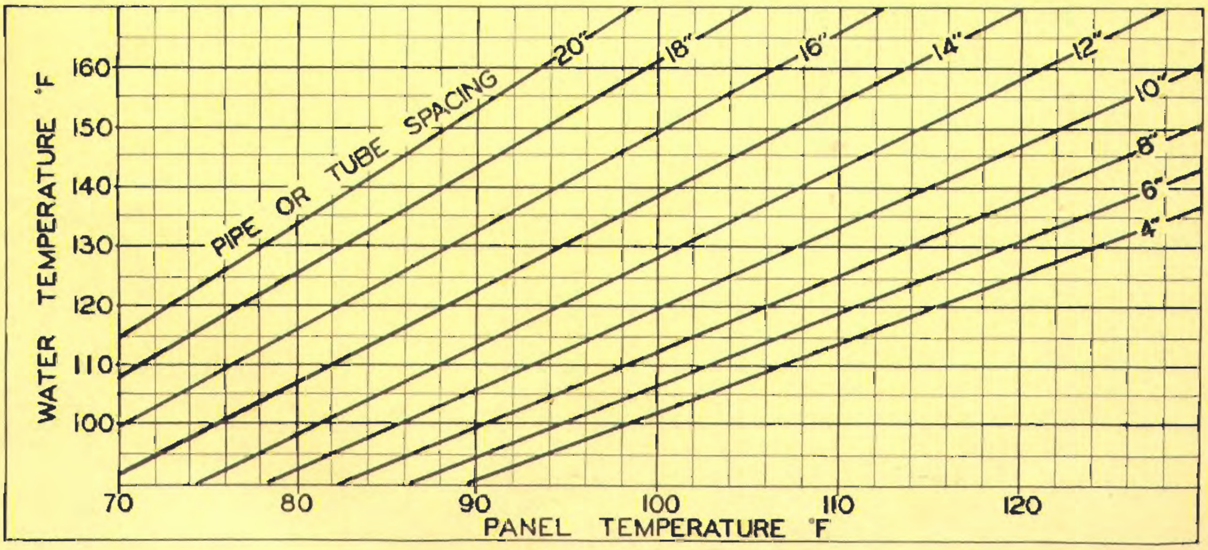


CHART 6

PIPE OR TUBE SPACING FOR CEILING COILS EMBEDDED IN PLASTER



DESIGN TABLES AND CHARTS (continued)

CHART 8

CONVERSION CHART TO DETERMINE PERCENTAGE FACTOR FOR MONOFLO RISER CAPACITIES WITH KNOWN PRESSURE DROP THROUGH HEATING UNITS

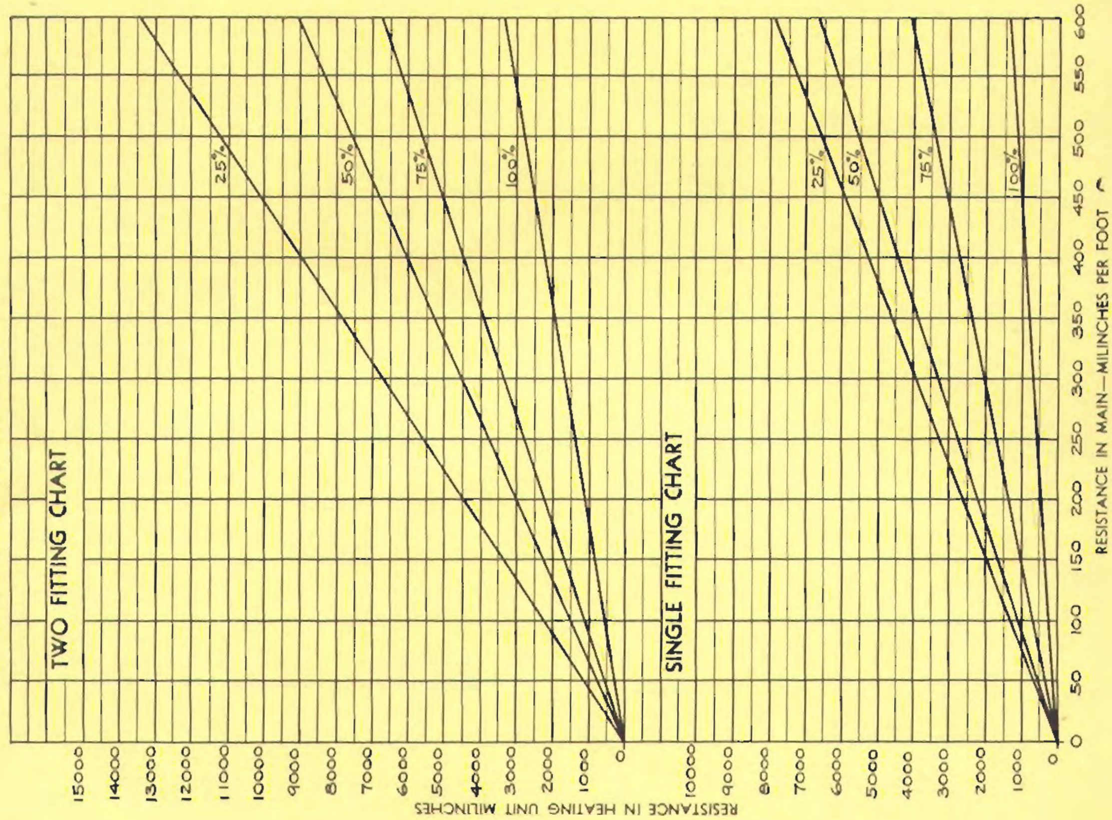
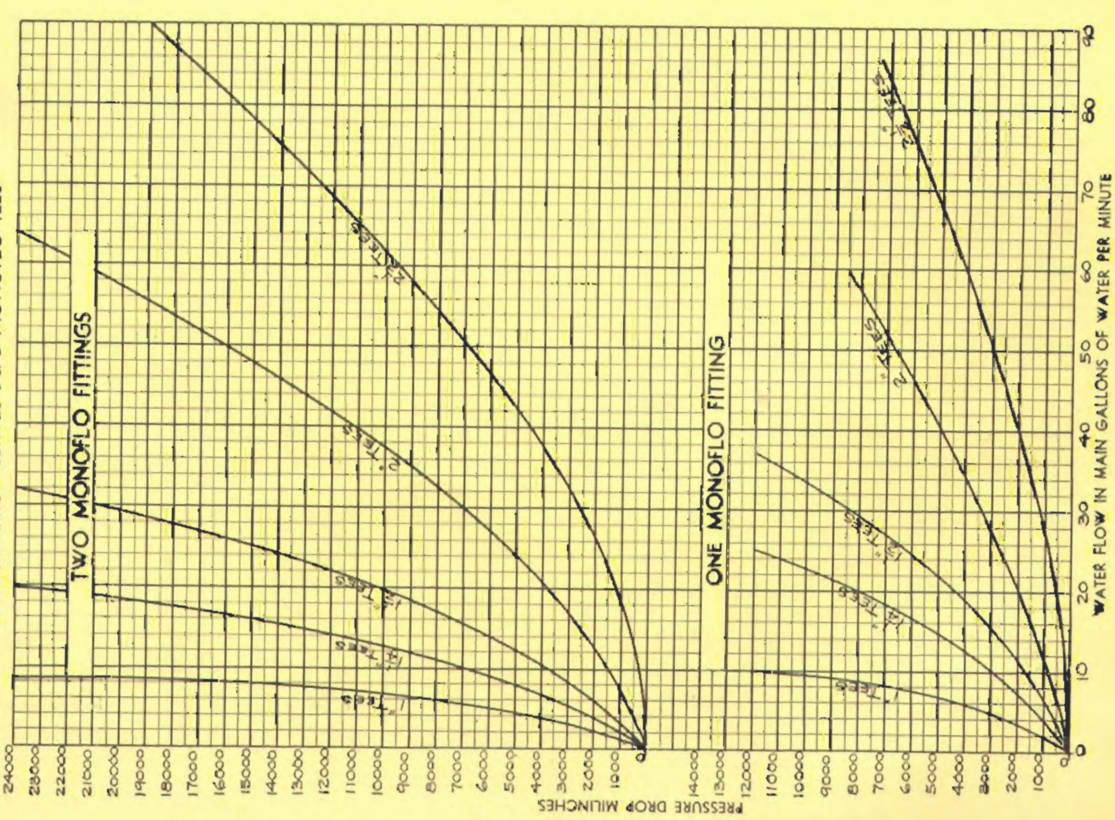


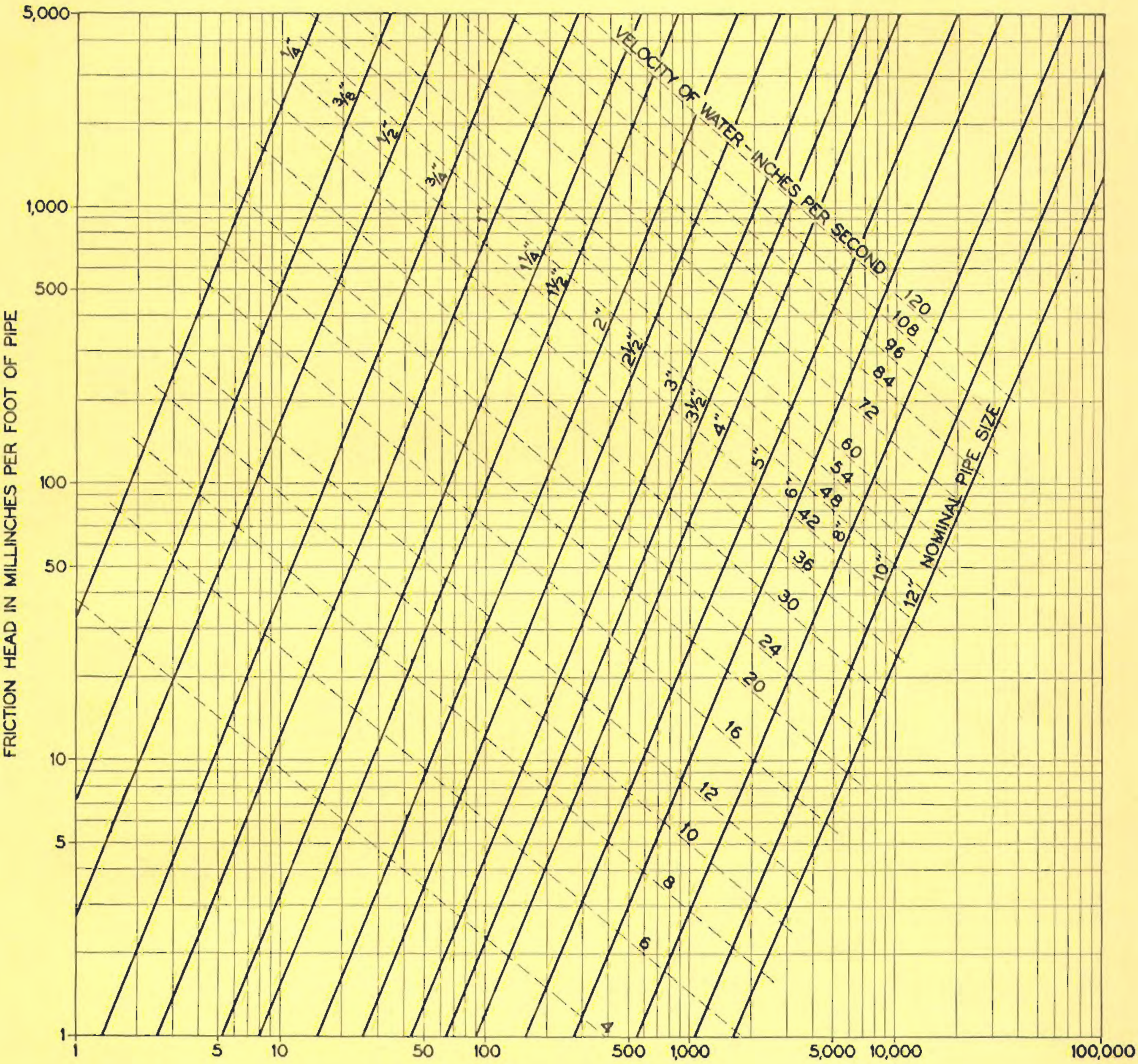
CHART 7

PRESSURE DROP CURVES B & G MONOFLO TEES



DESIGN TABLES AND CHARTS (continued)

CHART 9 — Friction heads in black iron pipes for a 20°F temperature difference in the water in the flow and return lines.



HOW TO USE THIS CHART

The above chart will enable the designer to accurately determine the milinch resistance and velocity occurring in pipes from 1/4" to 12" at any given flow.

Example:

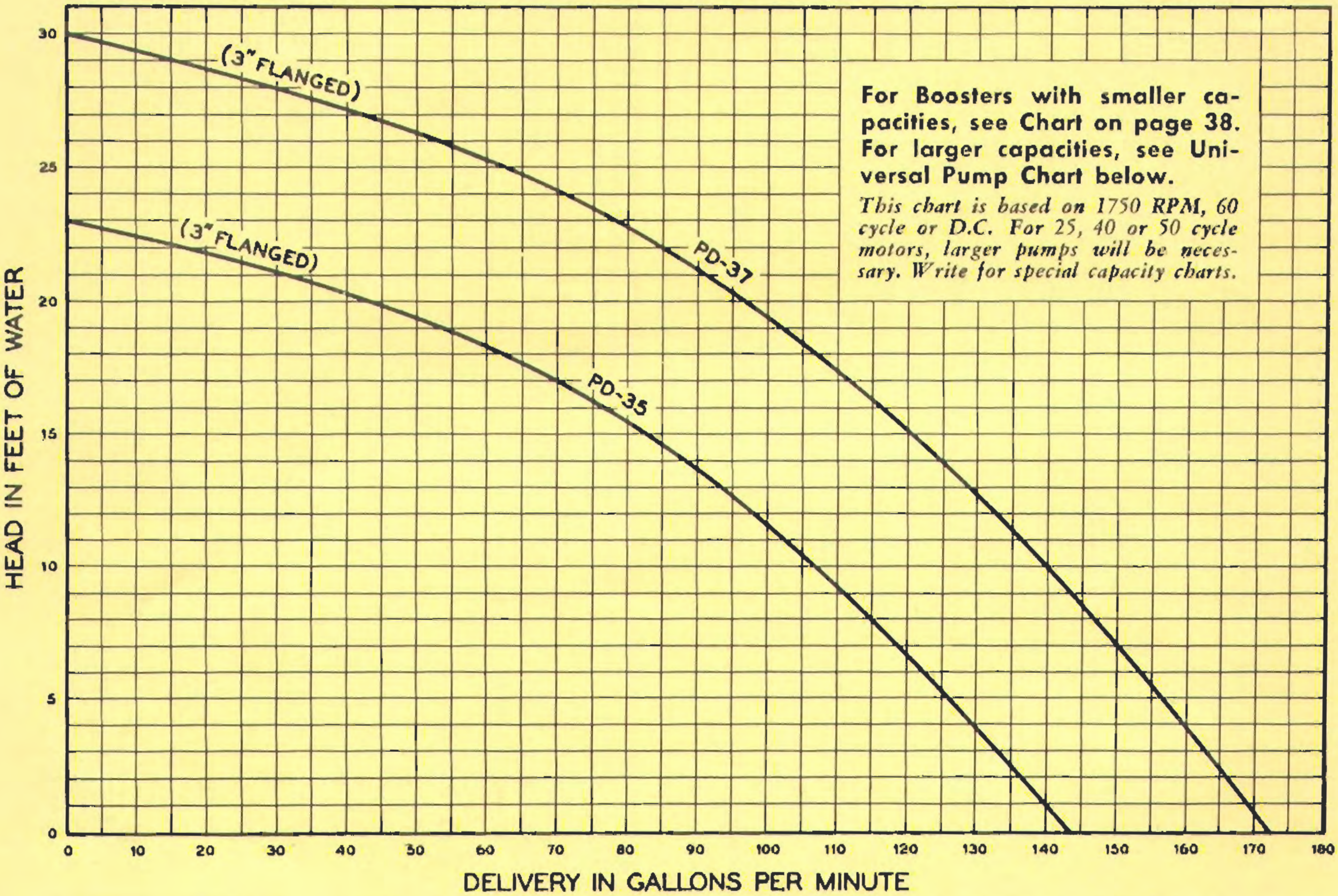
When carrying a heating load of 100,000 BTU at a flow of 10 GPM, what is the resistance and velocity in a 1 1/4" pipe?

Reading up from the 100,000 BTU point at the bottom of the Chart to the intersection with 1 1/4" pipe size, extend a line to the left border, where a resistance of 225 milinches per foot is indicated.

The velocity is indicated by the broken lines and is read at the intersection of the BTU line and the pipe size line. In this example it is shown to be 26" per second.

DESIGN TABLES AND CHARTS (continued)

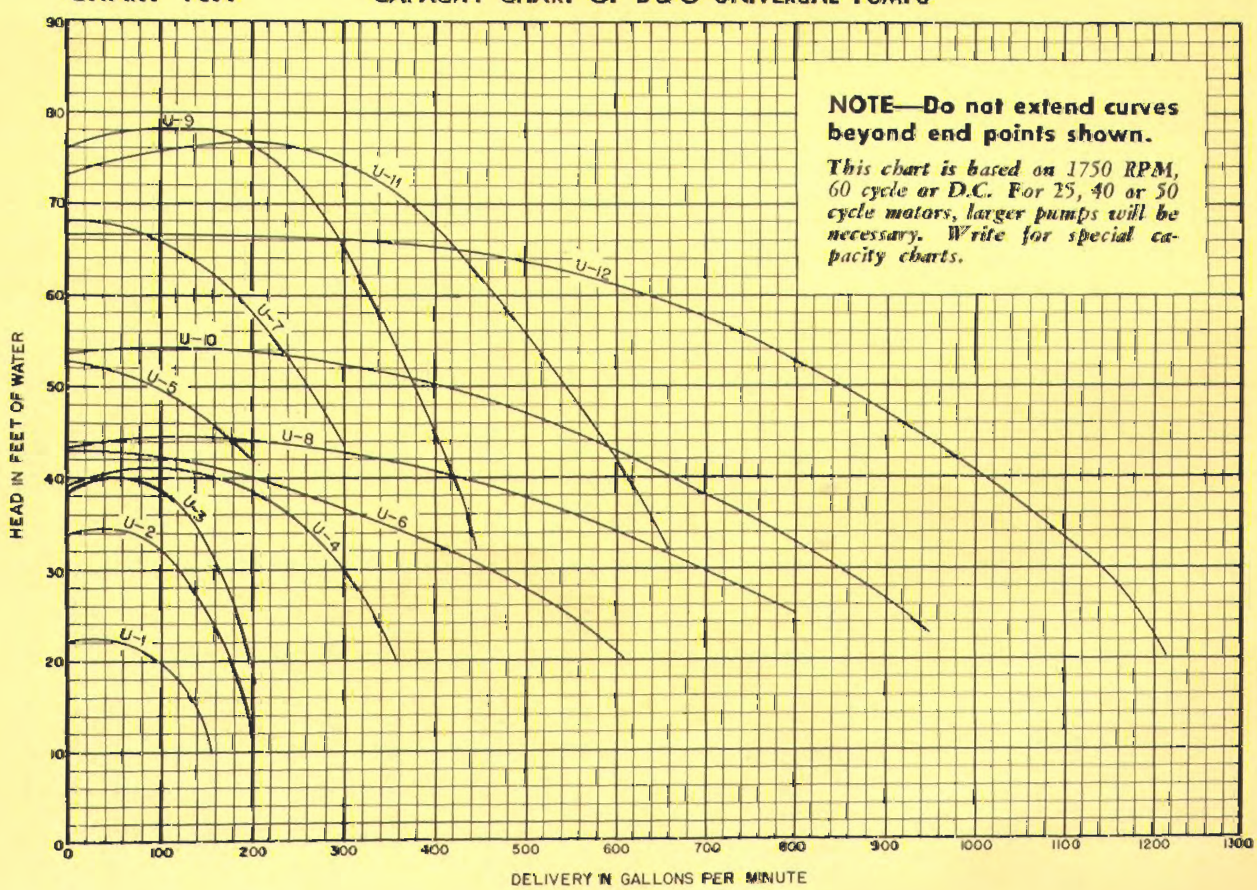
CHART 10 PD BOOSTER CAPACITY CHART



For Boosters with smaller capacities, see Chart on page 38. For larger capacities, see Universal Pump Chart below.

This chart is based on 1750 RPM, 60 cycle or D.C. For 25, 40 or 50 cycle motors, larger pumps will be necessary. Write for special capacity charts.

CHART 10A CAPACITY CHART OF B & G UNIVERSAL PUMPS



NOTE—Do not extend curves beyond end points shown.

This chart is based on 1750 RPM, 60 cycle or D.C. For 25, 40 or 50 cycle motors, larger pumps will be necessary. Write for special capacity charts.

DESIGNING A TWO-PIPE FORCED HOT WATER SYSTEM

In designing a two-pipe forced hot water system, the same six steps as used in designing a B & G Monoflo System (Page 25) are followed.

These are:

1. **RADIATION REQUIRED.**
2. **PIPING LAYOUT.**
3. **AMOUNT OF WATER NEEDED TO CARRY THE HEATING LOAD.**
4. **SELECTION OF BOOSTER.**
5. **PIPE SIZING.**
6. **SELECTION OF BOILER.**

The procedure for each step, with the exception of Piping Layout (2) and Pipe Sizing (5), is identical with that of the Monoflo System designing.

REVERSE RETURN SYSTEM PREFERABLE TO A DIRECT RETURN SYSTEM

A reverse return system is preferable because each radiator's circuit is of approximately equal length, thereby eliminating many problems of "balance" or equal distribution of hot water through the system. The design procedure, however, for either direct return or reverse return systems is identical.

The differences between one-pipe and two-pipe designing can be best illustrated by carrying through the calculations required by a typical two-pipe layout. The sketch on page 47 shows a two-pipe, reverse return system for a two-story house. Going through the Six Steps—

STEP No. 1

RADIATION REQUIRED

Figured on the basis of a 200 BTU heat emission, assume that this house requires 600 sq. ft. of radiation. The radiators in the sketch are sized accordingly.

STEP No. 2

PIPING LAYOUT

The sketch is correctly laid out for a reverse return system of two circuits.

STEP No. 3

AMOUNT OF WATER IN GALLONS NEEDED TO CARRY THE HEATING LOAD

600 (sq. ft. of radiation) × 200 (BTU heat emission per sq. ft.) 120,000 BTU

$$\frac{120{,}000}{9600} = 12.5 \text{ gallons per minute}$$

STEP No. 4

SELECTION OF BOOSTER

Referring to the Booster Capacity Chart on page 38, a 1" pump is shown to deliver 12.5 gallons per minute at a 4¾' Head Pressure. Therefore, this size of pump is selected to carry the heating load.

NOTE!

Some degree of judgment should be used in selecting a Booster. It may be more economical to go to a larger size pump with a higher Head Pressure because of the savings made in pipe sizes. In this example, a trial calculation shows that the increased cost of a 1" Booster over that of a ¾" is more than offset by the reduced cost of smaller piping. Good practice, however, indicates that Head Pressures should be such that pipes are sized at not greater than 500 milinches resistance per foot.

STEP No. 5

PIPE SIZING

Assume that in the sketch the longest circuit is 102 feet long. *This measurement includes the length of the main and the longest radiator branch.* Adding 50% to this figure, to compensate for friction losses of the fittings—

102 + 51 = 153 ft. = Total Equivalent Length of pipe.

The longest circuit is selected because it obviously offers the greatest resistance. Therefore, if the pump head is sufficient to circulate this circuit, it will be more than adequate to circulate all other circuits.

Now refer to Pipe Sizing Table on page 39. Table A shows Total Equivalent Pipe lengths for pressure heads from 2 ft. to 100 ft. Table B gives the carrying capacities (in thousands of BTU) of various sized pipes at different friction heads. The friction heads are expressed in milinches (see page 21 for definition of milinch).

Reading to the right from 4½ ft. Head Pressure (which is the closest and next lower head pressure to the required 4¾ ft.), the closest Equivalent Length to our system length of 153 ft. is found to be in the 350 milinch column and is 154 ft. (Table A). *All pipes including mains and risers are sized from this column.*

SIZING THE SUPPLY MAIN

Following down the 350 milinch column into Table B, 120,000 BTU is not shown, so we use the next larger figure, which is 130,000 BTU. Reading to the left, this amount of BTU is shown to be carried by a 1¼" pipe. This size pipe is therefore used for the trunk main (A-B).

DESIGNING A TWO-PIPE SYSTEM (continued)

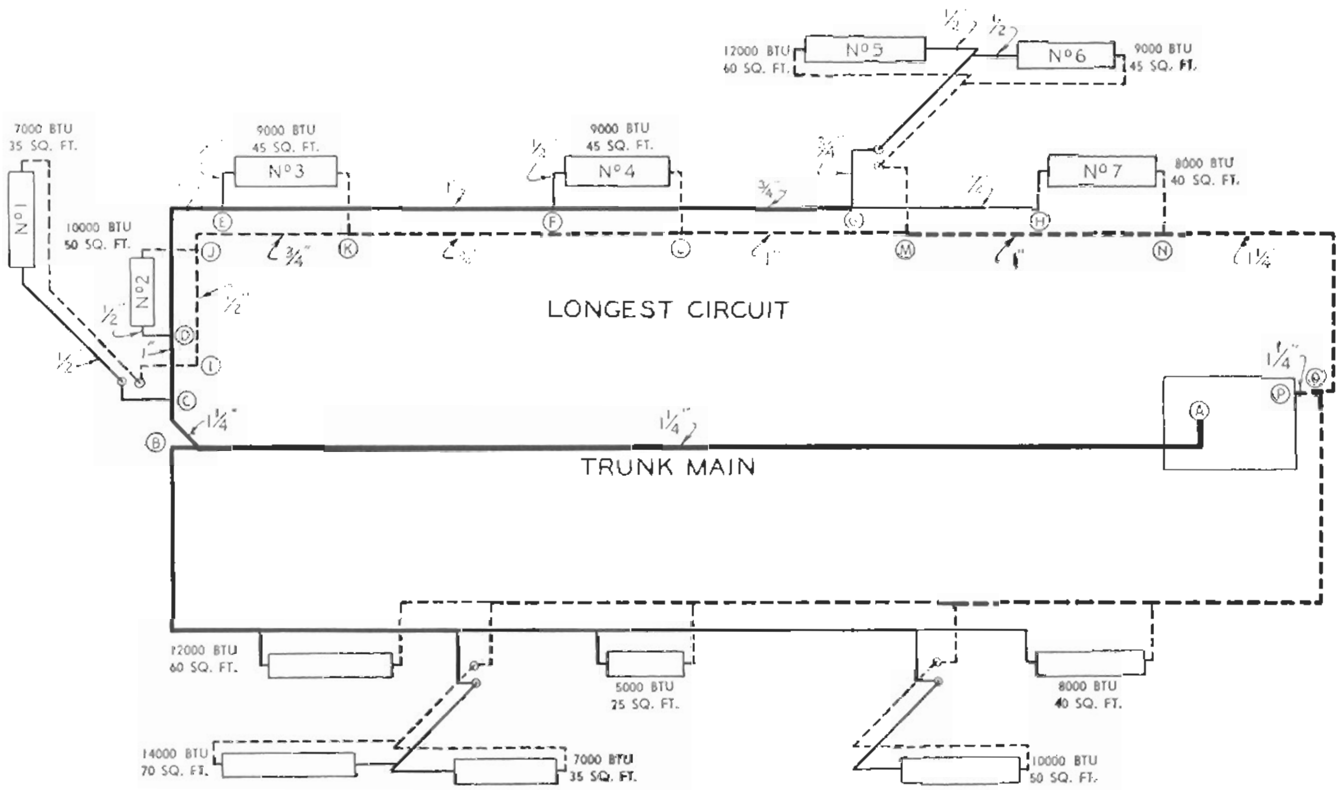


Fig. 71. Example of two-pipe reverse return forced hot water system piping layout.

Step No. 5 (continued)

The load branches at B with 320 sq. ft. of radiation on one branch and 280 sq. ft. on the other. Pipe section B-C supplies 320 feet of radiation or 64,000 BTU. Reference to Table B, in the column in which we are working (350 milinch) shows that a 1¼" pipe will carry this load.

Section C-D has a heating load of 57,000 BTU, which requires a 1" pipe.

Section D-E has a load of 47,000 BTU, which the Table shows will be carried by 1" pipe.

Section E-F with 38,000 BTU requires a 1" pipe.

Section F-G with 29,000 BTU requires a ¾" pipe.

Section G-H with only 8,000 BTU will be handled by a ⅜" pipe, but since ½" pipe is considered the smallest practical size for radiator risers, it should be used here.

SIZING THE RETURN MAIN

Section P-O carries the entire heating load of 120,000 BTU and requires a 1¼" pipe.

Section O-N carries 64,000 BTU and requires 1¼" pipe.

Section N-M with a heating load of 56,000 BTU requires a 1" pipe.

Section M-L with 35,000 BTU calls for 1" pipe.

Section L-K carries 26,000 BTU and requires ¾" pipe.

Section K-J with 17,000 BTU requires ¾" pipe.

Section J-I carries 7,000 BTU and needs only ⅜" pipe, but since ½" pipe is considered the smallest practical size, it should be used here.

SIZING THE RISERS

The risers are sized in the same 350 milinch column and in the same manner as the mains—

Radiator No. 1	**7,000 BTU**	**½" Pipe**
Radiator No. 2	**10,000 BTU**	**½" Pipe**
Radiator No. 3	**9,000 BTU**	**½" Pipe**
Radiator No. 4	**9,000 BTU**	**½" Pipe**
Radiator No. 5 / Radiator No. 6	**21,000 BTU**	**¾" Pipe from Main; ½" Connections to No. 5, ½" Connections to No. 6**
Radiator No. 7	**8,000 BTU**	**½" Pipe**

The other main circuit, carrying a total of 280 sq. ft. of radiation, is sized in the same manner.

STEP No. 6

SELECTION OF BOILER

Selection of a properly sized boiler should be in accordance with the standards of the Heating, Piping and Air Conditioning Contractors' National Association, "Net BTU Load Recommendations for Heating Boilers."

NOTE! Inasmuch as the hot water ratings in some manufacturers' bulletins are based on 150 BTU per square foot heat emission, care should be taken to

DESIGNING A TWO-PIPE SYSTEM (continued)

Step No. 6 (continued)

correct these ratings for the BTU emission of the system you are designing. It is necessary to install a water boiler of the same size and number of sections as required for steam when using a heat emission factor of 240 BTU.

PIPE SIZING A DIRECT RETURN SYSTEM

Pipe sizing a Direct Return System is done in exactly the same manner as above. In general, however, this type of installation is not recommended, as errors in design have a more serious effect on the "balance" of the system.

CONVERTING AN OLD GRAVITY HOT WATER SYSTEM TO FORCED CIRCULATION

In modernizing an old gravity hot water heating system, it is not necessary to change the radiators, nor is it ordinarily required to alter the piping except around the boiler.

Assuming that the system was originally designed on the old standard 150 BTU basis, count the square feet of radiation in the entire building and multiply by 150. This will give the total BTU heat loss.

Example:

900 sq. ft. × 150 BTU   135,000 BTU

To determine the size of pump needed to carry the heating load, follow the same procedure as for new forced circulation systems—

$$\frac{135{,}000}{9600} = \text{14 gallons per minute}$$

Referring to the Booster Capacity Chart (page 38) it will be seen that a 1″ Booster will deliver 14 gallons per minute at a 4¼ foot Head Pressure. **Because of the uncertainties of design in old systems with large pipe sizes it is advisable to use a pump one size larger than indicated by the chart. Therefore, the pump selected in this case should be 1¼″.**

On direct return systems with long circuits, a return connection to the ends of the supply mains may be needed to properly heat end radiators. See Fig. 84 on page 50.

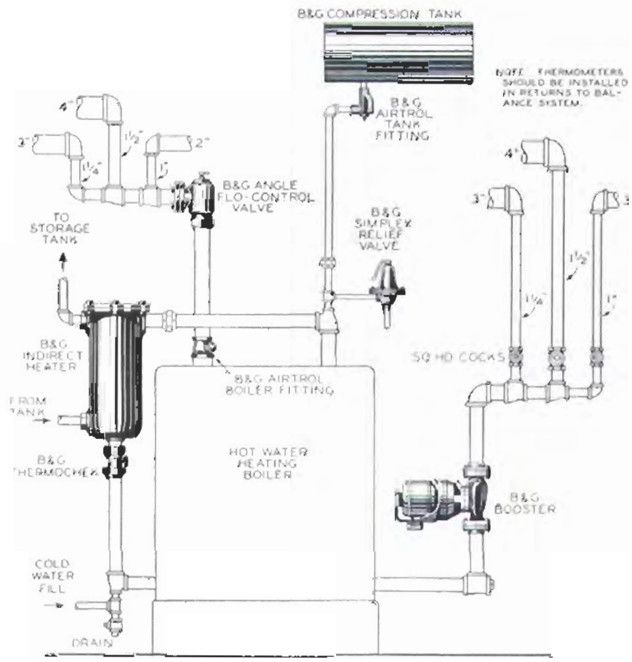


Fig. 72. Showing typical reduction in size of boiler connections on a gravity system converted to forced circulation.

CHANGING THE TEMPERATURE DROP IN AN INSTALLED SYSTEM — EITHER ONE OR TWO-PIPE

If for any reason it is desired to change the temperature drop from 20° to 10° in a system already installed, it will be necessary to materially increase the pump size.

As explained on page 19, the pressure drop in a system varies as the square of the velocity. Since changing to a 10° temperature drop doubles the amount (or velocity) of circulating water required by a 20° drop, a typical comparative calculation for 600 sq. ft. of radiation with a 200 BTU Heat Emission is as follows:

20° **drop—**

600 sq. ft. × 200 BTU = 120,000 BTU

$$\frac{120{,}000 \text{ BTU}}{20 \times 60 \times 8} = \text{12.5 gallons per minute}$$

The Booster Capacity Chart shows that this quantity will be delivered by a 1″ Booster at a 4¾′ Pressure Head.

10° drop—In accordance with the rule given on page 19, divide the increased gallonage by the primary gallonage and square the result:

$$\frac{120{,}000 \text{ BTU}}{10 \times 60 \times 8} = \text{25 gallons}$$

$$\frac{\text{25 gallons}}{\text{12.5 gallons}} = 2 \qquad \text{2 squared} = 4$$

Now multiply the original Pressure Head (4¾′) by the above result (4) which gives the increased Booster Pressure Head necessary:

4 × 4¾′ Head = 19′ Head

Therefore, the pump selected must deliver 25 gallons per minute against a Head Pressure of 19′.

RIGHT AND WRONG CONNECTIONS

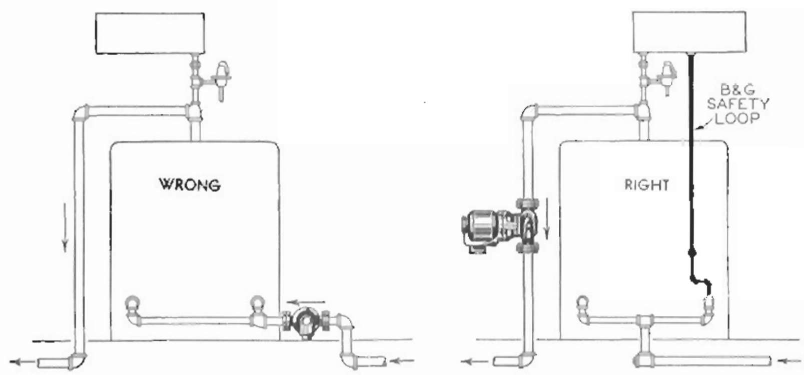


Fig. 73. On installations with up-fed radiation on same level as the boiler, be sure to install a B & G Safety Loop from compression tank to bottom of boiler as shown at right.

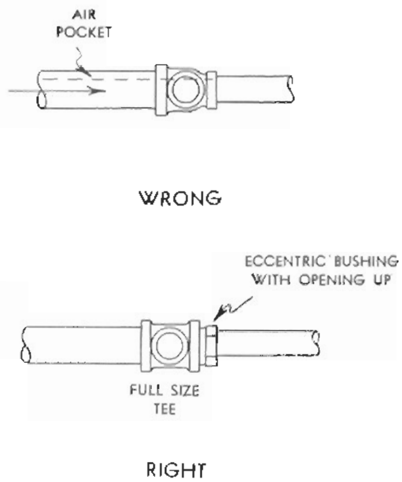


Fig. 76. Right and wrong way to reduce pipe size.

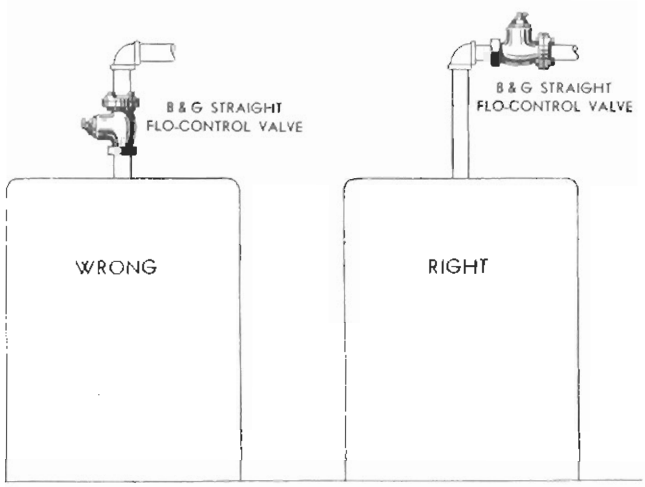


Fig. 74. The B & G Straight Flo-Control Valve should always be installed in a horizontal position.

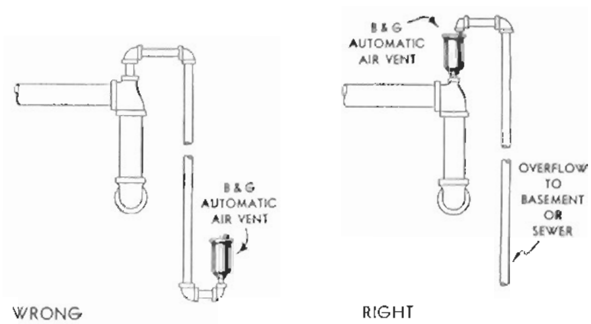


Fig. 77. Never install an automatic air vent as shown in the left hand diagram.

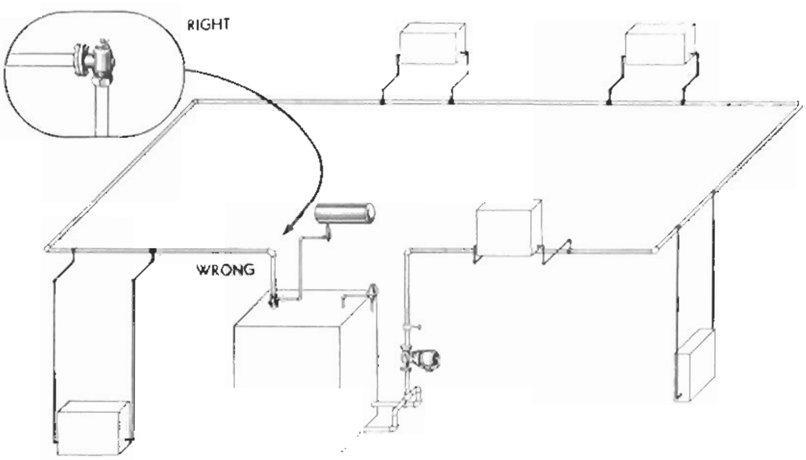


Fig. 75. A B & G Flo-Control Valve should be installed as noted—otherwise, during mild weather, the radiators above the main will be heated by gravity circulation, while the radiators below the main will receive no heat.

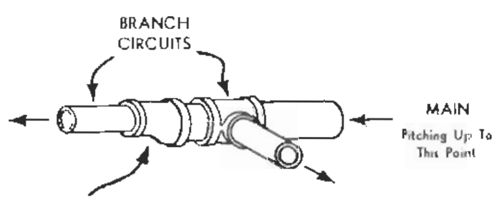


Fig. 78. Right method of taking branch circuits off a trunk main.

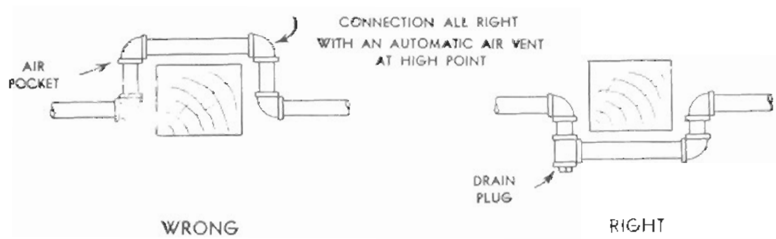


Fig. 79. Right and wrong methods of running horizontal pipes around an obstruction.

RIGHT AND WRONG CONNECTIONS (continued)

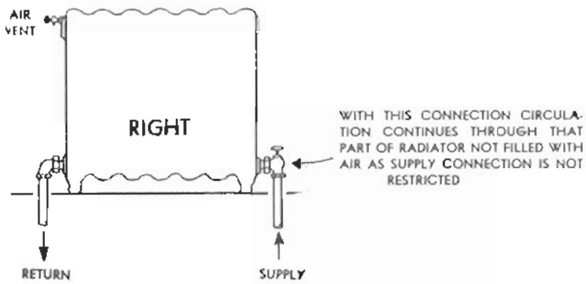


Fig. 80. Proper method of connecting radiators above the main of either one or two-pipe systems.

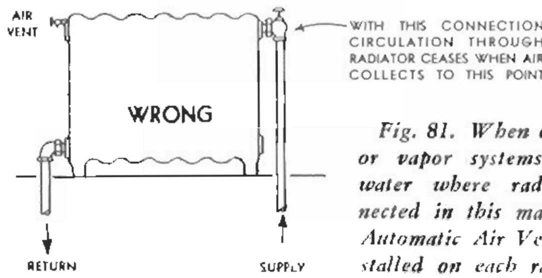


Fig. 81. When converting steam or vapor systems to forced hot water where radiators are connected in this manner, a B & G Automatic Air Vent should be installed on each radiator.

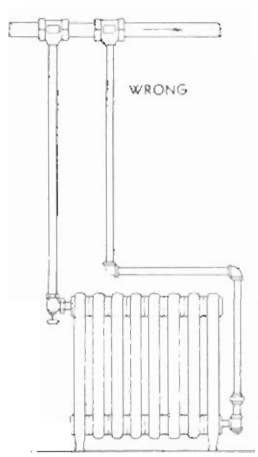


Fig. 82. Connections to radiators below the main should be as direct as possible, with risers spaced the full width of the radiator.

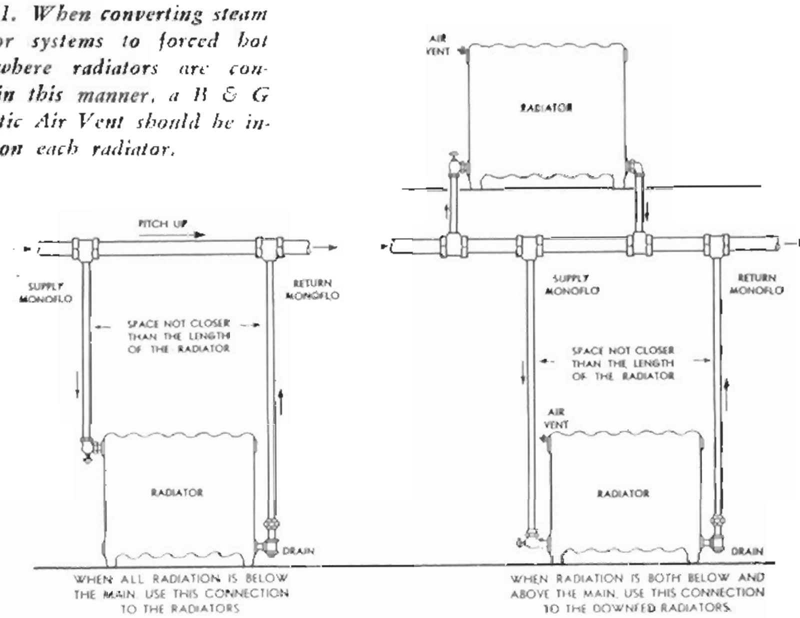


Fig. 83. Correct connections for radiators above and below the main of Monoflo system.

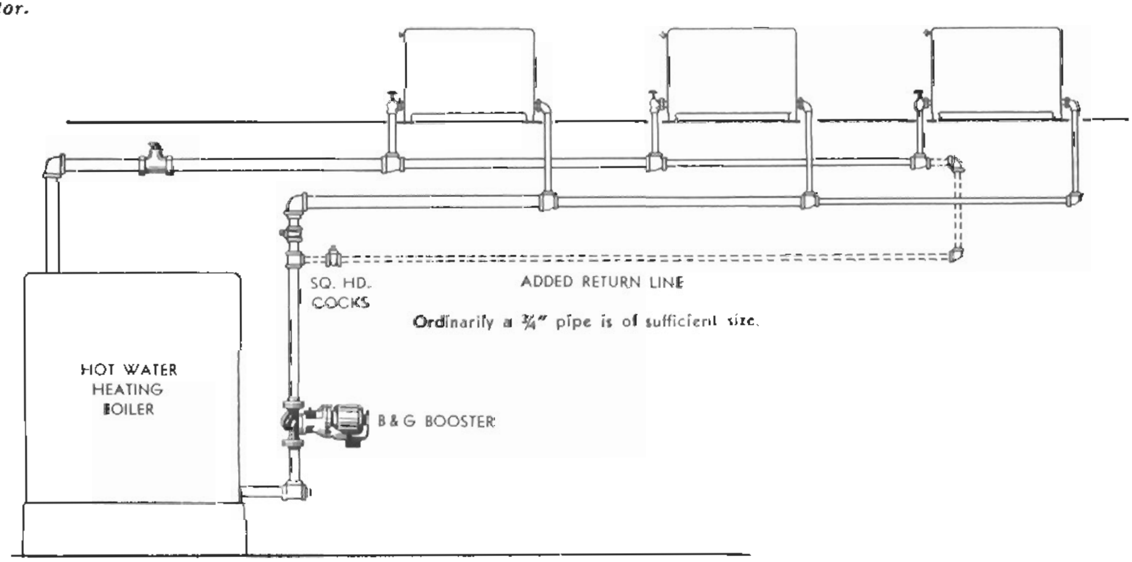


Fig. 84. On two-pipe, "direct return" systems with a long pipe run, an additional return line should be installed as indicated above.

HOT WATER SYSTEM ENGINEERING IN LARGE BUILDINGS

Generally speaking, the engineering of a hot water heating system for a large building is an amplification and refinement of the smaller installation. Piping design, due to the more extensive opportunity for error, must be more carefully calculated.

Best results will be obtained if a large job is considered and designed as a group of smaller installations, or, in other words, zoned. This practice produces two valuable results. First, it affords a more accurate control at a lower cost than possible in any other type of system. Second, the greater number of zones into which a large installation is divided, the greater the simplicity of design.

High buildings produce a high static head in a water system. This may be overcome by zoning the system in 4-story heights, each zone drawing hot water from a steam convertor. Accuracy of temperature control by this method is obvious. Where convertors are *not used*, care must be exercised to select boiler, valves and radiators designed for higher operating pressures.

This same vertical zoning nullifies "chimney effect" in tall buildings. "Chimney effect" is the rising of warm air through the building as in a chimney, causing a decided low pressure area at the bottom floors. In unzoned buildings this makes satisfactory heating difficult because heating the lower floors to the proper degree causes overheating of the upper floors. The ease with which forced hot water can be zoned makes this type of system especially well adapted to the large building.

Sun and wind likewise seriously affect the heating of a building and can be compensated for by proper zoning.

The low, spread-out building offers no problem in static pressure, but does require greater than ordinary circulating Head Pressures to maintain an economical heat distribution system. Here again zones eliminate the need for specially built equipment, thereby saving in initial cost and providing a better controlled system.

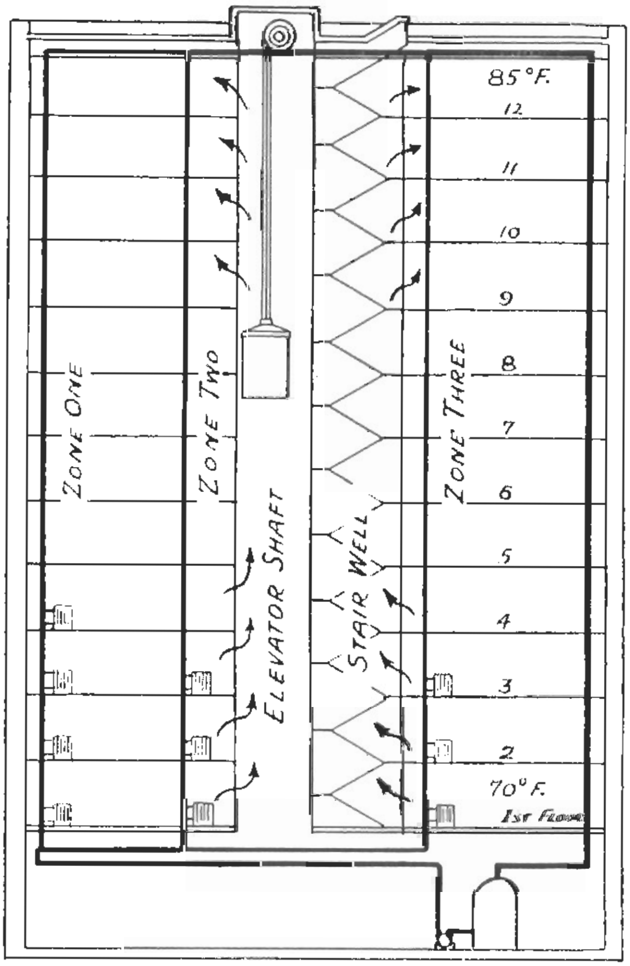


Fig. 85. "Chimney effect" is caused by warm air rising from lower to upper floors.

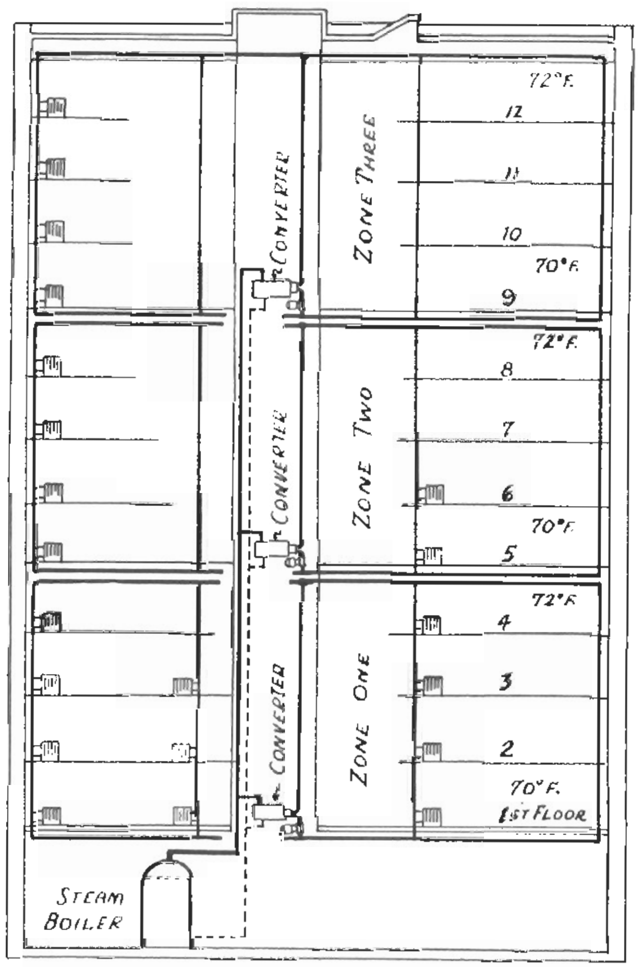


Fig. 86. Illustrates method of zoning vertically to prevent high static head.

DESIGNING A RADIANT PANEL HEATING SYSTEM

It should be stated that the following pages are not intended to be a complete treatise on Panel Heating. From the viewpoint of the research engineer, Panel Heating is a complex subject involving complicated formulae pertaining to combinations of radiant and convected heat. Certain characteristics, however, in the behavior of the heat given off by panels effect a degree of self balancing. Fortunately also, the temperature of the water in the system can be adjusted over a wide range, thus providing an ample safety factor against errors in calculation.

Taking advantage of this and other adjustment features permits safe use of relatively simple design procedure. The following B & G Seven Step Method applies to pipe coils embedded in concrete or plaster. Panel heating is not limited to these two applications and in subsequent data the design procedure will be furnished for coils in the air space under a floor, over a ceiling and in the walls.

The seven steps in designing a Radiant Panel System are as follows:

1. **CALCULATION OF BUILDING HEAT LOSS**
2. **DESIGN OF HEATING PANELS**
3. **LAYOUT OF DISTRIBUTION PIPING FROM AND BACK TO THE BOILER**
4. **AMOUNT OF WATER NEEDED TO CARRY THE HEATING LOAD**
5. **SELECTION OF BOOSTER PUMP**
6. **SIZING THE DISTRIBUTION PIPING**
7. **SELECTION OF BOILER**

THREE DESIGN EXAMPLES

The design procedures herein are applied as follows:

Design Example "A" — A one story house on a concrete slab, with serpentine panels embedded in the concrete.

Design Example "B" — This is the same house as in Design Example "A", except that the panels are made up of grids.

Design Example "C" — This is a two story house with a basement. It offers a more complex design problem, involving both grids and serpentine coils.

The heating layouts for the above houses are included in their respective sections.

HANDY CALCULATION FORM

At the back of this manual is inserted a B & G Panel Heating Calculation Form, filled in with the results of all calculations required by Design Examples "A" and "B". It will serve as a guide and check for correct design procedure.

FOREWORD

There is a tendency to regard Radiant Panel Heating as something complex and hard to understand, involving entirely new principles and design procedures. Actually, in its basic concept it is identical with ordinary radiator heating. Radiant Panel Heating takes the best features of radiator heating and develops them to the ultimate, while eliminating the various disadvantages.

The primary physical difference is that radiator systems depend upon concentrated heating surfaces at high temperatures, whereas, radiant panels are large areas maintained at comparatively low temperatures. They differ further in that radiant panels are completely concealed in the floors, ceilings or walls.

History of Panel Heating

Strangely enough, Radiant Panel Heating is not new—it is actually the oldest known form of central heat. The civilization of ancient Rome included it as one of its comforts. Public baths and private villas were heated by hot gases from charcoal fires circulated through ducts in the floors and walls. This crude but effective method of radiant heating now receives the benefits of modern techniques in transmission and control of the heating medium and of automatic firing.

Early in the 20th Century, Radiant Panel Heating reappeared in Europe and in this country, using pipes installed in the floor or ceiling to convey the heating medium. Since that time, it has gone through a slow, thorough testing process which establishes beyond a question the advantages of its principles. The techniques of design and installation have been tested in a large number of installations so that today, definite simplified rules can be laid down.

The behavior of Radiant Heat Rays

To understand fully the relation of Radiant Heat Rays to human comfort, their characteristics must be examined.

Any heated object gives off Radiant Heat Rays; the sun, for instance, warms the earth with its emission of these rays. Radiant Rays behave very much like light rays, because they travel in straight lines and are absorbed and reflected to a degree depending upon the nature of the surface they strike against.

Radiant Rays pass through the air without appreciably raising its temperature—the outer spaces, for example, through which the sun's rays travel before they reach the earth, are intensely cold. These rays, however, warm every *solid* object they meet.

Radiant Rays always move from warm to cooler objects. When they strike a cooler surface, a portion of them is absorbed and the balance reflected. The absorbed rays warm the surface, which then becomes a radiant surface itself and *re-radiates* its own rays.

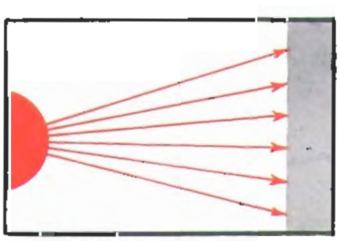
The effect of Radiant Rays is clearly demonstrated on days when the sun is bright but the air cool. When standing in the sunshine you are comfortably warm—moving into the shade causes a sensation of chilliness. You have been cut off from the sun's Radiant Rays and immediately notice a change in your comfort status.

Why Radiant Panel Heating?

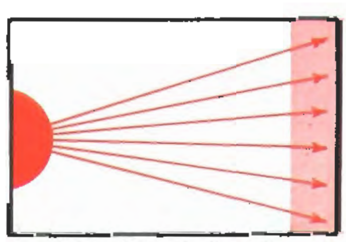
What are the reasons Radiant Panel Heating has so strongly gripped the imagination of the builder? They can be roughly divided into three appeals—aesthetic, physiological and economic.

From an aesthetic point of view, Radiant Panel Heating has qualifications which should cause every housewife to rejoice. The panels which provide Radiant Heat are *completely concealed* in either floor, ceiling or walls. No radiators or grilles—nothing to hamper furniture arrangement or decorative plans.

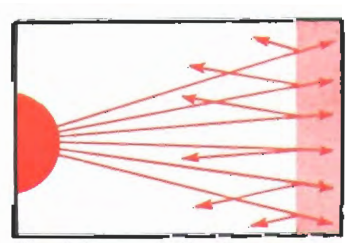
THE BEHAVIOR OF RADIANT RAYS



Radiant Rays move from warm to cooler surfaces.

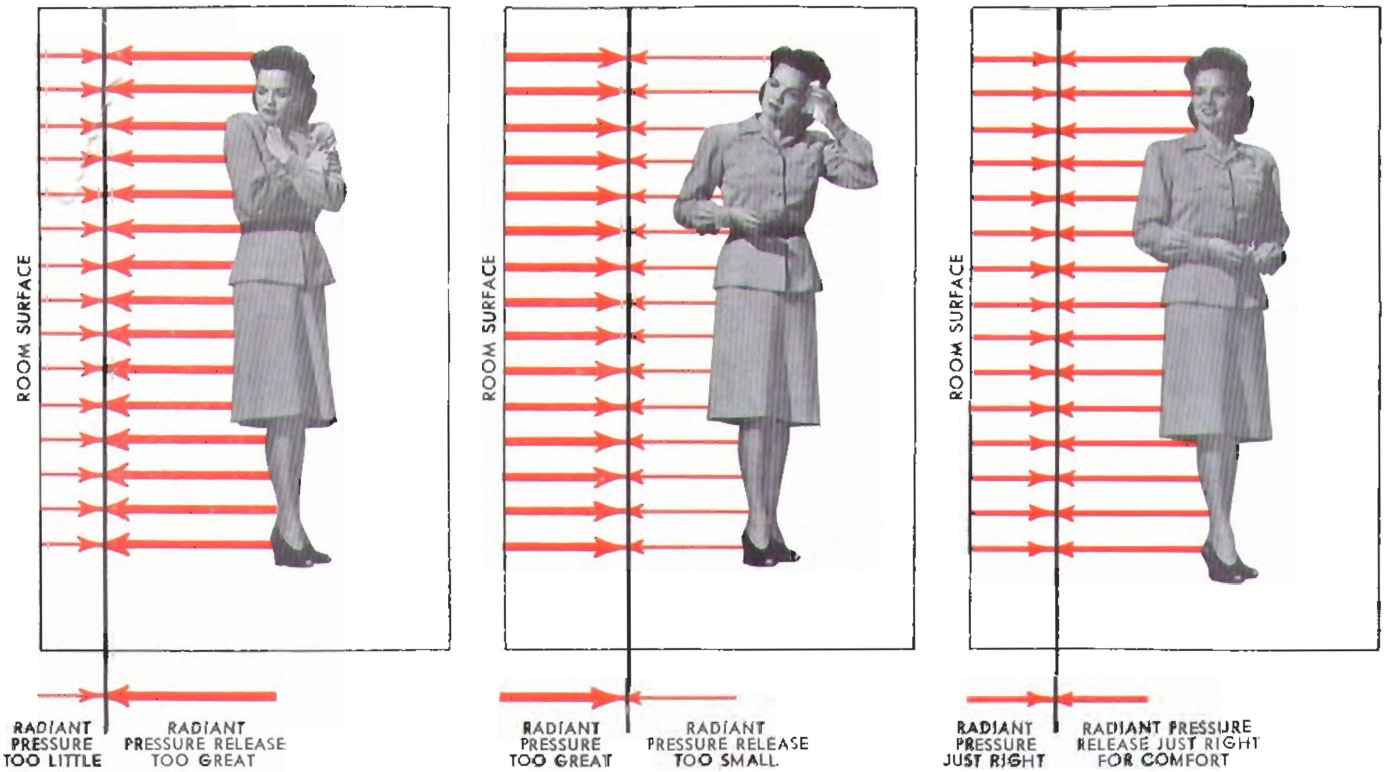


A portion of the Radiant Rays are absorbed by the cooler surface, thereby warming it.



The balance of the Rays are reflected to other surrounding cooler surfaces.

Considering the radiant heat in the body as Radiant Pressure, a controlled rate of release is required for comfort. By opposing it with Radiant Pressure from the room surfaces, the proper rate of emission can be established.



Thermal air currents are materially reduced, so that floor dirt is not picked up to be deposited on walls, ceilings or draperies. This cleaner air obviously creates a more sanitary condition in the home, as there is a lesser concentration of dust-borne disease germs.

Further, a Radiant Panel Heating System does not affect the location of partition walls or prevent later changes in the position of these walls.

The physiological advantages of Radiant Panel Heating . . . the comfort balance

In considering the principles of Radiant Panel Heating it is necessary to arrive at an entirely new concept of what keeps the body from feeling cold. It must be understood that comfort is not a matter of supplying heat to the body, but instead, one of *controlling the rate and manner in which heat is lost from the body.*

The body itself generates more heat than is necessary for its needs, and to be comfortable, must get rid of the excess. Excess body heat is dissipated in three principal ways—by Radiation, Convection and Evaporation.

The Radiation loss is the amount of heat given off by the warm body to surrounding cooler objects. The Convection loss is the heat carried away by the passage of air over the skin and clothing. The Evaporation loss is the heat used in converting moisture on the surface of the body into vapor.

Comfort demands that heat shall escape from the body at the same rate at which it is produced and in a certain manner. Let us, therefore, examine the usual methods of heating, which may or may not permit escape of body heat in a manner which produces maximum comfort.

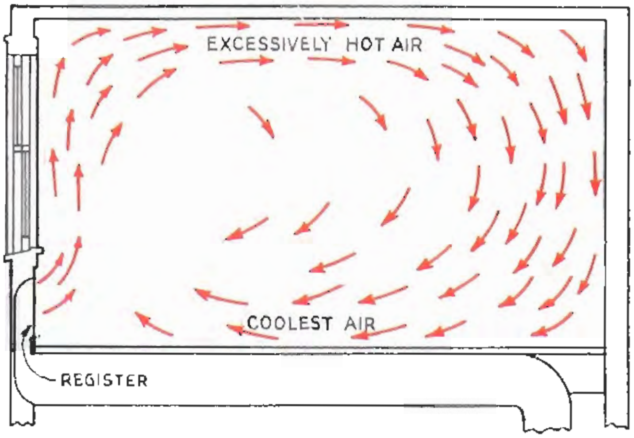
A person in normal sedentary activity loses heat at the rate of about 400 BTU per hour. Scientific investigation indicates that greatest bodily comfort is achieved when heat losses occur in approximately the following proportions: 190 BTU by Radiation, 120 BTU by Convection and 90 BTU by Evaporation. Since Radiation and Convection losses account for about 310 BTU, the problem of providing comfort is principally concerned with establishing the proper balance between the two.

The above values are relative, as the total will vary with bodily activity, age, sex, etc., but may be considered as practical for design purposes.

As explained before, it is a fundamental principle of radiant heat transfer that heat will flow only from a warm surface to one of lower temperature. Therefore, the body can lose heat by radiation to any surface at a lower temperature and gain heat from any warm surface regardless of air temperature. Radiation is thus controlled by surface temperature only. A person in a room filled with warm air, but having cold walls, would lose heat by radiation but very little by convection.

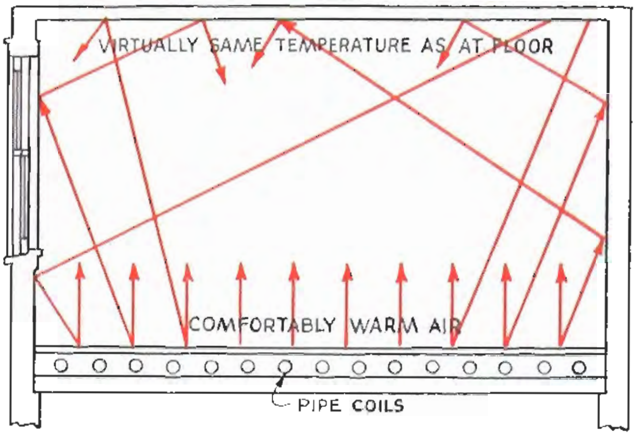
It is evident that the heating of enclosed spaces can be accomplished by two methods; first, by the conventional method, in which the air is heated to a sufficiently high degree and second, by Radiant Panel Heating.

A RADIANT HEATING SYSTEM DISTRIBUTES HEAT MORE UNIFORMLY IN EVERY ROOM



ORDINARY HEATING SYSTEM

In this type of system, air is delivered at high temperature to heat the room. Since heated air rises, the temperature at the ceiling is much higher than at the floor, which may be uncomfortably cool.



RADIANT HEATING SYSTEM

Radiant Rays from the pipe coils in the floor directly strike or are reflected like light rays to all room surfaces, warming them to the proper degree. Note that air temperature varies but little from floor to ceiling, with warmest air at the floor, where it should be for maximum comfort.

in which the temperature of the surfaces surrounding the body is raised.

It is within the range of everybody's experience that the conventional way may lead to discomfort. Excessively high air temperatures to overcome the effects of cold walls result in stuffiness and dryness. Or in other words, loss of body heat principally by radiation to cold room surfaces is not conducive to maximum comfort.

Economic reasons for Radiant Panel Heating

The approved heating medium for radiant panels is forced hot water—hence all the well known operating economies of this type of system are achieved. The automatic modulation of the heat supply to meet all variations in the weather prevents overheating and fuel waste.

How Radiant Rays are used to heat the home

Regardless of the kind of heating system, radiant heat is always a factor. The walls, floor and ceiling must be warmed before comfort can be achieved—*warm air alone is not sufficient!*

In the conventional heating system, the attempt to warm the structure is made either by Convection heating alone or by a combination of Convection and Radiation heating. For example, with a warm air heating system, the heated air introduced into the room is expected to warm the walls, floor and ceiling.

This approach to correct heating has the disadvantage of requiring that room air be maintained at a temperature frequently so high that the comfort balance is disturbed.

In Radiant Panel Heating the process is reversed. Instead of overheating the room air to heat the structure, the room surfaces are warmed from behind and the air becomes warmed by contact with them. Instead of *concentrated areas* of high temperature heat emission, such as registers and radiators, *large areas* of mildly heated floor, ceiling and walls supply over-all mellow warmth with a lower, more refreshing room air temperature.

By accurately controlling the temperature of the room surfaces, *as it is done in Radiant Panel Heating*, the amount of body heat given off by Radiation can likewise be controlled to the correct proportion for maximum comfort.

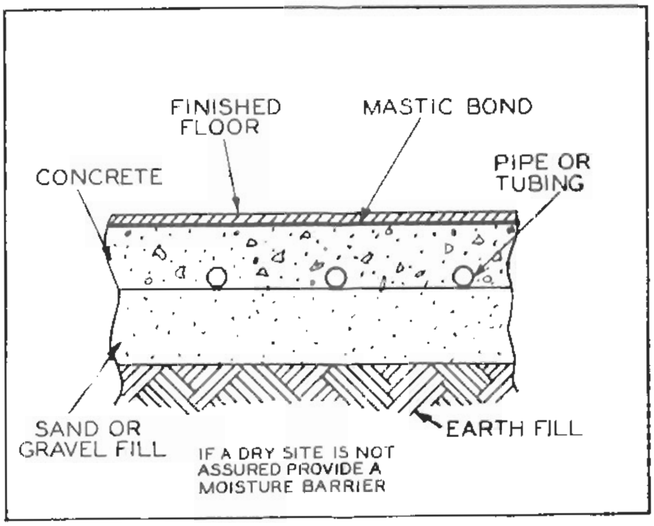
The method most used to obtain these large heating areas is to install pipe coils in the floor or ceiling and sometimes in the walls. In any case the heating effect is the same, as Radiant Rays, like light rays, travel and are reflected in all directions, without being affected by air currents. The pipe coils can be installed in any of the constructions normally used in building. Some examples are shown on page 56.

At what temperature should the Radiant Panel Heated home be kept?

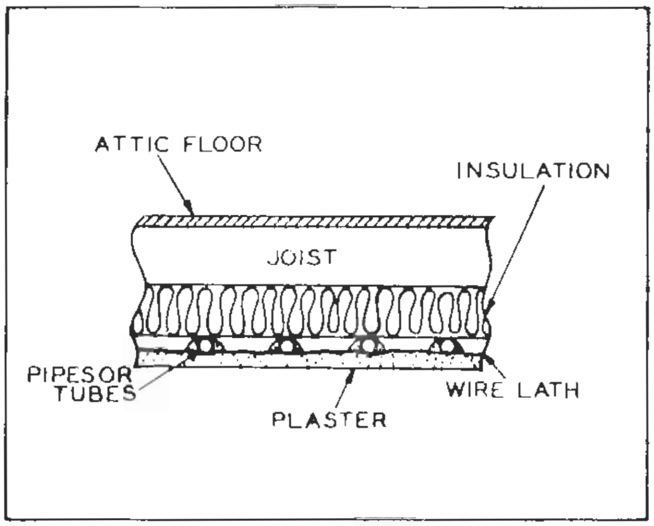
Generally speaking, the practice is to design the modern Radiant Panel Heating System so that the air temperature is somewhat lower than that maintained in the conventionally heated home. To compensate for the increased loss of body heat by Convection, the temperature of the room surfaces is raised to decrease the heat loss by Radiation.

Lower air temperatures have distinct advantages in that the air feels fresher, more invigorating and humidity conditions are greatly improved.

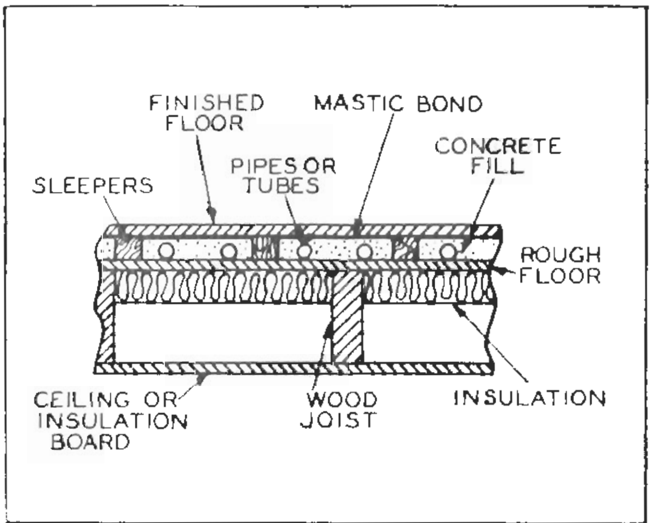
TYPICAL FLOOR AND CEILING PANEL INSTALLATIONS



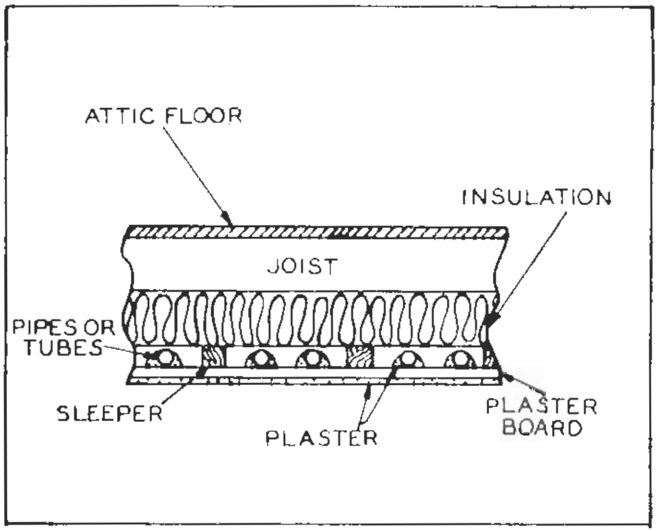
FLOOR SLAB ON GROUND



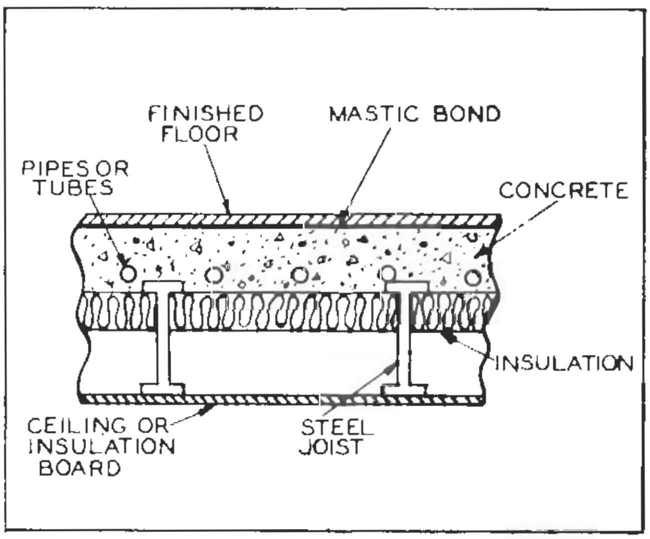
CEILING PANEL



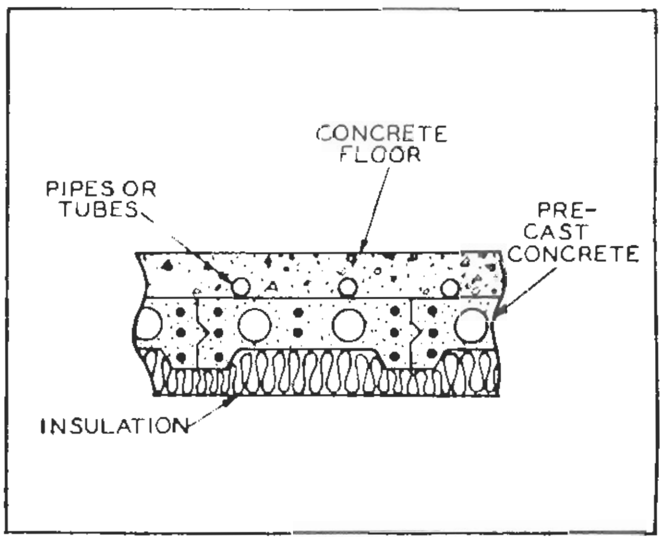
FLOOR ON WOOD JOIST, AIR SPACE BELOW



CEILING PANEL



FLOOR ON STEEL JOIST, AIR SPACE BELOW



PRE-CAST CONCRETE FLOOR

Fig. 87

DESIGNING A RADIANT PANEL SYSTEM—EXAMPLE "A"

ONE-STORY HOUSE WITH SERPENTINE COILS

STEP No. 1

CALCULATION OF BUILDING HEAT LOSS

In the house being used as design example "A", the various construction materials and corresponding "U" factors are given below. The "U" factors are taken from the tables on Pages 87 to 96.

Design Conditions

0°F outside temperature
+ 70°F inside temperature
10 M.P.H. wind velocity
Note: Garage to be heated to 55°F

Floor: 4" concrete slab on 6" gravel or sand fill. Tile or terrazza on concrete with mastic bond between concrete and tile.

There is little information available which indicates the heat conductivity of the earth under a concrete slab construction. The condition for each locality will vary because of the characteristics of the ground.

The ASH & VE Guide states that a "U" factor of .1 is ample in most instances for slab or basement heat loss to the ground. It is suggested, therefore, that 3 BTU per sq. ft. per hour be used in calculating the reverse heat loss of a slab. A dry sand or stone fill under the concrete will be helpful in maintaining this value.

Where slabs are laid directly on the ground, it is desirable that the pipe coils are not closer than 3 feet from the outside edge. If it is necessary to lay the coils closer than 3 feet, insulation must be interposed between the slab and the foundation, so that the equivalent of at least 3 feet of concrete exists. For this condition, the following values may be used in computing edge loss to the ground.

BTU LOSS PER HOUR PER LINEAL FOOT OF SLAB EXPOSED EDGE

BTU heat loss based on water temperature of approximately 130°F in ¾" tubes.

TABLE K

Equivalent distance of concrete from edge to first coil	DESIGN TEMPERATURE		
	0°—70°	-10° to 70°	-20° to 70°
1 Foot	81	88	97
2 Feet	50	55	60
3 Feet	33	37	40
4 Feet	25	28	30

For this example, it is suggested that a heat resistance equivalent to 4' of concrete be interposed at the edge of the slab (see calculation below). This will keep heat losses low enough to avoid snow melting around the outside of the building.

The heat loss through side walls below grade can be considered as 4 BTU per sq. ft. per hour.

Outside Walls: 4" brick veneer, 8" cinder blocks, plaster (¾") on metal lath, furred.
"U" = .25 (from Page 91)

Ceiling: Metal lath and plaster, 3⅝ Rockwool fill, no flooring above. (Assume outside temperature in attic space, which is ventilated.) Ceiling height 8'6"
"U" = .079 (from Page 92)

Glass: Single thickness, storm sash, weather stripped, windows double hung.
"U" = .45 (from Page 95)
Garage — no storm sash or weather stripping.
"U" = 1.13 (from Page 95)

Doors: Storm doors, weather stripped. Figure same as for glass.
"U" = .45 (from Page 95)
Garage — no storm doors or weather stripping.
"U" = 1.13 (from Page 95)

Infiltration: 10 M.P.H. wind (see Page 96)
For residence — Double hung wood sash windows.
13 cu. ft./hr. per foot of crack x .018 = .24
"U" = .24
For Garage — 21 cu. ft./hr. x .018 = .38
"U" = .38

CALCULATION FOR TOTAL SPACE HEAT LOSS AND TOTAL PANEL HEAT LOSS

Knowing the above "U" factors, the heat loss for each room can be determined. The calculation is as follows:

Net area (or crack length) x "U" factor x Temp. Diff. = Heat Loss in BTU/hr.

Starting with the Living Room and Entry, the handy form can be used to tabulate the heat losses from the various surfaces.

CALCULATION FOR INSULATION AGAINST EDGE LOSS

In residential installations using floor panels, it is necessary to use most of the available floor area to maintain a reasonable surface temperature. Therefore, it is often necessary to place the first coil or pipe near

PANEL LAYOUT—DESIGN EXAMPLE "A"

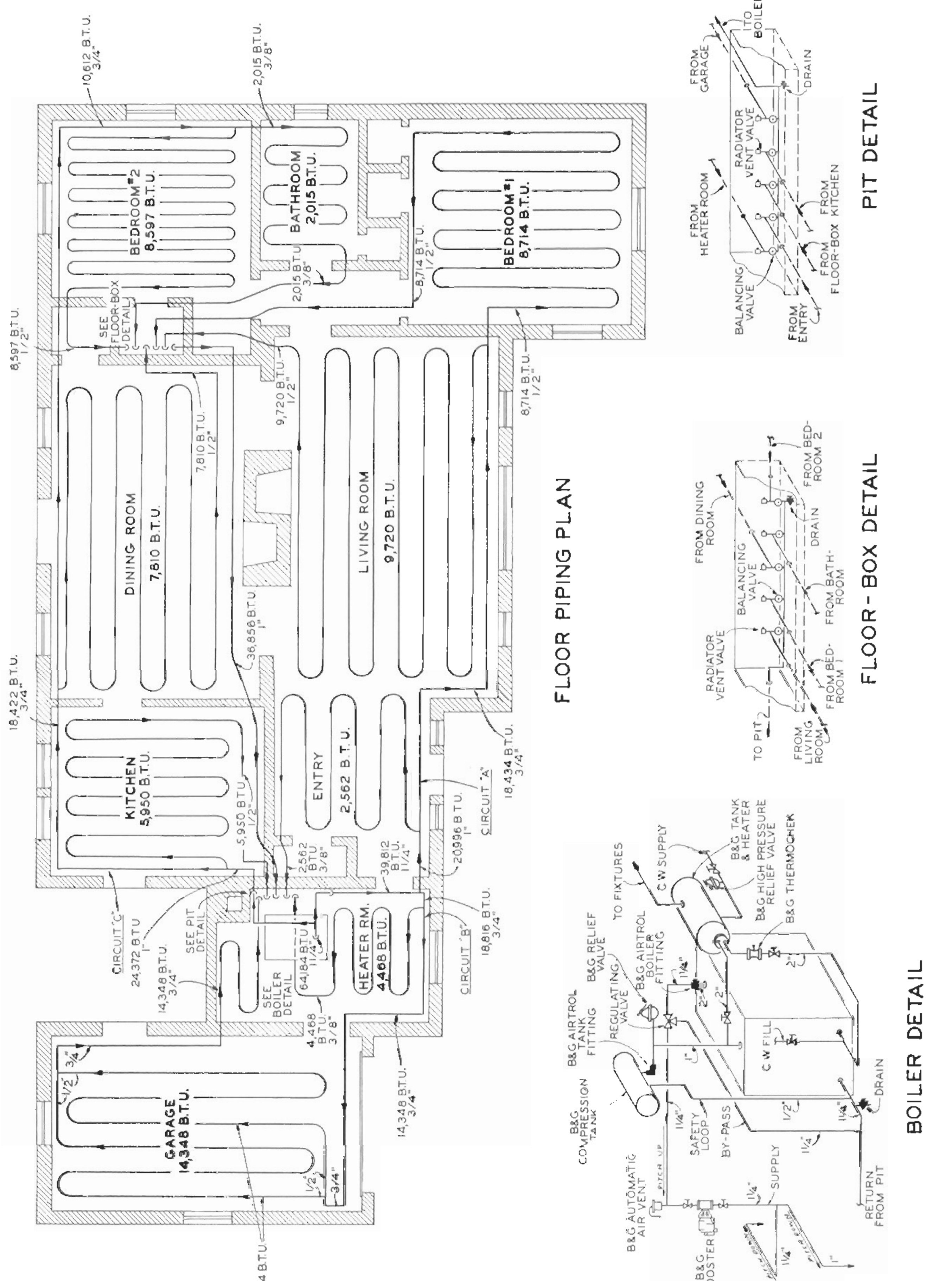


Fig. 88

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "A" (continued)

Step No. 1 (continued)

the outside wall. As a general rule, the first pipe may be placed one half the tube spacing from the inside face of an outside wall.

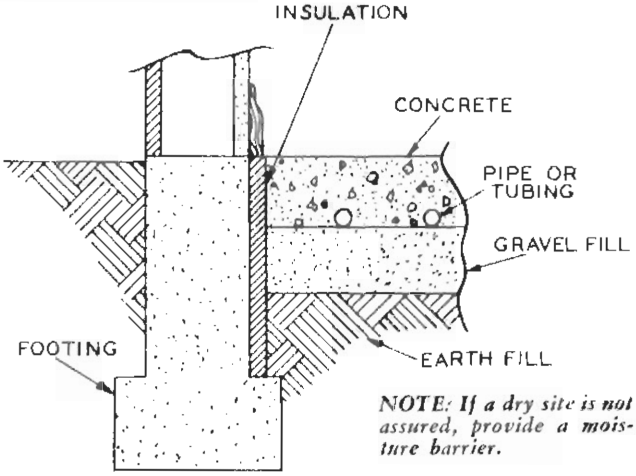


Fig. 89. Insulation for Floor Slab.

Fig. 89 shows a section of the floor adjacent to the outside wall. Since the footing wall is 12″ and the first tube is 6″ inside of the wall, there are 18″ of concrete between the tube and the outside earth. It is desired, however, to have the equivalent of 4′ of concrete, or a total loss of 25 BTU per linear foot of edge. Therefore, insulation equivalent to 2½′ or 30″ of concrete must be introduced.

Concrete has a "k" value of approximately 12 BTU per hour per sq. ft. per degree F. per *inch* of thickness. To determine the required thickness of insulation the following equation is used:

$$\frac{30'' \text{ (Insulation equivalent required)}}{12 \text{ BTU ("k" value of concrete)}} = \frac{X \text{ (Thickness of insulation)}}{k \text{ (Conductivity of insulation)}}$$

Weather-proofed building board insulation has a "k" value of .33 BTU per hour per sq. ft. per degree F. per inch of thickness. Substituting this value in above equation—

$$\frac{30}{12} = \frac{X}{.33}$$

$$X = \frac{30 \times .33}{12} \qquad X = .82'' \text{ required thickness of insulating board}$$

Therefore, 1″ insulating board should be used as this is a standard thickness. For greatest effectiveness, the insulation should be carried as deep as the frost line.

When a basement is heated with coils in the floor, the edge loss is no longer a factor, because of the distance below grade. In this case, the losses to be considered are the side wall loss of 4 BTU per sq. ft., the down loss of 3 BTU per sq. ft. and the normal loss through basement walls above the grade.

Note that in Table L there are two totals—one giving the heat loss of all surfaces *except* the floor and edge loss and the other including the floor and edge loss. The first total, or space loss, is used to determine the panel size. The second, or total panel loss, is used in calculating the amount of water which must be circulated.

The reason for this distinction is due to the fact that there is a *reverse* loss from panel sections into the basement or into the ground when the building is erected on a concrete slab.

REVERSE LOSS OF PANEL SECTIONS

In the case of a conventional heating system, the heat loss to the basement is considered as a heat loss

TABLE L

ROOM	Part of Structure	Net area or crack length	"U" Factor	Temp. Diff.	Heat Loss BTU/hr.	Total Space Loss BTU/hr.	Total Panel Loss BTU/hr.
Living Room And Entry	Glass	72.5	.45	70	2284	2284	2284
	Outside Walls	233.5	.25	70	4086	4086	4086
	Inside Walls						
	Floor						
	Ceiling	390	.079	70	2157	2157	2157
	Infiltration	117	.24	70	1960	1960	1960
	Reverse Loss	345	3		1035		1035
	Edge Loss	30.4	25		760		760
				Total Space Loss		10487	
				Total Panel Loss			12282

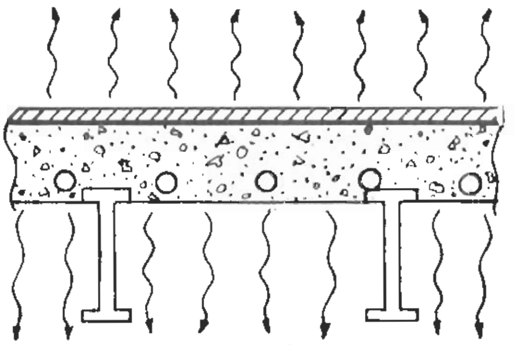
DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "A" (continued)

from the rooms above and is taken into consideration in sizing the radiators. The heat loss to the attic is similarly handled.

In panel heating systems, the heat loss to the basement is not a loss from the rooms above but is a *reverse loss* from the heating panels.

Inasmuch as the entire panel is being heated by the pipe coil, or grid, the heat which is being supplied to any enclosure is only part of the total heat supplied by the coil. The opposite side of the coil will similarly lose heat.

If a coil is placed in a construction in such a way that heat can be used from both sides, it becomes necessary to calculate the amount which will be dissipated from each side. If the heat from one side is not usable, it is necessary to eliminate this waste by introducing the proper amount of insulation. It is obvious that the amount of resistance placed between the panel coil and the surface from which the heat will be lost, determines the amount of heat which will finally leave this surface.



Heat desired in both directions.

In any case, the total amount of heat to be supplied by the coil is that which enters the enclosure to be warmed and that which is dissipated from the reverse side of the coil. The sum of the two must be used in calculating the total heat load of the coil.

Using the same procedure as followed in determining the heat loss of the living room, the heat losses of all rooms are:

	Total Space Loss BTU/hr	Total Panel Loss BTU/hr
Living Room and Entry	10487	12282
Bedroom No. 1	7320	8714
Bath	1640	2015
Bedroom No. 2	7505	8597
Dining Room	6560	7810
Kitchen	5110	5950
Laundry and Heater Room	3680	4468
Garage	12203	14348
	54505	64184

STEP No. 2

DESIGN OF HEATING PANELS

Definition of terms used and calculations necessary

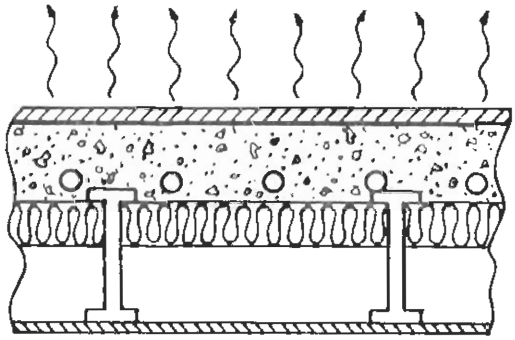
RADIANT HEATING

Radiant heating is the transmission of heat through space by wave motion. It is heat energy which travels and behaves much like light. Radiant heat rays always move from warm to cooler surfaces. The radiant heat output of a hot body depends upon the temperature differential between it and the cooler objects to which it is radiating.

CONVECTION HEATING

Convection heating is the transmission of heat by the circulation of a liquid or gas, such as air. The convected heat output of a hot body depends upon the temperature and movement of the gas or liquid which surrounds it.

Fig. 90



Panel insulated to permit heat emission in one direction only.

MEAN RADIANT TEMPERATURE

MRT is the abbreviation for Mean Radiant Temperature, or the *weighted average* of room surface temperatures. The following method for determining MRT is simple and sufficiently accurate.

Assume that one surface area is 100 sq. ft. at a temperature of 50°F and another surface area is 50 sq. ft. at 70°F.

First, add the areas: 100 + 50 = 150

Next, multiply each area by its temperature and add the products.

100 (sq. ft.) x 50 (°F) = 5000
50 (sq. ft.) x 70 (°F) = 3500
Total 8500

Now divide the sum of the products by the sum of the areas—

$$\frac{8500}{150} = 56.6 \text{ MRT of the two surfaces}$$

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "A" (continued)

Step No. 2 (continued)

In Radiant Panel design procedure, the MRT of all room surfaces, *except the surface used as the heating panel,* is computed. For example, if the floor is to be the heating panel, the MRT needed is that of the glass, doors, walls and ceiling.

MEAN EFFECTIVE TEMPERATURE

MET is the abbreviation for the term Mean Effective Temperature. It is the *average* of the MRT of the unheated surfaces and the room air temperature.

$$\text{MET} = \frac{\text{MRT} + \text{Air Temperature}}{2}$$

PANELS

Floors, walls, ceilings or any combination of these surfaces can be used as the heating panel, but in general, floor or ceiling panels are more practical. The panels give off heat by radiation and convection in approximately the following percentages:-

Surface	*Convected Heat*	*Radiant Heat*
Floor	45%	55%
Ceiling	33%	67%
Wall	40%	60%

HEATING PANEL SURFACE TEMPERATURE

This is the temperature at which the surface of the heating panel must be maintained in order to establish the desired MET. The highest recommended heating panel surface temperatures are listed in the ASH & VE Guide as follows:

Plastered Ceiling	115°F
Plastered Walls	120°F
Floor	90°F
Floor border and aisles	120°F

KIND OF PIPES PERMISSABLE

Either ferrous or non-ferrous pipe or tubing can be used for embedding in plaster or concrete.

COILS

The type of coil is optional—either grid or serpentine (See illustration on following page). It should be understood that the heating results obtained will be the same from either type of coil, provided that the pipe size and spacing is the same. The difference between the two becomes apparent when designing for the proper flow of water through the system.

If serpentine coils are used, more care in designing must be exercised to guard against excessive pressure drop through the coil. An obstruction in a serpentine coil will prevent the entire coil from heating, whereas, an obstruction in a grid coil will cause only a partial stoppage for which compensation can be made.

The total space and panel heat loss of the example house has been determined in Step No. 1. In Step No. 2 the size of the panels necessary to heat each room is calculated.

Starting with the Living Room and Entry, the MRT of all *unheated* surfaces is determined. As explained before, this is obtained by multiplying each room area by its inside surface temperature.

NOTE: ALL CHARTS NECESSARY TO HEATING PANEL DESIGN ARE ON PAGES 41 AND 42.

Referring to Chart 2, the inside surface temperatures of the Living Room, with an outside temperature of 0°F, are shown to be:

Surface	*"U" Factor*	*Surface Temperature*
Glass	.45 (from Step 1)	49.5 (from Chart 2)
Outside Wall	.25 " " "	58 " " "
*Inside Wall		70
Floor (not considered)		
Ceiling	.079 (from Step 1)	65 " " "

The MRT is now computed by the calculation—

$$\frac{\text{The sum of surface areas in sq. ft.} \times \text{their surface temperatures}}{\text{Sum of the areas}}$$

Therefore:

Glass	72.5 x 49.5	=	3,588
Outside Wall	233.5 x 58	=	13,543
Inside Wall	422 x 70	=	29,540
Ceiling	390 x 65	=	25,350
	1118.0		72,021

$$\frac{72021}{1118} = 64.5 \text{ MRT}$$

The MET is next calculated by this formula.

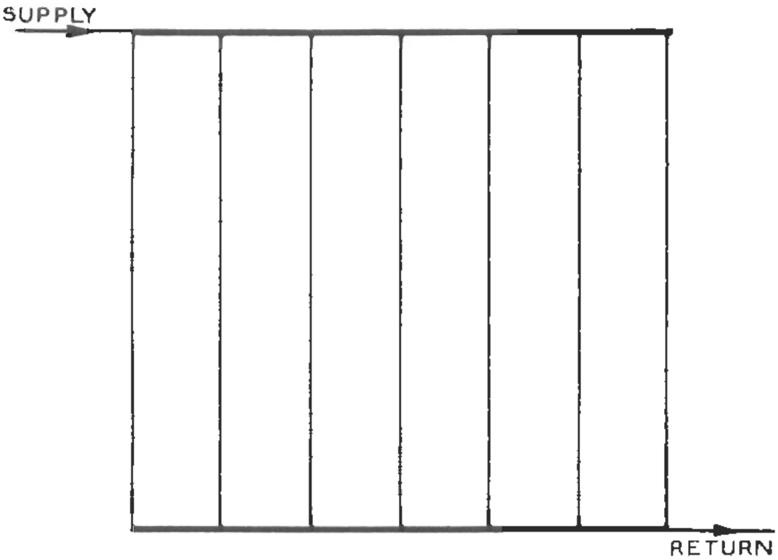
$$\frac{\text{MRT} + \text{Air Temp.}}{2} = \text{MET}$$

Substituting the proper figures in the above equation, we have:

$$\frac{64.5 + 70}{2} = 67.25 \text{ MET}$$

* *Inside walls are considered to be at the same temperature as the room air, hence, no "U" factor is shown.*

EXAMPLES OF RADIANT PANEL PIPE COILS



Grid-type Coils

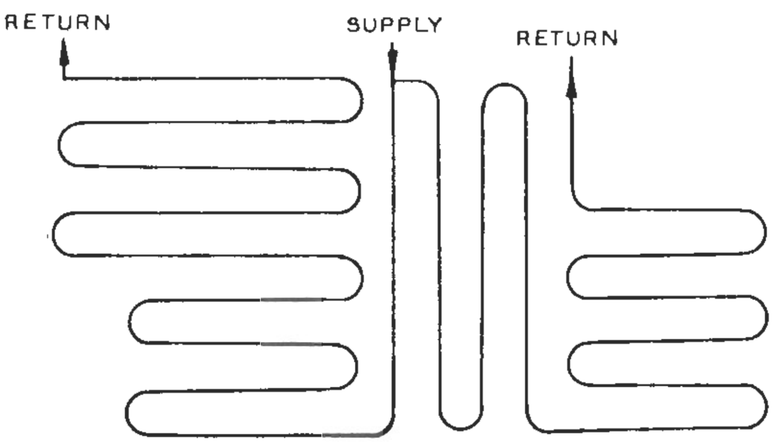
In the grid-type coil, the cross members are welded or brazed into headers. When fabricated as shown by the photographs on this page, a strong, tight weld is effected with no projections to cause resistance to the flow of water. Grid coils have a relatively low pressure drop.

To avoid the possibility of short circuiting, grids should be constructed so that the ratio of the header length to the lateral length does not exceed ¾ to 1.

Header drilled to receive cross member.

Shoulder prevents cross member from projecting into header.

A strong, tight weld is effected.



Serpentine Coils

These coils are continuous in length, with welded or brazed joints. The pressure drop through a serpentine coil is much greater than through a grid and must be taken into account when calculating the water flow through the system.

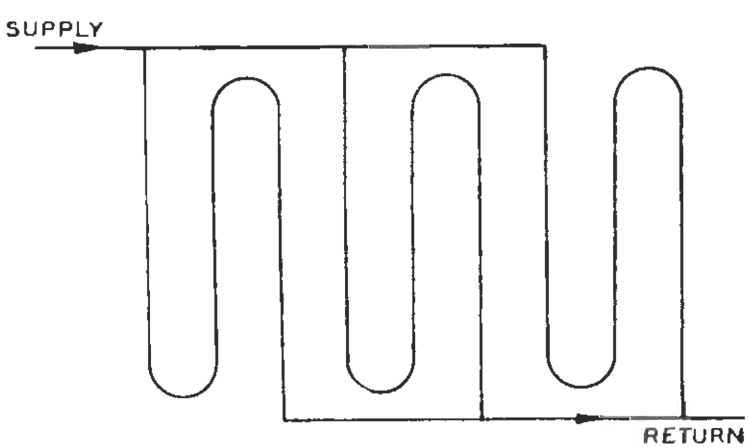


Fig. 91

Serpentine Coils in Reverse Return

This arrangement, in which the first coil to receive water is the last to return it, is preferable to a direct return. The coils are of equal length, hence properly balanced.

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "A" (continued)

Step No. 2 (continued)

The BTU requirement per sq. ft. of heating panel is next determined by the equation—

$$\frac{\text{10487 (Total space loss in BTU/hr.)}}{\text{**345 (Floor area in sq. ft.)}} = \text{30.4 BTU per sq. ft. of panel}$$

From Chart 3, we find that to obtain 30.4 BTU per sq. ft. of panel with an MET of 67.25, the panel temperature must be 79°.

Before determining the spacing of the pipes making up the panel, it is necessary to arbitrarily select a water temperature. Experience has shown that a temperature range of from 120° to 140° is practical.

As a rule, the highest panel temperature required in the building is the governing factor in selecting the water temperature. Accordingly, it is best to determine the required panel temperature for each room before starting the pipe spacing calculations. The various required panel temperatures in this example are determined by the same procedure as just shown for the Living Room.

Living Room and Entry	**— 79° Panel Temperature**
Bedroom #1	**— 85° " "**
Bath	**— 85° " "**
Bedroom #2	**— 90° " "**
Dining Room	**— 79° " "**
Kitchen	**— 85° " "**
Laundry & Heater Room	**— 85° " "**
*****Garage**	**— 80° " "**

In the above tabulation, 90° in Bedroom No. 2 is shown to be the highest panel temperature required. Reference to Chart 5 shows that with a water temperature of 140°, the pipes should be spaced on 9" centers. This spacing is not too small for good practice, so the selection of 140° water is satisfactory.

Table M on following page is suggested as a handy way to tabulate the data required for each room.

Using Chart 5 in the same manner as for Bedroom No. 2, the panels for the balance of the rooms are shown to require the following pipe spacings—

Living Room and Entry	**18"**
Bedroom No. 1	**14"**
Bath	**14"**
Bedroom No. 2	**9"**
Dining Room	**18"**
Kitchen	**14"**
Laundry and Heater Room	**14"**
*****Garage**	**18"**

PANEL SIZES

The Living Room and Entry have a total floor area of 390 sq. ft. Eliminating the area of the closets at the Entry, reduces the available area to 345 sq. ft.

Although the Living Room and Entry are considered as one room, because there is no separating wall, the irregular shape of the combined areas makes it necessary to install two panels.

In the Entry area, there is room to install a panel 8' long and 7'6" wide. It has previously been established that with 140° water, pipes on 18" centers will supply the heat requirement of the room. Within the width of 7'6", six tubes can be installed on 18" centers.

In the Living Room there is space for a panel 20' long and 10'6" wide. In the width of 10'6", eight tubes can be installed on 18" centers.

Using the same method for the other rooms, panel sizes are—

	Panel Size	*No. of tubes*
Living Room	**20' x 10'6"**	**8**
Entry	**8' x 7'6"**	**6**
Bedroom #1	**11' x 10'6"**	**10**
Bath	**5' x 5'10"**	**6**
Bedroom #2	**10' x 9'**	**13**
Dining Room	**20' x 9'**	**7**
Kitchen	**10' x 8'2"**	**8**
Laundry & Heater Room	**5'6" x 4'8"**	**5**
Garage	**18' x 7'6" (see below)**	**6**

SPECIAL DESIGNING REQUIRED FOR GARAGE

The garage requires special handling since the air temperature is to be 55° and the pipe spacing chart is based on a 70° air temperature.

When considering lower air temperatures for practical purposes it is safe to assume that the MET is equal to the air temperature. Therefore, reference to the BTU Emission Chart 3 shows that at a 55 MET and 80° panel temperature, the emission rate is 90 BTU per sq. ft. The amount of panel area required is thus—

$$\frac{\text{12203 (BTU load)}}{\text{90 (BTU per sq. ft.)}} = \text{135 sq. ft. panel area required}$$

Reference to Tube Spacing Chart 5 shows that with 140° water and 80° panel temperature, 18" spacing is required.

** *This is the area of the floor minus the area of the closets, as it is not necessary to extend the heating panel under closet floors.*

*** *See special treatment of garage.*

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "A" (continued)

SERPENTINE PANEL DESIGN

For the panels, the piping will be ½" nominal pipe size, formed into serpentine coils. Pipe is to be embedded in the concrete floor with a minimum cover of 2".

At this point, it might be well to consider the ways in which a serpentine coil can be laid out. Because of flow conditions, pipe size and length of coil, many problems of arrangement present themselves.

It is desirable to arrange the piping so as to avoid pockets or air traps, such as might be caused by crossing the pipes. It is also necessary to limit the pressure drop through a coil to keep the pump within an economical size.

The desirable maximum pressure drop has been found to be not in excess of 3 feet (36000 milinches). In some instances, it may be necessary to change the spacing between coil passes in order to maintain the desired piping arrangement. When the number of tubes or spaces must be changed to fit the required amount of coil into the available space, it is advisable to decrease the tube spacing and increase the amount of pipe.

Because pressure drop is a limiting factor in the design of the serpentine coil, it is necessary to know the total flow required in each coil. The total flow required in each panel is listed in Step 1 on page 60 under heading "Panel Loss."

CALCULATION FOR RESISTANCE IN SERPENTINE COILS

The Living Room has an area available for a panel 20' x 10'6" = 210 sq. ft. This will permit installing a panel of 8 tubes on 18" centers, with a total tube length of approximately 170 ft. To this must be added elbow equivalents for each return bend. One 180° open return bend in ½" tubing has a resistance equal to 1.04 ft. of straight tubing. Seven return bends, therefore, introduce a resistance of 7.28 ft. and the total equivalent length becomes approximately 177 ft. The required flow through the coil is 9720 BTU (12282 BTU combined Living Room and Entry panel loss — 2562 BTU Entry panel loss = 9720 BTU.) Referring to the Pipe Sizing Chart on page 39, and reading to the right from ½" pipe size, the nearest and next largest load, or 11000 BTU is shown to be carried at a resistance of 200 milinches. However, since 9720 BTU per hour is only 120 BTU greater than the 9600 BTU carrying capacity indicated in the 150 milinch column, it is safe to use the 150 milinch figure. An exact resistance can be arrived at by interpolation.

177 (total equivalent length) x 150 (milinch resistance per ft.) = 26,550 (total milinch resistance)

$$\frac{\text{26550 (total milinch resistance)}}{\text{12000 (milinches per ft.)}} = \text{2.21 ft. of Head Pressure}$$

Since this required Head Pressure is not in excess of 3 ft., the coil is satisfactory:

Calculated by the same method as above, the Head Pressures required in the remaining coils are as follows:

Living Room	**2.21 ft.**
Entry	**.25 ft.**
Bedroom No. 1	**1.47 ft.**
Bath	**.20 ft.**
Bedroom No. 2	**1.90 ft.**
Dining Room	**1.95 ft.**
Kitchen	**.80 ft.**
Laundry	**.18 ft.**
Garage	**.74 ft.** (see next page)

TABLE M

ROOM	Part of Structure	Area in Sq. Ft.	Surface Temp.	Surf. Temp. x Area		
Living Room And Entry	Glass	72.5	49.5	3588	MRT of Unheated Surface 64.5	Panel Temp. 79
	Outside Walls	233.5	58	13543		
	Inside Walls	422	70	29540		
	Floor				MET $\frac{\text{MRT + Air Temp.}}{2}$ 67.25	Pipe or Tube Dia. ½"
	Ceiling	390	65	25350		
	Infiltration					
	Reverse Loss				BTU Per Sq. Ft. of Panel 30.4	Pipe or Tube Space 18"
	Edge Loss					
		1118.0		72021		

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "A" (continued)

Step No. 2 (continued)

Note on the heating plan on Page 58 that the garage coil is split into two sections in a semi-grid arrangement. This is necessary because the resistance in a single coil exceeds 3 ft. of Head Pressure.

The development of the garage coil design is as follows:

In Figure 92 below is a plan of the garage using a single coil. Measuring the total pipe coil length, it will be found that there is 120 feet of ½" pipe plus 6 return bends. Since a return bend is equal to one elbow equivalent and one elbow in ½" pipe equals 1.04 ft. of ½" pipe, we find that we have an equivalent of 6.24 ft. of pipe due to elbows. Adding this length to the straight pipe length of 120 ft., we have 120 + 6.24 = 126 ft. equivalent length of coil.

The flow rate required in the garage is 14,348 BTU/hr. Referring to Table B of the Pipe Sizing Chart on page 39, we find that at a flow rate of 14,348 BTU, we will have a friction loss of 350 milinches per foot in ½" pipe.

Then multiplying the equivalent length of 126 ft. by 350 milinches:

126 × 350 = 44,100 milinch resistance

$$\frac{44{,}100}{12{,}000} = 3.67 \text{ ft. of Head required}$$

Since this is greater than the three foot limit, it is necessary to reduce the friction loss either by increasing pipe size or dividing the coils into two or more sections. In this case, divide the coils and retain the ½" pipe size.

Now check the resistance conditions in the coils as illustrated in Figure 93.

A tee diverts 50% of the water to the first coil and 50% to the second coil. Each coil, therefore, carries one-half of the heating load or 7174 BTU. The table of elbow equivalents on page 38 shows that at 50% diversion a ½" tee is equivalent to 4 elbows. One 90° elbow in ½" pipe = 1.04 ft. 4 elbows x 1.04 = 4 ft. equivalent length.

The flow entering the tee is the sum of the two coils or 14,348 BTU. At this flow the resistance in a ½" pipe is 350 milinches per foot.

Therefore, 4 ft. equivalent length x 350 milinches per foot = 1400 milinches resistance due to the tee.

The resistance can be checked through either of the two coils as they are of equal length and in parallel. In the first coil, we have approximately 58 feet of straight ½" pipe, plus 2 open return bends (one open return bend equals one elbow) and one 90° elbow, for a total equivalent of 3 elbows.

3 elbows × 1.04 equivalent length per elbow = 3.12 ft. equivalent length

58 feet straight pipe + 3.12 elbow equivalents = 61 ft. total equivalent pipe length

DIAGRAMS BELOW SHOW HOW DIVIDING A COIL MATERIALLY REDUCES THE PRESSURE DROP

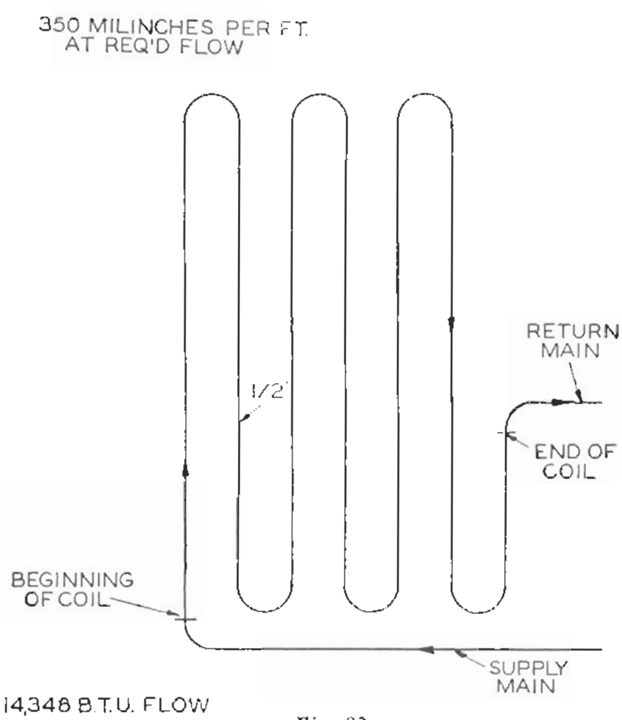


Fig. 92

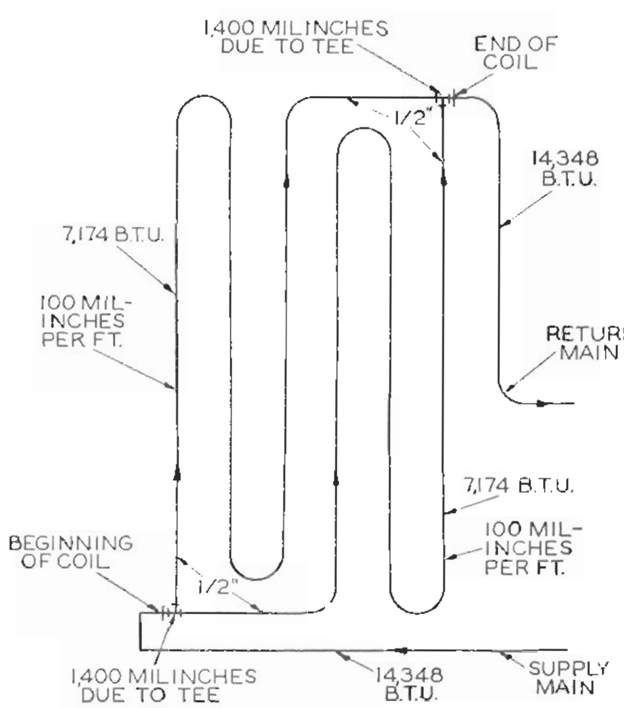


Fig. 93

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "A" (continued)

In this coil there is a flow of 7174 BTU, which is equal to a flow resistance of approximately 100 mil-inches per foot. (See Table B in Pipe Sizing Chart on page 39.)

61 ft. total equivalent length × 100 milinches per foot = 6100 milinches resistance through the coil

To the flow of the first coil is now added the flow of the second coil, the total flow entering the return main through a tee. Since the flow in each coil is equal, the tee resistance is at 50% flow or equal to 4 elbows.

4 × 1.04 = 4 ft. equivalent length

The flow at this point is the sum of the two coils or 14,348 BTU. At this flow in a ½" pipe, the resistance is 350 milinches per foot.

4 × 350 = 1400 milinches resistance due to the tee

Adding all the resistances determined above gives the total pressure drop through both coils.

1400	**milinch resistance through first tee**			
6100	"	"	"	**coil**
1400	"	"	"	**second tee**
8900	**total milinch resistance**			

$$\frac{\textbf{8900 milinch pressure drop in coil}}{\textbf{12000 milinches per foot}} = \textbf{.74 ft. of Head}$$

From the above, it will be seen that dividing the coil into two sections materially reduces the total pressure drop.

STEP No. 3

LAYOUT OF DISTRIBUTION PIPING FROM AND BACK TO BOILER

It is evident that each particular radiant panel installation presents its own problem in the arrangement of the distribution piping. After panel sizes have been determined and the panels drawn in to scale on the layout, the arrangement of the distribution piping becomes a matter of bringing water to the various panels with the shortest possible runs of pipe. See Fig. 94

In this basementless house there is only one elevation at which to run pipe. Care must be exercised to avoid crossing pipes, which would create air pockets or traps.

It is possible to drop supply mains into the floor at various locations in the boiler room, since at this point, the supply line can be run overhead. In this example, the supply main has two branches—one running along the front of the building, the other along the back.

It is desirable to provide an individual return line from each panel, in which a balancing valve can be installed. This permits an adjustment of water flow to compensate for possible errors in design.

Since in this example there are nine separate panels, it is difficult to bring all returns directly back into the boiler room. As it is not desirable to have floor boxes in each room, the clothes closet in Bedroom No. 2 has been selected as a location where several returns can be collected in one floor box. It is possible to carry the returns overhead in the attic space to the boiler room if floor boxes are objectionable. A single return is then run back to the boiler, thus eliminating the congestion which would result if all nine returns were brought back individually (See detail of floor box and pit at boiler, Page 58).

STEP No. 4

AMOUNT OF WATER REQUIRED TO CARRY THE HEATING LOAD

The formula for determining the number of gallons of water per minute which must be circulated to carry the heating load is as follows—

$$\frac{\textbf{Total Heat loss of panels in BTU}}{\textbf{20 x 60 x 8}} = \textbf{Gallons per minute (GPM)}$$

From the calculation in Step No. 1, the total *panel* heat loss is known to be 64,184 BTU.

Therefore:

$$\frac{64184}{10000} = 6.42 \text{ GPM}$$

STEP No. 5

SELECTION OF BOOSTER PUMP

Definitions of "Pressure Drop", "Head Pressure", and "Milinches" are given on pages 19, 20 and 21.

A flow of 6.42 GPM is required. Reference to the Booster Capacity Chart shows that this flow will be produced at a 6.2 ft. Head by a 1" Booster. A 1" Booster is selected rather than a ¾" because as shown hereafter, the smaller pump will not produce a sufficient Head Pressure.

In this design example, however, there are two additional factors to consider which affect pump selection. The pressure drop of the serpentine coils and that of the Regulating Valve must be considered.

The Regulating Valve shall be considered to have a pressure drop of 1 ft. at the flow rate required.

Reference to the listing of pressure drops through the various coils shows that the greatest pressure drop is 2.21 ft. in the Living Room. Adding this to the 1 ft. drop of the Regulating Valve totals 3.21 ft. which must

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "A" (continued)

Step No. 5 (continued)

be deducted from the pump head of 6.2 ft. This leaves a Head of 3 ft. available for piping.

It has been stated before that for an economical balance between pump size and pipe size, the minimum head for any piping circuit should be 2.5 ft. Therefore, the 3 ft. Head provided by a 1" Booster is satisfactory.

STEP No. 6

SIZING THE DISTRIBUTION PIPING

The piping layout of the example house is divided into three circuits, labeled A, B and C on the plan. The longest circuit is A, supplying the Entry, Living Room and Bedroom No. 1. See Fig. 95.

Measuring the circuit from the boiler to the panel in Bedroom No. 1, from the panel to the floor box in Bedroom No. 2 and back to the boiler, the length is found to be 150 feet. *Note that the length of the coil is not included in the measurement!* Adding 50% or 75 ft. to this length for the resistance of the fittings, brings the Total Equivalent Length to 225 feet.

Again refer to the Pipe Sizing Chart on Page 39. It was determined in Step 5 that a 1" Booster would deliver the required 6.42 GPM at a head pressure of 6.2 ft. However, 3.21 ft. of this head is required to compensate for the pressure drop through the Regulating Valve and the coil. Thus 3 ft. of head is available for the balance of the piping.

In Table A of the Pipe Sizing Chart, reading to the right from 3 ft. of Head Pressure, the nearest larger Equivalent Length is found to be 240 ft. This appears in the 150 milinch column.

The pipes will, therefore, be sized on the basis of a 150 milinch friction head per foot of pipe.

The total heating load in this example is 64,184 BTU. Reading downward in the 150 milinch column in Table B to the nearest *larger* figure, it is found to be 78,000 BTU. Reading left from this figure shows the required pipe size to be 1¼".

The trunk supply main, therefore, from the point where it leaves the boiler to the point where it branches, will be 1¼" pipe.

SIZING THE CIRCUITS

One branch of the supply main feeds Circuits A and B which carry the following load—

Entry	—	**2562 BTU**
Living Room	—	**9720 "**
Bedroom No. 1	—	**8714 "**
Laundry and Heater Room	—	**4468 "**
Garage	—	**14348 "**
		39812 BTU

Referring again to Pipe Sizing Table in the 150 milinch column, the next largest figure is 78,000 BTU. Reading to left from this figure shows that a 1¼" pipe will carry the load. This size of pipe is, therefore, used up to the point where the branch divides into Circuits A and B. Circuit A carries the following load--

Entry	—	**2562 BTU**
Living Room	—	**9720 "**
Bedroom No. 1	—	**8714 "**
		20996 BTU

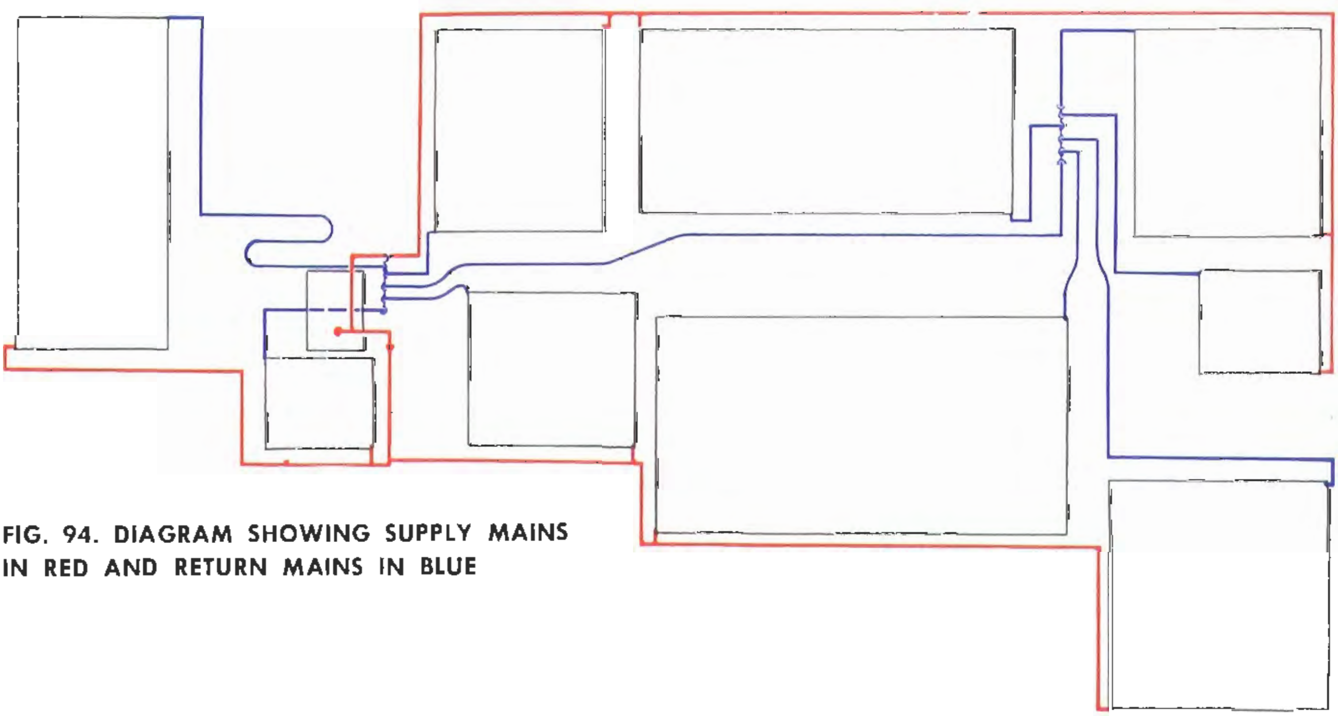


FIG. 94. DIAGRAM SHOWING SUPPLY MAINS IN RED AND RETURN MAINS IN BLUE

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "A" (continued)

The nearest larger figure in the 150 milinch column is 37,000 BTU, which requires a 1" pipe. 1" pipe is, therefore, installed up to the point where the Entry panel is taken off.

The heating load then becomes —

Living Room	—	**9720 BTU**
Bedroom No. 1	—	**8714 "**
		18434 BTU

Reference to Table B shows that 18,434 BTU will be carried by a ¾" pipe which is used up to the point where the Living Room is taken off Circuit A.

The remaining pipe in this circuit supplies the panel in Bedroom No. 1 which has a requirement of 8714 BTU. Table B shows that a ½" pipe will carry this load.

The return mains from the panels in Bedroom No. 1 and Living Room are run to a floor box in Bedroom No. 2. The return from the Entry goes directly to the boiler pit.

Their loads are —

Entry	—	**2562 BTU**
Living Room	—	**9720 "**
Bedroom No. 1	—	**8714 "**

Reference to Table B shows that the Entry load can be carried by a ⅜" pipe and that Living Room and Bedroom No. 1 loads will require ½" pipe.

A total of five returns enter the floor box in Bedroom No. 2, so the return from this point to the boiler must be sized accordingly. The five panels returning to the floor box are —

Living Room	—	**9720 BTU**
Bedroom No. 1	—	**8714 "**
Bath	—	**2015 "**
Bedroom No. 2	—	**8597 "**
Dining Room	—	**7810 "**
		36856 BTU

Table B shows that this load can be carried by a 1" pipe.

At the pit in the boiler room, all returns are brought to a header. This header and its connection to the boiler carry the entire load of the system, namely, 64,184 BTU, and should be of 1¼" pipe.

The supply and return mains of circuits B and C are sized in a similar manner.

STEP No. 7

SELECTION OF BOILER

Selection of a properly sized boiler should be in accordance with the standards of the Heating, Piping and Air Conditioning Contractors National Association, as published in their semi-annual bulletin, "Net Load Recommendations for Heating Boilers".

Where domestic water is to be provided see page 3 for additional boiler load.

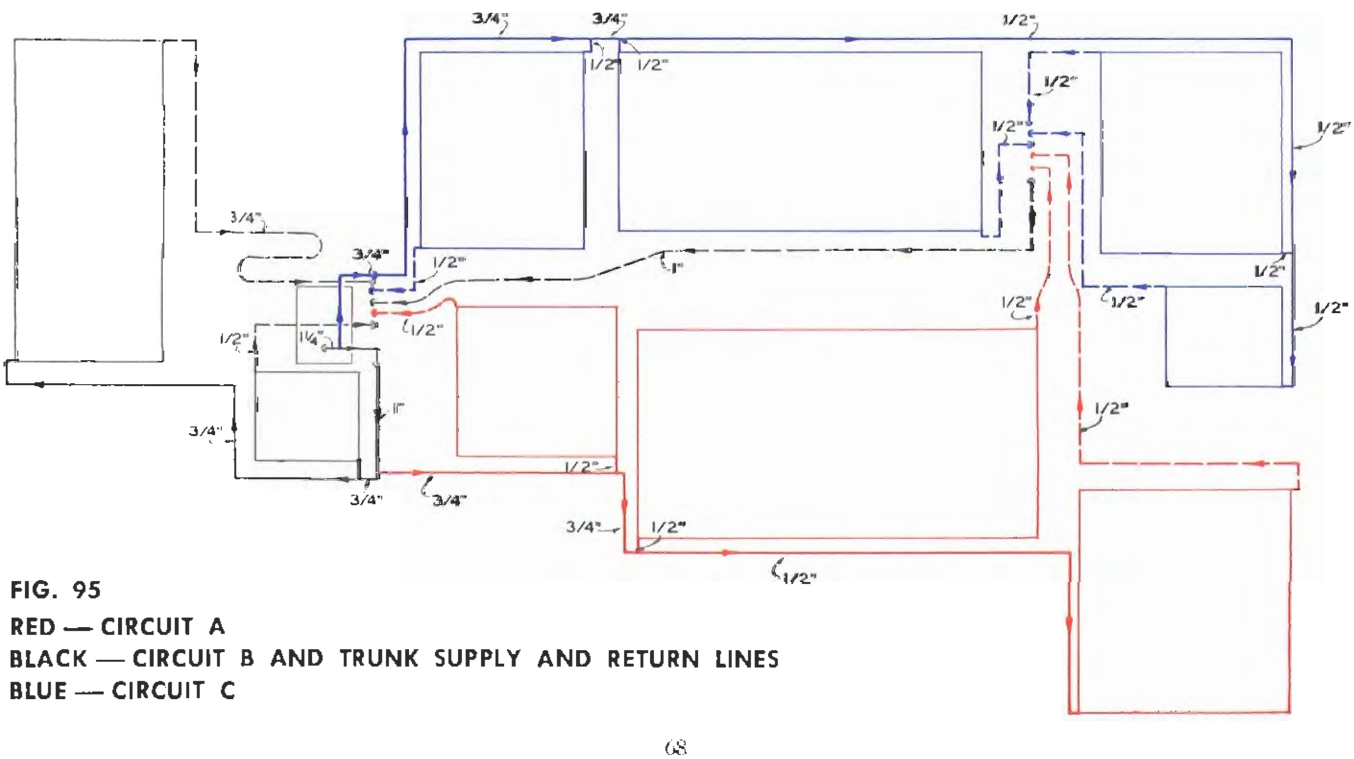


FIG. 95

RED — CIRCUIT A

BLACK — CIRCUIT B AND TRUNK SUPPLY AND RETURN LINES

BLUE — CIRCUIT C

DESIGNING A RADIANT PANEL SYSTEM—EXAMPLE "B"

ONE-STORY HOUSE WITH GRIDS

STEPS No. 1 and 2

HEAT LOSS CALCULATION AND PANEL DESIGN

For this example of radiant panel design, the same house as in Example "A" will be used, the only difference being that the heating panels will be grids, instead of serpentine coils. The grids are to be constructed using 1″ headers and ½″ cross members.

Since all characteristics up to the point of designing the panels remain the same, it is only necessary to restate them in the table below. It is only in calculating the hydraulics of the system that the procedure changes.

TABLE N

	Space Loss	Panel Loss	Panel Temp.	Pipe Space	Panel Size	No. of Tubes
Living Room	8402	9720	79°	18″	20′ x 10′6″	8
Entry	2085	2562	79°	18″	8′ x 7′6″	6
Bedroom No. 1	7320	8714	85°	14″	11′ x 10′6″	10
Bath	1640	2015	85°	14″	5′ x 5′10″	6
Bedroom No. 2	7505	8597	90°	9″	10′ x 9′	13
Dining Room	6560	7810	79°	18″	20′ x 9′	7
Kitchen	5110	5950	85°	14″	10′ x 8′2″	8
Laundry	3680	4468	85°	14″	5′6″ x 4′8″	5
Garage	12203	14348	80°	18″	18′ x 7′6″	6
Total	54505	64184				

STEP No. 3

LAYOUT OF DISTRIBUTION PIPING

Layout of distribution piping is similar to the serpentine panel installation in example House "A".

STEP No. 4

AMOUNT OF WATER REQUIRED TO CARRY THE HEATING LOAD

Since the heating load carried is exactly the same as in example House "A", the amount of water required is also 6.42 GPM.

STEP No. 5

SELECTION OF BOOSTER PUMP

In Step No. 4, it was established that 6.42 GPM were needed to carry the heating load.

Refer now to the Booster Capacity Chart on page 38. Locate the 6.42 GPM point on the lower edge and move straight upward to the intersection with the curve of the 1″ Booster. Reading to the left shows that this pump will deliver the 6.42 GPM at a Head Pressure of 6.2 feet.

The reason for the selection of a 1″ Booster is to produce an economic balance between pump and pipe sizes.

There is an additional factor which must be considered in selecting the Booster, namely the pressure drop introduced by the Regulating Valve. (See Boiler Detail on Page 70.) Most manufacturers furnish pressure drop figures for various sizes of valves. In this example consider the Regulating Valve to have a pressure drop of 1 ft. at the flow rate required.

Thus if a 1″ Booster is selected which will deliver 6.42 GPM at a 6.2 ft. Head and 1 ft. of this Head is required to overcome the resistance of the Regulating Valve, there will be 5.2 ft. of Head Pressure available for piping and fittings, which is sufficient.

STEP No. 6

SIZING THE DISTRIBUTION PIPING

The piping layout of the example house is divided into three circuits, labeled A, B and C on the plan. The longest circuit is A, supplying the Entry, Living Room and Bedroom No. 1.

Measuring the circuit from the boiler to the panel in Bedroom No. 1, through the panel to the floor box in Bedroom No. 2 and back to the boiler, the length is found to be 171 feet. *(The length of a grid panel is the sum of one header and one cross member.)* Adding 50% or 85 ft. to this length for the resistance of the fittings brings the Total Equivalent Length to 256 feet.

PANEL LAYOUT— DESIGN EXAMPLE "B"

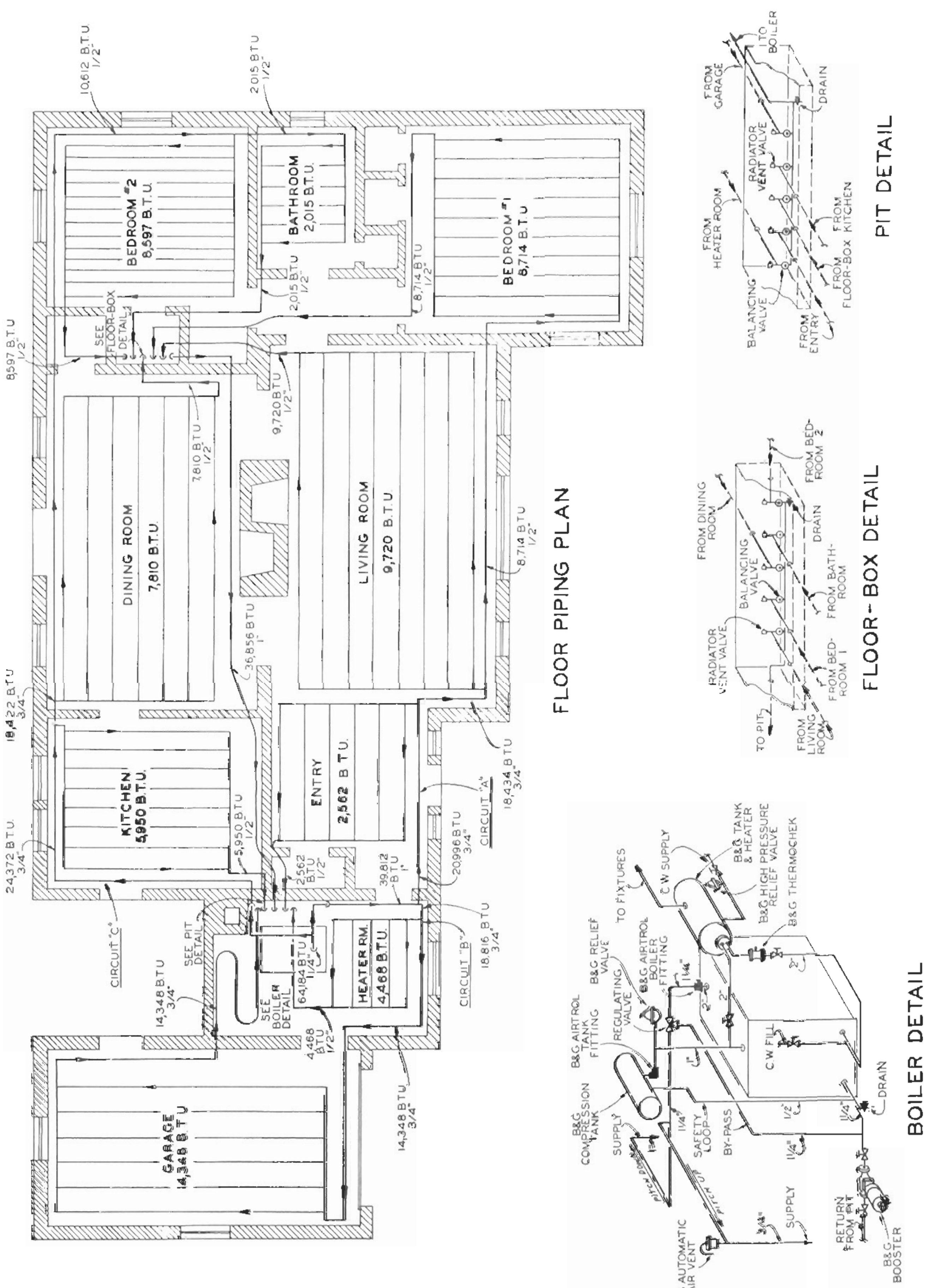


Fig. 96

DESIGNING A RADIANT PANEL SYSTEM—EXAMPLE "B" (continued)

Refer now to the Pipe Sizing Table on page 39. It was determined in Step No. 5 that with a 1" Booster, a Head of 5.2 ft. will be available for piping. Reading to the right from 5 feet of Head Pressure in Table A, the nearest *larger* Equivalent Length is found to be 300 feet. This appears in the 200 milinch column.

Therefore, the pipes will be sized on the basis of a 200 milinch friction head per foot of pipe.

The total heating load in this example is 64,184 BTU. Reading downward in the 200 milinch column in Table B to the nearest *larger* figure, it is found to be 90,000 BTU. Reading left from this figure shows the required pipe size to be 1¼".

The trunk supply main, therefore, from the point where it leaves the boiler to the point where it branches, must be 1¼".

SIZING THE CIRCUITS

One branch of the supply main feeds Circuits A and B which carry the following load--

Entry	—	**2562 BTU**
Living Room	—	**9720 "**
Bedroom No. 1	—	**8714 "**
Laundry and Heater Room	—	**4468 "**
Garage	—	**14348 "**
		39812 BTU

Referring again to Table B in the 200 milinch column, the next largest figure is 42,000 BTU. Reading to left from this figure shows that a 1" pipe will carry the load. This size of pipe is, therefore, used up to the point where the branch divides into Circuits A and B. Circuit A carries the following load -

Entry	—	**2562 BTU**
Living Room	—	**9720 "**
Bedroom No. 1	—	**8714 "**
		20996 BTU

The nearest larger figure in the 200 milinch column is 23,900 BTU, which requires a ¾" pipe. ¾" pipe is, therefore, installed up to the point where the Entry panel is taken off.

The heating load then becomes--

Living Room	—	**9720 BTU**
Bedroom No. 1	—	**8714 "**
		18434 BTU

Reference to Table B shows that 18434 BTU will be carried by a ¾" pipe which is used up to the point where the Living Room is taken off Circuit A.

The remaining pipe in this circuit supplies the panel in Bedroom No. 1 which has a requirement of 8714 BTU. Table B shows that a ½" pipe will carry this load.

The return mains from the panels in Bedroom No. 1 and Living Room are run to a floor box in Bedroom No. 2. The return from the Entry goes directly to the boiler pit.

Their loads are—

Entry	—	**2562 BTU**
Living Room	—	**9720 "**
Bedroom No. 1	—	**8714 "**

Reference to Table B shows that each of these loads can be carried by a ½" pipe and the returns are sized accordingly. The individual supply pipes from circuit main to panel headers are similarly sized.

A total of five returns enter the floor box in Bedroom No. 2, so the return from this point to the boiler must be sized accordingly. The five panels returning to the floor box are—

Living Room	—	**9720 BTU**
Bedroom No. 1	—	**8714 "**
Bath	—	**2015 "**
Bedroom No. 2	—	**8597 "**
Dining Room	—	**7810 "**
		36856 BTU

Table B shows that this load can be carried by a 1" pipe.

At the pit in the boiler room, all returns are brought to a header. This header and its connection to the boiler carry the entire load of the system, namely, 64184 BTU, and should be of 1¼" pipe.

The supply and return mains of circuits B and C are sized in a similar manner.

STEP No. 7

SELECTION OF BOILER

Selection of a properly sized boiler should be in accordance with the standards of the Heating, Piping and Air Conditioning Contractors National Association, as published in their semi-annual bulletin, "Net Load Recommendations for Heating Boilers".

Where domestic water is to be provided, see page 3 for additional boiler load.

DESIGNING A RADIANT PANEL SYSTEM—EXAMPLE "C"

A TWO-STORY HOUSE USING BOTH GRID AND SERPENTINE COILS

The building used here as an example has a full basement, a first floor consisting of living-room, entry hall, stairway to second floor, dining room, kitchen and bathroom. The second floor consists of the stair hall, three bedrooms, bathroom and small sewing room.

There is an attic space above the second floor with access by a disappearing stairway located in the stair hall ceiling. The attic is to be considered as unheated space.

DESIGN CONDITIONS

Outside temperature — 0°F

Inside temperature —	Basement	65°F
	First Floor	70°F
	Second Floor	70°F

Wind Velocity — 10 miles per hour

ZONE CONTROL

The building is to be divided into two zones. Zone No. 1 is to include basement and first floor. Zone No. 2 will handle the second floor rooms.

Each zone is to have a mixing valve, outdoor-type control and by-pass line. The mixing valve is to regulate the temperature of the water circulating through the system. Operation of the valve is controlled by the outdoor-type temperature control.

A thermostat may be installed in one room of each zone to act as a high limit control. This thermostat is connected into the circuit, so that when satisfied it will cut off the heat input to the zone.

The boiler water is to be maintained at a constant temperature by an aquastat which controls the oil, gas or stoker firing unit. A high limit aquastat is also to be installed to shut off the electric current to the burner in case the maintaining aquastat fails. A safety control on the firing unit is also recommended to provide a shut-off in case of fuel or ignition failure.

All of the above mentioned controls are standard types of equipment and can be furnished by a number of different manufacturers. Many of them are required on automatically fired boilers by local and state laws.

CONSTRUCTION DETAILS

Construction materials and their corresponding "U" factors (from tables on pages 87 to 96) are as follows:

Basement — Source of heat to be both ceiling and floor panels.

4" concrete floor. Heat loss 3 BTU per sq. ft. (See page 57)

12" concrete walls to grade (floor level is 4 ft. below grade). Heat loss 4 BTU per sq. ft. (See page 86)

12" brick wall, 4 ft. above grade—no interior finish. "U" = .36

Wood casement windows, caulked.
Glass—single glazed. "U" = 1.13
Infiltration "U" = 21 × .018 = .38

Ceiling height, 8' 0"

First Floor — Source of heat to be floor panels.

Floor — 4" Reinforced concrete on concrete joists, 24" on centers. (No "U" factor because this is the heating panel.)

Walls — 12" brick, gypsum lath (⅜") plastered—furred. "U" = .24

Windows — Double hung wood sash, weather stripped, storm sash.
Glass — "U" = .45
Infiltration — "U" = 13 × .018 = .24

Ceiling — ½" plaster on ⅜" gypsum lath. No upward loss to be considered as rooms above are heated.

Ceiling height: 8' 0"

Second Floor — Source of heat to be ceiling panels.

Floor — Maple or oak flooring on yellow pine subflooring on joists. No downward loss to be considered as rooms below are heated.

Walls — 8" brick, gypsum lath (⅜") plastered—furred. "U" = .30

Windows — Double hung wood sash, weather stripped, storm sash.
Glass — "U" = .45
Infiltration — "U" = 13 × .018 = .24

Ceiling — 1" plaster on metal lath, insulated as per later calculation. "U" = .16 (See explanation of ceiling loss on page 78.)

Ceiling height — 8' 0"

PANEL LAYOUT— DESIGN EXAMPLE "C"

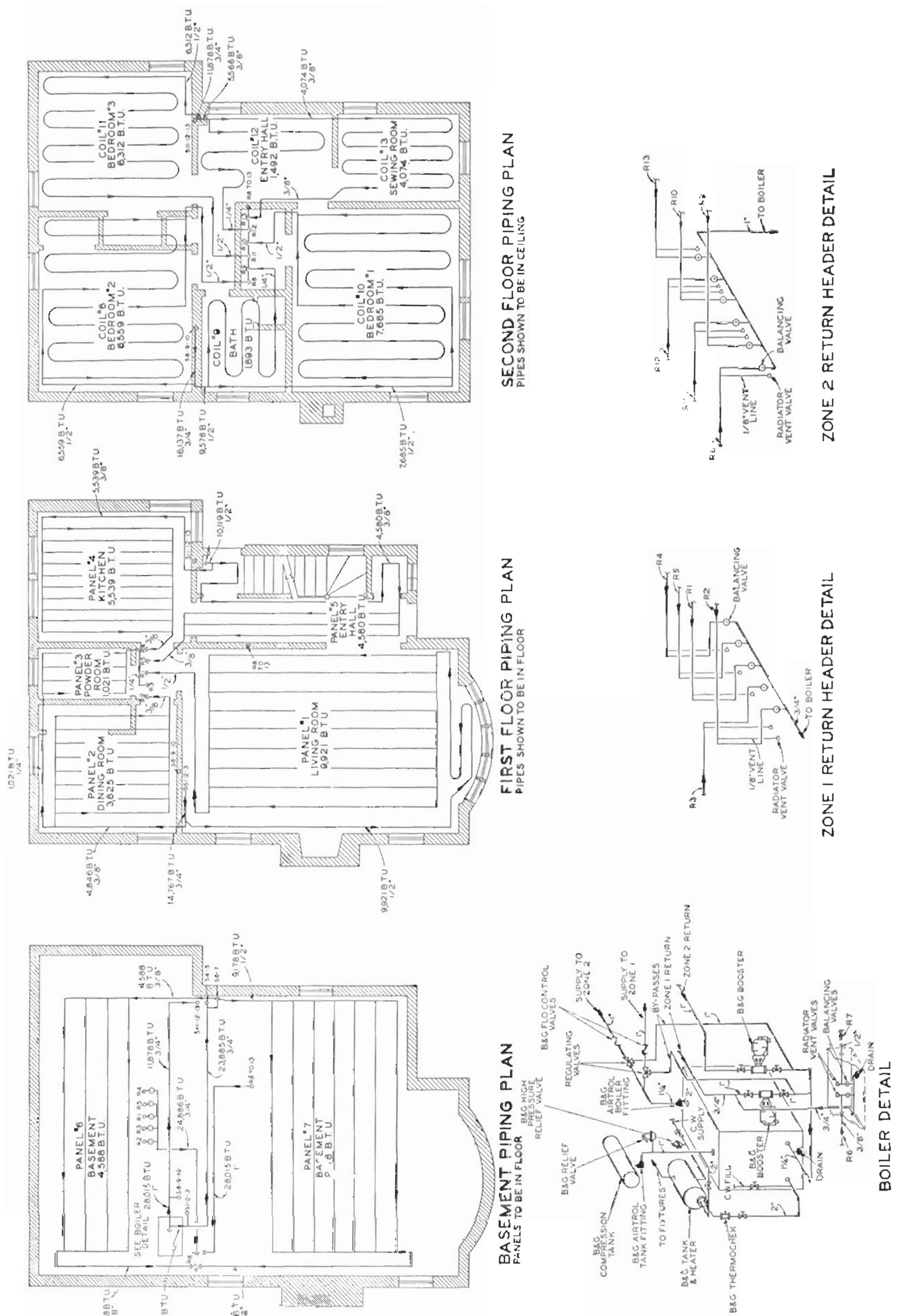


Fig. 97

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "C" (continued)

STEP No. 1

HEAT LOSS CALCULATION

The heat loss for each room is found by the same method as outlined for Example House "A". Some special calculations, however, are necessary for a structure of this type and will be taken up as the need arises.

In this example, the *space* heat losses for each room are as shown in the table below.

The total *panel* heat losses are dependent upon the reverse losses and will be calculated in Step 2.

SPACE	Total Space loss in BTU per hour
Basement	15366
Living Room	8030
Entry Hall	5002
Kitchen	4843
Powder Room	858
Dining Room	3314
Sewing Room	3329
Bedroom No. 1	5647
Bath	1383
Bedroom No. 2	4834
Bedroom No. 3	4834
	57440

STEP No. 2

HEATING PANEL DESIGN

FIRST FLOOR PANELS — GRID TYPE

Referring to Chart 2, on page 41, the inside surface temperatures of the Living Room, with an outside temperature of 0°F, are shown to be:

Surface	"U" Factor	Surface Temperature
Glass	.45	49.5
Outside walls	.24	58.0
*Inside walls		70.0
*Ceiling		70.0
Floor (not considered, as it is the heating panel)		

The MRT is now computed by the calculation:

$$\frac{\text{The sum of the surface areas in sq. ft.} \times \text{their surface temperatures}}{\text{the sum of the areas}} = \text{MRT}$$

Therefore:

	Surf. Sq. Ft.	Surf. Temp.	
Glass	80	× 49.5	= 3960
Outside Wall	248	× 58	= 14384
Inside Wall	260	× 70	= 18200
Ceiling	326	× 70	= 22820
	914		59364

$$\frac{59364}{914} = 65 \text{ MRT}$$

The MET (Mean Effective Temperature) is next calculated by this formula —

$$\frac{\text{MRT} + \text{AIR Temperature}}{2} = \text{MET}$$

Substituting the proper figures —

$$\frac{65 + 70}{2} = 67.5 \text{ MET}$$

The BTU emission required per sq. ft. of heating panel is next determined by the equation —

$$\frac{\text{8030 (Total space loss in BTU per hr.)}}{\text{326 (Available floor area in sq. ft.)}} = \text{24.6 BTU per sq. ft. of panel}$$

Since the panels for the first story are to be in the floor, refer next to Chart 3 on Page 41. This chart shows that to obtain 24.6 BTU per sq. ft. of panel, with an MET of 67.5, the panel temperature must be 76°F.

Using the same methods, the MET, BTU emission and panel temperature for each room is as follows:

	MET	BTU per sq. ft.	Panel Temp.
Living Room	67.5	24.6	76°
Entry Hall (floor)**	68.4	40.0	85°
Kitchen	67.0	40.4	85°
Powder Room	69.0	30.6	82°
Dining Room	67.3	37.6	83°

In the tabulation above, 85° for the Entry Hall and Kitchen panels is the highest temperature required and is the basis for selection of the proper water temperature.

**The surface temperature of inside walls is considered to be the same as the inside air temperature. The ceiling is also considered as an inside wall because the space above the living room is to be heated to the same degree.*

***See special handling of Entry Hall on page 75*

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "C" (continued)

Step No. 2 (continued)

Referring to Chart 5, it is evident that for a panel surface temperature of 85°, there are several pipe spacing options. With 130° average water temperature the pipe must be spaced on 11" centers which is satisfactory.

The pipe spacing for each room, based on 130° average water temperature, can now be determined from Chart 5—

Living Room	**— 18" spacing**	
Entry Hall (floor)	**— 11"**	"
Kitchen	**— 11"**	"
Powder Room	**— 14"**	"
Dining Room	**— 13"**	"

For the first floor, grid-type panels are to be used, with headers of 1" pipe and cross members of ½" pipe. (See page 62.) These pipe sizes will permit sufficient coverage of concrete within the 4" floor slab.

In the Living Room, there is sufficient area to install a panel 18' long by 12' wide after making allowance for supply and return piping. The cross members in a grid panel are usually run in the long dimension to minimize the number of welds and waste lengths of pipe.

It has been previously established that with 130° water, pipes on 18" centers will supply the heat requirement of the Living Room. Therefore, within the width of 12', nine pipes can be installed.

The balance of rooms on the first floor with the exception of the Entry Hall are similarly laid out.

Room	*Panel Size*	*Pipe Spacing*	*Number of Pipes*
Kitchen	**10' × 8'3"**	**11"**	**10**
Powder Room	**6'6" × 3'3"**	**13"**	**4**
Dining Room	**9' × 7'7"**	**13"**	**8**

SPECIAL DESIGNING FOR ENTRY HALL

The Entry Hall presents an additional problem. There is only 100 sq. ft. of floor area available and since the direct heating load is 5002 BTU, the heating load per sq. ft. is 50 BTU. Reference to Chart 3 shows that 50 BTU per sq. ft. at an MET of 68.4 makes it necessary to carry a 90° panel temperature. It has been previously established, however, that 85° was to be the maximum floor panel surface temperature. It has also been established that the MET for this room is 68.4 which will allow a maximum output of 40 BTU per sq. ft. Therefore, 100 sq. ft. × 40 BTU = 4000 BTU available.

5002 BTU required
4000 BTU available

1002 BTU to be provided by a supplementary panel

There is a ceiling area of 44 sq. ft. available (second floor ceiling above the stair well) and it can be used to provide the additional panel area.

Since 1002 BTU total emission must be furnished by this ceiling panel, the emission per sq. ft. required is —

$$\frac{1002 \text{ BTU}}{44 \text{ sq. ft.}} = 22.7 \text{ BTU per sq. ft.}$$

On Chart 4 (ceiling chart) it is shown that at an MET of 68.4 and an emission of 22.7 BTU per sq. ft., the panel temperature will be 80°F. Referring to Chart 6, the pipe spacing for these conditions is indicated as 19".

BASEMENT PANELS — GRID TYPE

The total *space* heat loss of the basement has been determined to be 15,366 BTU per hour. Following the same methods of calculation as for the first floor rooms, the MET is determined to be 65° with a heat emission of 36 BTU per sq. ft. and panel temperature of 74°, *if the basement floor alone were to be used as the heating panel!*

The panels in the first floor, however, also act as ceiling panels in the basement and some of this reverse heat loss is to be used. The balance of required heat is to be supplied by panels in the basement floor. By using floor panels to supply the major portion of heat, a better control of temperature is achieved. In this case, assume that 25%, or 3,841 BTU, will be furnished by the ceiling panels and 75%, or 11,525 BTU by the floor panels.

Since the several basement ceiling panels are at different temperatures, it is necessary to determine the average downward heat input.

Space	*Panel Temp.*	*Panel Area*	*Product*
Living Room	**76°**	**326**	**24776**
Entry Hall	**85°**	**100**	**8500**
Kitchen	**85°**	**120**	**10200**
Powder Room	**82°**	**28**	**2296**
Dining Room	**83°**	**88**	**7304**
		662	**53076**

$$\frac{53076}{662} = 80° \text{ average surface temperature of basement ceiling panels}$$

The MET of the basement is 65°, since when considering air temperatures lower than 70° it is safe to assume that the MET is equal to the air temperature.

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "C" (continued)

On Chart 4, it is shown that with a surface temperature of 80° and an MET of 65°, the downward, or reverse loss of the panels is 40 BTU per sq. ft. The total reverse loss is therefore— -

662 sq. ft. total panel area × 40 BTU per sq. ft. = 26480 BTU

This is a much greater heat emission than is required from the ceiling panels, so insulation must be introduced to block off the excess.

26480 BTU total input from ceiling
3841 BTU desired input
22639 BTU to be blocked out by insulation

or,

$$\frac{22639 \text{ BTU}}{662 \text{ sq. ft. panel area}} = 34.2 \text{ BTU per sq. ft. to be blocked out by insulation}$$

The desired input from the ceiling panels is, therefore —

40 BTU — 34.2 BTU = 5.8 BTU per sq. ft.

To determine the amount of insulation required, the following equations are used:

$$Q = U A \Delta t$$

Where Q = desired emission, or 5.8 BTU per sq. ft.

U = combined coefficient of insulation

A = The area normal to the path of heat flow. In this example we are considering unit area or A = 1. Therefore, A = 1 drops out of the equation.

Δt = Temperature difference between surface of the insulated panel and the air temperature in basement, or 130° — 65°.

***Note:* It is assumed that when a panel is insulated, the surface temperature of the panel adjacent to the insulation is at water temperature — in this case 130°. (See Figure 98 on next page.)**

Solving for "U" —

$$U = \frac{Q}{\Delta t}$$

$$U = \frac{5.8 \text{ (BTU)}}{130^\circ - 65^\circ \text{ (Temp. Diff.)}}$$

$$U = \frac{5.8 \text{ (BTU)}}{65^\circ \text{ (Temp. Diff.)}}$$

$$U = .089$$

Therefore, an insulation must be selected which has a combined coefficient of .089.

Next, determine the thickness of insulation required by the following equation — -

$$U = \frac{1}{\frac{x}{k} + \frac{1}{f_i}}$$

where

U = combined coefficient, or .089

x = required thickness in inches

k = conductivity, or .27 (rock wool)

f_i = film coefficient of inside air, or 1.65

Solving for x —

$$.089 = \frac{1}{\frac{x}{.27} + \frac{1}{1.65}}$$

$$x = \left(\frac{1}{.089} - \frac{1}{1.65}\right) .27$$

$$x = (11.2 - .606)\ .27$$

x = 2.86 inches of insulation required

It is recognized that the above method provides more insulation than necessary and that this will raise the temperature of the panel surface. It is conservative, however, and will produce satisfactory results. The exact method of calculation is practical only in research work.

The remaining heat load of 11525 BTU is to be supplied from panels in the basement floor. It has been previously determined that the basement floor temperature is 74° with an emission of 36 BTU per sq. ft. Hence —

$$\frac{11525}{36} = 320 \text{ sq. ft. of panel required}$$

In the Laundry section there is room to install one grid panel 20′ long x 5′ wide with tubes on 20″ centers, for a panel area of 100 sq. ft. In the front of the basement there is sufficient space for one grid panel 20′ long x 10′ wide with tubes on 20″ centers for a panel area of 200 sq. ft. The sum of the areas of the two panels is 300 sq. ft. — the supply and return mains will make up the balance of 20 sq. ft.

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "C" (continued)

Step No. 2 (continued)
TOTAL HEAT LOSS OF FIRST FLOOR AND BASEMENT PANELS

Knowing that the reverse heat loss from the first floor panels has been limited by insulation to an average of 5.8 BTU per sq. ft., the total *panel* heat loss can be determined by the following calculation —

Panel area × BTU per sq. ft. reverse loss + space loss = total panel loss

Room	Reverse loss in BTU	Space loss in BTU	Total panel loss in BTU
Living Room	1891	8030	9921
Entry Hall (floor)	580	4000	4580
Kitchen	696	4843	5539
Powder Room	163	858	1021
Dining Room	511	3314	3825
	3841	21045	24886
Basement	2241	*11525	13766

**This is the space loss of 15366 BTU minus the reverse loss from the ceiling panels of 3841 BTU.*

SECOND FLOOR PANELS — SERPENTINE TYPE

For the second story, serpentine panels are to be installed in the ceiling. First, consider Bedroom No. 1.

Referring to Chart 2, the inside surface temperatures, with an outside air temperature of 0° are shown to be —

Surface	"U" Factor	Surface Temperature
Glass	.45	49.5°
Outside walls	.30	56°
**Inside walls		70°
**Floor		70°
Ceiling (not considered because it is the heating panel)		

***The surface temperature of the floor and inside walls is considered to be 70°, because the spaces below and surrounding are heated to the same degree.*

The MRT is now found by the calculation - -

$$\frac{\text{The sum of the surface areas in sq. ft.} \times \text{surface temperatures}}{\text{the sum of the areas}}$$

Glass	45 sq. ft. × 49.5 surface temp. =	2228
Outside Wall	171 sq. ft. × 56 surface temp. =	9576
Inside Walls	216 sq. ft. × 70 surface temp. =	15120
Floor	182 sq. ft. × 70 surface temp. =	12740
	614	39664

$$\frac{39664}{614} = 64.6 \text{ MRT}$$

The MET is next calculated —

$$\frac{64.6\ (\text{MRT}) + 70^\circ\ (\text{air temperature})}{2} = 67.3 \text{ MET}$$

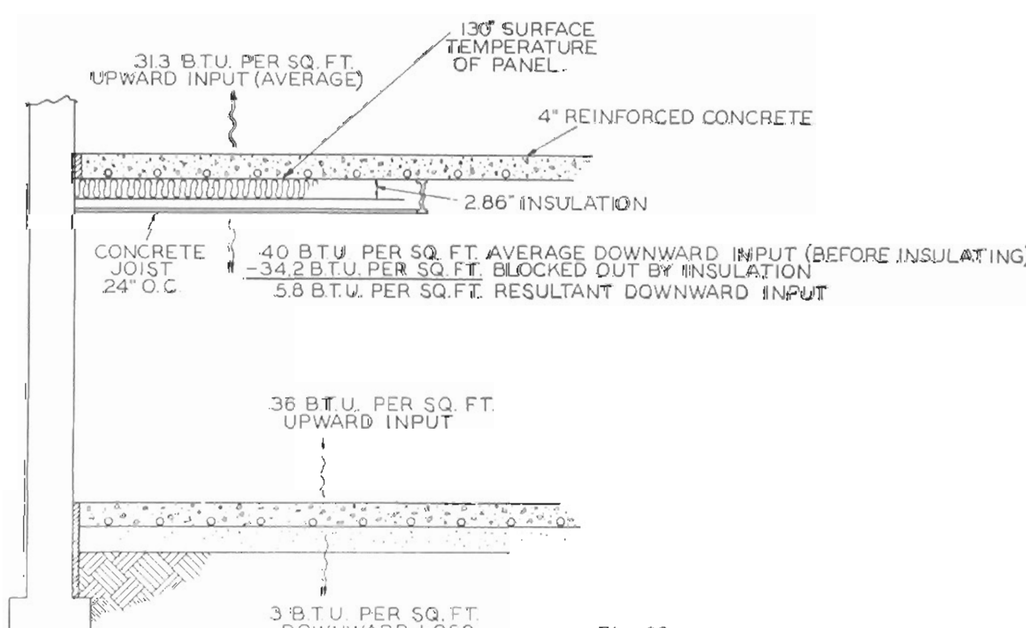


Fig. 98

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "C" (continued)

The BTU emission per sq. ft. of heating panel is next determined —

$$\frac{\text{5647 (total space loss in BTU per hr.)}}{\text{182 (available ceiling area in sq. ft.)}} = \text{31 BTU per sq. ft.}$$

Since the panels on the second floor are to be in the ceiling, refer to Chart 4. Here it is shown that to obtain 31 BTU per sq. ft. of panel with an MET of 67.3, the panel temperature must be 85°.

It has been pointed out previously that the highest panel surface temperature must be determined before deciding upon a water temperature. Therefore, the MET, BTU per sq. ft. and panel temperature for the balance of the second story rooms should next be calculated in the same manner as for Bedroom No. 1.

Room	*MET*	*BTU/sq. ft.*	*Panel Temp.*
Bedroom No. 1	67.3	31	85°
Sewing Room	67	50	97°
Bath	68.5	30	88°
Bedroom No. 2	67.5	31	85°
Bedroom No. 3	67	36	87°
Entry Hall	68.4	22.7	80°

In the above tabulation, 97° for the Sewing Room is the highest required panel temperature. Reference to Chart 6 shows that with a water temperature of 130° the pipes should be spaced on 13" centers. This spacing is satisfactory, so the design of all second floor ceiling panels should be based on 130° water.

Chart 6 shows the following spacings for the other rooms —

Room	*Pipe Spacing*
Bedroom No. 1	17"
Sewing Room	13"
Bath	16"
Bedroom No. 2	17"
Bedroom No. 3	16"
Entry Hall	19"

SERPENTINE PANEL DESIGN

For the second story panels, the piping will be ⅜" nominal pipe size, formed into serpentine coils. This pipe size permits adequate covering with plaster and is not so small as to introduce excessive resistance.

At this point, it might be well to consider the ways in which a serpentine coil can be laid out. Because of flow conditions, pipe size and length of coil, many problems of arrangement present themselves.

In ceiling coils, as in floor coils, it is desirable to arrange the piping so as to avoid pockets or air traps, such as might be caused by crossing the pipes. It is also necessary to limit the pressure drop through a coil to keep the pump within an economical size.

The desirable maximum pressure drop has been found to be not in excess of 3 feet (36000 milinches). In some instances, it may be necessary to change the spacing between coil passes in order to maintain the desired piping arrangement. When the number of tubes or spaces must be changed to fit the required amount of coil into the available space, it is advisable to decrease the tube spacing and increase the amount of pipe.

Because pressure drop is a limiting factor in the design of the serpentine coil, it is necessary to know the total flow required in each coil. The total flow is determined by the sum of the *space* heat loss and the *reverse* heat loss to the attic.

REVERSE HEAT LOSS TO THE ATTIC AND INSULATION REQUIRED

The reverse loss of the ceiling coils to the attic must be controlled by introducing the proper amount of insulation.

Consider the reverse side of the panel as being at the same temperature as the water in the coils — 130°. Next, assume that the ceiling loss is within satisfactory limits if equal to a heat transmission coefficient of .16. Thus with 70° in the second floor rooms and 0° in the attic *(attic is fully ventilated)* the calculation is —

70° (temperature differential) × .16 (coefficient) = 11.2 BTU per sq. ft. heat loss through the ceiling

The calculation now follows the same form as that for determining the insulation required to block reverse heat loss to the basement. Solving first for the combined coefficient "U" —

$$Q = U \Delta t$$

$$U = \frac{Q}{\Delta t}$$

$$U = \frac{11.2}{130 - 0}$$

$$U = .086$$

Therefore, an insulation must be selected having a combined coefficient of .086.

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "C" (continued)

Step No. 2 (continued)

Next, determine the thickness of insulation required —

$$U = \frac{1}{\frac{x}{k} + \frac{1}{f_o}}$$

where

U = combined coefficient, or .086

x = required thickness in inches

k = conductivity, or .27 (rock wool)

f_o = film coefficient outside air, or 6.00 (fully ventilated attic)

Solving for "x" —

$$.086 = \frac{1}{\frac{x}{.27} + \frac{1}{6.00}}$$

$$x = \left(\frac{1}{.086} - \frac{1}{6.00}\right).27$$

x = 3.08 inches of insulation required

It is recognized that the above method provides more insulation than necessary and that this will raise the temperature of the panel surface. It is conservative, however, and will produce satisfactory results. The exact method of calculation is practical only in research work.

In this example, 11.2 BTU per sq. ft. reverse loss through the ceiling has been considered as acceptable. In Bedroom No. 1, the ceiling panel area is 182 sq. ft. The reverse loss, therefore, will be 182 × 11.2 = 2038 BTU. Add to this the space loss of 5647 BTU and the total load which must be carried by the coil becomes 7685 BTU per hour.

The total panel loads on the balance of the second story ceiling coils can be similarly determined and are as follows:

Room	Reverse loss in BTU	Space loss in BTU	Total panel loss in BTU
Bedroom No. 1	2038	5647	7685
Sewing Room	745	3329	4074
Bath	510	1383	1893
Bedroom No. 2	1725	4834	6559
Bedroom No. 3	1478	4834	6312
Entry Hall (ceiling)	492	1000	1492
	6988	21027	28015

In designing the ceiling coil for Bedroom No. 1, it has been determined that the tubes must be spaced on 17″ centers and that the total heating load is 7685 BTU per hour.

CALCULATION FOR RESISTANCE IN SERPENTINE COILS

Bedroom No. 1 has an area of 14′ × 13′ = 182 sq. ft. This will permit installing a panel of 10 tubes on 17″ centers, with a total tube length of approximately 144 ft. To this must be added elbow equivalents for each return bend. One 180° open return bend in ⅜″ tubing has a resistance equal to .8 ft. of straight tubing. Ten return bends, therefore, introduce a resistance of 8 ft. and the total equivalent length becomes 152 ft. At a flow of 7685 BTU through a ⅜″ tube, there is a resistance of 350 milinches per foot, as shown in Table B of Pipe Sizing Table on Page 39.

152 (total equivalent length) × 350 (milinch resistance per ft.) = 53200 Total milinches (total resistance through coil)

$$\frac{\textbf{53200 (total milinch resistance)}}{\textbf{12000 (milinches per ft.)}} = \textbf{4.43 ft. of Head Pressure}$$

Since it is necessary to limit the pressure drop through a single coil to 3 ft. (36000 milinches) this coil is too long.

To reduce the resistance, the coil length can be shortened by making two or more coils in a semi-grid arrangement. (See diagram on Page 80.) The resistance in each coil can be kept approximately equal by making the coils the same length.

Therefore, since 10 tubes are needed, the coil can be split into two equal sections of 5 tubes each.

Now check the resistance conditions in the coils. (See diagram on Page 80.)

A tee diverts 50% of the water to the first coil and 50% to the second coil. Each coil, therefore, carries one-half of the heating load or 3842 BTU. The table of elbow equivalents on Page 38 shows that at 50% diversion a ⅜″ tee is equivalent to 4 elbows. One 90° elbow in ⅜″ pipe = .8 ft. 4 elbows × .8 = 3.2 ft. equivalent length. The flow entering the tee is the sum of the two coils or 7685 BTU. At this flow the resistance in a ⅜″ pipe is 350 milinches per ft. Therefore, 3.2 ft. equivalent length × 350 milinches per foot = 1120 milinches resistance due to the tee.

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "C" (continued)

The resistance can be checked through either of the two coils as they are of equal length and in parallel. In the first coil, we have approximately 60 feet of straight ⅜" pipe, plus 4 open return bends (one open return bend equals one elbow) and one 90° elbow, for a total equivalent of 5 elbows.

5 elbows × .8 equivalent length per elbow = 4 feet equivalent length

60 feet straight pipe + 4 feet elbow equivalent = 64 feet total equivalent pipe length

In this coil there is a flow of 3842 BTU, which is equal to a flow resistance of approximately 100 milinches per foot. (See Table B in Pipe Sizing Table on Page 39.)

64 feet total equivalent length × 100 milinches per foot = 6400 milinches resistance through the coil

The flow of the first coil is now added to the flow of the second coil, entering the return main through a tee. Since the flow in each coil is equal, the tee resistance is at 50% flow or equal to 4 elbows.

4 × .8 ft. = 3.2 ft. equivalent length

The flow at this point is the sum of the two coils or 7685 BTU. At this flow in a ⅜" pipe, the resistance is 350 milinches per foot.

3.2 × 350 = 1120 milinches resistance due to the tee

Adding all the resistances determined above gives the total pressure drop through both coils.

1120 milinch pressure drop through first tee
6400 " " " " coil
1120 " " " " second tee
8640 total milinch pressure drop.

$$\frac{\textbf{8640 milinch pressure drop in coil}}{\textbf{12000 milinches per foot}} = \textbf{.72 ft. of Head}$$

From the above, it will be seen that dividing the coil into two sections materially reduces the total pressure drop.

Calculated by the same method as above, the pressure drop in the various second floor coils are as follows:

Bedroom No. 1	—	**.72 ft.**
Sewing Room	—	**.50**
Bath	—	**.09**
Bedroom No. 2	—	**.34**
Bedroom No. 3	—	**2.20**
Entry Hall	—	**.047**

DIAGRAMS BELOW SHOW HOW DIVIDING A COIL MATERIALLY REDUCES THE PRESSURE DROP.

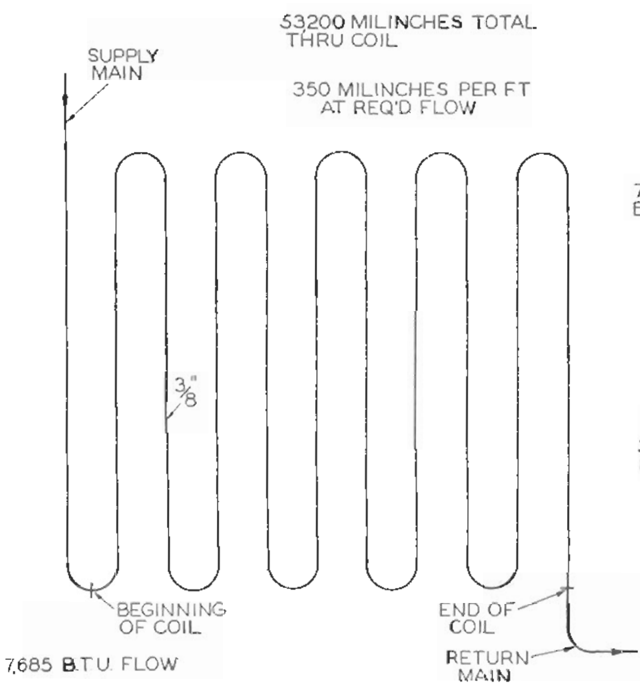


Fig. 99

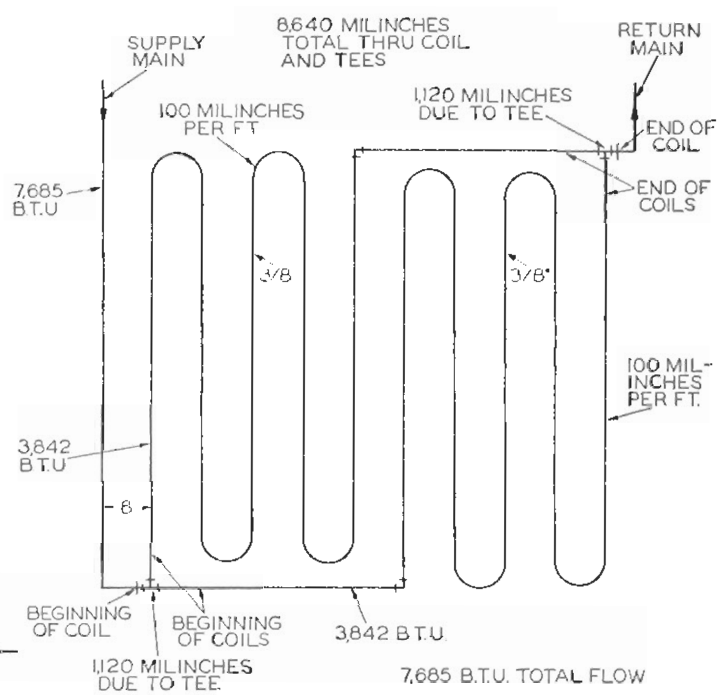


Fig. 100

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "C" (continued)

STEP No. 3

LAYOUT OF DISTRIBUTION PIPING

In this design example, the boiler is located in the basement. For better control of temperature, the piping is to be arranged in two zones. Zone No. 1 will be the basement and first floor. Zone No. 2 will be the second floor.

As outlined at the beginning of this section, each zone is to have a Pump, Flo-Control Valve and zone control system. The control is at the option of the designer, but in this example the use of a three-way type mixing valve with outdoor-indoor control is indicated, for the purpose of showing the pressure drop allowance which must be made when selecting the pump.

The arrangement of the distribution piping obviously hinges upon the plan of the building. The layout shown on Page 73 is a typical example and should be carefully studied.

The primary rules which must be observed in making a distribution piping layout are —

1. Each panel must be properly vented.
2. Each panel must have a balancing valve so that the flow rate can be controlled.
3. In both floor and ceiling installations, it is always advisable to avoid crossing the pipes. In this example, supplies and returns can be brought up to the first floor at any point desired and any necessary crossing of pipes can be made at the basement ceiling where from 12″ to 18″ of vertical height is available for this purpose.

STEP No. 4

AMOUNT OF WATER NECESSARY TO CARRY THE HEATING LOAD

In this design example there are two zones, each with its own pump. The respective total *panel* heating loads are —

Zone No. 1		Zone No. 2	
Living Room	9921 BTU	Bedroom No. 1	7685 BTU
**Entry Hall (first floor)	4580 "	Sewing Room	4074 "
		Bath	1893 "
Kitchen	5539 "	Bedroom No. 2	6559 "
Powder Room	1021 "	Bedroom No. 3	6312 "
Dining Room	3825 "	**Entry Hall (second floor)	1492 "
Basement	*13766 "		
	38652 BTU		28015 BTU

The same procedure as given on Page 66, is followed in determining the gallons of water per minute which must be circulated.

$$\frac{38652}{10000} = 3.9 \text{ GPM} \qquad \frac{28015}{10000} = 2.8 \text{ GPM}$$

**See page 75 for calculation of basement floor panel load.*

***The panel heating loads for the Entry Hall are split between the floor panel on the first floor and the ceiling panel on the second floor. The respective reverse losses to the basement and attic are also added.*

STEP No. 5

SELECTION OF BOOSTER PUMPS

On pages 19, 20 and 21 an explanation is given of pressure drop, head pressure and measurement of pressure drop by milinches. It might be well, at this point, to turn back and review these explanations.

In this design example, there are two factors to consider. The pressure drop through the Regulating Valve must be taken into account and also the pressure drop due to the use of serpentine coils in Zone No. 2.

Most manufacturers of Regulating Valves furnish pressure drop figures for various sizes of valves. In this example, consider the Valve to have a pressure drop of 1 ft. at the flow rate required in each zone.

In Zone No. 1, a flow of 3.9 GPM is required. The Regulating Valve in the circuit has a pressure drop of 1 ft. Thus, if a 1″ Booster is selected with a capacity of 3.9 GPM at a 6.25 ft. head and 1 ft. of this head is required to overcome the resistance of the Regulating Valve, there will be 5.25 ft. of head pressure available for the piping and fittings, which is sufficient.

In Zone No. 2, the pressure drop effects of both the Regulating Valve and the serpentine coils must be considered. In this Zone a flow of 2.8 GPM is required. Reference to the Booster Capacity Chart shows that this flow will be produced at a 6.25 ft. head by a 1″ Booster.

Reference to the table of pressure drops for the various coils in Zone No. 2 (Page 80) shows that the

DESIGNING A RADIANT PANEL SYSTEM—EXAMPLE "C" (continued)

greatest pressure drop is 2.2 ft. in Bedroom No. 3. This 2.2 ft. added to the 1 ft. drop of the Regulating Valve totals 3.2 ft. which must be deducted from the pump head of 6.25 ft., leaving a head of 3 ft. available for piping.

It has been stated before that for an economical balance between pump size and pipe sizes, the minimum head for any piping circuit should be 2.5 ft. Therefore, a 1" Booster is necessary.

STEP No. 6

SIZING THE DISTRIBUTION PIPING

In a two zone system, it is necessary to measure the longest circuit of distribution piping in each zone to arrive at the Equivalent Length of each zone. (See Step No. 6, Example "A" for explanation of Equivalent Length.) Note that it is possible to have one zone with a considerably greater Equivalent Length than the other.

EQUIVALENT LENGTH — ZONE NO. 1

Zone No. 1 includes the two panels in the basement floor and all of the panels in the first floor.

In looking at the plan, it is obvious that the circuit through the Living Room panel is the longest. Measurement of this circuit is made as follows: from the boiler outlet to the point where the supply main branches into two zones — through the supply main of Zone No. 1 to the riser marked S1-2-3 through supply main S1 to the Living Room panel, through one header and one cross member of the panel, through the return R1 back to the boiler through the return header to the return connection at the boiler. The actual length of this circuit is 130 ft.

To this length should be added 50% or 65 ft. to compensate for the resistance of the fittings — bringing the total Equivalent Length to 195 ft.

It was determined in Step No. 5 that a 1" Booster will deliver the *required* 3.9 GPM at a head of 6.25 ft. However, 1 ft. of this head is used up by the resistance of the Regulating Valve; thus 5.25 ft. of head is available for the balance of the piping.

Refer now to the Pipe Sizing Table on Page 39. In Table A, reading to the right from 5 ft. of head pressure, the nearest *larger* equivalent length is 200 ft. This appears in the 300 milinch column.

Therefore, the pipes for Zone No. 1 will be sized on the basis of a 300 milinch friction head per foot of pipe.

EQUIVALENT LENGTH — ZONE NO. 2

Now determine the proper milinch column in which to size the piping for Zone No. 2. Following the same procedure as outlined for Zone No. 1, measure the longest circuit. The longest circuit is the one to the ceiling panel of Bedroom No. 1 and actually measures 120 ft. *Note that the length of the serpentine coil is not included!* To this length is added 50% or 60 ft. to allow for the resistance of the fittings, making the total Equivalent Length 180 ft.

Again refer to the Pipe Sizing Table on Page 39. It was determined in Step 5 that a 1" Booster would deliver the required 2.8 GPM at a head pressure of 6.25 ft. However, 3.2 ft. of this head is required to compensate for the pressure drop through the Regulating Valve and the coil. Thus 3 ft. of head is available for the balance of the piping.

In Table A of the Pipe Sizing Table, reading to the right from 3 ft. of head pressure, the nearest Equivalent Length is found to be 180 ft. This appears in the 200 milinch column.

The pipes for Zone No. 2 will, therefore, be sized on the basis of a 200 milinch friction head per foot of pipe.

SIZING THE SUPPLY AND RETURN MAINS UP TO THE BRANCH TO THE TWO ZONES

It has been determined that Zone No. 1 piping is to be sized at 300 milinches per foot while Zone No. 2 is to be sized at 200 milinches. The question naturally arises as to the proper sizing of the supply piping from the boiler to the point of branch-out to the two zones and also the sizing of the return piping from the point where the two zones join into a common return to the boiler.

These pipes are to be sized on the basis of the *lower* pressure drop figure, or 200 milinches per foot.

The total panel heating load for this example is 66667 BTU. Therefore, the boiler outlet connection must be able to carry 66667 BTU at a pressure drop per foot of pipe not greater than 200 milinches. Referring to the 200 milinch column in Table B in the Pipe Sizing Table, it will be seen that the common supply main must be 1¼" pipe. The common return must also be 1¼" pipe.

DESIGNING A RADIANT PANEL SYSTEM — EXAMPLE "C" (continued)

Step No. 6 (continued)

PIPE SIZING ZONE NO. 1

Now size the supply main for Zone No. 1 from the 300 milinch column in Table B. Zone No. 1 carries a total load of 38652 BTU. In Table B, the next largest figure is 53000 BTU, requiring a 1" pipe. This is over the required capacity, but *select the nearest pipe size which will carry more than the indicated load!*

Panels 1, 2, 3 are taken off the first riser and have a total load of 14267 BTU. As shown in Table B a ¾" pipe will carry this load.

The balance of the zone piping can be sized in accordance with the above method, as explained in detail in Example "A".

PIPE SIZING ZONE NO. 2

Zone No. 2 is now pipe sized but on the basis of 200 milinches per foot.

Zone No. 2 carries a total load of 28015 BTU. Reference to Table B under the 200 milinch column shows that a 1" pipe will carry 42000 BTU and is the size to be selected.

The balance of the pipes in Zone No. 2 can now be sized in the manner previously explained.

STEP No. 7

SIZING THE BOILER

Selection of a properly sized boiler should be in accordance with the standards of the Heating, Piping and Air Conditioning Contractors National Association, as published in their semi-annual bulletin, "Net Load Recommendations for Heating Boilers."

Where domestic water is to be provided, see page 3 for additional boiler load.

CONTROL OPTIONS

Many panel heating systems have been installed, and with a large degree of success, with a room thermostat acting as a limit control on the pump only. In this type of installation, the boiler water is generally maintained by an aquastat at a temperature about 10° higher than the maximum water temperature required by the panels. If a domestic water heater is installed on or in the boiler, the aquastat should be set to maintain boiler water temperature at approximately 180°.

When a domestic water heater is installed and the boiler is maintained at a temperature greater than the maximum panel temperature required, a by-pass line from the return header to the supply header must be installed. A valve must be installed in this by-pass line to regulate the temperature of the water going to the panels.

When the room thermostat calls for heat, the pump starts. With this type of control, the system is called an intermittent circulation system. For a minimum initial installation cost, this method of control can be considered as acceptable.

The intermittent circulation system, however, as applied to panel heating, has a definite shortcoming. The lag which occurs between the time the pump starts and heat is actually delivered may cause a considerable temperature drop in the space being heated. This is especially true in mild weather when a rapid drop in temperature occurs.

To minimize this tendency, one of the many good mixing valves now available can be used. When a mixing valve is used, the pump runs continuously during the heating season, and the flow of water through the system is likewise continuous. The temperature of the boiler water is maintained at the desired degree by an aquastat similar to that used in an intermittent circulation system. The temperature of the circulating water is varied in accordance with outdoor temperature.

The balanced action of the control opens and closes the mixing valve in such a manner as to admit the proper amount of boiler water into the water circulating through the panels. This method of control is obviously much more accurate.

HEAT LOSS DETERMINATION

Definition of terms used and calculations necessary

In any building there is a continual loss of heat from all exposed surfaces and because of air changes caused by infiltration. Therefore, the amount of heat which must be furnished by the heating system is dependent upon these factors. The greater the maximum difference between inside and outside temperature, the greater must be the capacity of the heating plant.

At any condition determined to be a comfort condition, the heat loss must be equalled by the heat gain to maintain the condition. Heat loss is measured by the BTU method.

DESIGN TEMPERATURE

In designing the system, consider the outside temperature to be 15 degrees higher than the coldest recorded temperature during the past ten years. Thus, if −20° is the lowest temperature, then −5° is the temperature the system should be designed to meet. This is called the Design Temperature. The room temperature to be maintained can be selected from the Comfort Temperature Table below.

COMFORT TEMPERATURES WITH NORMAL RELATIVE HUMIDITY

Operating Rooms	**86°F**
Swimming Pools	**80°F**
Homes, Offices, Theatres	**70°F**
School Rooms, Hospital Wards	**68°F**
Stores, Light mfg., Machine shops	**65°F**
Gymnasiums	**55°F**
Foundries	**55°F**

INFILTRATION HEAT LOSS

Wind pressure causes a movement of air through a building from the windward to the leeward side. Heated inside air is thus displaced by cold outside air, by leakage through the cracks around the doors and windows. This leakage of air must be considered in calculating the heating load.

The Tables on Page 96 show the infiltration of air through walls, windows and doors in accordance with their construction. Note that the infiltration through plastered walls is so small that it may be omitted from calculations for the ordinary job which is properly sealed at floor levels. Since the strength of the wind has a material effect on the amount of infiltration, the average wind velocity for the locality should be determined from the Table in Section VI, headed "Climatic Conditions in U.S. and Canada".

The amount of crack used for computation *should not be less than half the total crack in the outside walls of the room.* In the room with one exposed wall, take all the crack; with two exposed walls, take the wall having the most crack; with three or four exposed walls, take the wall having the most crack; but never take less than half the total crack.

Measurement of crack should be as follows:

Double hung windows—
3 times the width plus 2 times the height

Wood casement windows—
2 times the width plus 2 times the height

Metal pivoted sash—
Total perimeter of the movable or ventilating sections

To carry through a typical calculation, assume that a 10 x 10 x 8 room has one exposed wall and two 3 x 5 double-hung wood sash windows. The average wind velocity is 10 miles per hour.

Measuring the two windows shows the total crack to be 38 feet. From Table on Page 96—

Infiltration per foot of crack through average non-weather stripped window at 10 mile wind velocity = 21 cubic ft.

21 x 38 ft. of crack = 798 cubic feet infiltration

At a room temperature of 70°, .018 BTU will raise one cubic foot of air one degree Fahrenheit. Therefore, to heat 798 cubic feet of air from −5° to 70° requires:

798 x .018 x 75 (difference in temperature between —5° and 70°) = 1047 BTU

COEFFICIENTS OF HEAT TRANSMISSION "k" AND "U" FACTORS

The coefficient of heat transfer is an expression of the ability of a material or combination of materials to transmit heat from the hot to the cold side. The "k" factor is given in BTU per hr. per sq. ft. per degree difference Fahrenheit per inch of thickness for any homogeneous material. The "U" factor is a combination of "k" factors expressing the ability of combined materials to pass heat and is expressed in BTU per hr. per sq. ft. per degree difference F. for the combination.

STRUCTURE HEAT LOSS

This is the heat loss through windows, doors and walls. Outside metal and thin section wood doors are

HEAT LOSS DETERMINATION (continued)

figured as all glass; heavy wood doors according to the table of Heat Loss Coefficients, or "U" factors, starting on Page 87.

If the room has two windows — 3 ft. x 5 ft., the total glass area is 30 sq. ft. In the Table on Page 95, the coefficient of heat loss ("U" factor) for single glass is shown to be 1.13 per square foot per hour per degree difference in temperature. Heat loss through these windows is thus:

30 (glass area) x 1.13 ("U" factor) x 75 (Temperature difference) = 2542 BTU

Amount of heat lost through exposed walls is figured next. If one wall is exposed, the area is 10 x 8 = 80 sq. ft.—from which is deducted the 30 sq. ft. of glass previously figured, leaving 50 sq. ft. of net exposed wall area.

If the wall is 4" brick veneer, 8" hollow tile backing, plastered ¾" on metal lath furred, the heat loss per sq. ft. per hour is .25 (from Table on Page 91), or

50 (net wall area) x .25 ("U" factor) x 75 (Temperature difference) = 937 BTU

EXPOSED FLOOR AND CEILING HEAT LOSS

The next step is to determine heat losses through exposed floors and ceilings or through partitions separating rooms maintained at different temperatures. The latter should be considered as exposed walls, with the difference that the temperature in an unheated room is not the same as the outside temperature. The temperature of unheated rooms is estimated as 35° above outside temperature. Where floors are directly on the ground, the ground is figured at 40° above outside temperature. Heat loss coefficients for ceiling, floor, roof and partition construction are found on Pages 87 to 96.

Let us assume that the room we have been figuring is under a flat type of roof. If the construction is wood having a deck 1 inch thick with roofing paper and insulation board and with metal lath and plaster ceiling, the heat loss coefficient is given in the tables on Page 94 as .16. Hence:

10 x 10 ceiling area = 100 sq. ft.

100 (ceiling area) x .16 ("U" factor) x 75 (Temperature difference) = 1200 BTU

Now add up the BTU requirements from preceding calculations. These are:

1047 (Heat Loss by Infiltration)
2542 (Heat Loss through Windows)
937 (Heat Loss through Walls)
1200 (Heat Loss through Ceiling)

5726 BTU required to heat room to 70° with outside temperature —5°.

If there had been an unheated attic above this room, the roof structure and ceiling of the top floor must be taken into consideration and a combined coefficient of transmission determined. Assuming that the roof is of a pitched type and there are no dormers, windows or vertical wall spaces, the formula for calculating the combined coefficient for the top floor ceiling is as follows:

$$\frac{A \times B}{A + \frac{B}{C}} = \text{"U" (combined coefficient)}$$

where:

A = Coefficient of transmission of the roof
B = Coefficient of transmission of the ceiling
C = Number of square feet of roof area in attic divided by the number of square feet of ceiling area in top floor

EXAMPLE OF COMBINED COEFFICIENT FOR A ROOF WITHOUT DORMERS

A = .46
B = .69
Roof area: 12 x 10 = 120 Sq. Ft.
Ceiling area: 10 x 10 = 100 Sq. Ft.

$$C = \frac{120 \text{ (roof area)}}{100 \text{ (ceiling area)}} = 1.2$$

$$\frac{.46 \times .69}{.46 + \frac{.69}{1.2}} = .306 \text{ combined coefficient}$$

Therefore the heat loss is—

100 (ceiling area) x .306 (comb. coefficient) x 75 (temp. differential) = 2325 BTU

If the unheated attic contains windows and vertical wall spaces, these must be taken into consideration in calculating the roof area and also its coefficient A. In this case, an approximate value of A may be obtained as the summation of the coefficient of each individual section such as the roof, vertical walls or windows, times its percentage of total area. This coefficient may be used with reasonable accuracy in the above formula.

EXAMPLE OF COMBINED COEFFICIENT FOR ROOF WITH DORMER

Assume a ceiling construction the same as in the previous example (Coeff. = .69). The roof construction will also be the same as before (Coeff. = .46). There will, however, be a dormer 5'0" wide, with a window 3'0" x 2'6" (no storm sash). The vertical walls of the dormer are of wood construction, shingle covered and with a combined coefficient of .38.

HEAT LOSS DETERMINATION (continued)

The total areas of the glass, vertical walls and roof are as follows:

Material	Net Area	Coeff.	% of Total Area	Coeff. x % of Area
Glass	7.5 Sq. Ft.	1.13	.036	.041
Walls	36.5 Sq. Ft.	.38	.175	.067
Roof	165 Sq. Ft.	.46	.785	.36
Total	**209 Sq. Ft.**			**.468**

Combined Coefficient "A"

Using the same formula as in the previous example—

A = .47

B = .69

Roof area = 209 sq. ft. (including glass and vertical walls)

Ceiling area = 100 sq. ft.

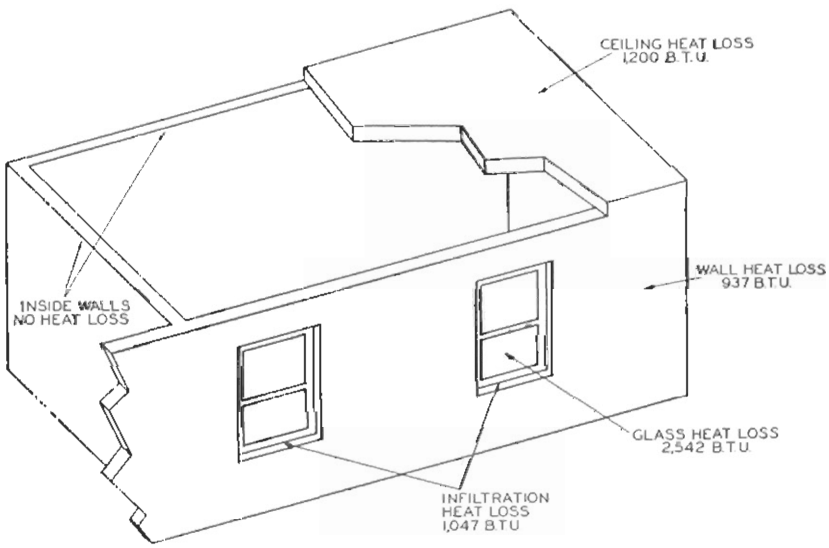
$$C = \frac{209}{100} = 2.09$$

$$\frac{.47 \times .69}{.47 + \frac{.69}{2.09}} = .403 \text{ combined coefficient}$$

Therefore, the heat loss is—

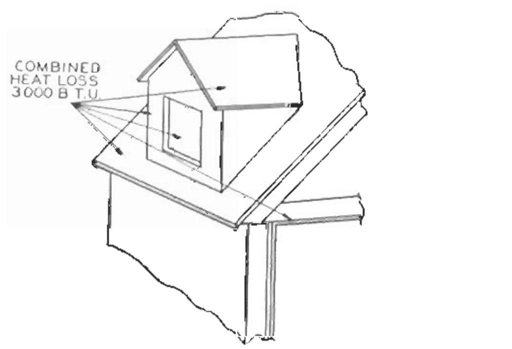
100 sq. ft. (ceiling area) x .403 (comb. coeff.) x 75 (temp. differential) = 3000 BTU

If, however, there are roof ventilators, so that the attic air is virtually at outside temperature, then the roof should be neglected and only the coefficient for the top floor ceiling construction used.



Heat losses of example room, as calculated on preceding page.

Pitched roofs and roofs with dormers require the calculation of a combined coefficient of heat loss.



HEAT LOSS TO GROUND

The heat loss figures shown in this illustration are acceptable for all ordinary design purposes.

NOTE: *If a dry site is not assured, provide a moisture barrier.*

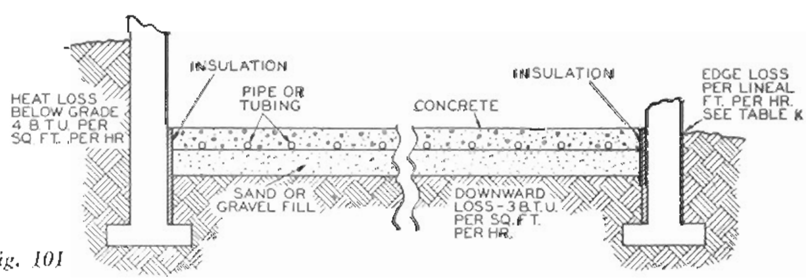


Fig. 101

HEAT TRANSMISSION TABLES

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Table 1. Conductances (C) for Surfaces and Air Spaces

All conductance values expressed in Btu per (hour) (square foot) (Fahrenheit degree temperature difference).

Section A. Surface Conductances for Still Air[a]

Position of Surface	Direction of Heat Flow	Surface Emissivity	
		$\epsilon = 0.83$	$\epsilon = 0.05$
Horizontal	Upward	1.95	1.16
Horizontal	Downward	1.21	0.44
Vertical		1.52[h]	0.74

Section B. Conductance of Vertical Spaces at Various Mean Temperatures[b]

Mean Temp Fahr Deg	Conductances of Air Spaces for Various Widths in Inches						
	0.128	0.250	0.364	0.493	0.713	1.00	1.500
20	2.300	1.370	1.180	1.100	1.040	1.030	1.022
30	2.385	1.425	1.234	1.148	1.080	1.070	1.065
40	2.470	1.480	1.288	1.193	1.125	1.112	1.105
50	2.560	1.535	1.340	1.242	1.168	1.152	1.149
60	2.650	1.590	1.390	1.295	1.210	1.195	1.188
70	2.730	1.648	1.440	1.340	1.250	1.240	1.228
80	2.819	1.702	1.492	1.390	1.295	1.280	1.270
90	2.908	1.757	1.547	1.433	1.340	1.320	1.310
100	2.990	1.813	1.600	1.486	1.380	1.362	1.350
110	3.078	1.870	1.650	1.534	1.425	1.402	1.392
120	3.167	1.928	1.700	1.580	1.467	1.445	1.435
130	3.250	1.980	1.750	1.630	1.510	1.485	1.475
140	3.340	2.035	1.800	1.680	1.550	1.530	1.519
150	3.425	2.090	1.852	1.728	1.592	1.569	1.559

Section C. Conductances and Resistances of Air Spaces Faced on One Surface with Reflective Insulation[c]

Location and Position of Air Space	Direction of Heat Flow	Temp[d] Diff Fahr Deg		Conductance[e] (C)			Resistance[e] $\left(\frac{1}{C}\right)$		
		Winter	Summer	No. of Air Spaces			No. of Air Spaces		
				1	2	3	1	2	3
Rafter Space (8 in.)									
Horizontal	Down	45			0.10	0.07		10.00	14.29
Horizontal	Up	45			0.27	0.17		3.70	5.88
Horizontal	Down		25		0.09	0.06		11.11	16.67
Horizontal	Up		25		0.24	0.16		4.17	6.25
30 deg slope	Down	45			0.15	0.10		6.67	10.00
30 deg slope	Up	45			0.25	0.17		4.00	5.88
30 deg slope	Down		25		0.13	0.09		7.69	11.11
30 deg slope	Up		25		0.23	0.14		4.35	7.14
Stud Space (3⅝ in.)									
Vertical[f]		30		0.34			2.94		
Vertical		40			0.23	0.13		4.35	7.69
Vertical[f]			15	0.32			3.13		
Vertical			20		0.18	0.11		5.56	9.09
Vertical[g]		30		0.46			2.17		

[a]Radiation and Convection from Surfaces in Various Positions, by G. B. Wilkes and C. M. F. Peterson (A.S.H.V.E. Transactions, Vol. 44, 1938, p. 513).

[b]A.S.H.V.E. Research Report No. 825—Thermal Resistance of Air Spaces, by F. B. Rowley and A. B. Algren (A.S.H.V.E. Transactions, Vol. 35, 1929, p. 165).

[c]Thermal Test Coefficients of Aluminum Insulation for Buildings, by G. B. Wilkes, F. G. Hechler and E. R. Queer (A.S.H.V.E. Transactions, Vol. 46, 1940).

[d]Temperature difference is based on total space between plaster base and sheathing, flooring or roofing.

[e]These air space conductance and resistance values are based on one reflective surface (aluminum) having an emissivity of 0.05 facing each space and are based on total space between plaster base and sheathing, flooring or roofing. The rafter and stud spaces are divided into equal spaces.

[f]Stud space is lined on plaster base side with loose paper with aluminum on surface facing air space. The resistance of the small air space between the plaster base and paper was 0.43.

[g]Radiation and Convection Across Air Spaces in Frame Construction, by G. B. Wilkes and C. M. F. Peterson (A.S.H.V.E. Transactions, Vol. 43, 1937, p. 351).

[h]The recommended surface conductance for calculating heat losses for still air for non-reflective surfaces is 1.65 Btu. For a 15 mph wind velocity, the recommended value is 6.0 Btu. These coefficients were derived from Fig. 3 which was based on tests conducted at the University of Minnesota, and apply to vertical surfaces.

HEAT TRANSMISSION TABLES

TABLE 2. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING AND INSULATING MATERIALS

These constants are expressed in Btu per (hour) (square foot) (Fahrenheit degree temperature difference). Conductivities (k) are per inch thickness and conductances (C) are for thickness or construction stated, not per inch thickness.

Material	Description	Density (Lb per Cu Ft)	Mean Temp (Fahr Deg)	Conductivity or Conductance (k)	Conductivity or Conductance (C)	Resistance Per Inch Thickness $\left(\frac{1}{k}\right)$	Resistance For Thickness Listed $\left(\frac{1}{C}\right)$	Authority
BUILDING BOARDS (NON-INSULATING)	Compressed cement and asbestos sheets	123	86	2.70	....	0.37	......	(1)
	Corrugated asbestos board	20.4	110	0.48	....	2.08	......	(2)
	Pressed asbestos mill board	60.5	86	0.84	....	1.19	......	(3)
	Gypsum board—gypsum between layers of heavy paper	62.8	70	1.41	....	0.71	......	(3)
	⅜ in. gypsum board	......	......	......	3.73	......	0.27	
	½ in. gypsum board	......	......	......	2.82	......	0.35	
	½ in. gypsum board	53.5	90	......	2.60	......	0.38	(1)
FRAME CONSTRUCTION COMBINATIONS	1 in. fir sheathing and building paper	......	30	......	0.86	......	1.16	(4)
	1 in. fir sheathing, building paper and yellow pine lap siding	......	20	......	0.50	......	2.00	(4)
	1 in. fir sheathing, building paper and stucco	......	20	......	0.82	......	1.22	(4)
	Pine lap siding and building paper, siding 4 in. wide	......	16	......	0.85	......	1.18	(4)
	Yellow pine lap siding	......	....	......	1.28	......	0.78	(4)
MASONRY MATERIALS BRICK	Damp or wet	......	....	5.0	....	0.20	......	(2)
	Common yellow clay brick[a]	......	....	4.8	....	0.21	......	(4)
	One tier yellow common clay brick, one tier face brick, approx. 8 in. thick[a]	......	....	......	0.77	......	1.30	(4)
CLAY TILE, HOLLOW	2 in. Tile, ½ in. plaster both sides	120.0	110	......	1.00	......	1.00	(2)
	4 in. Tile, ½ in. plaster both sides	127.0	100	......	0.60	......	1.67	(2)
	6 in. Tile, ½ in. plaster both sides	124.3	105	......	0.47	......	2.13	(2)
	8 in. Tile, average of 8 types (Walls No. 59, 63, 64, 66, 67, 90, 91, 92[a])	......	....	......	0.52	......	1.92	(4)
	12 in. Clay tile wall: 8 in. x 5 in. x 12 in. and 4 in. x 5 in. x 12 in.[a]	......	....	......	0.26	......	3.84	(4)
CONCRETE	Sand and gravel aggregate, various ages and mixes	......	....	11.35 to 16.36	....	0.09 to 0.06	......	(5)
	Sand and gravel aggregate	142	75	12.6	....	0.08	......	(4)
	Limestone aggregate	132	75	10.8	....	0.09	......	(4)
	Cinder aggregate	97	75	4.9	....	0.22	......	(4)
	Steam treated limestone slag aggregate[a]	74.6	75	2.27	....	0.44	......	(4)
	Pumice (Mined in California) aggregate[a]	65.0	75	2.42	....	0.41	......	(4)
	Expanded burned clay aggregate[a]	59.9	75	2.28	....	0.44	......	(4)
	Burned clay aggregate[a]	67.1	75	2.86	....	0.35	......	(4)
	Blast furnace slag aggregate	76.0	70	1.6	....	0.63	......	(3)
	Expanded vermiculite aggregate	20	90	0.68	....	1.47	......	(3)
	Expanded vermiculite aggregate	26.7	90	0.76	....	1.32	......	(3)

AUTHORITIES:

[1]U. S. Bureau of Standards, tests based on samples submitted by manufacturers.

[2]A. C. Willard, L. C. Lichty and L. A. Harding, tests conducted at the University of Illinois.

[3]J. C. Peebles, tests conducted at Armour Institute of Technology, based on samples submitted by manufacturers.

[4]F. B. Rowley, et al, tests conducted at the University of Minnesota.

[5]A.S.H.V.E. Research Laboratory.

[6]E. A. Allcut, tests conducted at the University of Toronto.

[a]See Thermal Conductivity of Building Materials, by F. B. Rowley and A. B. Algren (University of Minnesota *Engineering Experiment Station Bulletin* No. 12).

[b]Heat Transmission Through Insulation as Affected by Orientation of Wall, by F. B. Rowley and C. E. Lund (A.S.H.V.E. TRANSACTIONS, Vol. 49, 1943, p. 331).

[c]The Effect of Convection in Ceiling Insulation, by G. B. Wilkes and L. R. Vianey (A.S.H.V.E. TRANSACTIONS, Vol. 49, 1943, p. 196).

[d]See A.S.H.V.E. RESEARCH REPORT No. 915—Conductivity of Concrete, by F. C. Houghten and Carl Gutberlet (A.S.H.V.E. TRANSACTIONS, Vol. 38, 1932, p. 47).

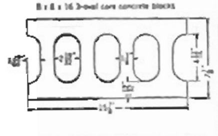
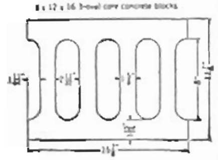
[e]See Heating, Ventilating and Air Conditioning, by Harding and Willard, revised edition, 1932.

[f]See BMS13, U. S. Department of Commerce, National Bureau of Standards, Washington, D. C.

[g]Roofing, 0.15 in. thick (1.34 lb per square foot), covered with gravel (0.83 lb per square foot), combined thickness assumed 0.25.

TABLE 2. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING AND INSULATING MATERIALS—Continued

These constants are expressed in Btu per (hour) (square foot) (Fahrenheit degree temperature difference). Conductivities (k) are per inch thickness and conductances (C) are for thickness or construction stated, not per inch thickness.

Material	Description	Density (Lb per Cu Ft)	Mean Temp (Fahr Deg)	Conductivity or Conductance (k)	Conductivity or Conductance (C)	Resistance Per Inch Thickness $\left(\frac{1}{k}\right)$	Resistance For Thickness Listed $\left(\frac{1}{C}\right)$	Authority
MASONRY MATERIALS—(Continued) CONCRETE—(Continued)	Expanded vermiculite aggregate	35	90	0.86	....	1.16	......	(3)
	Expanded vermiculite aggregate	50	90	1.10	....	0.91	......	(3)
	Concrete plank	76	75	2.5	....	0.40	......	(3)
	Cellular concrete	40.0	75	1.06	....	0.94	......	(3)
	Cellular concrete	50.0	75	1.44	....	0.69	......	(3)
	Cellular concrete	60.0	75	1.80	....	0.56	......	(3)
	Cellular concrete	70.0	75	2.18	....	0.46	......	(3)
8 In. Concrete Blocks 	8 in. three oval core, sand and gravel aggregate[a]	126.4	40	......	0.90	......	1.11	(4)
	8 in. three oval core, crushed limestone aggregate[a]	134.3	40	......	0.86	......	1.16	(4)
	8 in. three oval core, cinder aggregate[a]	86.2	40	......	0.58	......	1.73	(4)
	8 in. three oval core, burned clay aggregate[a]	67.7	40	......	0.50	......	2.00	(4)
	8 in. three oval core, expanded blast furnace slag aggregate[a]	......	40	......	0.49	......	2.04	(4)
12 In. Concrete Blocks 	12 in. three oval core, sand and gravel aggregate[a]	124.9	40	......	0.78	......	1.28	(4)
	12 in. three oval core, cinder aggregate[a]	86.2	40	......	0.53	......	1.88	(4)
	12 in. three oval core, burned clay aggregate[a]	76.7	40	......	0.47	......	2.13	(4)
GYPSUM	3 in. solid gypsum partition tile[a]	......	....	2.41	....	0.42	......	(4)
	3 in. three cell gypsum partition tile[a]	......	....	......	0.74	......	1.35	(4)
	4 in. three cell gypsum partition tile[a]	......	....	......	0.60	......	1.67	(4)
	87½ per cent gypsum, 12½ per cent wood chips	51.2	74	1.66	....	0.60	......	(4)
	Gypsum plaster	......	....	3.30	....	0.30	......	
PLASTERING MATERIALS	Gypsum plaster, ⅜ in. thick	......	73	......	8.80	......	0.11	(4)
	Cement plaster	......	....	8.00	....	0.13	......	(2)
	Wood, lath and plaster, total thickness ¾ in.	......	70	......	2.50	......	0.40	(4)
	Gypsum plaster and expanded vermiculite, 4 to 1 mix	39.9	75	0.85	....	1.18	......	(3)
	Insulating plaster 0.9 in. thick applied to ⅜ in. gypsum board	54.0	75	......	1.07	......	0.93	(3)
ROOFING	Asbestos shingles	65.0	75	......	6.0	......	0.17	(3)
	Asphalt, composition or prepared	70.0	75	......	6.5	......	0.15	(3)
	Asphalt shingles	70.0	75	......	6.5	......	0.15	(3)
	Built-up roofing, bitumen or felt, gravel or slag surfaced[g]	......	....	1.33	....	0.75	......	(2)
	Slate	......	....	10.00	....	0.10	......	
	Wood shingles	......	....	......	1.28	......	0.78	
WOODS	Balsa	20.0	90	0.58	....	1.72	......	(1)
	Balsa	8.8	90	0.38	....	2.63	......	(1)
	Balsa	7.3	90	0.33	....	3.03	......	(1)
	California redwood, 0 per cent moisture[a]	28.0	75	0.70	....	1.43	......	(4)
	Cypress	28.7	86	0.67	....	1.49	......	(1)
	Douglas fir, 0 per cent moisture[a]	34.0	75	0.67	....	1.49	......	(4)
	Eastern hemlock, 0 per cent moisture[a]	30.0	75	0.76	....	1.32	......	(4)
	Long leaf yellow pine, 0 per cent moisture[a]	40.0	75	0.86	....	1.16	......	(4)
	Mahogany	34.3	86	0.90	....	1.11	......	(1)

HEAT TRANSMISSION TABLES

TABLE 2. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING AND INSULATING MATERIALS—Continued

These constants are expressed in Btu per (hour) (square foot) (Fahrenheit degree temperature difference). Conductivities (k) are per inch thickness and conductances (C) are for thickness or construction stated, not per inch thickness.

Material	Description	Density (Lb per Cu Ft)	Mean Temp (Fahr Deg)	Conductivity or Conductance (k)	(C)	Resistance Per Inch Thickness $\left(\frac{1}{k}\right)$	For Thickness Listed $\left(\frac{1}{C}\right)$	Authority
WOODS—(Continued)	Hard maple, 0 per cent moisture[a]	46.0	75	1.05	....	0.95	......	(4)
	Maple	44.3	86	1.10	....	0.91	......	(1)
	Maple, across grain	40.0	75	1.20	....	0.83	......	(3)
	Norway pine, 0 per cent moisture[a]	32.0	75	0.74	....	1.35	......	(4)
	Red cypress, 0 per cent moisture[a]	32.0	75	0.79	....	1.27	......	(4)
	Red oak, 0 per cent moisture[a]	48.0	75	1.18	....	0.85	......	(4)
	Short leaf yellow pine, 0 per cent moisture[a]	36.0	75	0.91	....	1.10	......	(4)
	Soft elm, 0 per cent moisture[a]	34.0	75	0.88	....	1.14	......	(4)
	Soft maple, 0 per cent moisture[a]	42.0	75	0.95	....	1.05	......	(4)
	Sugar pine, 0 per cent moisture[a]	28.0	75	0.64	....	1.56	......	(4)
	Virginia pine	34.3	86	0.96	....	1.04	......	(1)
	West coast hemlock, 0 per cent moisture[a]	30.0	75	0.79	....	1.27	......	(4)
	White pine	31.2	86	0.78	....	1.28	......	(1)
	Yellow pine	......	....	1.00	....	1.00	......	(3)
	Sawdust, various	12.0	90	0.41	....	2.44	......	(1)
	Shavings, various from planer	8.8	90	0.41	....	2.44	......	(1)
	Shavings, from maple beech and birch (coarse)	13.2	90	0.36	....	2.78	......	(1)
INSULATING MATERIALS Blanket and Bat Insulations	Chemically treated wood fibers held between layers of strong paper	3.62	70	0.25	....	4.00	......	(3)
	Eel grass between strong paper	4.60	90	0.26	....	3.85	......	(1)
	Eel grass between strong paper	3.40	90	0.25	....	4.00	......	(1)
	Flax fibers between strong paper	4.90	90	0.28	....	3.57	......	(1)
	Chemically treated hog hair between kraft paper	5.76	71	0.26	....	3.85	......	(3)
	Chemically treated hog hair between kraft paper and asbestos paper	7.70	71	0.28	....	3.57	......	(3)
	Hair felt between layers of paper	11.00	75	0.25	....	4.00	......	(3)
	Kapok between burlap or paper	1.00	90	0.24	....	4.17	......	(1)
	Stitched and creped expanding fibrous blanket	1.50	70	0.27	....	3.70	......	(3)
	Paper and asbestos fiber with emulsified asphalt binder	4.2	94	0.28	....	3.57	......	(1)
	Cotton insulating bat	0.875	72	0.24	....	4.17	......	(3)
	Cotton fibers							
	Short Staple Linters, Fireproofed	6.25	90	0.25	....	4.00	......	(1)
	Short Staple Linters, Fireproofed	4.50	90	0.24	....	4.17	......	(1)
	Short Staple Linters, Fireproofed	2.45	90	0.24	....	4.17	......	(1)
	Short Staple Linters, Fireproofed	1.60	90	0.26	....	3.85	......	(1)
	Short Staple Linters, Fireproofed	0.85	90	0.29	....	3.45	......	(1)
	Short Staple Linters, Fireproofed	0.65	90	0.30	....	3.33	......	(1)
	Felted cattle hair	13.00	90	0.26	....	3.84	......	(1)
	Felted cattle hair	11.00	90	0.26	....	3.84	......	(1)
	Felted hair and asbestos	7.80	90	0.28	....	3.57	......	(1)
	Ground paper between two layers, each 3/8 in. thick made up of two layers of kraft paper (sample 3/4 in. thick)	12.1	75	......	0.40	......	2.50	(4)
Reflective	See Table 1, Section C	......	....	......	....	......	......	
Insulating Board	Made from sugar cane fiber	13.5	70	0.33	....	3.03	......	(3)
	Made from corn stalks	15.00	71	0.33	....	3.03	......	(3)
	Made from exploded wood fibers	17.90	78	0.32	....	3.12	......	(4)
	Made from hard wood fibers	15.20	70	0.32	....	3.12	......	(3)
	Made from wood fiber	15.90	72	0.33	....	3.03	......	(3)
	Made from wood fiber	15.00	70	0.33	....	3.03	......	(3)
	Made from wood fiber	......	52	0.33	....	3.03	......	(6)
	Made from wood fiber	8.50	72	0.29	....	3.45	......	(3)
	Made from wood fiber	15.20	....	0.33	....	3.03	......	(3)
	Made from wood fiber	16.90	90	0.34	....	2.94	......	(1)

See notes on Page 88

TABLE 2. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING AND INSULATING MATERIALS—Concluded

These constants are expressed in Btu per (hour) (square foot) (Fahrenheit degree temperature difference). Conductivities (k) are per inch thickness and conductances (C) are for thickness or construction stated, not per inch thickness.

Material	Description	Density (Lb per Cu Ft)	Mean Temp (Fahr Deg)	Conductivity or Conductance (k)	(C)	Resistance Per Inch Thickness $\left(\frac{1}{k}\right)$	For Thickness Listed $\left(\frac{1}{C}\right)$	Authority
INSULATING MATERIALS—Continued Insulating Board—Continued	Made from licorice root	16.1	81	0.34	....	2.94	......	(3)
	½ in. insulating boards without special finish[f] (eleven samples)	16.5 to 21.8	90	0.33 to 0.40	....	3.03 to 2.50	......	(1)
	1 in. insulating board[a]	13.2	....	0.34	....	2.94	......	(4)
Loose Fill Type	Made from ceiba fibers	1.90	75	0.23	....	4.35	......	(3)
	Made from ceiba fibers	1.60	75	0.24	....	4.17	......	(3)
	Fibrous material made from dolomite and silica	1.50	75	0.27	....	3.70	......	(3)
	Fibrous material made from slag	9.40	103	0.27	....	3.70	......	(1)
	Redwood bark	3.00	90	0.31	....	3.22	......	(1)
	Redwood bark	5.00	75	0.26	....	3.84	......	(3)
	Glass wool fibers 0.0003 in. to 0.006 in. in diameter	1.50	75	0.27	....	3.70	......	(3)
	Granular insulation made from combined silicate of lime and alumina	4.20	72	0.24	....	4.17	......	(3)
	Expanded vermiculite	......	....	0.48	....	2.08	......	(1)
	Expanded vermiculite, particle size— −3 + 14	6.2	....	0.32	....	3.12	......	(3)
	Regranulated cork about 3/16 in. particles	8.10	90	0.31	....	3.22	......	(1)
	Hand applied granular mineral wool 2 in. to 6 in. thick; horizontal position[b]. No covering	6.05 to 7.13	....	0.30 to 0.33	....	3.33 to 3.03	......	(4)
	4 in. machine blown granular mineral wool, horizontal position[b]. No covering	5.74	....	0.30	....	3.33	......	(4)
	Rock wool	10.0	90	0.27	....	3.70	......	(1)
Slab Insulations	Corkboard, no added binder	14.0	90	0.34	....	2.94	......	(1)
	Corkboard, no added binder	10.6	90	0.30	....	3.33	......	(1)
	Corkboard, no added binder	7.0	90	0.27	....	3.70	......	(1)
	Corkboard, no added binder	5.4	90	0.25	....	4.00	......	(1)
	Corkboard[a]	8.7	....	0.29	....	3.45	......	(4)
	Corkboard, asphaltic binder	14.5	90	0.32	....	3.12	......	(1)
	Chemically treated hog hair with film of asphalt	10.0	75	0.28	....	3.57	......	(3)
	Sugar cane fiber insulation blocks encased in asphalt membrane	13.8	70	0.30	....	3.33	......	(3)
	Made from 85 per cent magnesia and 15 per cent asbestos	19.3	86	0.51	....	1.96	......	(1)
	Made from shredded wood and cement	24.2	72	0.46	....	2.17	......	(3)
	Made from shredded wood and cement[a]	29.8	....	0.77	....	1.30	......	(4)

See notes on Page 88

TABLE 3. VARIATION IN SURFACE CONDUCTANCE COEFFICIENT WITH DIFFERENT TEMPERATURES OF SURROUNDING SURFACE

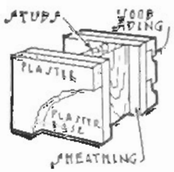
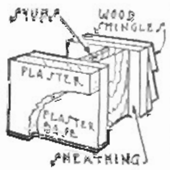
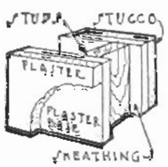
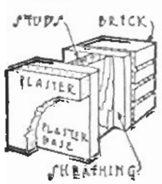
Surrounding Surface Temperature	75 F	70 F	69 F	60 F	50 F
Convection—Btu per (hr) (sq ft)	6.6	6.6	6.6	6.6	6.6
Radiation—Btu per (hr) (sq ft)	4.4	8.6	9.6	17.0	24.9
Total—Btu per (hr) (sq ft)	11.0	15.2	16.2	23.6	31.5

HEAT TRANSMISSION TABLES

Table 5. Coefficients of Transmission (*U*) of Frame Walls

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph.

No Insulation Between Studs[a] (See Table 6)

Exterior Finish	Interior Finish	Type of Sheathing: Gypsum (1/2 in. thick) A	Plywood (5/16 in. thick) B	Wood[f] (25/32 in. thick) Bldg. Paper C	Insulating Board (25/32 in. thick) D	Wall Number
Wood Siding (Clapboard) 	Metal Lath and Plaster[b]	0.33	0.32	0.26	0.20	1
	Gypsum Board (3/8 in.) Decorated	0.32	0.32	0.26	0.20	2
	Wood Lath and Plaster	0.31	0.31	0.25	0.19	3
	Gypsum Lath (3/8 in.) Plastered[c]	0.31	0.30	0.25	0.19	4
	Plywood (3/8 in.) Plain or Decorated	0.30	0.30	0.24	0.19	5
	Insulating Board (1/2 in.) Plain or Decorated	0.23	0.23	0.19	0.16	6
	Insulating Board Lath (1/2 in.) Plastered[c]	0.22	0.22	0.19	0.15	7
	Insulating Board Lath (1 in.) Plastered[c]	0.17	0.17	0.15	0.12	8
Wood[d] Shingles 	Metal Lath and Plaster[b]	0.25	0.25	0.26	0.17	9
	Gypsum Board (3/8 in.) Decorated	0.25	0.25	0.26	0.17	10
	Wood Lath and Plaster	0.24	0.24	0.25	0.16	11
	Gypsum Lath (3/8 in.) Plastered[c]	0.24	0.24	0.25	0.16	12
	Plywood (3/8 in.) Plain or Decorated	0.24	0.24	0.24	0.16	13
	Insulating Board (1/2 in.) Plain or Decorated	0.19	0.19	0.19	0.14	14
	Insulating Board Lath (1/2 in.) Plastered[c]	0.19	0.18	0.19	0.13	15
	Insulating Board Lath (1 in.) Plastered[c]	0.14	0.14	0.15	0.11	16
Stucco 	Metal Lath and Plaster[b]	0.43	0.42	0.32	0.23	17
	Gypsum Board (3/8 in.) Decorated	0.42	0.41	0.31	0.23	18
	Wood Lath and Plaster	0.40	0.39	0.30	0.22	19
	Gypsum Lath (3/8 in.) Plastered[c]	0.39	0.39	0.30	0.22	20
	Plywood (3/8 in.) Plain or Decorated	0.39	0.38	0.29	0.22	21
	Insulating Board (1/2 in.) Plain or Decorated	0.27	0.27	0.22	0.18	22
	Insulating Board Lath (1/2 in.) Plastered[c]	0.26	0.26	0.22	0.17	23
	Insulating Board Lath (1 in.) Plastered[c]	0.19	0.19	0.16	0.14	24
Brick Veneer[e] 	Metal Lath and Plaster[b]	0.37	0.36	0.28	0.21	25
	Gypsum Board (3/8 in.) Decorated	0.36	0.36	0.28	0.21	26
	Wood Lath and Plaster	0.35	0.34	0.27	0.20	27
	Gypsum Lath (3/8 in.) Plastered[c]	0.34	0.34	0.27	0.20	28
	Plywood (3/8 in.) Plain or Decorated	0.34	0.33	0.27	0.20	29
	Insulating Board (1/2 in.) Plain or Decorated	0.25	0.25	0.21	0.17	30
	Insulating Board Lath (1/2 in.) Plastered[c]	0.24	0.24	0.20	0.16	31
	Insulating Board Lath (1 in.) Plastered[c]	0.18	0.18	0.15	0.13	32

[a]Coefficients not weighted; effect of studding neglected.
[b]Plaster assumed 3/4 in. thick.
[c]Plaster assumed 3/8 in. thick.
[d]Furring strips (1 in. nominal thickness) between wood shingles and all sheathings except wood.
[e]Small air space and mortar between building paper and brick veneer neglected.
[f]Nominal thickness, 1 in.

Table 6. Coefficients of Transmission (*U*) of Frame Walls with Insulation Between Framing[a, b]

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph.

Coefficient with *no* Insulation between Framing	Coefficient with Insulation Between Framing: Mineral Wool or Vegetable Fibers in Blanket or Bat Form[c] (Thickness below) 1 in. A	2 in. B	3 in. C	3 5/8 in. Mineral Wool between Framing[d] D	Number
0.11	0.078	0.063	0.054	0.051	33
0.12	0.083	0.067	0.056	0.053	34
0.13	0.088	0.070	0.058	0.055	35
0.14	0.092	0.072	0.061	0.057	36
0.15	0.097	0.075	0.062	0.059	37
0.16	0.10	0.078	0.064	0.060	38
0.17	0.10	0.080	0.066	0.062	39
0.18	0.11	0.082	0.067	0.063	40
0.19	0.11	0.084	0.069	0.065	41
0.20	0.12	0.086	0.070	0.066	42
0.21	0.12	0.088	0.072	0.067	43
0.22	0.12	0.089	0.073	0.068	44
0.23	0.12	0.091	0.074	0.069	45
0.24	0.12	0.093	0.075	0.070	46
0.25	0.13	0.094	0.076	0.071	47
0.26	0.13	0.096	0.077	0.072	48
0.27	0.14	0.097	0.078	0.073	49
0.28	0.14	0.098	0.079	0.073	50
0.29	0.14	0.10	0.080	0.075	51
0.30	0.14	0.10	0.080	0.075	52
0.31	0.14	0.10	0.081	0.076	53
0.32	0.15	0.10	0.082	0.077	54
0.33	0.15	0.10	0.083	0.077	55
0.34	0.15	0.10	0.083	0.078	56
0.35	0.15	0.11	0.084	0.078	57
0.36	0.15	0.11	0.085	0.079	58
0.37	0.16	0.11	0.085	0.080	59
0.38	0.16	0.11	0.086	0.080	60
0.39	0.16	0.11	0.086	0.081	61
0.40	0.16	0.11	0.087	0.082	62
0.41	0.16	0.11	0.087	0.082	63
0.42	0.16	0.11	0.088	0.082	64
0.43	0.17	0.11	0.088	0.082	65
0.44	0.17	0.11	0.089	0.083	66

[a]This table may be used for determining the coefficients of transmission of frame constructions with the types and thicknesses of insulation indicated in Columns A to D inclusive between framing. Columns A, B and C may be used for walls, ceilings or roofs with only one air space between framing but are not applicable to ceilings with *no* flooring above. (See Table 11.) Column D is applicable to walls only. *Example:* Find the coefficient of transmission of a frame wall consisting of wood siding, 25/32 in. insulating board sheathing, studs, gypsum lath and plaster, with 2 in. blanket insulation between studs. According to Table 5, a wall of this construction with *no insulation* between studs has a coefficient of 0.19 (Wall No. 4D). Referring to Column B above, it will be found that a wall of this value with 2 in. blanket insulation between the studs has a coefficient of 0.084.

[b]Coefficients corrected for 2 x 4 framing, 16 in. on centers—15 per cent of surface area.

[c]Based on one air space between framing.

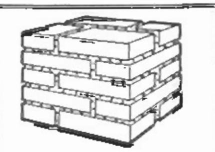
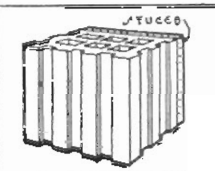
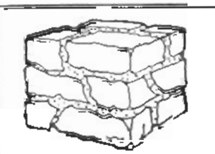
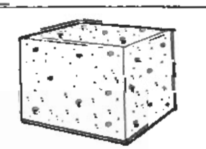
[d]No air space.

HEAT TRANSMISSION TABLES

Table 7. Coefficients of Transmission (U) of Masonry Walls

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph.

INTERIOR FINISH (Plus Insulation Where Indicated): A = Plain Walls—No Interior Finish; B = Plaster (½ in.) on Walls; C = Metal Lath and Plaster[f] Furred[h]; D = Gypsum Board (⅜ in.) Decorated—Furred[h]; E = Gypsum Lath (⅜ in.) Plastered[g]—Furred[h]; F = Insulating Board (½ in.) Plain or Decorated—Furred[h]; G = Insulating Board Lath (½ in.) Plastered[g]—Furred[h]; H = Insulating Board Lath (1 in.) Plastered[g]—Furred[h]; I = Gypsum Lath[g] Plastered Plus 1 in. Blanket Insulation—Furred[h]

Type of Masonry		Thickness of Masonry Inches	A	B	C	D	E	F	G	H	I	Wall Number
Solid[a] Brick		8	0.50	0.46	0.32	0.31	0.30	0.22	0.22	0.16	0.14	67
		12	0.36	0.34	0.25	0.25	0.24	0.19	0.19	0.14	0.13	68
		16	0.28	0.27	0.21	0.21	0.20	0.17	0.16	0.13	0.12	69
Hollow[b] Tile (Stucco Exterior Finish)		8	0.40	0.37	0.27	0.27	0.26	0.20	0.20	0.15	0.13	70
		10	0.39	0.37	0.27	0.27	0.26	0.20	0.19	0.15	0.13	71
		12	0.30	0.28	0.22	0.22	0.21	0.17	0.17	0.13	0.12	72
		16	0.24	0.24	0.19	0.19	0.18	0.15	0.15	0.12	0.11	73
Stone[c]		8	0.70	0.64	0.39	0.38	0.36	0.26	0.25	0.18	0.16	74
		12	0.57	0.53	0.35	0.34	0.33	0.24	0.23	0.17	0.15	75
		16	0.49	0.45	0.31	0.31	0.29	0.22	0.22	0.16	0.14	76
		24	0.37	0.35	0.26	0.26	0.25	0.19	0.19	0.15	0.13	77
Poured Concrete[d]		6	0.79	0.71	0.42	0.41	0.39	0.27	0.26	0.19	0.16	78
		8	0.70	0.64	0.39	0.38	0.36	0.26	0.25	0.18	0.16	79
		10	0.63	0.58	0.37	0.36	0.34	0.25	0.24	0.18	0.15	80
		12	0.57	0.53	0.35	0.34	0.33	0.24	0.23	0.17	0.15	81
Hollow Concrete Blocks		Gravel Aggregate										
		8	0.56	0.52	0.34	0.34	0.32	0.24	0.23	0.17	0.15	82
		12	0.49	0.46	0.32	0.31	0.30	0.22	0.22	0.16	0.14	83
		Cinder Aggregate										
		8	0.41	0.39	0.28	0.28	0.27	0.21	0.20	0.15	0.13	84
		12	0.38	0.36	0.26	0.26	0.25	0.20	0.19	0.15	0.13	85
		Light Weight Aggregate[e]										
		8	0.36	0.34	0.26	0.25	0.24	0.19	0.19	0.15	0.13	86
		12	0.34	0.33	0.25	0.24	0.24	0.19	0.18	0.14	0.13	87

[a] Based on 4 in. hard brick and remainder common brick.

[b] The 8 in. and 10 in. tile figures are based on two cells in the direction of heat flow. The 12 in. tile is based on three cells in the direction of heat flow. The 16 in. tile consists of one 10 in. and one 6 in. tile each having two cells in the direction of heat flow.

[c] Limestone or sandstone.

[d] These figures may be used with sufficient accuracy for concrete walls with stucco exterior finish.

[e] Expanded slag, burned clay or pumice.

[f] Thickness of plaster assumed ¾ in.

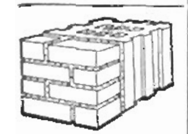
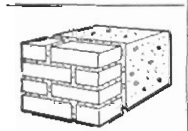
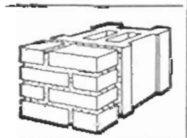
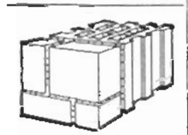
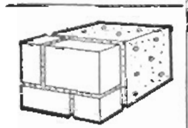
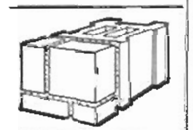
[g] Thickness of plaster assumed ½ in.

[h] Based on 2 in. furring strips; one air space.

Table 8. Coefficients of Transmission (U) of Brick and Stone Veneer Masonry Walls

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph.

INTERIOR FINISH (Plus Insulation Where Indicated): A = Plain Walls—no Interior Finish; B = Plaster (½ in.) on Walls; C = Metal Lath and Plaster[e]—Furred[g]; D = Gypsum Board (⅜ in). Decorated—Furred[g]; E = Gypsum Lath (⅜ in.) Plastered[f]—Furred[g]; F = Insulating Board (½ in.) Plain or Decorated—Furred[g]; G = Insulating Board Lath (½ in.) Plastered[f]—Furred[g]; H = Insulating Board Lath (1 in.) Plastered[f]—Furred[g]; I = Gypsum Lath Plastered[f] Plus 1 in. Blanket Insulation—Furred[g]

Typical Construction	Facing	Backing	A	B	C	D	E	F	G	H	I	Wall Number
	4 in. Brick Veneer[a]	6 in. Hollow Tile[b]	0.35	0.34	0.25	0.25	0.24	0.19	0.18	0.14	0.13	88
		8 in. Hollow Tile[b]	0.34	0.32	0.25	0.24	0.23	0.19	0.18	0.14	0.13	89
		6 in. Concrete	0.59	0.54	0.35	0.35	0.33	0.24	0.23	0.17	0.15	90
		8 in. Concrete	0.54	0.50	0.33	0.33	0.31	0.23	0.23	0.17	0.15	91
		8 in. Concrete Blocks[c] (Gravel Aggregate)	0.44	0.41	0.29	0.29	0.28	0.21	0.21	0.16	0.14	92
		8 in. Concrete Blocks[c] (Cinder Aggregate)	0.34	0.33	0.25	0.24	0.24	0.19	0.18	0.14	0.13	93
		8 in. Concrete Blocks[c] (Light Weight Aggregate)[d]	0.31	0.29	0.23	0.23	0.22	0.18	0.17	0.14	0.12	94
	4 in. Cut Stone Veneer[a]	6 in. Hollow Tile[b]	0.37	0.35	0.26	0.26	0.25	0.19	0.19	0.15	0.13	95
		8 in. Hollow Tile[b]	0.36	0.34	0.25	0.25	0.24	0.19	0.19	0.14	0.13	96
		6 in. Concrete	0.63	0.58	0.37	0.36	0.34	0.25	0.24	0.18	0.15	97
		8 in. Concrete	0.57	0.53	0.35	0.34	0.33	0.24	0.23	0.17	0.15	98
		8 in. Concrete Blocks[c] (Gravel Aggregate)	0.47	0.44	0.30	0.30	0.29	0.22	0.21	0.16	0.14	99
		8 in. Concrete Blocks[c] (Cinder Aggregate)	0.36	0.34	0.25	0.25	0.24	0.19	0.19	0.15	0.13	100
		8 in. Concrete Blocks[c] (Light Weight Aggregate)[d]	0.32	0.30	0.23	0.23	0.22	0.18	0.17	0.14	0.12	101

[a] Calculations based on ½ in. cement mortar between backing and facing except in the case of the concrete backing which is assumed to be poured in place.

[b] The hollow tile figures are based on two air cells in the direction of heat flow.

[c] Hollow concrete blocks.

[d] Expanded slag, burned clay or pumice.

[e] Thickness of plaster assumed ¾ in.

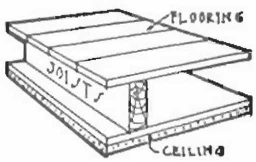
[f] Thickness of plaster assumed ½ in.

[g] Based on 2 in. furring strips; one air space.

HEAT TRANSMISSION TABLES

Table 11. Coefficients of Transmission (U) of Frame Construction Ceilings and Floors

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides) and are based on still air (no wind) conditions on both sides.



Type of Ceiling	Insulation Between, or on Top of, Joists (No Flooring Above)												With Flooring[g] (On Top of Ceiling Joists)		Number
	None	Insulating Board on Top of Joists		Blanket or Bat Insulation[f] Between Joists[a]			Vermiculite Insulation Between Joists[a]			Mineral Wool Insulation Between Joists[a]			Single Wood Floor[b]	Double Wood Floor[c]	
		½ In.	1 In.	1 In.	2 In.	3 In.	2 In.	3 In.	4 In.	2 In.	3 In.	4 In.			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
No Ceiling		0.37	0.24										0.45	0.34	1
Metal Lath and Plaster[d]	0.69	0.26	0.19	0.19	0.12	0.093	0.18	0.14	0.11	0.12	0.093	0.077	0.30	0.25	2
Gypsum Board (⅜ in.) Plain or Decorated	0.67	0.26	0.18	0.19	0.12	0.092	0.18	0.13	0.10	0.12	0.092	0.077	0.30	0.24	3
Wood Lath and Plaster	0.62	0.25	0.18	0.19	0.12	0.091	0.17	0.13	0.10	0.12	0.091	0.076	0.28	0.24	4
Gypsum Lath (⅜ in.) Plastered[e]	0.61	0.25	0.18	0.19	0.12	0.091	0.17	0.13	0.10	0.12	0.091	0.076	0.28	0.24	5
Plywood (⅜ in.) Plain or Decorated	0.59	0.24	0.18	0.19	0.12	0.091	0.17	0.13	0.10	0.12	0.091	0.076	0.28	0.23	6
Insulating Board (½ in.) Plain or Decorated	0.36	0.19	0.15	0.16	0.10	0.082	0.14	0.12	0.097	0.10	0.082	0.069	0.22[h]	0.19[h]	7
Insulating Board Lath (½ in.) Plastered[e]	0.35	0.19	0.15	0.15	0.10	0.081	0.14	0.11	0.096	0.10	0.081	0.068	0.21	0.18	8
Insulating Board Lath (1 in.) Plastered[e]	0.23	0.15	0.12	0.12	0.089	0.072	0.12	0.097	0.084	0.089	0.072	0.061	0.16	0.14	9

[a] Coefficients corrected for framing on basis of 15 per cent area, 2 in. x 4 in. (nominal) framing, 16 in. on centers.

[b] 25/32 in. yellow pine or fir.

[c] 25/32 in. pine or fir sub-flooring plus 13/16 in. hardwood finish flooring.

[d] Plaster assumed ¾ in. thick.

[e] Plaster assumed ½ in. thick.

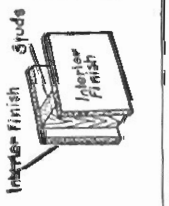
[f] Based on insulation in contact with ceiling and consequently no air space between.

[g] For coefficients for constructions in Columns M and N (except No. 1) with insulation between joists, refer to Table 6. *Example:* The coefficient for No. 3-N of Table 11 is 0.24. With 2 in. blanket insulation between joists, the coefficient will be 0.093. (See Table 6.) (Column D of Table 6 applicable only for 3⅝ in. joists.)

[h] For 25/32 in. insulating board sheathing applied to the under side of the joists, the coefficient for *single* wood floor (Column M) is 0.18 and for *double* wood floor (Column N) is 0.16. For coefficients with insulation between joists, see Table 6.

Table 9. Coefficients of Transmission (U) of Frame Partitions or Interior Walls[a]

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on still air (no wind) conditions on both sides.



Interior Finish	Single Partition (Finish on one side only of studs)	Double Partition (Finish on both sides of studs): No Insulation Between Studs	Double Partition: 1 In. Blanket[d] Between Studs, One Air Space	Partition Number
	A	B	C	
Metal Lath and Plaster[b]	0.69	0.39	0.16	1
Gypsum Board (⅜ in.) Decorated	0.67	0.37	0.16	2
Wood Lath and Plaster	0.62	0.34	0.15	3
Gypsum Lath (⅜ in.) Plastered[c]	0.61	0.34	0.15	4
Plywood (⅜ in.) Plain or Decorated	0.59	0.33	0.15	5
Insulating Board (½ in.) Plain or Decorated	0.36	0.19	0.11	6
Insulating Board Lath (½ in.) Plastered[c]	0.35	0.18	0.11	7
Insulating Board Lath (1 in.) Plastered[c]	0.23	0.12	0.082	8

[a] Coefficients not weighted; effect of studding neglected.

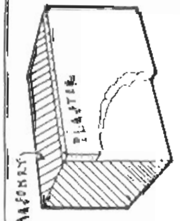
[b] Plaster assumed ¾ in. thick.

[c] Plaster assumed ½ in. thick.

[d] For partitions with other insulations between studs refer to Table 6, using values in Column B of above table in left hand column of Table 6. *Example:* What is the coefficient of transmission (U) of a partition consisting of gypsum lath and plaster on both sides of studs with 2 in. blanket between studs? *Solution:* According to above table, this partition with no insulation between studs (No. 4B) has a coefficient of 0.34. Referring to Table 6, it will be found that a wall having a coefficient of 0.34 with no insulation between studs, will have a coefficient of 0.10 with 2 in. of blanket insulation between studs (No. 56B).

Table 10. Coefficients of Transmission (U) of Masonry Partitions

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on still air (no wind) conditions on both sides.



Type of Partition		Thickness of Masonry (Inches)	No Finish (Plain walls)	Plaster One Side	Plaster Both Sides[a]	Partition Number
			A	B	C	
Hollow Clay Tile		3	0.50	0.47	0.43	9
		4	0.45	0.42	0.40	10
Hollow Gypsum Tile		3	0.35	0.33	0.32	11
		4	0.29	0.28	0.27	12
Hollow Concrete Tile or Blocks	Cinder Aggregate	3	0.50	0.47	0.43	13
		4	0.45	0.42	0.40	14
	Light Weight Aggregate[b]	3	0.41	0.39	0.37	15
		4	0.35	0.34	0.32	16
Common Brick		4	0.50	0.46	0.43	17

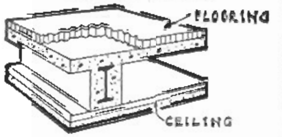
[a] 2 in. solid plaster partition, $U = 0.53$.

[b] Expanded slag, burned clay or pumice.

HEAT TRANSMISSION TABLES

TABLE 12. COEFFICIENTS OF TRANSMISSION (*U*) OF CONCRETE CONSTRUCTION FLOORS AND CEILINGS

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on still air (no wind) conditions on both sides.

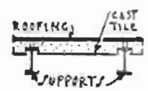
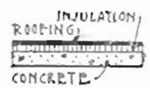
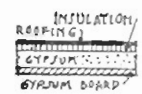
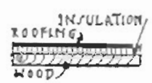
TYPE OF CEILING	THICKNESS OF CONCRETE[g] (INCHES)	TYPE OF FLOORING: No Flooring (Concrete Bare)	Tile[a] of Terrazzo Flooring on Concrete	1/8 In. Asphalt Tile[b] Directly on Concrete	Parquet[c] Flooring In Mastic on Concrete	Double Wood Floor on Sleepers[d]	NUMBER
		A	B	C	D	E	
No Ceiling	3 6 10	0.68 0.59 0.50	0.65 0.56 0.48	0.66 0.58 0.49	0.45 0.41 0.36	0.25 0.23 0.22	1 2 3
3/4 in. Plaster Applied to Underside of Concrete	3 6 10	0.62 0.54 0.46	0.59 0.52 0.44	0.60 0.53 0.45	0.43 0.39 0.34	0.24 0.22 0.21	4 5 6
Metal Lath and Plaster[e]—Suspended or Furred	3 6 10	0.38 0.35 0.32	0.37 0.34 0.31	0.37 0.33 0.32	0.30 0.28 0.26	0.19 0.18 0.17	7 8 9
Gypsum Board (3/8 in.) and Plaster[f]—Suspended or Furred	3 6 10	0.36 0.33 0.30	0.35 0.32 0.29	0.35 0.33 0.30	0.28 0.27 0.24	0.19 0.18 0.17	10 11 12
Insulating Board Lath (1/2 in.) and Plaster[f] Suspended or Furred	3 6 10	0.25 0.23 0.22	0.24 0.23 0.21	0.25 0.23 0.22	0.21 0.20 0.19	0.15 0.15 0.14	13 14 15

[a]Thickness of tile assumed to be 1 in.
[b]Conductivity of Asphalt Tile assumed to be 3.1.
[c]Thickness of wood assumed to be 13/16 in.; thickness of mastic, 1/8 in. ($k = 4.5$). Col. D may also be used for concrete covered with carpet.
[d]Based on 25/32 in. yellow pine or fir sub-flooring and 13/16 in. hardwood finish flooring with an air space between sub-floor and concrete.
[e]Thickness of plaster assumed to be 3/4 in.
[f]Thickness of plaster assumed to be 1/2 in.
[g]For other thicknesses of concrete, interpolate.

TABLE 14. COEFFICIENTS OF TRANSMISSION (*U*) OF FLAT ROOFS COVERED WITH BUILT-UP ROOFING. NO CEILING—UNDER SIDE OF ROOF EXPOSED

(See Table 15 for Flat Roofs with Ceilings)

These coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph.

TYPE OF ROOF DECK	THICKNESS OF ROOF DECK (INCHES)	NO INSULATION	INSULATION ON TOP OF DECK (COVERED WITH BUILT-UP ROOFING): Insulating Board (Thickness Below) 1/2 In.	1 In.	1 1/2 In.	2 In.	Corkboard (Thickness Below) 1 In.	1 1/2 In.	2 In.	NUMBER
		A	B	C	D	E	F	G	H	
Flat Metal Roof Deck[a] 		1.06	0.39	0.24	0.18	0.14	0.23	0.17	0.13	
Precast Cement Tile 	1 5/8 in.	0.84	0.37	0.24	0.17	0.14	0.22	0.16	0.13	2
Concrete 	2 in. 4 in. 6 in.	0.82 0.72 0.65	0.36 0.34 0.33	0.24 0.23 0.22	0.17 0.17 0.16	0.14 0.13 0.13	0.22 0.21 0.21	0.16 0.16 0.15	0.13 0.12 0.12	3 4 5
Gypsum Fiber Concrete[b] on 1/2 in. Gypsum Board 	2 1/2 in. 3 1/2 in.	0.38 0.31	0.24 0.21	0.18 0.16	0.14 0.13	0.12 0.11	0.17 0.15	0.13 0.12	0.11 0.10	6 7
Wood[c] 	1 in. 1 1/2 in. 2 in. 3 in.	0.49 0.37 0.32 0.23	0.28 0.24 0.22 0.17	0.20 0.17 0.16 0.14	0.15 0.14 0.13 0.11	0.12 0.11 0.11 0.096	0.19 0.17 0.16 0.13	0.14 0.13 0.12 0.11	0.12 0.11 0.10 0.091	8 9 10 11

[a]Coefficient of transmission of bare corrugated iron (no roofing) is 1.50 Btu per (hour)(square foot of projected area)(Fahrenheit degree difference in temperature) based on an outside wind velocity of 15 mph.
[b]87 1/2 per cent gypsum, 12 1/2 per cent wood fiber. Thickness indicated includes 1/2 in. gypsum board.
[c]Nominal thicknesses specified—actual thicknesses used in calculations.

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Table 16. Coefficients of Transmission (U) of Pitched Roofs

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph.

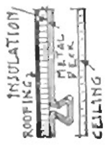
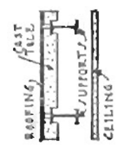
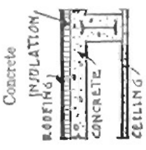
Type of Ceiling (Applied Directly to Roof Rafters)	Wood Shingles (On 1 x 4 Wood Strips[c] Spaced 2 In. Apart)				Asphalt Shingles or Roll Roofing (On Solid Wood Sheathing)[c]				Slate or Tile[b] (On Solid Wood Sheathing)[c]				Number
	Insulation Between Rafters				Insulation Between Rafters				Insulation Between Rafters				
	None	Blanket or Bat (Thickness Below)			None	Blanket or Bat (Thickness Below)			None	Blanket or Bat (Thickness Below)			
		1 In.	2 In.	3 In.		1 In.	2 In.	3 In.		1 In.	2 In.	3 In.	
	A	B	C[a]	D[a]	E	F	G[a]	H[a]	I	J	K[a]	L[a]	
No Ceiling Applied to Rafters	0.48[f]	0.15	0.10	0.081	0.52[f]	0.15	0.11	0.084	0.55[f]	0.16	0.11	0.085	1
Metal Lath and Plaster[d]	0.31	0.14	0.10	0.081	0.33	0.15	0.10	0.083	0.34	0.15	0.10	0.083	2
Gypsum Board (⅜ in.) Decorated	0.30	0.14	0.10	0.080	0.32	0.15	0.10	0.082	0.33	0.15	0.10	0.083	3
Wood Lath and Plaster	0.29	0.14	0.10	0.080	0.31	0.14	0.10	0.081	0.32	0.15	0.10	0.082	4
Gypsum Lath (⅜ in.) Plastored[e]	0.29	0.14	0.10	0.079	0.31	0.14	0.10	0.081	0.32	0.15	0.10	0.082	5
Plywood (⅜ in.) Plain or Decorated	0.29	0.14	0.099	0.079	0.30	0.14	0.10	0.081	0.31	0.15	0.10	0.081	6
Insulating Board (½ in.) Plain or Decorated	0.22	0.12	0.090	0.072	0.23	0.12	0.091	0.074	0.24	0.13	0.092	0.074	7
Insulating Board Lath (½ in.) Plastered[e]	0.22	0.12	0.088	0.072	0.22	0.12	0.090	0.073	0.23	0.12	0.091	0.074	8
Insulating Board Lath (1 in.) Plastered[e]	0.16	0.10	0.078	0.064	0.17	0.10	0.079	0.065	0.17	0.10	0.080	0.066	9

[a]Coefficients corrected for framing on basis of 15 per cent area, 2 in. x 4 in. (nominal), 16 in. on centers.
[b]Figures in Columns I, J, K and L may be used with sufficient accuracy for rigid asbestos shingles on wood sheathing. Layer of slater's felt neglected.
[c]Sheathing and wood strips assumed $^{25}/_{32}$ in. thick.
[d]Plaster assumed ¾ in. thick.
[e]Plaster assumed ½ in. thick.
[f]No air space included in 1-A, 1-E or 1-I; all other coefficients based on one air space.

Table 15. Coefficients of Transmission (U) of Flat Roofs Covered with Built-up Roofing. With Lath and Plaster Ceilings[a]

(See Table 14 for Flat Roofs with No Ceilings)

These coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph.

Type of Roof Deck	Thickness of Roof Deck (Inches)	No Insulation	Insulation on Top of Deck (Covered with Built-up Roofing)							Number
			Insulating Board (Thickness Below)				Corkboard (Thickness Below)			
			½ In.	1 In.	1½ In.	2 In.	1 In.	1½ In.	2 In.	
		A	B	C	D	E	F	G	H	
Flat Metal Roof Deck 		0.46	0.27	0.19	0.15	0.12	0.18	0.14	0.11	12
Precast Cement Tile 	1⅝ in.	0.43	0.26	0.19	0.15	0.12	0.18	0.14	0.11	13
Concrete 	2 in. 4 in. 6 in.	0.42 0.40 0.37	0.26 0.25 0.24	0.19 0.18 0.18	0.14 0.14 0.14	0.12 0.12 0.11	0.18 0.17 0.17	0.14 0.13 0.13	0.11 0.11 0.11	14 15 16
Gypsum Fiber Concrete[b] on ½ in. Gypsum Board 	2¼ in. 3½ in.	0.27 0.23	0.19 0.17	0.15 0.14	0.12 0.11	0.10 0.097	0.14 0.13	0.12 0.11	0.097 0.091	17 18
Wood[c] 	1 in. 1½ in. 2 in. 3 in.	0.31 0.26 0.24 0.18	0.21 0.19 0.17 0.14	0.16 0.15 0.14 0.12	0.13 0.12 0.11 0.10	0.11 0.10 0.097 0.087	0.15 0.14 0.13 0.11	0.12 0.11 0.11 0.095	0.10 0.095 0.092 0.032	19 20 21 22

[a]Calculations based on metal lath and plaster ceilings, but coefficients may be used with sufficient accuracy for gypsum lath or wood lath and plaster ceilings. It is assumed that there is an air space between the under side of the roof deck and the upper side of the ceiling.
[b]87½ per cent gypsum, 12½ per cent wood fiber. Thickness indicated includes ½ in. gypsum board.
[c]Nominal thicknesses specified—actual thicknesses used in calculations.

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TABLE 17. COMBINED COEFFICIENTS OF TRANSMISSION (U) OF PITCHED ROOFS[a] AND HORIZONTAL CEILINGS—BASED ON CEILING AREA[b]

Coefficients are expressed in Btu per (hour) (square foot of ceiling area) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph.

	TYPE OF ROOFING AND ROOF SHEATHING						
	WOOD SHINGLES ON WOOD STRIPS[d]			ASPHALT SHINGLES[e] OR ROLL ROOFING ON WOOD SHEATHING[e]			
CEILING COEFFICIENT[f] (FROM TABLE 11)	No Roof Insulation (Rafters Exposed) ($U_r = 0.48$)	½ In. Insulating Board on Under Side of Rafters ($U_r = 0.22$)	1 In. Insulating Board on Under Side of Rafters ($U_r = 0.16$)	No Roof Insulation (Rafters Exposed) ($U_r = 0.53$)	½ In. Insulating Board on Under Side of Rafters ($U_r = 0.23$)	1 In. Insulating Board on Under Side of Rafters ($U_r = 0.17$)	NUMBER
	A	B	C	D	E	F	
0.10	0.085	0.073	0.066	0.087	0.074	0.067	19
0.11	0.092	0.078	0.07	0.094	0.079	0.071	20
0.12	0.099	0.082	0.074	0.10	0.083	0.075	21
0.13	0.11	0.087	0.078	0.11	0.088	0.079	22
0.14	0.11	0.091	0.081	0.11	0.093	0.083	23
0.15	0.12	0.096	0.084	0.12	0.097	0.086	24
0.16	0.13	0.10	0.087	0.13	0.10	0.089	25
0.17	0.13	0.10	0.090	0.13	0.10	0.092	26
0.18	0.14	0.11	0.093	0.14	0.11	0.095	27
0.19	0.14	0.11	0.095	0.15	0.11	0.098	28
0.20	0.15	0.11	0.098	0.15	0.12	0.10	29
0.21	0.15	0.12	0.10	0.16	0.12	0.10	30
0.22	0.16	0.12	0.10	0.17	0.12	0.11	31
0.23	0.16	0.12	0.10	0.17	0.12	0.11	32
0.24	0.17	0.13	0.11	0.18	0.12	0.11	33
0.25	0.17	0.13	0.11	0.18	0.13	0.11	34
0.26	0.18	0.13	0.11	0.19	0.13	0.11	35
0.27	0.18	0.13	0.11	0.19	0.13	0.12	36
0.28	0.19	0.14	0.12	0.19	0.14	0.12	37
0.29	0.19	0.14	0.12	0.20	0.14	0.12	38
0.30	0.20	0.14	0.12	0.20	0.14	0.12	39
0.34	0.21	0.15	0.12	0.22	0.15	0.13	40
0.35	0.22	0.15	0.13	0.22	0.15	0.13	41
0.36	0.22	0.15	0.13	0.23	0.15	0.13	42
0.37	0.23	0.15	0.13	0.23	0.16	0.13	43
0.45	0.25	0.17	0.13	0.26	0.17	0.14	44
0.59	0.29	0.18	0.14	0.30	0.19	0.15	45
0.61	0.29	0.18	0.15	0.31	0.19	0.15	46
0.62	0.30	0.19	0.15	0.31	0.19	0.15	47
0.67	0.31	0.19	0.15	0.33	0.20	0.16	48
0.69	0.31	0.19	0.15	0.33	0.20	0.16	49

[a]Calculations based on ⅙ pitch roof ($n = 1.2$) using the following formula:

$$U = \frac{U_r \times U_{ce}}{U_r + \frac{U_{ce}}{n}}$$

U = combined coefficient to be used with ceiling area.
U_r = coefficient of transmission of the roof.
U_{ce} = coefficient of transmission of the ceiling.
n = the ratio of the area of the roof to the area of the ceiling.

[b]Use ceiling area (not roof area) with these coefficients.

[c]Coefficients in Columns D, E and F may be used with sufficient accuracy for tile, slate and rigid asbestos shingles on wood sheathing.

[d]Based on 1 x 4 in. strips spaced 2 in. apart.

[e]Sheathing assumed 25/32 in. thick.

[f]Values of U_{ce} to be used in this column may be selected from Table 11.

TABLE 18. COEFFICIENTS OF TRANSMISSION (U) OF DOORS, WINDOWS, SKYLIGHTS AND GLASS BLOCK WALLS

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in the temperature between the air inside and outside of the door, window, skylight or wall) and are based on an outside wind velocity of 15 mph.

		SINGLE	DOUBLE	TRIPLE
Section A. Windows and Skylights	U	1.13[ac]	0.45[ae]	0.281[ae]

	NOMINAL THICKNESS INCHES	ACTUAL THICKNESS INCHES	U EXPOSED DOOR	U[d] WITH GLASS STORM DOOR
Section B. Solid Wood Doors[bc]	1	25/32	0.69	0.42
	1¼	1 1/16	0.59	0.38
	1½	1 5/16	0.52	0.35
	1¾	1⅜	0.51	0.35
	2	1⅝	0.46	0.32
	2½	2⅛	0.38	0.28
	3	2⅝	0.33	0.25

	DESCRIPTION	U STILL AIR BOTH SIDES	U STILL AIR INSIDE 15 MPH OUTSIDE
Section C. Hollow Glass Block Walls	Smooth surface glass blocks 7¾ x 7¾ x 3⅞ in. thick	0.40	0.49
	Ribbed surface glass blocks 7¾ x 7¾ x 3⅞ in. thick	0.38	0.46

[a]See Heating, Ventilating and Air Conditioning, by Harding and Willard, revised edition, 1932.

[b]Computed using $C = 1.15$ for wood; $f_i = 1.65$ and $f_o = 6.0$.

[c]It is sufficiently accurate to use the same coefficient of transmission for doors containing thin wood panels as that of single panes of glass, namely, 1.13 Btu per (hour) (square foot) (degree difference between inside and outside air temperatures).

[d]These values may also be used with sufficient accuracy for wood storm doors. Neglect storm doors if loose and use values for exposed doors.

[e]Air spaces assumed to be ¾ in. or more in width.

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Table 1. Infiltration Through Walls[a]

Expressed in cubic feet per square foot per hour

Type of Wall		Wind Velocity, Miles per Hour: 5	10	15	20	25	30
8½ in. Brick Wall[b]	Plain	2	4	8	12	19	23
	Plastered[c]	0.02	0.04	0.07	0.11	0.16	0.24
13 in. Brick Wall[b]	Plain	1	4	7	12	16	21
	Plastered[c]	0.01	0.01	0.03	0.04	0.07	0.10
	Plastered[d]	0.03	0.10	0.21	0.36	0.53	0.72
Frame Wall, with lath and plaster[e]		0.03	0.07	0.13	0.18	0.23	0.26

[a]The values given in this table are 20 per cent less than test values to allow for building up of pressure in rooms and are based on test data reported in the papers listed in chapter footnotes.

[b]Constructed of porous brick and lime mortar—workmanship poor.

[c]Two coats prepared gypsum plaster on brick.

[d]Furring, lath, and two coats prepared gypsum plaster on brick.

[e]Wall construction: Bevel siding painted or cedar shingles, sheathing, building paper, wood lath and three coats gypsum plaster.

Table 2. Infiltration Through Windows

Expressed in Cubic Feet per Foot of Crack per Hour[a]

Type of Window	Remarks	Wind Velocity, Miles per Hour: 5	10	15	20	25	30
Double-Hung Wood Sash Windows (Unlocked)	Around frame in masonry wall—not calked	3	8	14	20	27	35
	Around frame in masonry wall—calked	1	2	3	4	5	6
	Around frame in wood frame construction	2	6	11	17	23	30
	Total for average window, non-weatherstripped, 1/16-in. crack and 3/64-in. clearance. Includes wood frame leakage	7	21	39	59	80	104
	Ditto, weatherstripped	4	13	24	36	49	63
	Total for poorly fitted window, non-weatherstripped, 3/32-in. crack and 3/32-in. clearance Includes wood frame leakage	27	69	111	154	199	249
	Ditto, weatherstripped	6	19	34	51	71	92
Double-Hung Metal Windows[f]	Non-weatherstripped, locked	20	45	70	96	125	154
	Non-weatherstripped, unlocked	20	47	74	104	137	170
	Weatherstripped, unlocked	6	19	32	46	60	76
Rolled Section Steel Sash Windows[k]	Industrial pivoted, 1/16-in. crack[g]	52	108	176	244	304	372
	Architectural projected, 1/8-in. crack	15	36	62	86	112	139
	Architectural projected, 3/16-in. crack	20	52	88	116	152	182
	Residential casement, 1/64-in. crack	6	18	33	47	60	74
	Residential casement, 1/32-in. crack	14	32	52	76	100	128
	Heavy casement section, projected, 1/64-in. crack	3	10	18	26	36	48
	Heavy casement section, projected 1/32-in. crack	8	24	38	54	72	92
Hollow Metal, vertically pivoted window		30	88	145	186	221	242

[a]The values given in this table, with the exception of those for double-hung and hollow metal windows, are 20 per cent less than test values to allow for building up of pressure in rooms, and are based on test data reported in the papers listed in chapter footnotes.

[b]The values given for frame leakage are per foot of sash perimeter as determined for double-hung wood windows. Some of the frame leakage in masonry walls originates in the brick wall itself and cannot be prevented by calking. For the additional reason that calking is not done perfectly and deteriorates with time, it is considered advisable to choose the masonry frame leakage values for calked frames as the average determined by the calked and non-calked tests.

[c]The fit of the average double-hung wood window was determined as 1/16-in. crack and 3/64-in. clearance by measurements on approximately 600 windows under heating season conditions.

[d]The values given are the totals for the window opening per foot of sash perimeter and include frame leakage and so-called *elsewhere* leakage. The frame leakage values included are for wood frame construction but apply as well to masonry construction assuming a 50 per cent efficiency of frame calking.

[e]A 3/32-in. crack and clearance represent a poorly fitted window, much poorer than average.

[f]Windows tested in place in building.

[g]Industrial pivoted window generally used in industrial buildings. Ventilators horizontally pivoted at center or slightly above, lower part swinging out.

[h]Architecturally projected made of same sections as industrial pivoted except that outside framing member is heavier, and it has refinements in weathering and hardware. Used in semi-monumental buildings such as schools. Ventilators swing in or out and are balanced on side arms. 1/8-in crack is obtainable in the best practice of manufacture and installation, 3/16-in. crack considered to represent average practice.

[i]Of same design and section shapes as so-called *heavy section casement* but of lighter weight. 1/64-in crack is obtainable in the best practice of manufacture and installation, 1/32-in. crack considered to represent average practice.

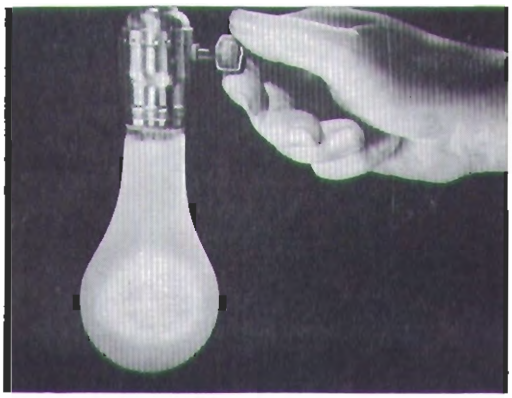
[j]Made of heavy sections. Ventilators swing in or out and stay set at any degree of opening. 1/64-in. crack is obtainable in the best practice of manufacture and installation, 1/32-in. crack considered to represent average practice.

[k]With reasonable care in installation, leakage at contacts where windows are attached to steel framework and at mullions is negligible. With 3/64-in. crack, representing poor installation, leakage at contact with steel framework is about one-third, and at mullions about one-sixth of that given for industrial pivoted windows in the table.

SECTION IV

ELECTRICAL CONTROLS

If electrical controls have seemed mysterious and complex, remember this: *they are only electric switches!* No different, in effect, than the switch with which you turn an electric light off and on. They perform the same function of making and breaking an electric circuit, but instead of being operated manually, they are operated automatically by changes in temperature or pressure.



DEFINITION OF ELECTRICAL TERMS

Before going further, let's consider some common electrical terms and what they mean. An electric current is measured in terms of Volts and Amperes. The amount of resistance to the passage of electric current must also be considered.

A Volt is the unit of electrical motive force—an Ohm the unit of resistance—and an Ampere the unit of current. Expressed mathematically, one Volt is the amount of electrical force required to send one Ampere of current through one Ohm of resistance.

The operation of a B & G Booster Pump, as shown below, illustrates the relationship between the Volt, the Ohm and the Ampere.

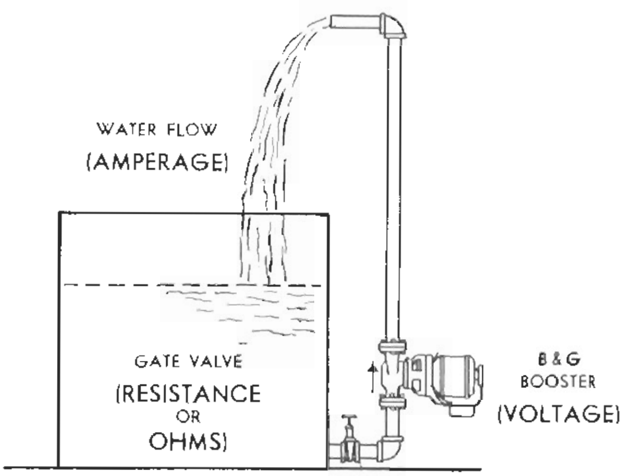


Fig. 102. See text for explanation of relationship between Volts, Ohms and Amperes.

If you will consider the pump as supplying the motive force or Voltage, then the valve and the pipe represents the resistance or Ohms and the water pumped through the pipe represents the Amperes. As the valve is closed down, the resistance increases and the amount of water delivered decreases. Similarly in an electrical circuit with a constant Voltage, the greater the resistance, the smaller is the number of Amperes.

There is one other important electrical term—the Watt. A Watt is the unit of electrical energy and is the product of amperes and volts. That is, one ampere of current flowing under a pressure of one volt gives one Watt of energy. 746 Watts is equal to one electrical horse power. (This assumes that the power consuming equipment is 100% efficient. The actual Wattage consumed depends therefore on the efficiency or power factor of the equipment.)

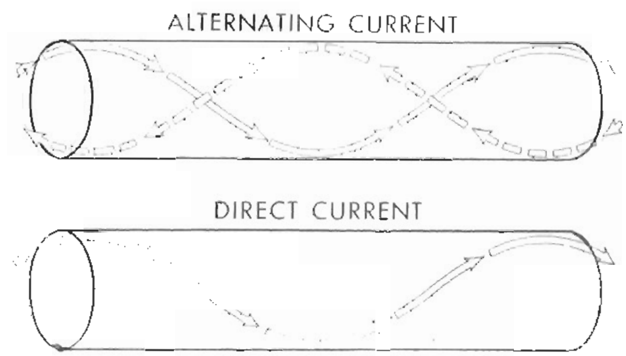


Fig. 103. Illustrating characteristics of direct and alternating current.

A Kilowatt is 1000 Watts and a Kilowatt Hour equals the consumption of 1000 Watts per hour.

Electrical current is produced by power companies in either one of two forms—Alternating Current or Direct Current. As the names imply, Alternating Current flows first in one direction, then the other. In most localities, the current changes direction 60 times a second, therefore, it is called 60 cycle current.

Direct Current, of course, flows in one direction only through the wires. Either kind of current is usually supplied in 110 volts for house lighting and appliances.

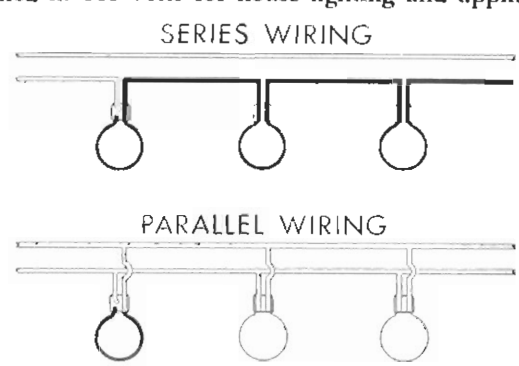


Fig. 104. Illustrating series and parallel wiring.

ELECTRICAL CONTROLS (continued)

In wiring a number of power consuming units on a single circuit, as a string of electric lights, the wiring can be either in "parallel" or "series." As shown in the illustration, "parallel" wiring permits control of individual units whereas with "series" wiring all units are either off or on at the same time.

TWO MAJOR CLASSIFICATIONS

There are two major classifications in electrical controls. First, those which are actuated by changes in room temperature. These are called Thermostats.

Second, those which are actuated by changes in the temperature or pressure of the heating medium itself. These are the Limit Controls.

They are installed in hot water boilers to maintain a certain temperature by controlling the operation of the burner. They are likewise used in steam boilers to control steam pressure, or in the furnace bonnet of warm air systems to control fan operation.

Limit Controls are either direct or reverse acting. Direct acting controls close the circuit when boiler temperature drops, thereby starting up the burner. Reverse acting controls open the circuit on a temperature drop. Applications of each will be discussed in connection with some installation diagrams to be shown.

A further classification divides both Thermostats and Limit Controls into Low and Line Voltage groups.

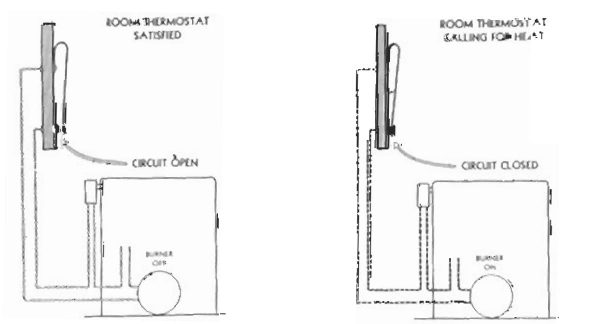


Fig. 105. Diagram illustrates how the closing of thermostat contacts permits flow of current to the automatic firing device.

LOW VOLTAGE CONTROLS

Low voltage controls are usually designed to operate on not over 25 volts. They can be installed with low voltage cable and thus effect a saving in the initial installation.

LINE VOLTAGE CONTROLS

Line voltage controls are operated directly from the house lighting or single phase power lines and must, therefore, be capable of carrying either 110 or 220 volts.

If Line voltage is three phase, a magnetic switch with a built-in holding coil must be used. The Line voltage control is then wired to the holding coil circuit which operates the magnetic switch. It is recommended that a three pole magnetic switch be used with all three phase circuits.

Line voltage controls are also rated for a definite motor load. This means that the motor they are controlling must not exceed the horse power for which the control is rated.

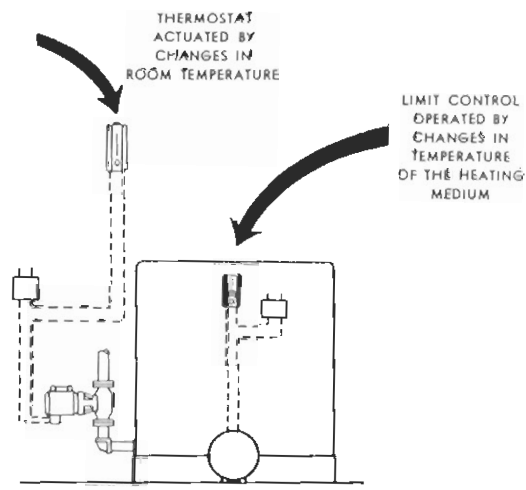


Fig. 106. Diagram illustrates the two different types of controls used to operate an automatically fired heating system.

THREE KINDS OF LOW VOLTAGE THERMOSTATS

Low Voltage Thermostats are available in three different types—

1. SNAP ACTION CONTROL

In this type, there are two electrical terminals which snap together with positive action each time the control closes its circuit.

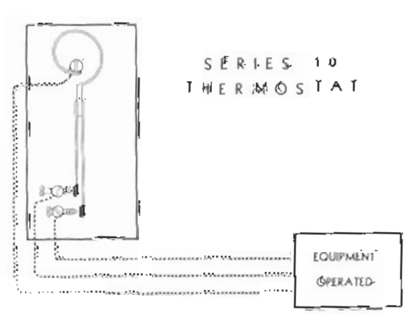


Fig. 107

2. SERIES 10

As illustrated, in figure 107, a Series 10 thermostat consists of two separate electrical contacts on one side of a movable blade.

3. SERIES 20

Series 20 has a contact on each side of a center movable blade, as illustrated in Fig. 108.

ELECTRICAL CONTROLS (continued)

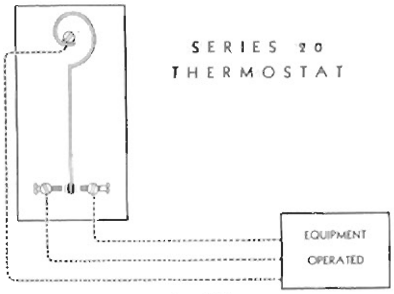


Fig. 108

RELAYS

A third kind of electrical control, which is not actuated by temperature changes, is the Relay. A Relay is a device for tying together the operation of low and line voltage equipment.

For example, a Thermostat operating on low voltage may be required to control a motor operating on line voltage. The wiring from the Thermostat is led into the Relay; thus any thermostat demands for heat actuate the relay mechanism which opens or closes the line voltage circuit operating the motor.

Fig. 109 is a diagrammatic sketch of a relay used in conjunction with low voltage thermostatic control of a circulating pump operating on line voltage.

The wires from the thermostat are led into the relay and connected to the relay coil and the secondary circuit of the transformer which reduces the 110 volt house circuit to the 20 volts required by the thermostat.

When heat is required, the thermostat closes its circuit and energizes the relay coil, pulling in the relay armature and completing the 110 volt circuit which operates the motor.

When the thermostat is satisfied, its contacts open, breaking the circuit and de-energizing the relay coil. The relay armature then snaps back and breaks the 110 volt circuit, causing the pump to stop.

When line voltage Thermostats are used, a Relay is unnecessary, unless motor load exceeds thermostat capacity.

HOW TO INSTALL THERMOSTATS

The thermostat should be installed in a place where it will record, as closely as possible, the average temperature of the home or space to be controlled. Avoid locations where temperature change is extremely slow, as for example, central halls with poor air circulation. The best location usually is an inside wall where it will

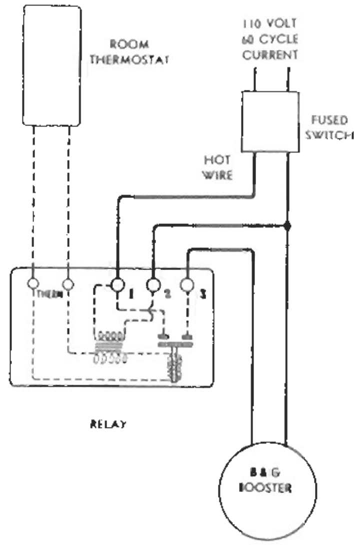


Fig. 109

be in the free circulation of air and unaffected by cold drafts or warm air coming from radiators or warm air grilles. In a home this is usually the living or dining room. It should not be located on a porton of a wall where it will be affected by hot or cold pipes or air ducts, nor should it be exposed to the direct rays of the sun from a window or door. Heat from electric lights should also be avoided.

CONTROLS FOR CONTINUOUS CIRCULATION SYSTEMS

This type of system has three basic differences—

1. The water in the system circulates continuously.
2. The Boiler is on a by-pass, with circulation through it controlled by a special valve.
3. Temperature regulation is achieved by coordinated action of an outdoor and indoor control.

NOTE!

The electrical circuits described and illustrated on the following pages are some of the most common and practical connections. There are many variations of these circuits which space will not permit including here.

Since the controls of one manufacturer do not match exactly those of another, in so far as terminal connections are concerned, the following descriptions apply only to the wiring and operation of the circuits. For further wiring details, contact the manufacturer of the electrical controls you are using.

For best results and ease in wiring the system, whereever possible *avoid mixing the controls of one manufacturer with those of another!*

WIRING DIAGRAMS

COMPARATIVE CHART ON PAGE 107 MAKES CONTROL SELECTION EASY

The diagrams on the following pages show the location of the controls and are labeled with key letters ("TA", "RC", etc.) which indicate the type of control suggested for the service required. By referring to the Comparative Chart on page 107, the model number of various manufacturers' controls can be quickly determined.

The wiring circuits shown are for current models of primary burner and stoker controls. For circuits of obsolete or special controls, consult control manufacturer.

The Bell & Gossett Co. recommends that in all automatically fired hot water heating systems a safety high limit line voltage water control be installed in series with the firing device, in addition to the limit control normally called for in the wiring diagrams.

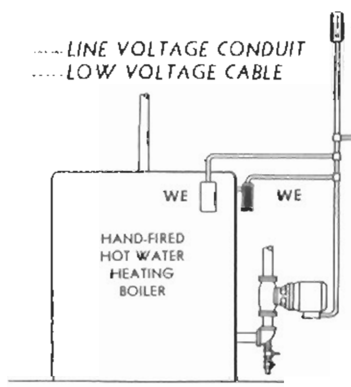


Fig. 110

Booster only on a hand-fired boiler with a line voltage thermostat

1—When heat is required, the line voltage room thermostat actuates the Booster pump.

2—A low temperature reverse action hot water immersion control set at 110° is wired in series with the room thermostat to hold the Booster pump off until reverse action control is satisfied. It eliminates the circulation of cold water if the fire is extinguished.

3—A high temperature reverse action hot water control set at 210° is wired in parallel with the room thermostat. If an oversize fire raises the boiler temperature beyond 210°, this control operates the pump independent of all other controls. For safe operation of the system this control should be on all coal fired installations.

4—An automatic mechanical draft and damper regulator on the boiler is adjusted to maintain boiler water temperature sufficient for weather conditions.

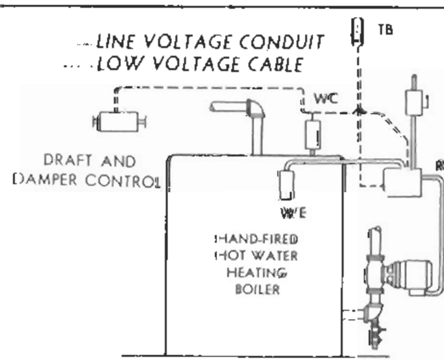


Fig. 111

Booster only on a hand-fired boiler using an electric draft and damper motor

1—When heat is required, the low voltage room thermostat actuates a double pole relay. One pole closes the circuit to the Booster pump and the other pole positions the draft and damper motor.

2—A hot water control in the boiler water as a high limit control is wired in series with the electrical connections from the relay to the draft and damper motor so that the draft and damper motor will close when this control is satisfied.

3—A high temperature reverse action hot water immersion control set at 210° is wired in parallel with the relay connections to the Booster pump. If an oversize fire raises the boiler temperature beyond 210°, this control operates the pump independent of all other controls. For the safe operation of the system this control should be on all coal fired installations.

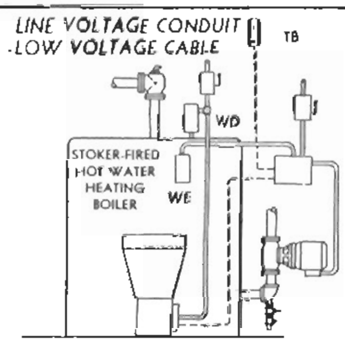


Fig. 112

Booster only on a stoker fired boiler

1—When heat is required, the low voltage room thermostat actuates a double pole relay. One pole closes the circuit to the Booster pump and the other pole closes the circuit to the stoker control panel thermostat terminal so that it is actuated whenever the room thermostat calls for heat.

2—A high temperature reverse action hot water immersion control set at 210° is wired in parallel with the relay connection to the Booster pump. If an oversize fire raises the boiler temperature beyond 210°, this control operates the Booster pump independent of all other controls to dissipate excess heat into the radiation. For safe operation of the system this control should be on all coal fired installations.

3—A limit control installed in the boiler water is connected to the stoker panel as recommended by the Stoker Control Manufacturers.

4—A Flo-control valve will give better temperature control, but is not essential for operating the system unless part of the radiation is below the main.

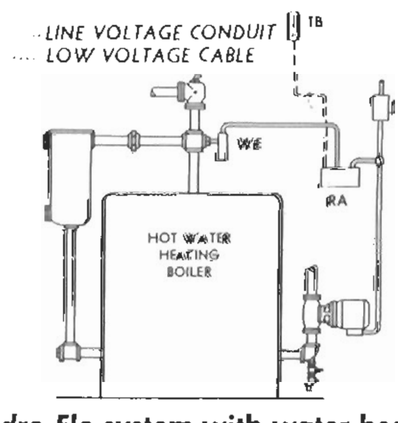


Fig. 113

B & G *Hydro-Flo* system with water heater on a stoker-fired boiler — low voltage thermostat

1—When heat is required, the low voltage room thermostat actuates a single pole relay, which closes the electrical circuit to the Booster pump.

WIRING DIAGRAMS (continued)

2—A high temperature reverse action hot water immersion control set at 210° is wired in parallel with the relay connections to the Booster pump. If an oversize fire raises the boiler temperature beyond 210°, this control operates the pump independent of all other controls to dissipate excessive heat into the radiation. For safe operation of the system this control should be on all coal fired installations.

3—A hot water control installed in the boiler is connected to the stoker panel to maintain a constant boiler water temperature.

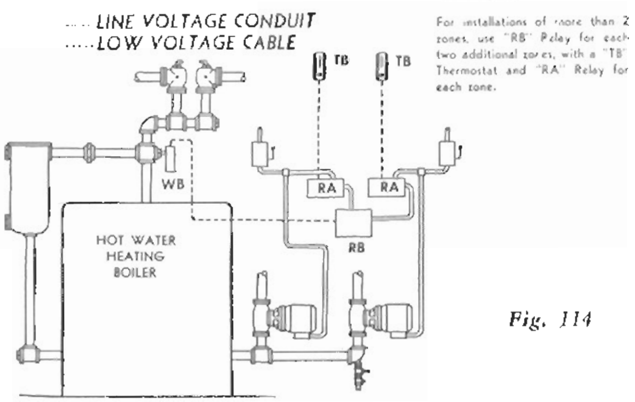


Fig. 114

2 Zone B & G *Hydro-Flo* system with water heater on a stoker-fired boiler using low voltage thermostats

1—Each zone is provided with a low voltage room thermostat and wired to a single pole relay which actuates the Booster pump for its zone.

2—A high temperature reverse action hot water immersion control set at 210° is wired to actuate a double pole relay. One pole of the relay is wired in parallel with the connections to the Booster pump of one zone and the other pole wired in parallel with the connections to the Booster pump of the other zone, so that if over-firing raises the boiler temperature beyond 210°, the reverse action control operates both pumps independent of the thermostats to dissipate this excess heat into the radiation. A reverse action control is important for safe operation of the system and should be on all coal fired installations.

3—A hot water control installed in the boiler is connected to the stoker panel to maintain a constant boiler water temperature.

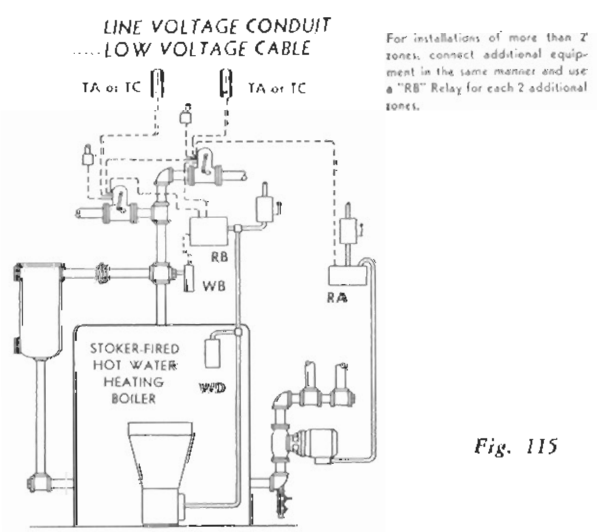


Fig. 115

2 Zone B & G *Hydro-Flo* system with water heater on a stoker-fired boiler using motorized valves

1—Each zone is provided with a low voltage room thermostat of a type that matches the requirements of the valve motor and wired to the thermostat terminals of its respective B & G motorized valve.

2—The motorized valve transformers are installed on outlet boxes convenient to the valves and each is wired to the transformer terminals marked "T" on the valve.

3—The auxiliary switch marked "S" on the terminal block is wired from each of the valves to the low voltage holding coil terminals of a single pole relay that actuates the circulating pump. When either valve is in an open position, this relay will operate the pump and continue to operate it until both valves are closed.

4—A high temperature reverse action hot water immersion control set at 210° is wired to actuate a double pole relay. One pole of the relay is wired in parallel with the connections to one of the zone thermostats and the other pole wired in parallel with the connections to the other zone thermostat. If an oversize fire raises the boiler temperature beyond 210°, the reverse action control opens both valves and operates the Booster pump independent of the room thermostats to dissipate this excess heat into the radiation. For safe operation of the system, a reverse action control should be used on all coal fired installations.

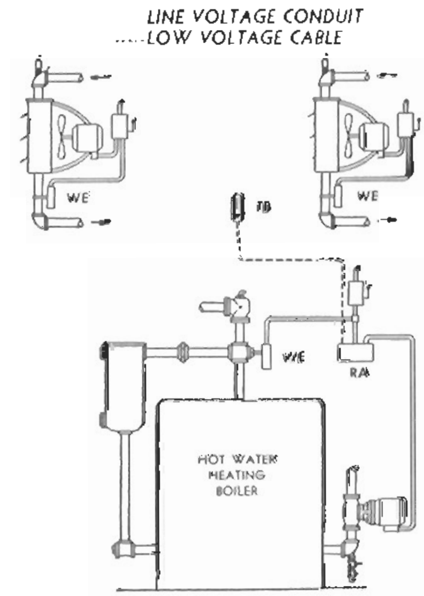


Fig. 116

B & G *Hydro-Flo* system with water heater using unit heaters with stoker-fired boiler

1—When heat is required, the low voltage room thermostat actuates the single pole relay. This relay closes the electrical circuit to the Booster pump.

2—A high temperature reverse action immersion control set at 210° is wired in parallel with the relay electrical connection to the Booster pump. If over-firing raises the boiler temperature beyond 210°, this control operates the pump independent of the room thermostat to dissipate this excess heat into the radiation. For safe operation of the system this control should be used on all coal fired installations.

3—A reverse action hot water control is installed in the return connections of each unit heater and wired to operate the unit heater motor. The adjustment of this control should be to a minimum differential and to operate the fan at temperatures which do not blow cold air into the room.

4—A hot water control installed in the boiler is connected to the stoker panel to maintain a constant boiler water temperature.

WIRING DIAGRAMS (continued)

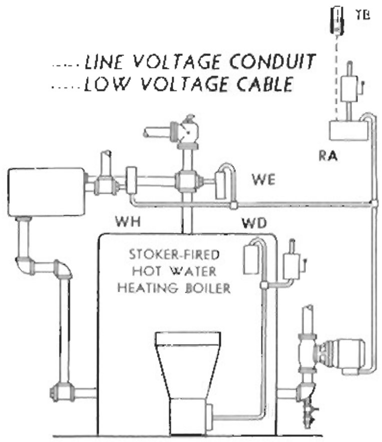


Fig. 117

B & G *Hydro-Flo* system with tankless heater on a stoker-fired boiler

1—When heat is required, the low voltage room thermostat actuates a single pole relay to close the electrical circuit to the Booster pump.

2—A high temperature reverse action hot water immersion control set at 210° is wired in parallel with the relay connections to the Booster pump. If over-firing raises the boiler temperature beyond 210°, this control operates the pump independent of all other controls to dissipate this excess heat into the radiation. For safe operation of the system this control should be used on all coal fired installations.

3—A low temperature reverse action hot water immersion control set at 120° and at its minimum differential is installed in the hot water outlet of the heater. It is wired in series with the electrical connections from the single pole relay to the Booster pump. Good results have also been obtained with this control by locating it in the boiler water and setting it at 150°. The purpose of this control is to give preference to the heating of the domestic water and to shut down the pump in the event the tankless heater water drops below a predetermined temperature. Usually the domestic water demand is only of a short duration and the brief shut down of the heating system is not noticeable.

4—A hot water control installed in the boiler is connected to the stoker panel to maintain a constant boiler water temperature.

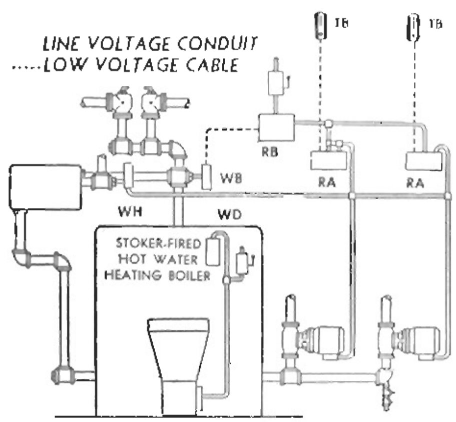


Fig. 118

2 Zone B & G *Hydro-Flo* system with tankless heater on a stoker-fired boiler

1—Each zone is provided with a low voltage room thermostat and wired to a single pole relay which actuates the Booster pump for that zone.

2—A high temperature reverse action hot water immersion control set at 210° is wired to actuate a double pole relay. One pole of the relay is wired in parallel with the single pole relay connections to the Booster pump of one zone and the other pole wired in parallel with the single pole relay connections to the Booster pump of the other zone. If over-firing raises the boiler temperature beyond 210°, the reverse action control operates both pumps independent of the thermostats to dissipate this excess boiler water temperature into the radiation. A reverse action control is important for safe operation of the system and should be on all coal fired installations.

3—A reverse action hot water immersion control installed in the hot water outlet of the heater is adjusted to close the circuit at 120° and is set at its minimum differential and wired to break the ground circuit wire to both of the circulating pumps. Good results have also been obtained with this control in the boiler water, set at 150°. The purpose of this control is to give preference to the heating of the domestic water and shut down the pumps in the event the heater water drops below a predetermined temperature. Usually the domestic water demand is only of a short duration and the brief shut down of the heating system not noticeable.

4—A hot water control installed in the boiler is connected to the stoker panel to maintain a constant boiler water temperature.

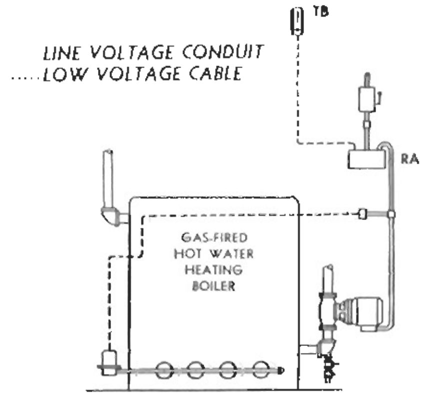


Fig. 119

Booster only on a gas-fired boiler with a low voltage thermostat

1—When heat is required, the low voltage room thermostat actuates a single pole relay which closes the electrical circuit to the Booster pump and the primary connections of the gas valve transformer.

2—The thermostat terminals on the gas valve are shunted together. With this circuit the gas valve must be of a type that automatically closes with an interruption of the electric current.

3—A high limit control is provided in the boiler for the gas burner. It may be either of the mechanical type or an electrical control wired into the gas valve circuit.

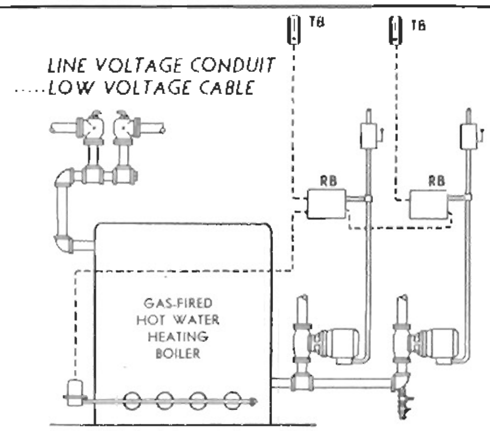


Fig. 120

NOTE: For installations of more than 2 zones, connect additional equipment in same manner.

2 Zone B & G *Hydro-Flo* system on gas-fired boiler

1—Each zone is provided with a low voltage room thermostat wired to a double pole relay having one pole wired to operate its zone Booster pump and the other pole wired to the thermostat terminals of the gas valve. The gas valve transformer is wired in the conventional manner to the gas valve.

WIRING DIAGRAMS (continued)

2—A high limit control is provided in the boiler for the gas burner. It may be either of the mechanical type or an electrical control wired into the gas valve circuit.

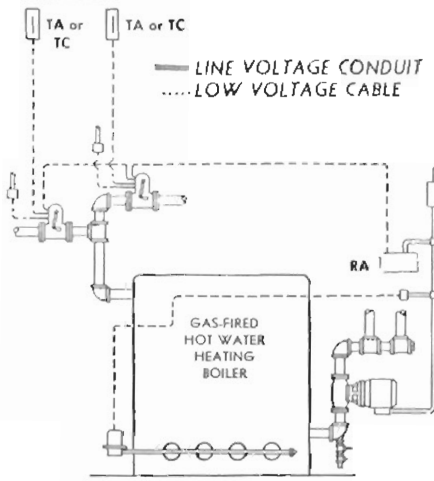


Fig. 121

FOR INSTALLATIONS OF MORE THAN TWO ZONES, CONNECT ADDITIONAL EQUIPMENT IN THE SAME MANNER

2 Zone B & G *Hydro-Flo* system with motorized valves on gas-fired boiler

1—Each zone is provided with a low voltage room thermostat of a type that matches the requirements of the valve motor and is wired to the thermostat terminals of its respective B & G motorized valve.

2—The motorized valve transformers are installed on outlet boxes convenient to the valve and each wired to the transformer terminals marked "T" on the valve.

3—The auxiliary switch marked "S" on the terminal block is wired from each of the valves to the low voltage holding coil terminals of a single pole relay which actuates the circulating pump and the gas valve through the primary connections of the transformer. With either valve in an open position, this relay operates the Booster pump until both valves are closed.

4—A high limit control is provided in the boiler for the gas burner. It may be either of the mechanical type or an electrical control wired into the gas valve circuit.

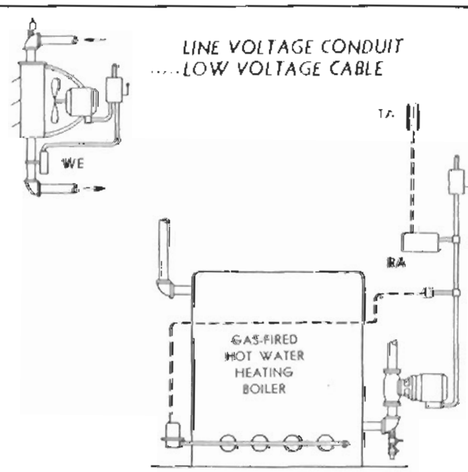


Fig. 122

Unit heaters connected to a gas-fired boiler

1—When heat is required, the low voltage room thermostat actuates the single pole relay which closes the electrical circuit to the Booster pump and to the primary of the gas valve transformer.

2—The thermostat terminals on the gas valve are shunted together. With this circuit the gas valve must be of a type that automatically closes with an interruption of the electric current.

3—A reverse action hot water control is installed in the return connections of each unit heater and wired to operate the unit heater motor. The adjustment of this control should be to a minimum differential and to operate the fan at temperatures which do not blow cold air into the room.

4—A high limit control is provided in the boiler for the gas burner. It may be either of the mechanical type or an electrical control wired into the gas valve circuit.

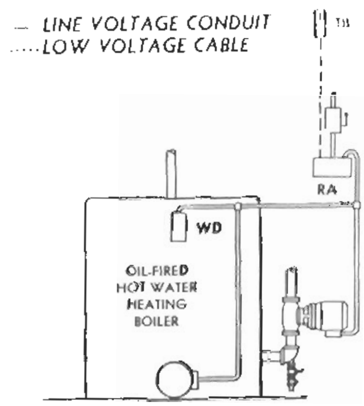


Fig. 123

Booster only on an oil-fired boiler using a low voltage thermostat

1—When heat is reqnired, the low voltage room thermostat actuates a single pole relay which closes the electrical circuit to the Booster pump and to the oil burner controls.

2—A high limit immersion control is wired in series with the electrical line to the line voltage terminal on the oil burner control panel.

3—If the oil burner panel has separate thermostat terminals, these should be shunted together.

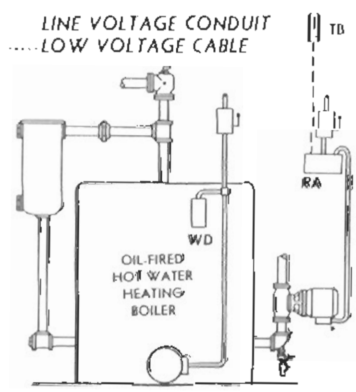


Fig. 124

B & G *Hydro-Flo* system with water heater on a low temperature oil-fired boiler using a low voltage thermostat

1—When heat is required, the low voltage room thermostat actuates a single pole relay which closes the electrical circuit to the Booster pump.

2—A hot water control installed in the boiler is wired to maintain a constant boiler water temperature sufficient to heat the domestic water with the indirect heater. An additional safety high limit control can be wired in series with the hot line to the oil burner control panel. This control is set 20° higher than the first mentioned hot water control. The second control will only operate in the event that the first one fails.

3—If the oil burner panel has separate thermostat terminals, these should be shunted together.

WIRING DIAGRAMS (continued)

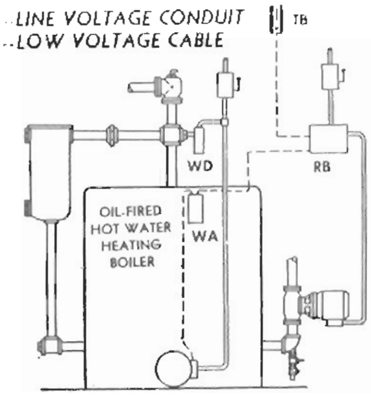


Fig. 125

B & G *Hydro-Flo* system with water heater on a high temperature oil-fired boiler using a low voltage thermostat

1—When heat is required, the low voltage room thermostat actuates a double pole relay which closes the electrical circuit to the Booster pump through one pole of the relay and closes the electrical circuit to the thermostat terminals on the oil burner panel through the other pole of this relay.

2—A high limit immersion control is wired in series with the electrical line to the line voltage terminal on the oil burner control panel. This high limit control should be adjusted to a maximum setting that will provide sufficient boiler water temperature to heat the building.

3—Another hot water immersion control installed in the boiler should be wired in parallel with the thermostat terminals of the oil burner control panel. This hot water control should be adjusted to maintain a boiler water temperature of 160° or high enough to heat the domestic water by means of the indirect heater. This control will turn the burner on and off to maintain this low limit temperature within the boiler. Whenever the room thermostat calls for heat, the boiler water temperature will be built up beyond the setting of this control to a temperature sufficient to heat the building or to the setting of the hot water control listed under paragraph 2.

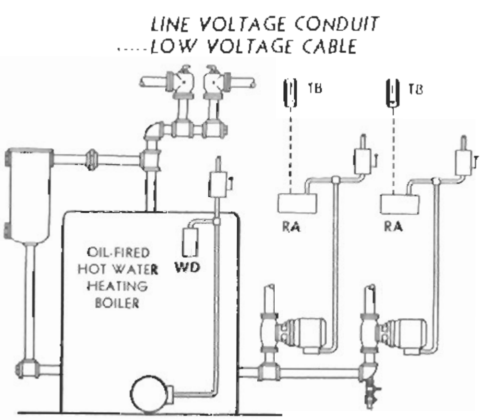


Fig. 126

NOTE: For installations of more than 2 zones, connect additional equipment in same manner

2 Zone B & G *Hydro-Flo* system with water heater on a low temperature oil-fired boiler using low voltage thermostats

1—Each zone is provided with a low voltage thermostat, wired to a single pole relay which operates its respective Booster pump.

2—A hot water control installed in the boiler is wired in series with the electrical line to the oil burner control. This hot water control is adjusted to maintain a constant boiler water temperature.

3—If the oil burner panel has separate thermostat terminals, these should be shunted together.

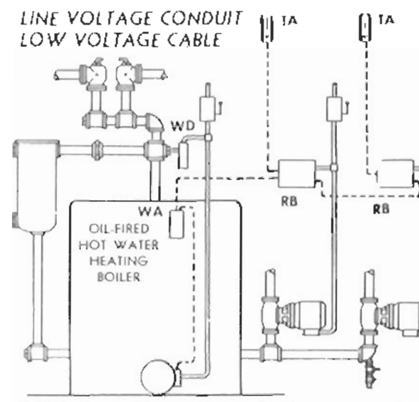


Fig. 127

NOTE: For installations of more than 2 zones, connect additional equipment in same manner.

2 Zone B & G *Hydro-Flo* system with water heater on a high temperature oil-fired boiler using low voltage thermostats

1—Each zone is provided with a low voltage thermostat that actuates a double pole relay having one pole wired to operate its respective pump and the other pole wired to the thermostat terminals of the oil burner control panel.

2—A high limit immersion control is wired in series with the electrical line to the line voltage terminal on the oil burner control panel. This hot water control should be adjusted to a maximum setting that will provide sufficient boiler water temperature to heat the building.

3—Another hot water control installed in the boiler is wired across the thermostat terminals of the oil burner control panel. This control should be adjusted to maintain a boiler water temperature of 160° or high enough to heat the domestic water by means of the indirect heater. This control will also turn the burner on and off to maintain the low limit temperature within the boiler. When either of the room thermostats call for heat, the boiler water temperature will be built up beyond the setting of this control to a temperature sufficient to heat the building or to the setting of the hot water control listed under paragraph 2.

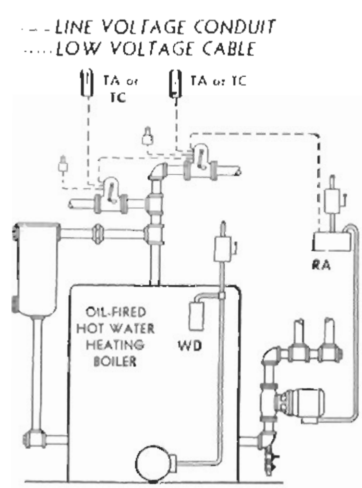


Fig. 128

FOR INSTALLATIONS OF MORE THAN 2 ZONES, CONNECT ADDITIONAL EQUIPMENT IN THE SAME MANNER.

2 Zone B & G *Hydro-Flo* system with water heater using motorized valves on a low temperature oil-fired boiler

1—Each zone is provided with a low voltage room thermostat of a type that matches requirements of the valve motor and is wired to the thermostat terminals of its respective B & G motorized valve.

WIRING DIAGRAMS (continued)

2—The motorized valve transformers are installed on outlet boxes convenient to the valve and each is wired to the transformer terminals marked "T" on the valve.

3—The auxiliary switch marked "S" on the terminal block is wired from each of the valves to the low voltage holding coil terminals of a single pole relay that actuates the Booster pump. When either valve is in an open position, this relay will operate the Booster pump and continue to operate it until both valves are closed.

4—A high limit immersion control is wired in series with the electrical line to the line voltage terminal on the oil burner control panel. This hot water control should be adjusted to a maximum setting that will provide sufficient boiler water temperature to heat the building.

5—If the oil burner panel has separate thermostat terminals, these should be shunted together.

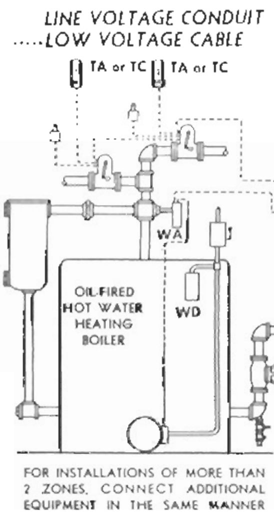


Fig. 129

2 Zone B & G *Hydro-Flo* system with water heater using motorized valves on a high temperature oil-fired boiler

1—Each zone is provided with a low voltage room thermostat of a type that matches requirements of the valve motor and is wired to the thermostat terminals of its respective B & G motorized valve.

2—The motorized valve transformers are installed on outlet boxes convenient to the valve and each wired to the transformer terminals marked "T" on the valve.

3—The auxiliary switch marked "S" on the terminal block is wired from each of the valves to the low voltage holding coil terminals of a double pole relay. One pole of this relay is wired to actuate the Booster pump and the other pole is wired to the thermostat terminals of the oil burner control panel.

4—A high limit immersion control is wired in series with the electrical line to the line voltage terminal on the oil burner control panel. This hot water control should be adjusted to a maximum setting that will provide sufficient boiler water temperature to heat the building.

5—Another hot water control installed in the boiler is wired across with the thermostat terminals of the oil burner control panel. This control should be adjusted to maintain a boiler water temperature of 160° or high enough to heat the domestic water by means of the indirect heater. This control will also turn the burner on and off to maintain the low limit temperature within the boiler. When either of the room thermostats call for heat, the boiler water temperature will be built up beyond the setting of this control to a temperature sufficient to heat the building or to the setting of the hot water control listed under paragraph 2.

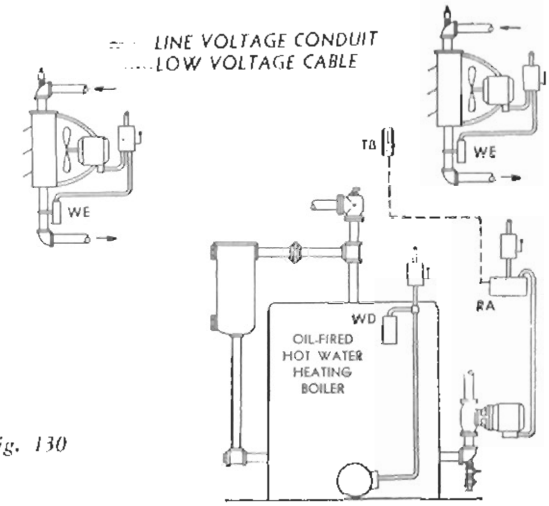


Fig. 130

B & G *Hydro-Flo* system using unit heaters with an oil-fired boiler

1—When heat is required, the low voltage room thermostat actuates a single pole relay that operates the Booster pump.

2—A reverse action hot water control is installed in the return connections of each unit heater and wired to operate the unit heater motor. The adjustment of this control should be to a minimum differential and to operate the fan at temperatures which do not blow cold air into the room.

3—A hot water control installed in the boiler is wired in series with the electrical line to the oil burner control. This hot water control is adjusted to maintain a constant boiler water temperature.

4—If the oil burner panel has separate thermostat terminals, these should be shunted together.

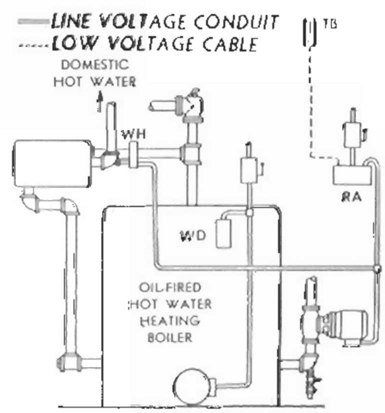


Fig. 131

B & G *Hydro-Flo* system with tankless heater on an oil-fired low temperature system

1—When heat is required, the low voltage room thermostat actuates a single pole relay that closes the electrical circuit to the Booster pump.

2—A low temperature reverse action hot water control set at 120° and at its minimum differential is installed in the hot water outlet of the heater. It is wired in series with the electrical connections from the single pole relay to the Booster pump. Good results have also been obtained with this control by locating it in the boiler water and setting it at 150°. The purpose of this control is to give preference to the heating of the domestic water and shut down the pump in the event the heater water drops below a predetermined temperature. Usually the domestic water demand is only of a short duration and the brief shut down of the heating system not noticeable.

3—A hot water control installed in the boiler is wired in series with the electrical line to the oil burner control and is adjusted to maintain a constant boiler water temperature.

4—If the oil burner panel has separate thermostat terminals, these should be shunted together.

WIRING DIAGRAMS (continued)

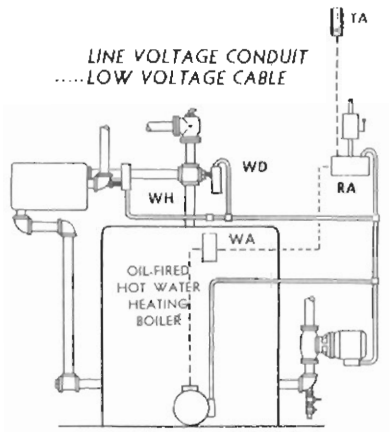


Fig. 132

B & G *Hydro-Flo* system with tankless heater on an oil-fired high temperature system

1—When heat is required, the low voltage room thermostat actuates a double pole relay. One pole is wired to operate the Booster pump and the other pole is wired to the thermostat terminals on the oil burner control panel.

2—A high limit control in the boiler is wired in series with the electrical line to the line voltage terminal on the oil burner control panel. This hot water control should be adjusted to a maximum setting that will provide a boiler water temperature high enough to heat the building.

3—Another hot water control installed in the boiler is wired across the thermostat terminals of the oil burner control panel. This control should be adjusted to maintain a boiler water temperature of 160° or high enough to heat the domestic water with the indirect heater and will turn the burner on and off to maintain this low limit temperature within the boiler. Whenever the room thermostat calls for heat, the boiler water temperature will be built up beyond the setting of this control to a temperature sufficient to heat the building or to the setting of the hot water control listed under paragraph 2.

4—A low temperature reverse action hot water control set at 120° and at its minimum differential is installed in the hot water outlet of the heater. It is wired in series with the electrical connection from the double pole relay to the Booster pump mentioned in paragraph 1. Good results have also been obtained with this control by locating it in the boiler water and setting it at 150°. The purpose of this control is to give preference to the heating of the domestic water and shut down the pump in the event the heater water drops below a predetermined temperature. Usually the domestic water demand is only of a short duration and the brief shut down of the heating system not noticeable.

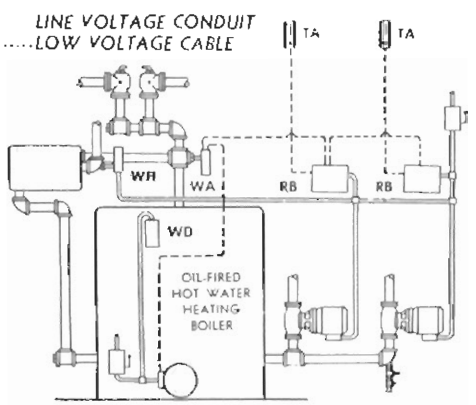


Fig. 133

2 Zone B & G *Hydro-Flo* system with tankless heater on an oil-fired high temperature boiler

1—Each zone is provided with a low voltage room thermostat and is wired to a double pole relay. One pole of the relay actuates its respective Booster pump and the other pole is wired to the thermostat terminals of the oil burner panel.

2—A reverse action hot water control installed in the hot water outlet of the heater is adjusted to close the circuit at 120° and is set at its minimum differential and wired to break the ground circuit wire to both of the Booster pumps. Good results have also been obtained with this control in the boiler water set at 150°. The purpose of this control is to give preference to the heating of the domestic water and shut down the pumps in the event the heater water drops below a predetermined temperature. Usually the domestic water demand is only of a short duration and the brief shut down of the heating system not noticeable.

3—A high limit immersion control is wired in series with the electrical line to the line voltage terminal on the oil burner control panel. This hot water control should be adjusted so that it will provide sufficient boiler water temperature to heat the building.

4—Another hot water control installed in the boiler is wired across the thermostat terminals of the oil burner control panel. This hot water control should be adjusted to maintain a boiler water temperature of 160° or high enough to heat the domestic water with the indirect heater. This control will turn the burner on and off to maintain the low limit temperature within the boiler. When either of the room thermostats call for heat, the boiler water temperature will be built up beyond the setting of this control to a temperature sufficient to heat the building or to the setting of the hot water control listed under paragraph 3.

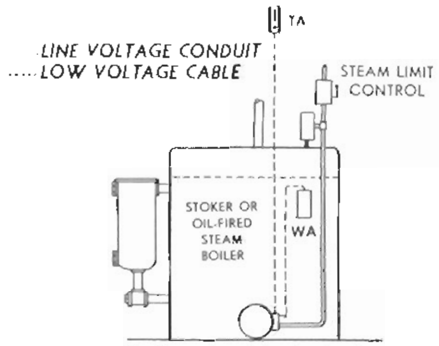


Fig. 134

This diagram is only to show location of controls and equipment on the boiler.

Indirect or tankless heater on a steam heating boiler, fired with an oil burner or stoker using room thermostat

1—The electrical controls are wired in the conventional manner specified for a steam heating system.

2—A hot water control installed below the water line of the heating boiler is wired in parallel with the room thermostat. This control will maintain a constant boiler water temperature below the steaming temperature of the boiler. Whenever the room thermostat calls for heat the oil burner will be operated in the conventional manner until either the thermostat is satisfied or the steam pressure within the system has been built up to the setting of the limit control.

COMPARATIVE CONTROL CHART

NOTE: The chart below is as complete as space will permit. Before mixing controls of one manufacturer with those of another, be sure to check carefully their current carrying capacities and operation with your circuit as these factors differ in many instances.

Thermostats — For Heating Systems — Close Circuit on Temperature Drop

KEY LETTER	CLASSIFICATION	DETROIT LUBRICATOR		MERCOID		MINNEAPOLIS - HONEYWELL		PENN ELECTRIC SWITCH		PERFEX		WHITE RODGERS	
		MODEL	TYPE	MODEL	TYPE	MODEL	TYPE	MODEL	TYPE	MODEL	TYPE	MODEL	TYPE
TA	Low Voltage	411PH	2-Wire	H	2-Wire	T10A T81	Series 10 2-Wire					122#2 132#2	2-Wire
TB	Low Voltage—Heat Anticipating	411CH	2-Wire			T11A	Series 10	870A01C-AA	2-Wire	150A 155A	2-Wire	120#3 130#2	2-Wire
TC	Low Voltage—Double Circuit	NONE				T21A	Series 20					135#2	*SPDT 3-Wire
TD	Line Voltage	CA401		RA	2-Wire	T44A	2-Wire	872A01C	2-Wire	100D	2-Wire	180#1	2-Wire
TE	Line Voltage—Heavy Duty	855	2-Wire	855	2-Wire	TA42A T42A	2-Wire	874A01	2-Wire	200D	2-Wire	176#6	2-Wire

Hot Water Control — Immersion Type — Bi-Metal Operator

KEY LETTER	CLASSIFICATION	DETROIT LUBRICATOR		MERCOID		MINNEAPOLIS - HONEYWELL		PENN ELECTRIC SWITCH		PERFEX	
WA	Low Voltage—Direct Acting	653	2-Wire	115W	2-Wire	L144A	Series 10	440AT02	2-Wire	650D2	2-Wire
WB	Low Voltage—Reverse Acting	CA655R	2-Wire	115W-3	2-Wire	L144B	Series 10	440AT01	2-Wire	650D3	2-Wire
WC	Low Voltage—Double Circuit	NONE				L244A	*SPDT Series 20			650E1	*SPDT 3-Wire
** WD	Line Voltage—Direct Acting	CA655	2-Wire	437	2-Wire	L444A	2-Wire	440AT02	2-Wire	650D2	2-Wire
*** WE	Line Voltage—Reverse Acting	CA655R	2-Wire	437-3	2-Wire	L444B	2-Wire	440AT01	2-Wire	650D3	2-Wire
**** WF	Line Voltage—Double Circuit	NONE		437-153	*SPDT 3-Wire					650E1	*SPDT 3-Wire

Hot Water Control — Immersion Type — Volatile Filled Operator

KEY LETTER	CLASSIFICATION	DETROIT LUBRICATOR		MERCOID		MINNEAPOLIS - HONEYWELL		PENN ELECTRIC SWITCH		PERFEX		WHITE RODGERS	
WG	Line Voltage—Direct Acting	250	MH-1 ML-1	DA36 or DA37	2-Wire	T415A	2-Wire	Type 430	2-Wire	600D 600D4	2-Wire	1118#3 1118#8	2-Wire
WH	Line Voltage—Reverse Acting	#250	MH-1 Reverse ML-1 "	DA36-3 or DA37-3	2-Wire	T415B	2-Wire	Type 431	2-Wire	600D1 600D5	2-Wire	1105#4 1105#9	2-Wire
WI	Line Voltage—Double Circuit	NONE		DA36-153 or DA37-153	*SPDT 3-Wire	T415M T615A	*SPDT 3-Wire					1131#2 1131#5	*SPDT 3-Wire

Relays — With Low Voltage Holding Circuit — For 115 Volts 60 Cycle Current

KEY LETTER	LOAD CIRCUIT SWITCHING ACTION	DETROIT LUBRICATOR MODEL	CONTROL CIRCUIT	MERCOID MODEL	CONTROL CIRCUIT	MINNEAPOLIS - HONEYWELL MODEL	CONTROL CIRCUIT	PENN ELECTRIC SWITCH MODEL	CONTROL CIRCUIT	PERFEX MODEL	CONTROL CIRCUIT	WHITE RODGERS MODEL	CONTROL CIRCUIT
RA	Single Pole Single Throw Normally Open	CA295	2-Wire	V2-3A108	2-Wire	R19A R182A	Series 10 Series 10 Series 20 2-Wire	793 791BE01LU	2-Wire 2-Wire	5000D4 5010D6	2-Wire 2-Wire Series 10	809-1	2-Wire
RB	Double Pole Single Throw Normally Open	CA295 1 Pole Low Voltage	2-Wire	V3-103A108	2-Wire	R132A R182B	Series 10 Series 10 Series 20 2-Wire	791BE01LU 793	2-Wire	5010D7	2-Wire Series 10		
RC	Single Pole Double Throw	NONE		V3-153A108	2-Wire	R182C	Series 10 Series 20 2-Wire	791BE02LU	2-Wire				
RD	Double Pole Double Throw	NONE				R182C	Series 10 Series 20 2-Wire	791BE02LU	2-Wire			805-1	2-Wire

* SPDT—Single Pole Double Throw.
** WG controls can be substituted for WD.
*** WH controls can be substituted for WE.
**** WI controls can be substituted for WF.

INDIRECT HEATER

Where to use

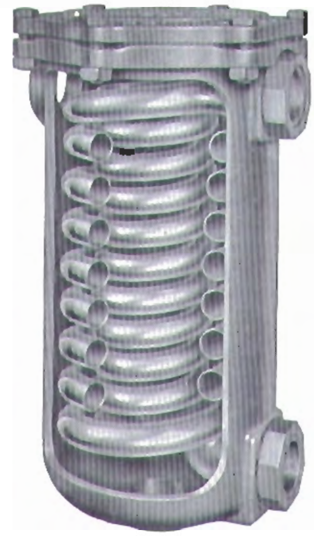
Any steam, vapor or hot water heating boiler can be equipped with this type of Indirect Heater. With the proper electrical controls, the Heater will furnish an ample supply of hot water *winter and summer,* at a saving over other methods where a separate water heating unit is required.

This Heater is well adapted to installation on either steel or cast iron sectional boilers. It should be used with a storage tank of suitable capacity.

For best results, storage tank should be horizontal and as close to the ceiling as possible. On steam boilers, install with top of heater close to the water line. On hot water heating systems, keep top of heater level with or above top of boiler. If tank is low or small, heater size should be increased for faster recovery.

For year around hot water supply on all automatically fired installations, select heater size on 180° boiler water temperature.

Single Coil Heater



Double Coil Heater

Horizontal Tube Heater

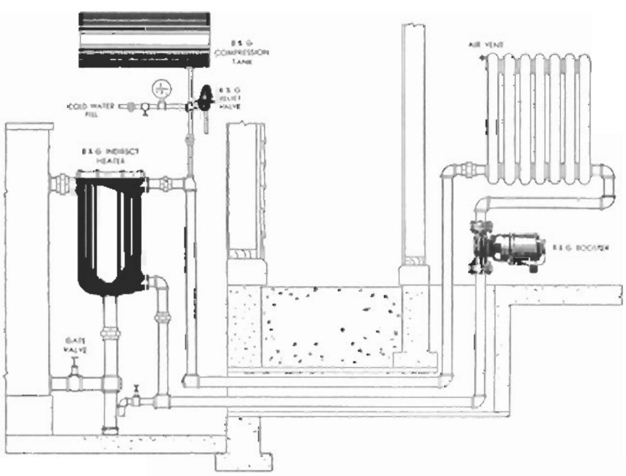


Fig. 136. Garages can be satisfactorily heated with a B & G Indirect Heater if a thermostatically operated B & G Booster is installed in the garage return line. This overcomes the poor heating usually encountered in attempting to heat the garage by gravity circulation.

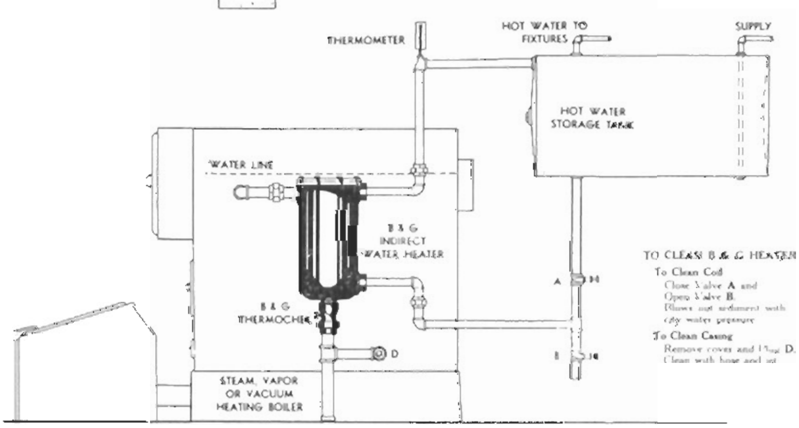


***Fig. 135.** B & G Indirect Heater installed below water line of steel steam boiler. Only one tapping for the supply line to heater is required for this type of boiler.*

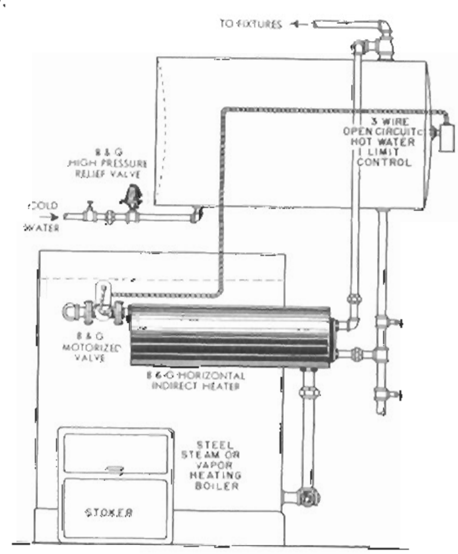


Fig. 137. An excellent control of water temperature is obtained by installing a B & G Indirect Heater and B & G Motorized Valve, as indicated in this diagram. The Motorized Valve shuts off circulation of boiler water through the Heater whenever storage tank water reaches the desired degree.

SEE B & G CATALOG FOR SIZES AND CAPACITIES

B & G *HYDRO-FLO* PRODUCTS (continued)

INDIRECT HEATER INSTALLATIONS (continued)

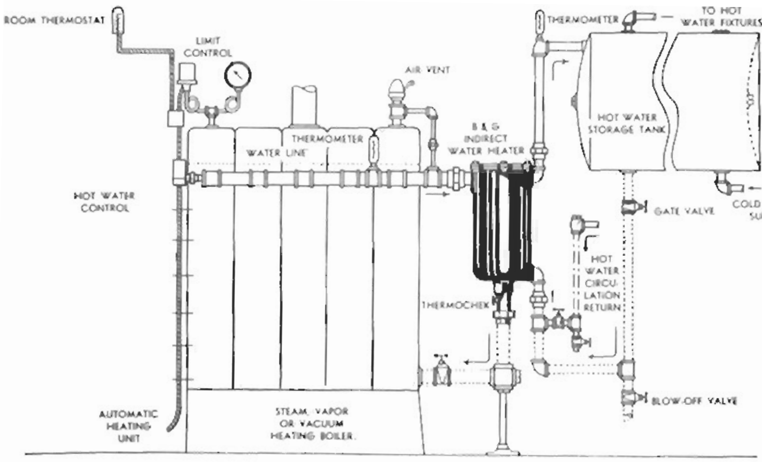


Fig. 138. All sections of a sectional cast iron boiler must be tapped when installing an Indirect Heater.

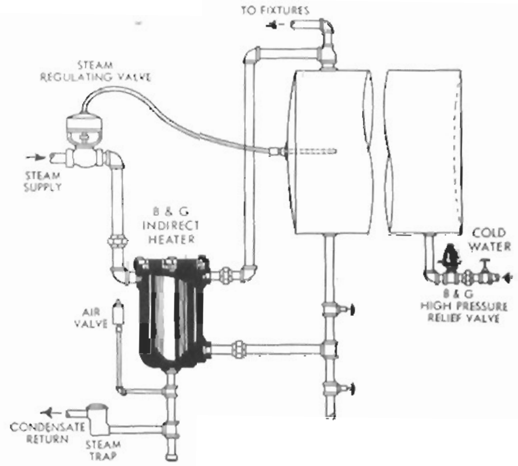


Fig. 141. B & G Indirect Heaters may be used with low pressure steam.

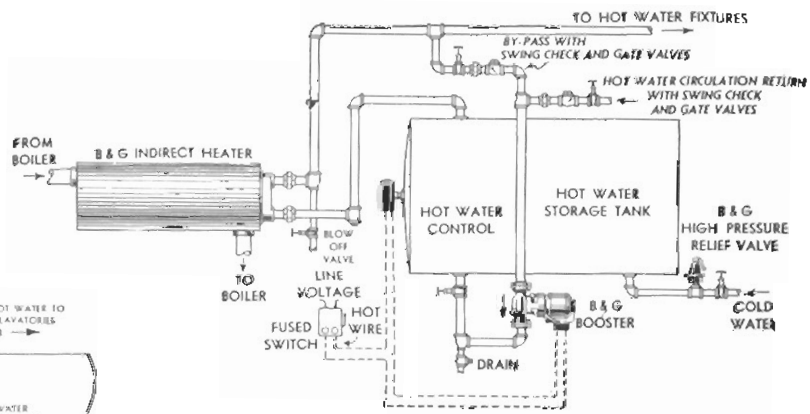


Fig. 142. Semi-tankless pumped installation. Tempered water stored in tank is drawn through the Indirect Heater before going to the fixtures.

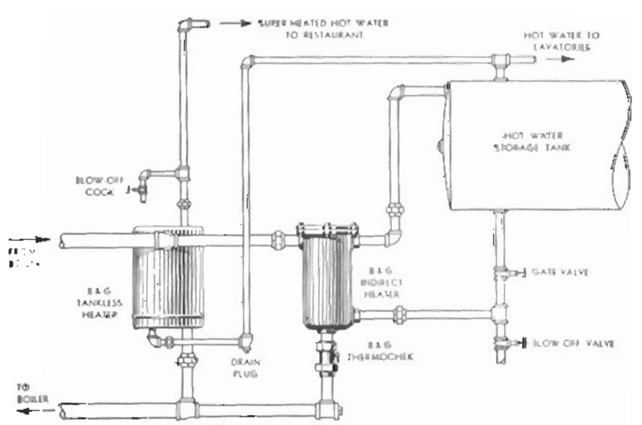
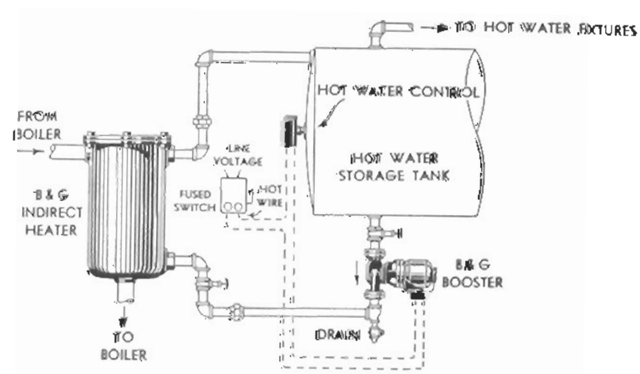


Fig. 139. An excellent installation where two different water temperatures are required. The Indirect Heater supplies hot water to the storage tank for use at the lower temperature. Hot water for the higher temperature is also drawn from the storage tank but is passed through the Tankless Heater where it is super heated. This application is frequently used in restaurants, hospitals, hotels and factories.

Fig. 140. Where it is impossible to raise the storage tank to the proper height for good gravity circulation, the use of a B & G Booster, installed as indicated, will supply a remedy. The Booster provides forced circulation between Heater and tank, with its operation controlled by a Hot Water Control in the tank.



SEE B & G CATALOG FOR SIZES AND CAPACITIES

B & G *HYDRO-FLO* PRODUCTS (continued)

TANKLESS HEATERS

Where to use

(Do not use in hard water territories without a water softener)

The B & G Tankless Heater is designed to meet the need for a heater of unusual capacity which can be installed in basements lacking space for storage tanks—or where service water conditions would make it necessary to use expensive copper or other non-ferrous tanks. It likewise saves the cost of a storage tank, pipe, fittings and stand. The use of a B & G Watermixer is recommended on all tankless heater installations. In hard water territories, a water-softener will prevent liming.

This heater also solves the problem of keeping the basement clear for use as a recreation room as it fits snugly to the boiler.

Where pressure is higher than 40 lbs., it is advisable to install a reducing valve in the cold water supply to the heater.

Nos. 20 and 30 Heater

BOILER LOAD

For residential use, where hot water is drawn in comparatively small quantities, little load is placed on the boiler. Remember, however, that when the water "draw" is more or less constant, as in restaurants, a heavy load is placed on the boiler. Care must be taken that the boiler has sufficient capacity to handle this load. See page 3.

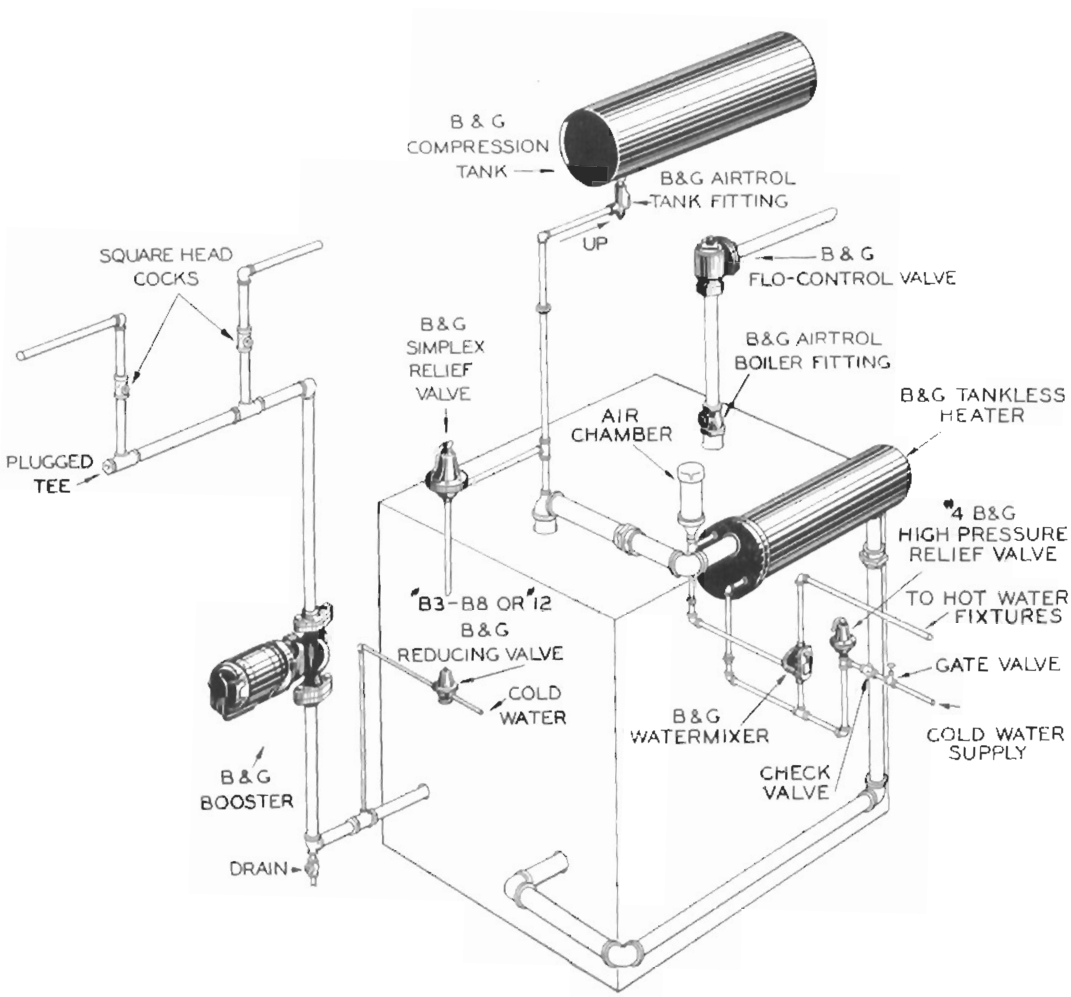


Fig. 143. B & G No. 20 or 30 Tankless Heater installed on a hot water boiler.

SEE B & G CATALOG FOR SIZES AND CAPACITIES

B & G HYDRO-FLO PRODUCTS (continued)

TANK AND HEATER

BOLTED TYPE HEAD

An excellent heater for hard water territory

The B & G Tank and Heater offers many advantages, as it both heats and stores the water in the same unit. It can be operated by passing either steam or hot water through the coil and is an excellent heater for hard water territories. Large capacity in compact space makes this heater particularly suitable for boiler rooms with low head room.

SCREW TYPE BRONZE HEAD

This unit is used for similar purposes as the heater shown above but is equipped with a screw type head.

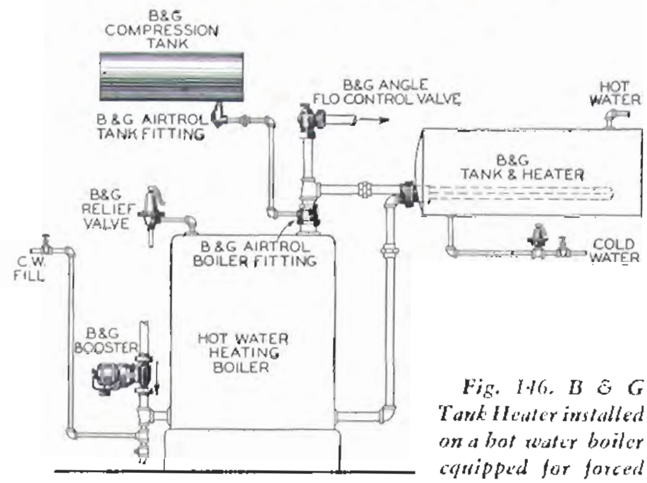


Fig. 146. B & G Tank Heater installed on a hot water boiler equipped for forced circulation and year around domestic hot water supply.

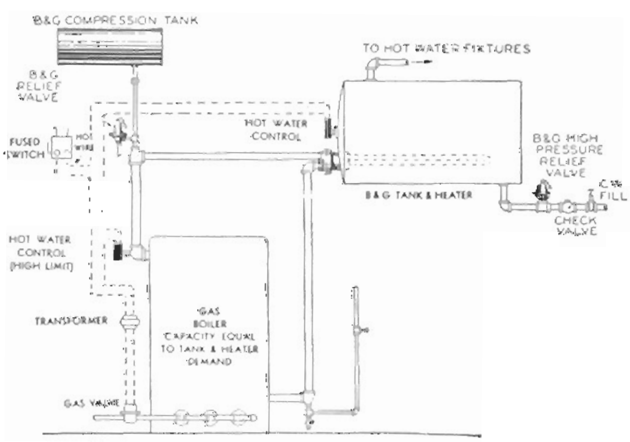


Fig. 144. Correct installation of a B & G Tank and Heater on a gas-fired boiler.

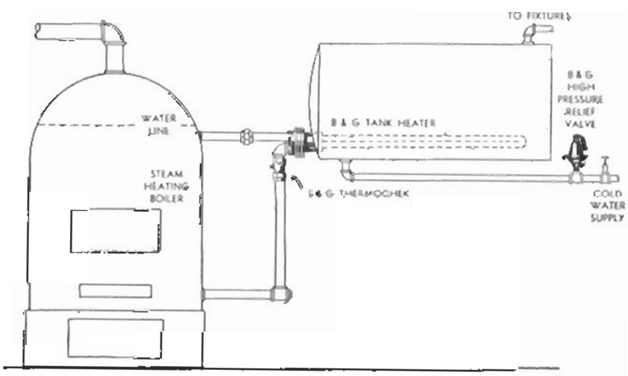


Fig. 147. Installation of a B & G Tank Heater below the water line on a steel steam boiler. Note the Thermochek for controlling storage tank temperature.

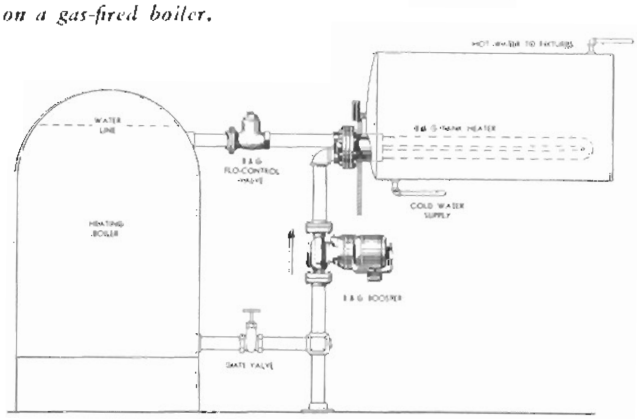


Fig. 145. Excellent control of hot water temperature is obtained with this installation. The Hot Water Control in the tank starts the Booster whenever water temperature falls below the desired degree. The Flo-Control Valve prevents gravity circulation when the Booster is not running.

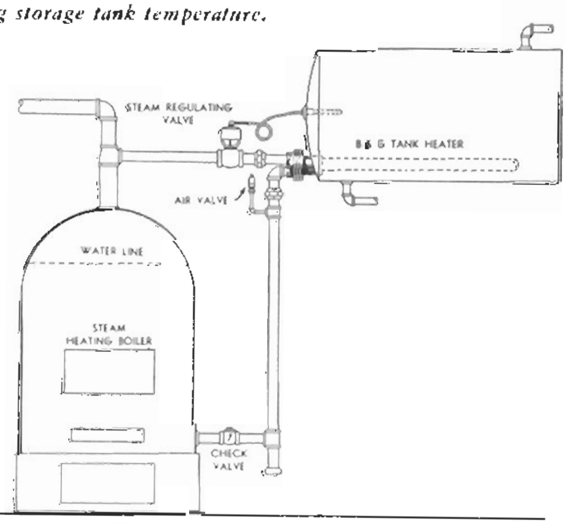
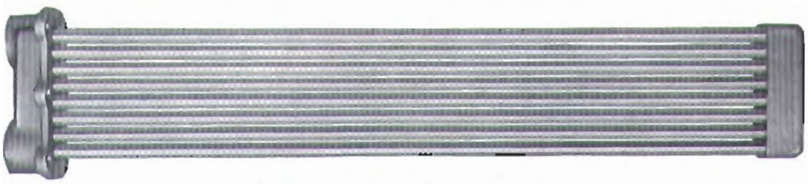


Fig. 148. B & G Tank Heater heated with live steam. The steam regulating valve prevents overheating of the water in the storage tank.

SEE B & G CATALOG FOR SIZES AND CAPACITIES

B & G HYDRO-FLO PRODUCTS (continued)



Offset Unitem.

UNITEM HEATERS

Where to use

Unitem Heaters are for use in either steam or hot water steel boilers of any size or make. When installed in steam boilers they are placed below the water line; hence it is not necessary to have steam pressure on the boiler in order to obtain a continuous supply of domestic hot water. These heaters have an excellent record for economy in forced circulation hot water heating systems, with thousands now in operation in apartments, schools and industrial plants. This heater can be installed for either tank or tankless operation. A different style head is required for each type.

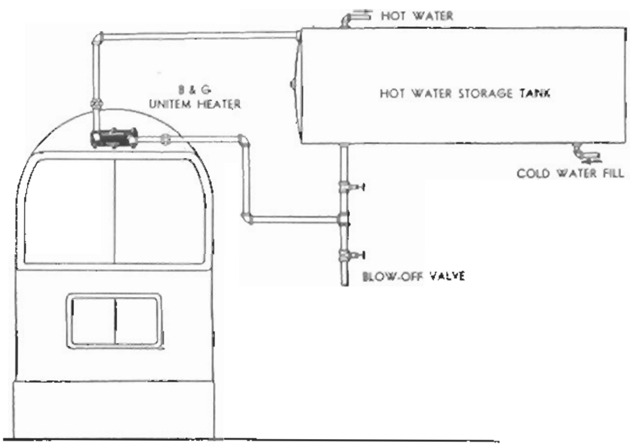


Fig. 149. This standard storage tank installation assures plenty of hot water in the tank to take care of peak demand periods.

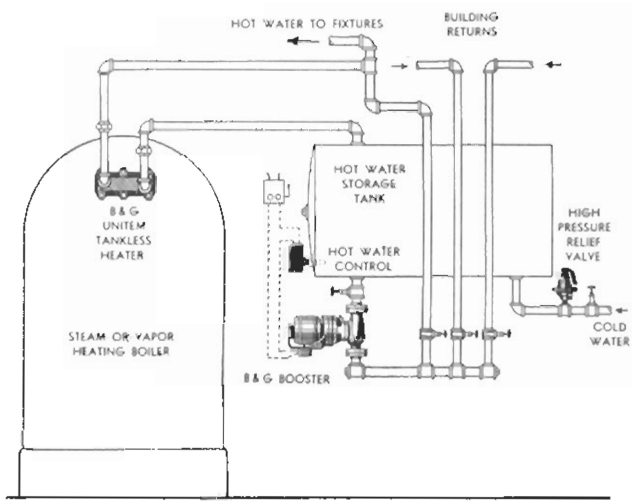


Fig. 152. Semi-tankless, pumped installation. The Booster remarkably increases water heating efficiency, permits low tanks and delivers instant hot water to all fixtures.

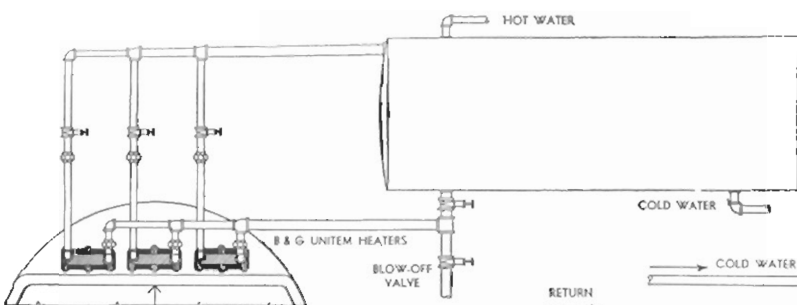


Fig. 150. A multiple B & G Unitem Heater storage tank installation—with Heaters connected in parallel.

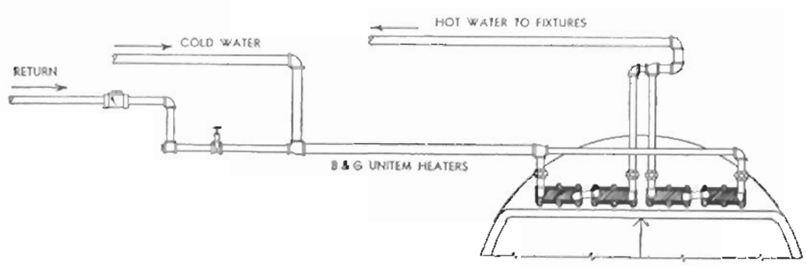


Fig. 153. Multiple B & G Unitem Heater tankless installation—with Heaters connected in series.

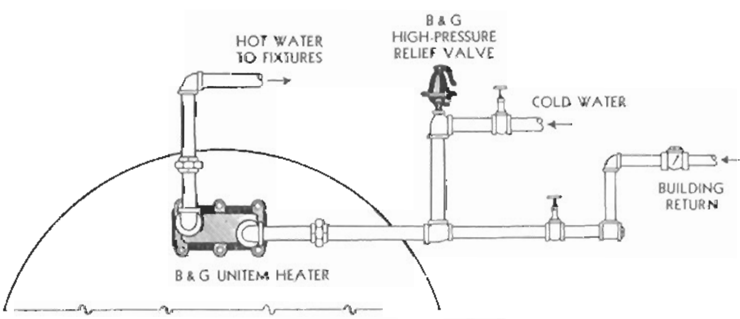


Fig. 151. Tankless installation—particularly suitable where lack of space prohibits a storage tank or where there is a heavy and constant "draw".

SEE B & G CATALOG FOR SIZES AND CAPACITIES

B & G *HYDRO-FLO* PRODUCTS (continued)

TYPE "SU" HEATER

INSTANTANEOUS

Where to use

The heaters described herein are of the "steam to water" type. The ratings are all based on steam in the shell and the heated water flowing through the tubes.

These B & G Type "SU" Instantaneous Water Heaters are ideal for industrial plants or wherever large volumes of hot water are required continuously for service water supply or process work. No storage tank is required, thereby saving space. The abundance of heat transfer surface in these units heats water instantly as it is needed.

The B & G Type "SU" Water Heater can be easily connected to any steam boiler or system. Additional boiler capacity for the Water Heater depends on the other steam loads imposed on the boiler. If the capacity of the boiler is required continuously for other demands, additional capacity must be provided for the water heater.

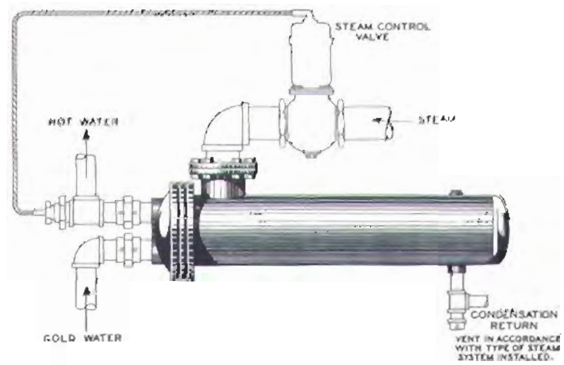


Fig. 154. Installation of "SU" Heater, showing the control equipment used to keep service water at a predetermined temperature.

TYPE "WU" HEATER

INSTANTANEOUS

Where to use

The "WU" Instantaneous Water Heater (water to water heat transfer) is equipped with a B & G Booster which pumps boiler water through the shell, thereby greatly increasing the capacity of the Heater. Large volumes of hot water are produced by an amazingly small unit.

Because of pumped circulation, the connecting pipes and fittings are radically reduced in size. Hence, material cost is trimmed to the bone and cutting and threading can be done on the job. No storage tank needed—another substantial saving.

Controls service water temperature

The Booster also provides a means of closely controlling service water temperature. A hot water control, installed in the hot service water supply line, starts the Booster whenever service water temperature goes below the desired degree. The Booster pumps boiler water through the shell of the Heater *until service water is again at the correct temperature,* and is then stopped by the control.

The combined cost of the "WU" Heater, Booster, pipe, fittings and labor is actually less than for a gravity-circulated heater installation big enough to do the same job.

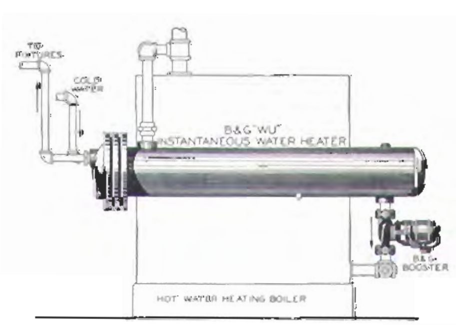


Fig. 155. Installation on hot water boiler. When the "WU" Heater is installed on a hot water boiler, the B & G Booster should discharge into boiler.

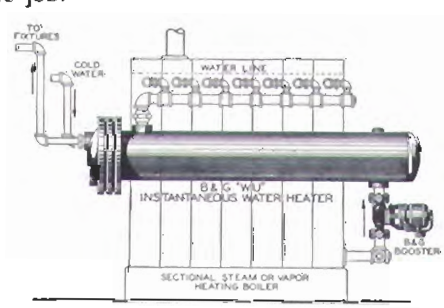
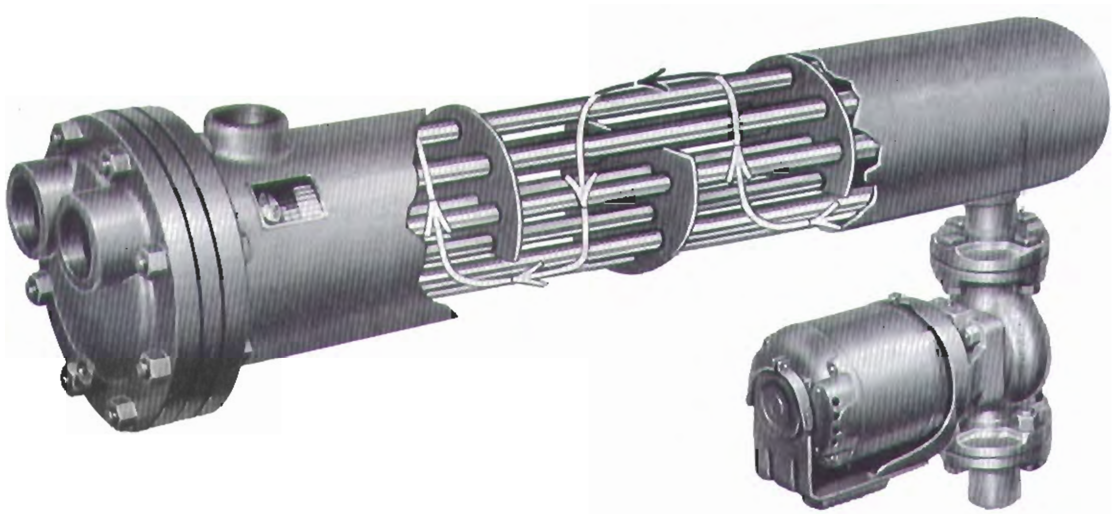


Fig. 156. Installation on steam boiler. Diagram shows how B & G Booster is installed to circulate boiler water through the "WU" Instantaneous Water Heater. Note that boiler water is discharged into the heater.

SEE B & G CATALOG FOR "WU" CAPACITIES. "SU" CAPACITIES SENT ON REQUEST.

B & G *HYDRO-FLO* PRODUCTS (continued)

TYPE "CWU" RADIATION HEATER



Where to use

The B & G *Hydro-Flo* Radiation Heater now makes possible the advantages of Forced Hot Water heating in new additions to a building even though the present heating plant employs a steam boiler.

Besides assuring better heating, a Forced Hot Water system can generally be installed at less expense, as the supply and return mains are usually easier to run than those for steam.

Installation and operation

The B & G Radiation Heater is a "shell and tube" heat exchanger and is installed below the water line of a steam boiler. Hot boiler water is pumped by a B & G Booster through the shell, thereby heating the water for the heating system, which is pumped through the tubes of the Heater. Pumped circulation of boiler water gives the Heater much greater capacity.

Pumping the water through both the heater and the heating system not only affords excellent temperature control, but also permits the use of much smaller pipe and fittings. This reduces both material and labor costs. In fact, the installation of a "CWU" Radiation Heater, including Boosters, pipe, fittings and labor is, in most instances, the most economical method of enlarging steam heating systems.

Temperature control in the system is very simple and accurate. A room thermostat starts both pumps when heat is needed. If the steam boiler is automatically fired, a water temperature control installed in the boiler will start and stop the burner to maintain a minimum required boiler water temperature.

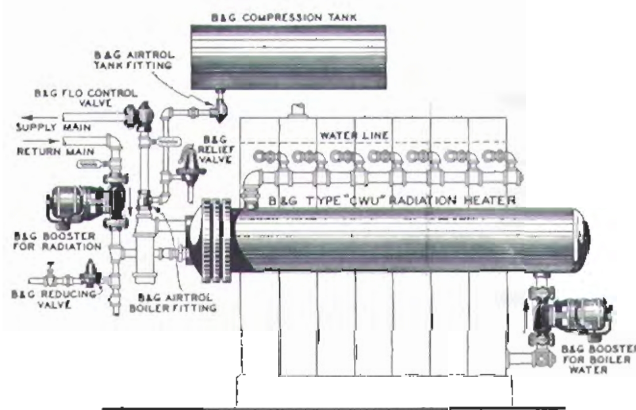


Fig. 157. B & G Radiation Heater installed on sectional cast iron boiler. Note that direction of boiler water flow is from bottom of boiler through shell of heater. If boiler has submerged upper nipple construction, no header connection as shown is needed; one connection to boiler is sufficient.

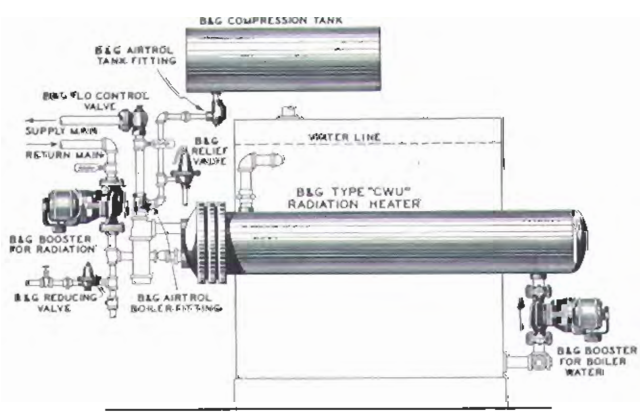


Fig. 158. B & G Radiation Heater installed on steel boiler. Note that direction of boiler water flow is from bottom of boiler through shell of heater. If it is necessary to cut an opening in boiler, it is advisable to check with local boiler codes or laws, especially if boiler is other than a low pressure heating boiler.

SEE B & G CATALOG FOR SIZES AND CAPACITIES

B & G *HYDRO-FLO* PRODUCTS (continued)

TYPE "CSU" CONVERTOR

Where to use

In general, any device which transmits heat from one medium to another may be called a convertor. Thus, a boiler which transmits the heat of combustion to water or steam, or a radiator which transmits the heat of steam or water to air, may be called a convertor.

Specifically, the term convertor is restricted to the device used to transmit heat from steam to water, or from water to water, where the heated water is used as the heating medium for a heating system.

Although there are many patterns and designs in convertors, all convertors are built on the same general principle. This is to direct the flow of fluids so that the heating fluid is separated from the fluid to be heated by a material which has a high coefficient of heat transfer. Thus, there is no mixture of the fluids, only the transfer of heat from hot to cold fluid.

In practice, the convertor is usually made of a shell or tank, which usually contains the heating medium. Immersed in the tank or shell are copper tubes through which the cool medium circulates, absorbing the heat of the heating medium which surrounds the tubes.

The convertor is frequently used in buildings where steam is required for processing work but where the advantages of a hot water heating system are desirable. Steam from the boiler is passed through the convertor, where it heats the water in the copper tubing. The water is then pumped to the units of the heating system as needed.

The effect of pressure drop in Convertors

It is wise to be generous in sizing a convertor, just as in the selection of a boiler. Generous size provides a margin of safety, and as a rule, the large unit does not absorb as much of the available pump power.

Heat transfer is affected by the velocity of the heating and absorbing materials; the greater the velocity, the greater the transfer. But as the velocity increases, the friction increases approximately as the square of the velocity. Thus if the velocity is doubled, the resistance is increased four times, but the heat transfer is increased by only one half.

It is apparent then, that a convertor can be made to increase its capacity by increasing the velocity of either one or both of the fluids passing through it. But in so doing, while reducing the first cost by installing a smaller unit, the operating cost is increased all out of proportion. The saving in first cost will be outweighed many times by the increase in power cost.

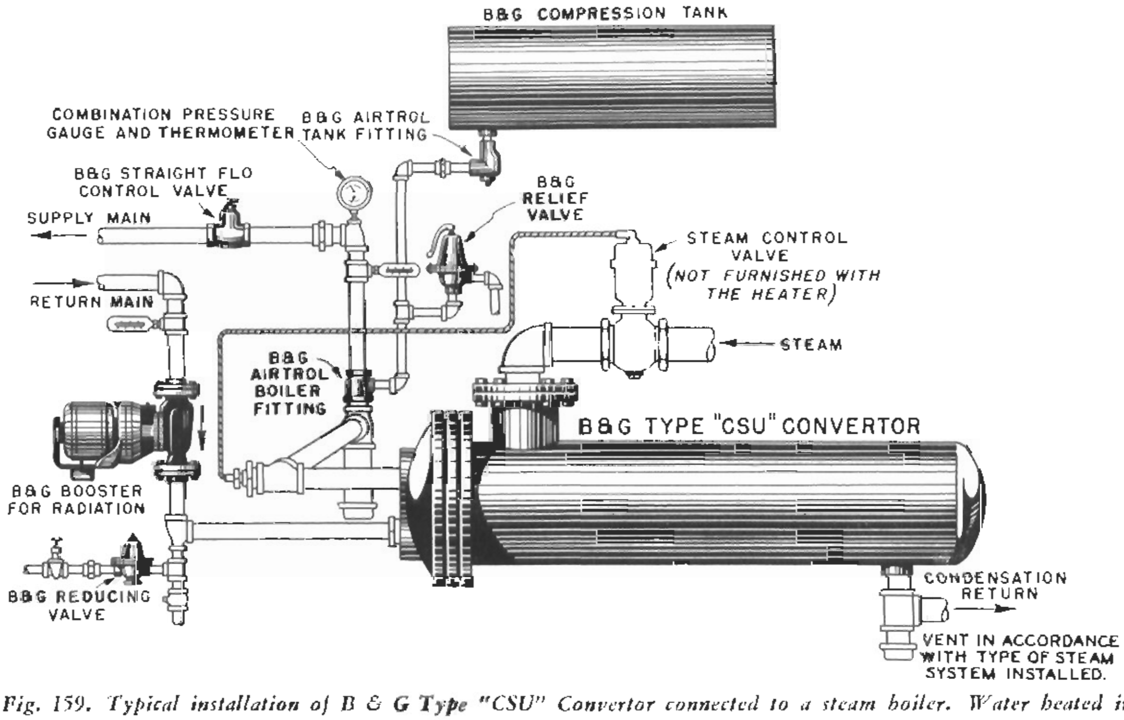


Fig. 159. Typical installation of B & G Type "CSU" Convertor connected to a steam boiler. Water heated in the Convertor is pumped through the heating system with a B & G Booster.

SIZES AND CAPACITIES SENT ON REQUEST

B & G *HYDRO-FLO* PRODUCTS (continued)

AIR-TANKLESS WATER HEATER

(PATENT NO. 2290347)

Where to use

The B & G Air Tankless Heater is a combination tankless heater and air tank. It is designed to meet the need for a heater which can be installed in basements lacking space for storage tanks or where service water conditions would make it necessary to use expensive copper or other non-ferrous tanks. It likewise saves the cost of a storage tank, pipe, fittings, stand and standard expansion tank.

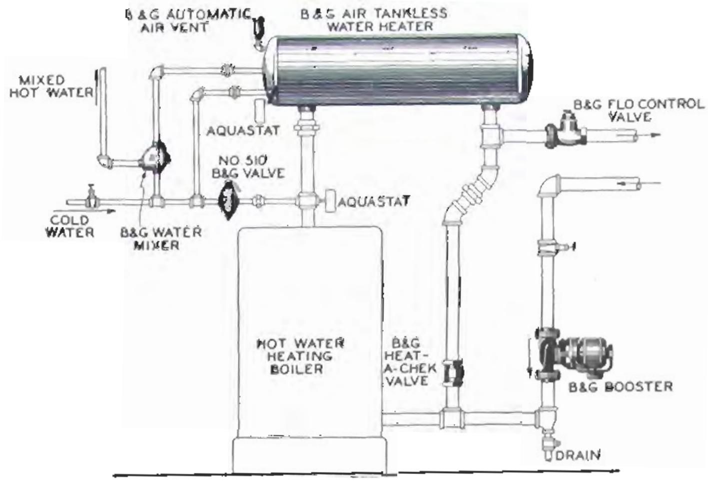


Fig. 160. Typical installation of B & G Air Tankless Water Heater.

CLEAN-A-COIL VALVE

Where to use

The B & G Clean-A-Coil Valve offers genuine help in keeping heater coils free of sediment and lime. *Every time a faucet is opened, the Clean-A-Coil Valve AUTOMATICALLY and thoroughly backwashes the heater!*

When all faucets are closed, the water circulates in the usual manner—from the heater to the tank and back to the heater again. When any faucet is opened, the operation of the Clean-A-Coil Valve causes the water to *reverse* its usual direction of flow. Cold water enters through the Valve, flows through the heater in the direction *opposite* to the normal flow and thence into the tank.

This back-wash flow is much more turbulent than the heating cycle flow and its scrubbing action effectively cleans out sediment.

Ideal for side arm gas water heaters

Where the temperature differential between incoming cold water and the hot water in the heater is great enough, the entering cold water contracts the heater tubes sufficiently to crack off lime. Since large temperature differentials generally occur where direct flame is applied to heater coils, the Clean-A-Coil Valve is particularly effective on side arm gas water heaters.

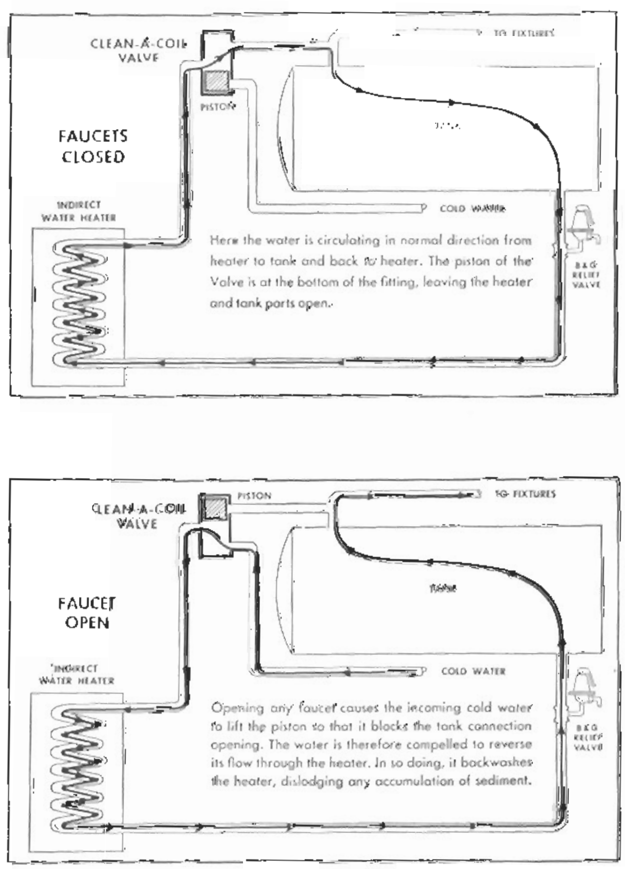


Fig. 161. Diagrams show how Clean-A-Coil Valve reverses the flow of water when a faucet is opened.

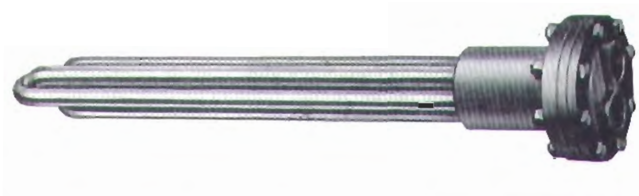
B & G *HYDRO-FLO* PRODUCTS (continued)

HEATER UNIT

TANK HEATER—WITH OR WITHOUT COLLAR

Where to use

The heating unit of the Tank and Heater may be purchased separately, either with or without the collar, for inserting in already installed tanks.



THERMOCHEK

Where to use

The B & G Thermochek offers protection to indirect water heater installations employing a storage tank. It may be used on any type of automatic or hand-fired steam or hot water boiler and with all types of Indirect Heaters, *except those built into the boiler.*

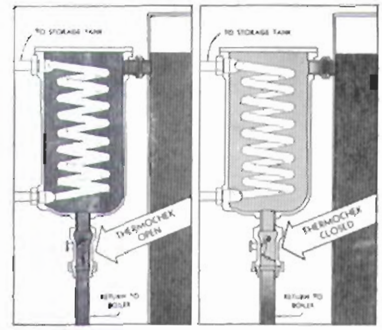


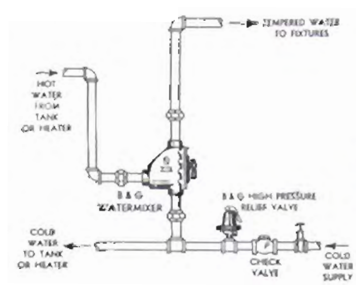
Fig. 163. The Thermochek is installed in the return line from heater to boiler. It remains open, permitting circulation of boiler water through the heater jacket, until storage tank temperature reaches the desired degree. It then automatically closes, shutting off the flow of boiler water, until hot water demands lower the storage tank temperature.

1. Reduces tank corrosion. Research by manufacturers of hot water storage tanks shows clearly that water heated above 160° has a rapid deteriorating effect on galvanized tanks. They are emphatic in recommending the use of a dependable temperature control to lengthen tank life.
2. Minimizes liming of heater coils and service water piping. In most localities, water heated beyond 140° causes rapid formation of lime and sediment. The Thermochek prevents this overheating by accurately controlling the temperature of the water in the storage tank. Operation is completely automatic.

WATERMIXER

Where to use

The B & G Watermixer can be installed with any type of direct or indirect domestic water heater to maintain the outlet water at a uniform temperature.



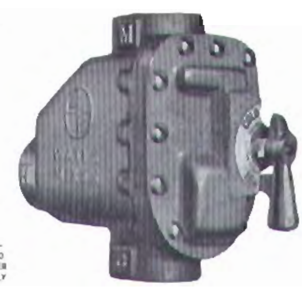


Fig. 164. Typical installation of B & G Watermixer.

The ordinary tempering valve is seriously affected by variations in pressure drop through the heater, as the correct adjustment is dependent upon a constant pressure. Since the pressure drop varies in accordance with the rate of "draw," it is obviously impossible for the conventional tempering valve to maintain a uniform water temperature at the outlet. In a small tankless heater, for example, the drop in pressure may be as much as 8 to 10 lbs.

The B & G Watermixer completely eliminates this difficulty by its new and exclusive design. A bi-metal coil, submerged in the *mixed* water, is employed to open and close a balanced valve. This valve is so constructed that differences in pressure drop do not affect its operation.

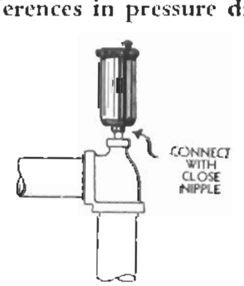


Fig. 162. Method of connecting B & G Automatic Air Vent.

AUTOMATIC AIR VENT

An improved valve for automatically and positively removing air from the piping of any type of hot water heating system. *When installing, use a close 1/8″ nipple.* At slight additional charge, a copper overflow connector can be furnished. For overflow pipe from the connector use 1/4″ O.D. copper tubing.

SEE B & G CATALOG FOR SIZES AND CAPACITIES

B & G *HYDRO-FLO* PRODUCTS (continued)

BOOSTER PUMP

Where to use

For modern forced circulation systems. The B & G Booster is the heart of a modern forced hot water heating system. In combination with a B & G Flo-Control Valve and B & G Indirect Heater, both heat and domestic hot water are furnished for the usual cost of heat alone.

For improving gravity hot water heating systems. The B & G Booster ends slow, uncertain heating in old style gravity hot water systems by greatly speeding up sluggish circulation. By increasing circulation over the prime heating parts of the boiler, heat is picked up rapidly, thereby reducing loss through the chimney.

For circulating hot or cold service water. In large service water installations, a B & G Booster assures instant water at every faucet. Where a heater installation is undersized, a B & G Booster will increase its capacity by as much as 25%. A distant or low storage tank, where gravity circulation is difficult or impossible, can be effectively and economically circulated by this pump unit.

SEE PAGE 38 FOR BOOSTER CAPACITY CHART

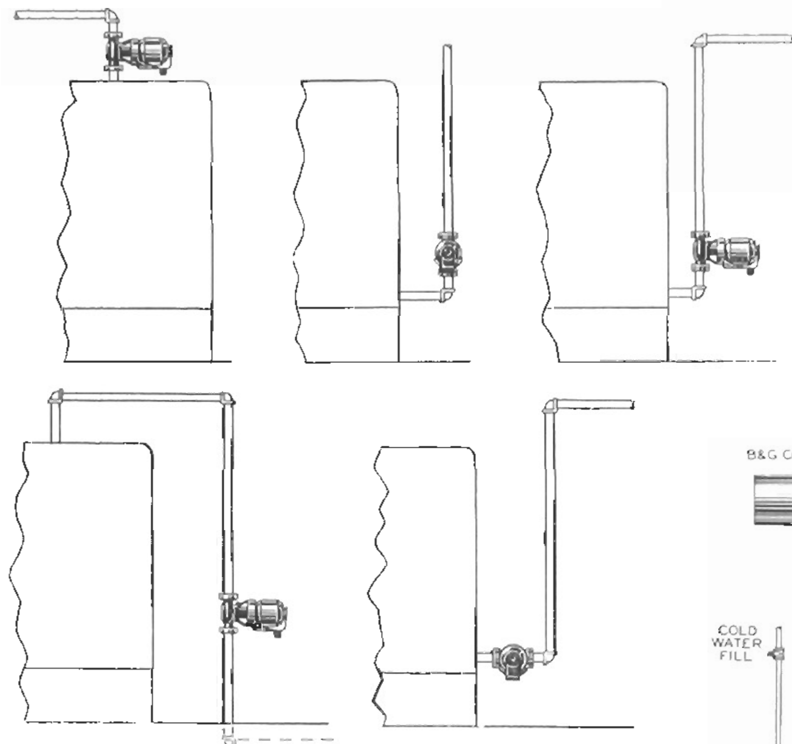


Fig. 165. The B & G Horizontal Booster is adaptable to installation in a choice of many different positions (see above)—a great convenience in meeting every situation which may be encountered. The fact that the B & G Booster can be installed in an upright pipe has many advantages. It can be placed high enough above the floor to avoid the hazard of a flooded basement. Sediment and sludge cannot accumulate when Circulators are installed in this manner and no pocket of water is left to freeze when the system is drained. All horizontal type Boosters are flanged.

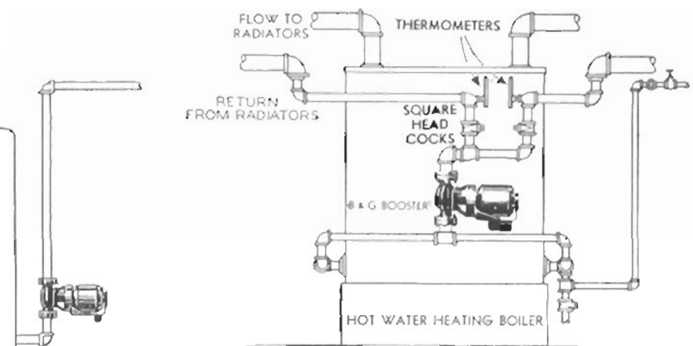


Fig. 166. Showing a B & G Booster used to improve circulation in an old gravity system. Lower boiler temperatures may be carried, thus reducing fuel consumption.

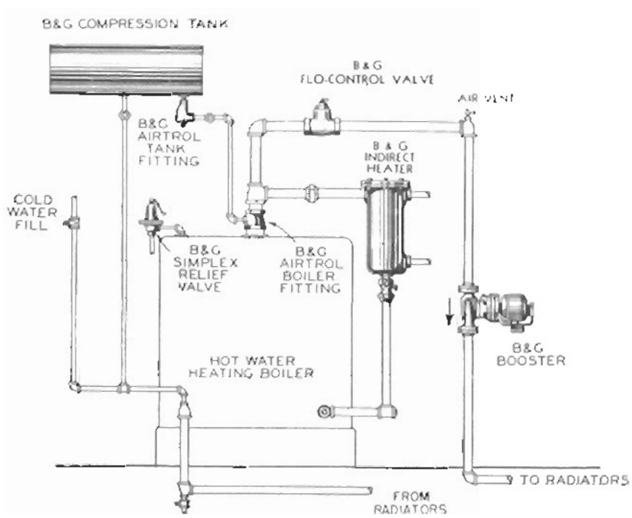


Fig. 167. Forced circulation system with radiators on same level as boiler and mains below floor. Note equalizing connection to compression tank.

SEE B & G CATALOG FOR DIMENSIONS AND COMPLETE DESCRIPTION

B & G *HYDRO-FLO* PRODUCTS (continued)

BOOSTER INSTALLATIONS (continued)

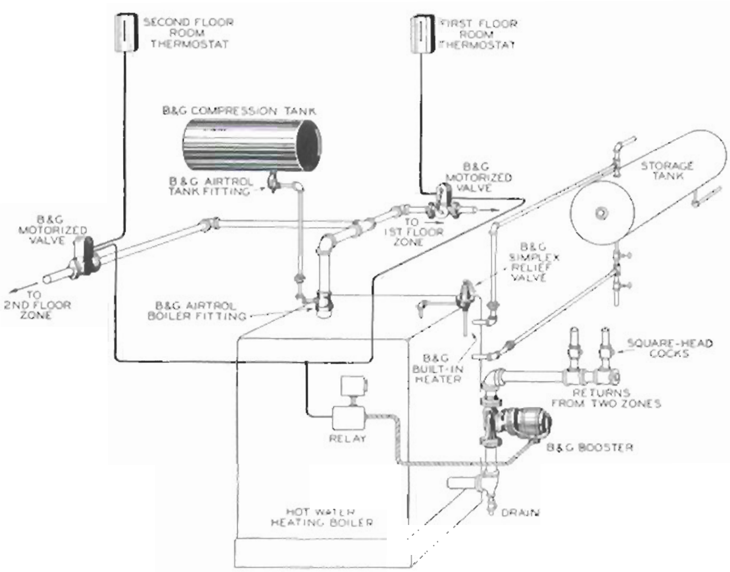


Fig. 168. Booster used in conjunction with Motorized Valves to provide a two zone control. The Motorized Valves are opened and closed by the room thermostats. The Booster starts simultaneously when either valve opens.

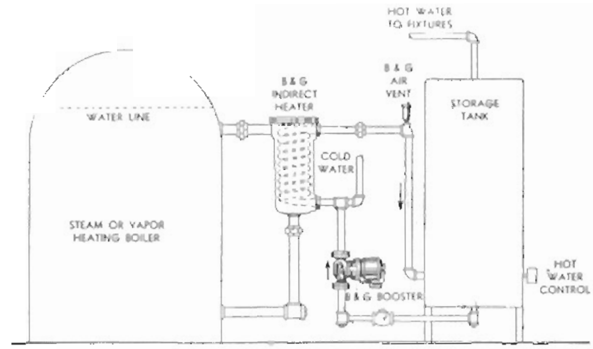


Fig. 171. Booster circulating the water between a B & G Indirect Heater and a vertical storage tank. Forced circulation assures ample hot water, not possible otherwise because of the low position of tank.

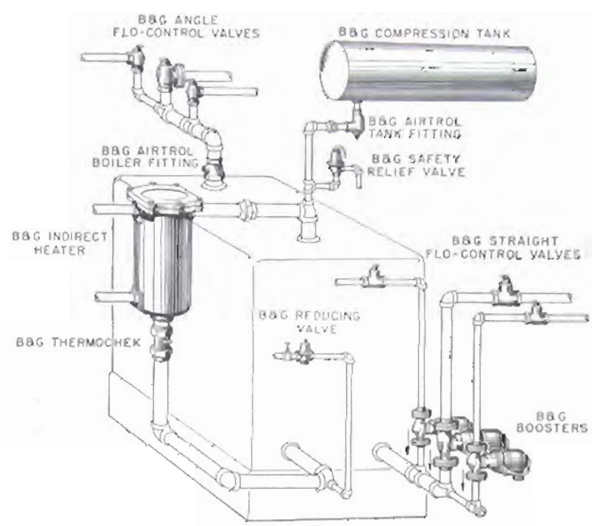


Fig. 172. Three zone hot water installation with B & G Boosters supplying forced circulation.

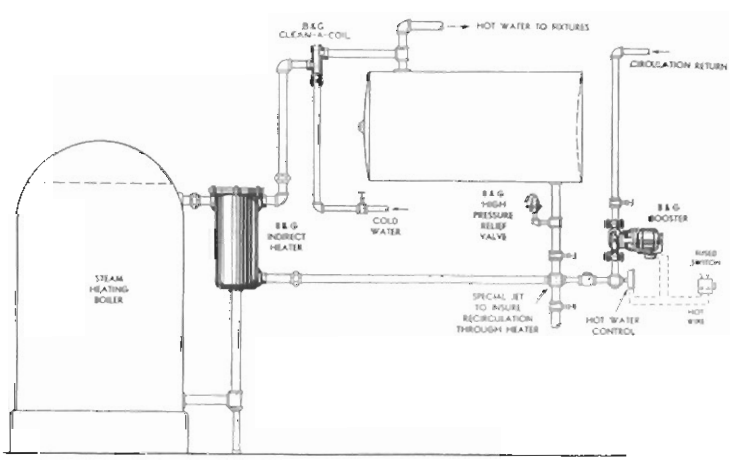


Fig. 169. B & G Booster used to circulate hot water to fixtures.

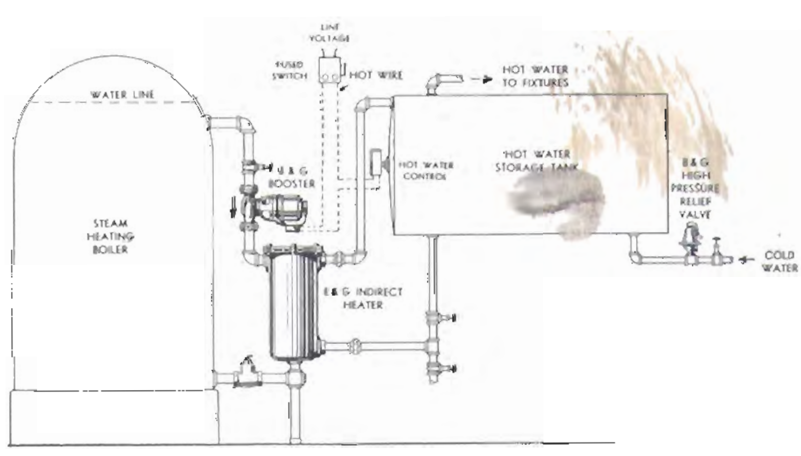
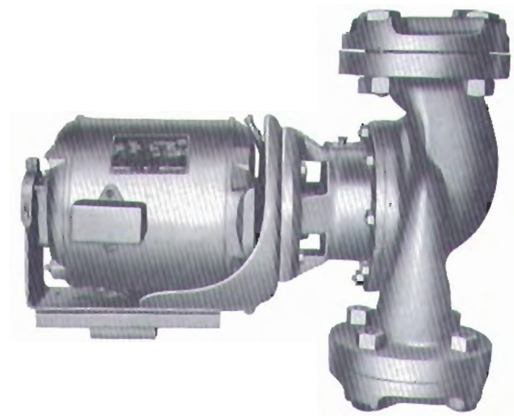


Fig. 170. B & G Booster used to circulate boiler water through a low heater.

SEE B & G CATALOG FOR DIMENSIONS AND COMPLETE DESCRIPTION

B & G *HYDRO-FLO* PRODUCTS (continued)

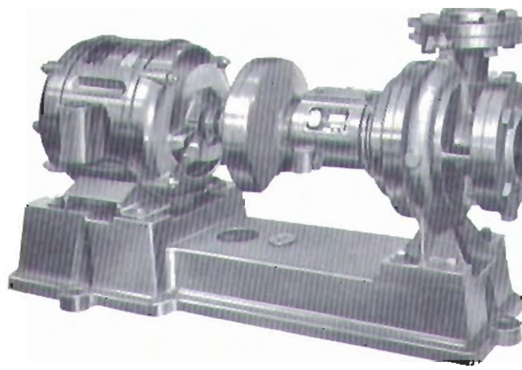
"PD" BOOSTER PUMPS



These Booster-type pumps are designed to fill the need for an intermediate range of heads and capacities between the standard B & G Booster and B & G Universal Pump. They are as large as is practical for a pipe-mounted circulator and have application in large apartments, industrial and commercial buildings, hospitals, schools and garden apartments.

"PD" Pumps have all the features of design and construction which have made the B & G Booster the largest selling pump in its field. See page 45 for capacities.

UNIVERSAL PUMPS



Where to use

THE B & G UNIVERSAL PUMP is designed primarily for large warm water heating systems in apartment buildings, office buildings, factories, schools, etc. The installation can be operated as one large single zone or divided into several zones by controlling the circulation of the pumped water through each circuit with a B & G Motorized Valve, operated by a zone thermostat; the pump being either operated continuously or until all valves are in the closed position. See page 45 for Capacity Chart.

MONOFLO FITTINGS

Where to use

Cast Iron
Monoflo Fitting

Copper
Monoflo Fitting

The obvious advantages of cost, neatness of installation and the elimination of involved designing in the one-pipe Monoflo System have justified its rapid growth in popularity.

The Monoflo Fitting is entirely different from other devices claiming to perform the same functions. For these reasons:—

1. It is scientifically designed to induce flow into the radiators without penalizing the pump with excessive resistance.
2. It is not dependent upon variations in main sizes to obtain proper resistances.
3. It permits radiators *below* the main to be operated as successfully as those above the main.
4. It maintains a uniform distribution of hot water to radiators, regardless of position.

Comparison with other fittings of this type will show Monoflo Fittings to be units of exceptionally precise manufacture. They are made by a machine designed especially for the purpose which taps the threads so accurately that installation is always easy.

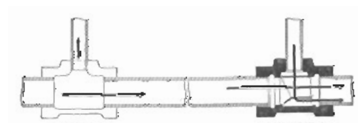


Fig. 173. For most installations where radiators are above the main, only one Monoflo Fitting need be used for each radiator.

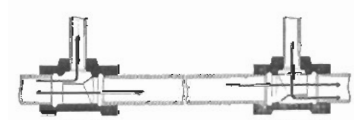


Fig. 174. Where structural characteristics of the installation might cause a question as to proper circulation, use both a Supply and Return Monoflo Fitting.

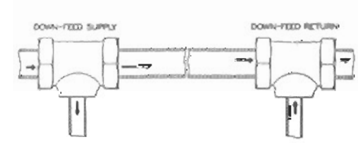


Fig. 175. Radiators below the main require the use of both a Supply and Return Monoflo Fitting. Just turn the Fitting over for down-feed operation.

SEE B & G CATALOG FOR SIZES AND DIMENSIONS

B & G *HYDRO-FLO* PRODUCTS (continued)

Angle Pattern Valve
Sizes 1" - 1¼" screwed 2 ends
1½" - 2" - 2½" - 3" flanged 1 end —screwed 1 end

Straight Pattern Valve
Sizes 1"-1¼"-1½" screwed 2 ends
2" - 2½" - 3" - 4" flanged 1 end —screwed 1 end

FLO-CONTROL VALVES

Where to use

Flo-Control Valves are used in forced circulation hot water heating systems to prevent the circulation of hot boiler water when heat is not needed in the radiators. They thus permit the year around operation of an Indirect Water Heater as well as providing a method of maintaining a uniform room temperature during heating season.

See Page 31 for Installation Diagrams

RELIEF AND REDUCING VALVES

Nos. 175-250-499-1000 Safety Relief Valves

Designed and Built to ASME Code Requirements
Tested by National Board and labelled with ASME symbol.

Not "pop" type valves! Diaphragm operation transmits more power during opening and closing of valve. These valves establish a new standard in low differential between opening and closing pressures. This is important if boiler is at high temperature, as dropping the boiler pressure considerably below that at which the boiler water will flash into steam can create an annoying hammering condition.

Metal-to-metal seats are ground and polished—no guides to stick or jam.

No. 175

Nos. 250 and 499

Under normal operating conditions, thermal expansion within the system lifts the valve just far enough to discharge water at a low rate of flow. Under emergency conditions, the valve is opened wide to its full rated capacity.

Capacities from 175,000 to 1,000,000 BTU/hr —maximum setting 30 lbs.

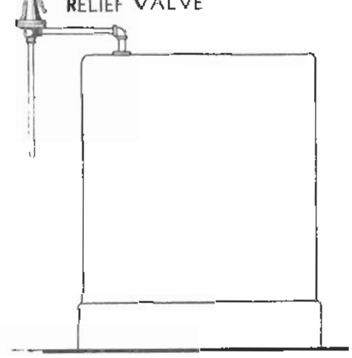


Fig. 176. Low Pressure Relief Valve installed on hot water boiler.

Simplex Relief Valve

Body is of heavy cast iron construction and valve seat of rust proof bronze. Any pressure in excess of 30 lbs. lifts the extremely large, phosphorus bronze diaphragm to relieve the system. The large area of the diaphragm assures ample lifting power and positive action. No guides to set up friction or become corroded.

Simplex

No. 1000

No. 3 Dual Unit Valve

The B & G No. 3 Dual Unit is a low-priced combination relief and reducing valve—yet is built to the high standards of all B & G Products and offers many outstanding superiorities. The body and all parts exposed to water are made of corrosion-proof metals—with built-in strainer and extra large relief diaphragm.

The Reducing Valve is factory-set at 12 lbs. but can be easily adjusted to meet varying building heights. No chattering—the special composition valve disk seats on stainless steel and is practically noiseless in operation.

Dual Unit

No. 8 Dual Unit Valve

Same valve as No. 3 Dual Unit, but with iron body.

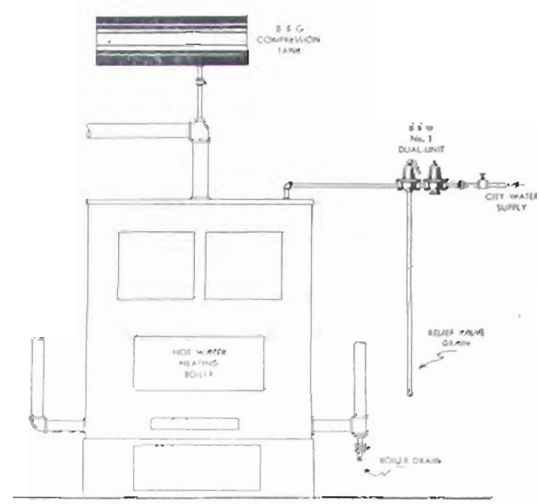
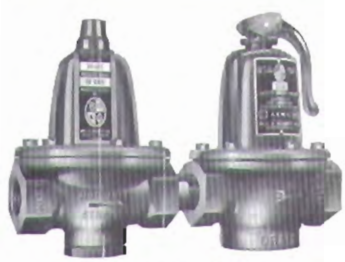


Fig. 177. Dual Unit Valve installed on hot water boiler.

SEE B & G CATALOG FOR SIZES

B & G *HYDRO-FLO* PRODUCTS (continued)



D-175 and D-250

Nos. A3 and A8

Nos. 4-5-9-10 High Pressure Relief Valve

No. 500

No. 12

Nos. B3 and B8

RELIEF AND REDUCING VALVES (continued)

Nos. D-175 and D-250 Dual Unit Valves

Designed and Built to ASME Code Requirements

Combination relief and reducing valves with the relief valve tested by the National Board and labelled with the ASME symbol. Capacities 175,000 and 250,000 BTU/hr—reducing valve factory-set at 12 lbs.

No. A3 (brass body) and No. A8 (iron body) Relief Valve

The same Relief Valve used in the B & G Dual Unit. Size ½″ only. Maximum setting 30 lbs.

Nos. 4-5-9-10 High Pressure Relief Valve

Designed to give protection against excess pressure in service water systems. Diaphragm operated, with all working parts made of brass. Nos. 4-5, brass body; Nos. 9-10, iron body.

No. 500 Self-Filling Valve

This unit combines the function of a Relief Valve, Reducing Valve, Strainer and By-Pass Valve, including an Emergency Relief Valve to protect boiler against water hammer in the domestic water system. All parts exposed to water are of corrosion-resistant bronze.

The relief valve opens at 30 lbs. pressure. The factory setting of the Reducing Valve is 12 lbs. and can be adjusted for varying building heights. By-Pass Valve is ½″ and permits rapid filling of the system—an exclusive feature. Relief Valve setting non-adjustable.

No. 510 Self-Filling Valve

Exact duplicate of No. 500—without Emergency Relief.

No. 12 Reducing Valve

All working parts are brass, with built-in strainer. Factory-adjusted at 12 lbs., suitable for 1, 2 and 3-story buildings. Easy adjustment.

Nos. B3 and B8 Reducing Valve

No. B3 has brass body—available only with male and female connection.

No. B8 has iron body—available only with male and female connection.

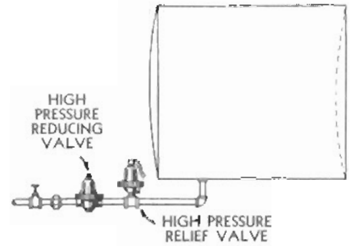


*Fig. 178. **Valve installation for domestic water service.***

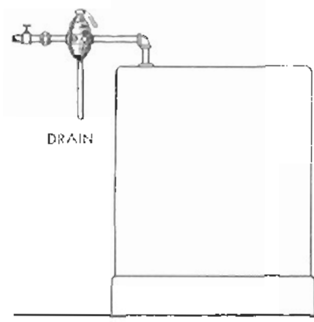


Fig. 179. No. 500 Valve installed on hot water boiler.

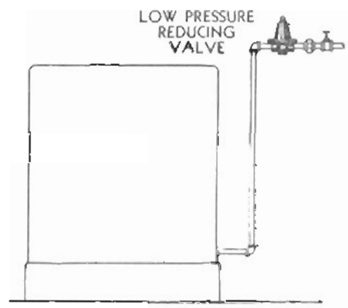


Fig. 180. Method of installing Low Pressure Reducing Valve on hot water boiler.

Nos. 6 and 7 High Pressure Reducing Valve

Protects plumbing fixtures against excessive line pressures. Factory-adjusted for 150 lbs. initial pressure, 45 lbs. delivery pressure. Other pressures must be specified when ordering. All parts brass, built-in strainer, extra large diaphragm.

SEE B & G CATALOG FOR SIZES

B & G *HYDRO-FLO* PRODUCTS (continued)

COMPRESSION TANK

Where to use

The use of a compression tank on closed hot water heating systems is now universally recognized as essential. Expansion of heated water is taken up by the tank, providing a cushion of compressed air against sudden pressures and water hammer shocks which might injure the boiler.

On high temperature installations, a closed system with a compression tank is absolutely imperative, in order that sufficient pressure can be developed to prevent boiling of the water in the system. B & G Compression Tanks can be installed either in the basement or any convenient place in the system.

B & G Compression Tanks are not to be confused with ordinary range boilers, but are built for the specific purpose of assuring safety to the system. They are carefully manufactured of copper-bearing steel, welded to absolute air-tightness and must pass exacting tests before leaving the factory.

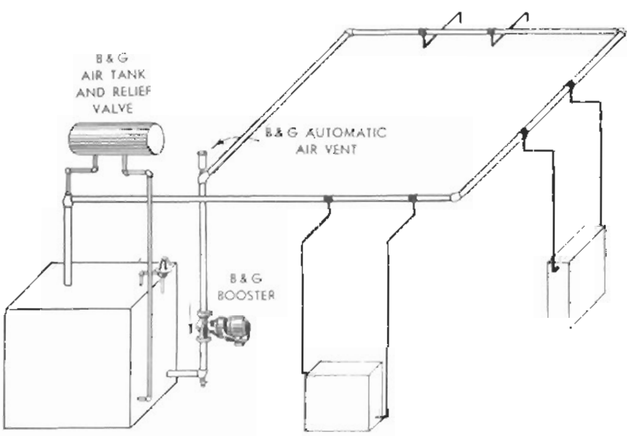


Fig. 182. System with all radiation below main.

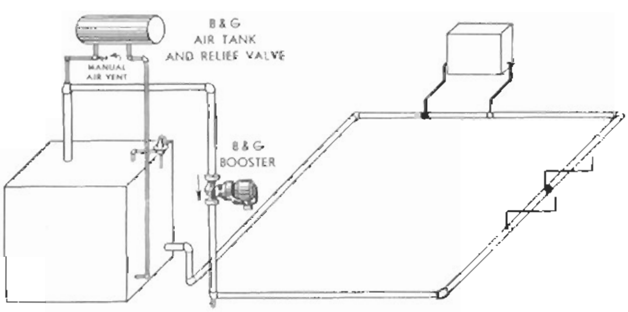


Fig. 183. System with main below floor and radiation on same level as boiler.

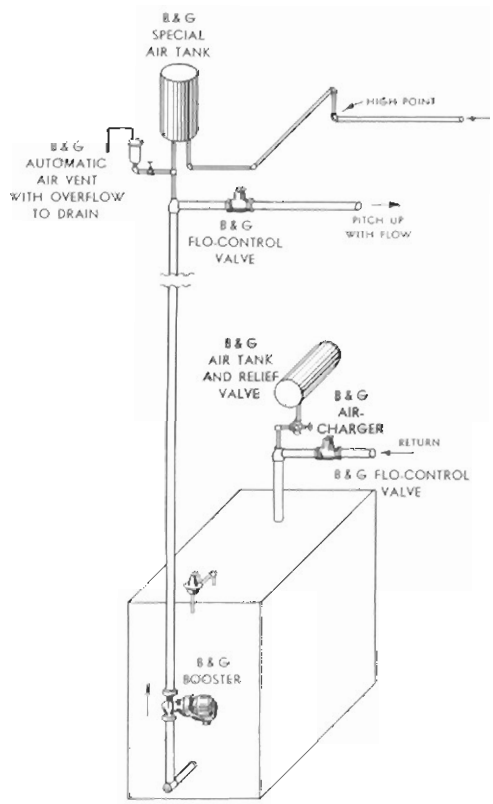


Fig. 184. Overhead system for high buildings.

AIR CHARGER AND TANK DRAINER

Five minutes' time and a simple twist of a valve handle twice each year will assure the owner of an "air charged" tank. No more water-logged tanks—*complete simple operating instructions come packed with each valve.* Size ½" with ⅛" tapping for vent tube.

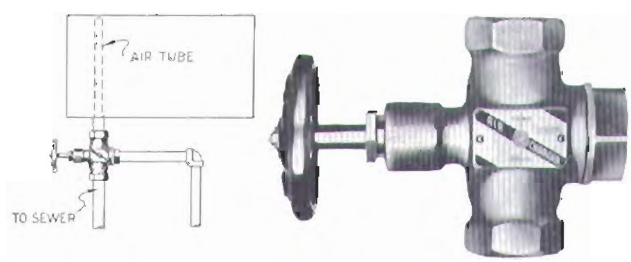


Fig. 185. Method of installing a B & G Air Charger and Tank Drainer.

SEE B & G CATALOG FOR SIZES AND CAPACITIES

B & G *HYDRO-FLO* PRODUCTS (continued)

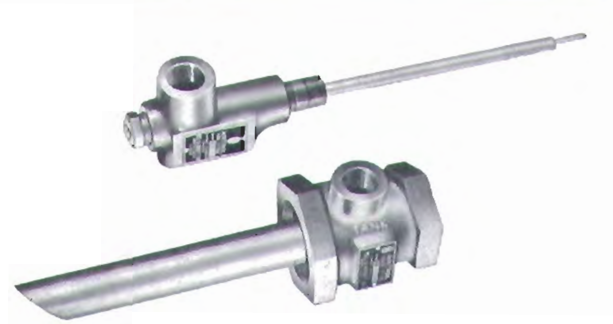
AIRTROL SYSTEM

Where to use

The B & G Airtrol System successfully eliminates the accumulation of air in the radiators of hot water heating systems—*an annoying problem never before satisfactorily solved!*

When water is heated it releases air in nearly direct proportion to the temperature of the water. In other words, the hotter the water, the less air it can hold in solution. Conversely, as the water cools it re-absorbs air until the original content is restored.

It is this physical relationship between air and water which in the past has caused air binding in the system and sometimes waterlogging of the expansion tank.



B & G Airtrol System now provides a genuine remedy—amazingly simple and effective. It consists of two basic parts—the Boiler Fitting and the Tank Fitting. Their combined function is to trap air in the compression tank and prevent its return to the boiler, piping and heat distributing units.

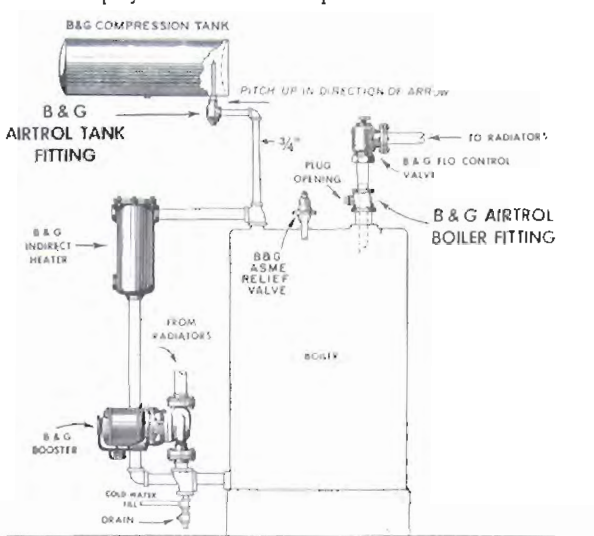


Fig. 186. Installation on boiler with external type water heater.

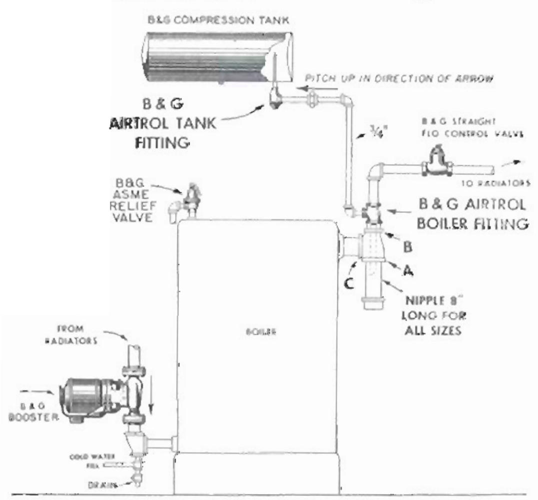


Fig. 187. Installation on boiler with side opening. See table below for correct sizes of reducing tee.

SIZES OF AIRTROL BOILER FITTINGS	SIZES OF REDUCING TEE		
	A	B	C
ABF—1"	2"	2"	
ABF—1¼"	2½"	2"	
ABF—1½"	3"	2"	Same As Boiler
ABF—2"	4"	3"	Outlet Tapping
ABF—2½"	6"	3"	
ABF—3"	6"	4"	
ABF—4"	8"	6"	

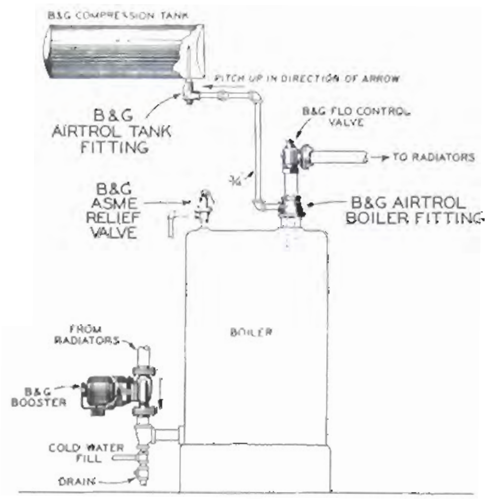


*Fig. 188. **Installation on boiler with built-in water heater.***

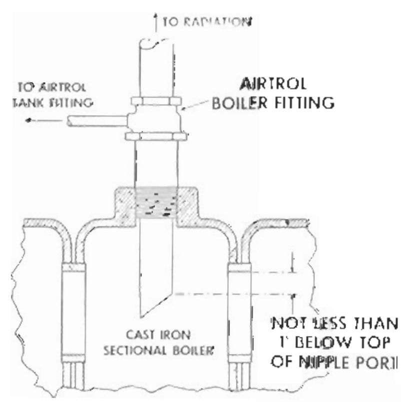


Fig. 189. Airtrol Boiler Fitting installation in cast iron boiler showing correct depth of tube.

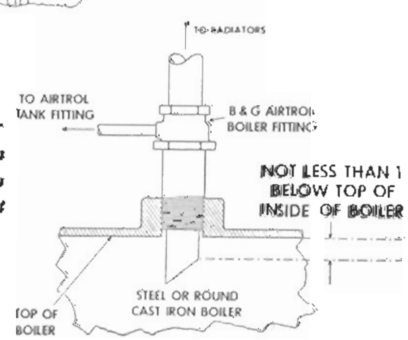


Fig. 190. Airtrol Boiler Fitting installation in steel or round cast iron boiler, showing correct depth of tube.

B & G *HYDRO-FLO* PRODUCTS (continued)

AIRTROL SYSTEM (continued)

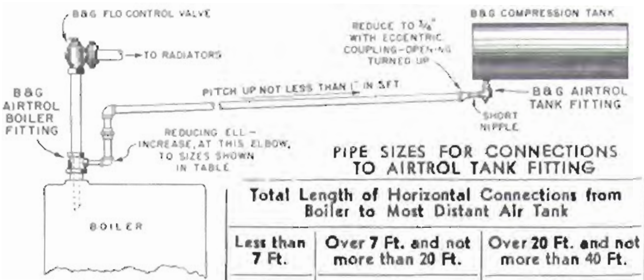


Fig. 191

PIPE SIZES FOR CONNECTIONS TO AIRTROL TANK FITTING

Total Length of Horizontal Connections from Boiler to Most Distant Air Tank		
Less than 7 Ft.	Over 7 Ft. and not more than 20 Ft.	Over 20 Ft. and not more than 40 Ft.
¾"	1"	1¼"

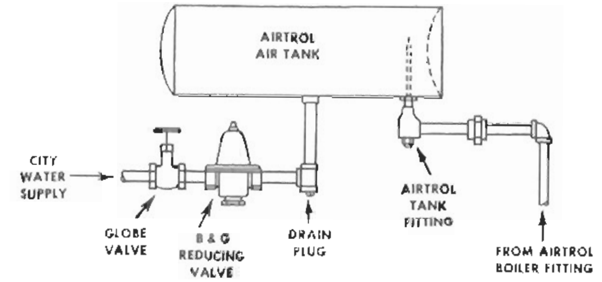
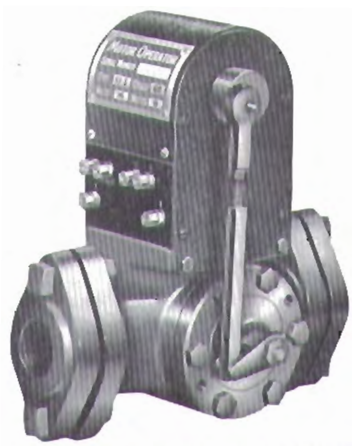


Fig. 192. Installation of B & G Reducing Valve for automatic fill.



MOTORIZED VALVE

For hot water systems only

Where to use

B & G Motorized Valves are ideal for zoned hot water heating systems, as they offer a positive control of boiler water flow at very small operating cost. For example, a six zone forced circulation system would require six Valves and one Booster pump. Since these Valves open in a few seconds and as they use no current when opened or closed, their economy of operation is apparent.

They are also used in gravity hot water systems to shut off the flow of boiler water when heat is not needed in the radiators. An indirect water heater can thus be used to supply domestic hot water the year around.

Very heavy construction is used in all moving parts, yet the valve is exceptionally compact. A straight-through instead of globe construction eliminates air-binding.

This Valve can be installed in either vertical or horizontal pipes and in any position except upside down. Transformer is furnished separately at no extra cost for mounting on any convenient outlet box. This Valve has auxiliary low voltage contact for energizing relay. Do not use this valve to control the flow of steam.

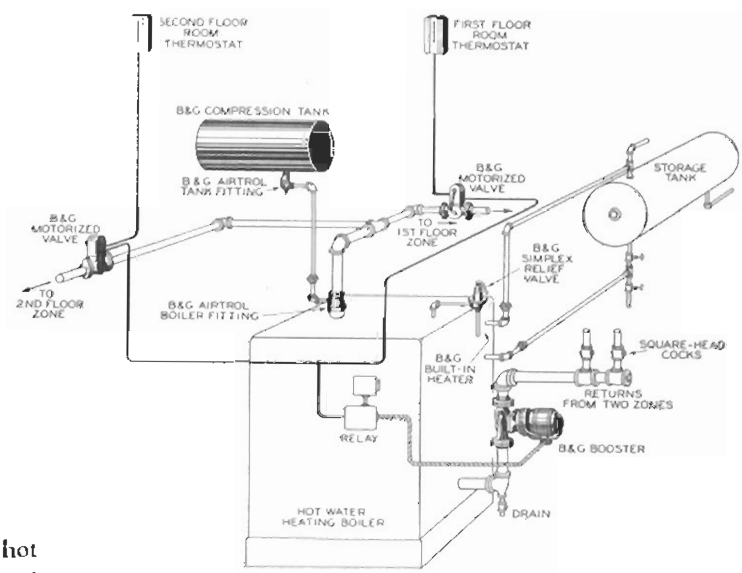


Fig. 193. Two zone forced hot water system with supply of heat controlled by B & G Motorized Valves.

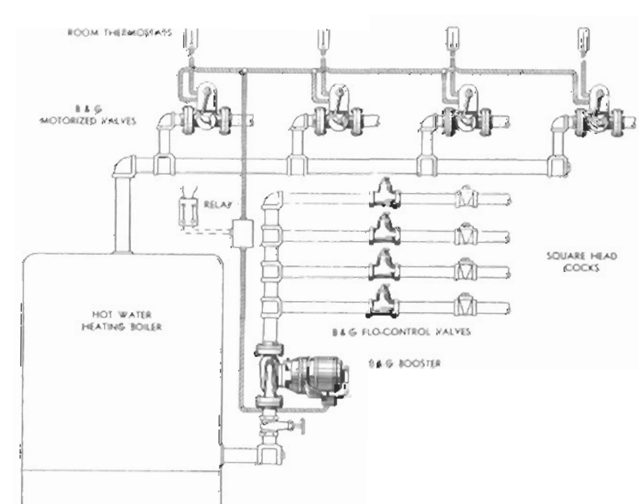


Fig. 194. Four zone forced hot water heating system with zones controlled by B & G Motorized Valves. The Booster starts simultaneously with the opening of any Motorized Valve.

SEE B & G CATALOG FOR SIZES AND DIMENSIONS

SECTION VI

SUPPLEMENTARY DATA

CLIMATIC CONDITIONS IN U. S. AND CANADA

COMPILED FROM WEATHER BUREAU RECORDS*

STATE	CITY	AVERAGE TEMPERATURE OCTOBER 1ST–MAY 1ST	LOWEST TEMPERATURE EVER REPORTED	AVERAGE WIND VELOCITY DEC., JAN., FEB., MILES PER HOUR	DIRECTION OF PREVAILING WIND DEC., JAN., FEB.
ALA.	BIRMINGHAM	53.8	−10	8.5	N
	MOBILE	58.9	−1	10.4	N
ARIZ.	FLAGSTAFF	35.8	−25	7.8	SW
	PHOENIX	59.5	12	6.4	E
ARK.	FORT SMITH	50.4	−15	8.1	E
	LITTLE ROCK	51.6	−12	8.7	NW
CALIF.	LOS ANGELES	58.5	28	6.3	NE
	SAN FRANCISCO	54.2	27	7.6	N
COLO.	DENVER	38.9	−29	7.5	S
	GRAND JUNCTION	38.9	−21	5.3	NW
CONN.	NEW HAVEN	38.4	−15	9.7	N
D. C.	WASHINGTON	43.4	−15	7.1	NW
FLA	JACKSONVILLE	62.0	10	9.2	NE
GA.	ATLANTA	51.5	−8	12.1	NW
	SAVANNAH	58.5	8	9.5	NW
IDAHO	LEWISTON	42.3	−23	5.3	E
	POCATELLO	35.7	−28	9.6	SE
ILL.	CHICAGO	36.4	−23	12.5	W
	SPRINGFIELD	39.8	−24	10.1	NW
IND.	EVANSVILLE	45.1	−16	9.8	S
	INDIANAPOLIS	40.3	−25	11.5	SW
IOWA	DUBUQUE	33.9	−32	7.1	NW
	SIOUX CITY	32.6	−35	11.6	NW
KANSAS	CONCORDIA	39.8	−25	8.1	S
	DODGE CITY	41.4	−26	9.8	NW
KY.	LOUISVILLE	45.3	−20	9.9	SW
LA.	NEW ORLEANS	61.6	7	8.8	N
	SHREVEPORT	56.2	−5	8.9	SE
ME.	EASTPORT	31.5	−23	12.0	W
	PORTLAND	33.8	−21	9.2	NW
MD.	BALTIMORE	43.8	−7	7.8	NW
MASS.	BOSTON	38.1	−18	11.2	W
MICH.	ALPENA	29.6	−28	12.4	W
	DETROIT	35.8	−24	12.7	SW
	MARQUETTE	28.3	−27	11.1	NW
MINN.	DULUTH	24.3	−41	12.6	SW
	MINNEAPOLIS	29.4	−33	11.3	NW
MISS.	VICKSBURG	56.8	−1	8.3	SE
MO.	ST. JOSEPH	40.7	−24	9.3	NW
	ST. LOUIS	43.6	−22	11.6	S
	SPRINGFIELD	44.3	−28	10.8	SE
MONT.	BILLINGS	34.0	−49	....	W
	HAVRE	27.6	−57	9.5	SW
NEBR.	LINCOLN	37.0	−29	10.5	S
	NORTH PLATTE	35.4	−35	8.5	W
NEV.	TONOPAH	39.4	−10	10.0	SE
	WINNEMUCCA	37.9	−28	8.7	NE
N. H.	CONCORD	33.3	−35	6.6	NW
N. J.	ATLANTIC CITY	41.6	−9	15.9	NW
N. Y.	ALBANY	35.2	−24	8.1	S
	BUFFALO	34.8	−20	17.2	W
	NEW YORK	40.7	−14	17.1	NW

* United States data from U. S. Weather Bureau.
Canadian data from Meteorological Service of Canada.

CLIMATIC CONDITIONS IN U. S. AND CANADA

COMPILED FROM WEATHER BUREAU RECORDS*

STATE OR PROVINCE	CITY	AVERAGE TEMPERATURE OCTOBER 1ST–MAY 1ST	LOWEST TEMPERATURE EVER REPORTED	AVERAGE WIND VELOCITY DEC., JAN., FEB., MILES PER HOUR	DIRECTION OF PREVAILING WIND DEC., JAN., FEB.
N. M.	SANTA FE	38.3	−13	7.8	NE
N. C.	RALEIGH	50.0	−2	8.2	SW
	WILMINGTON	54.2	5	8.5	SW
N. DAK.	BISMARCK	24.6	−45	9.1	NW
	DEVILS LAKE	20.3	−44	10.6	W
OHIO	CLEVELAND	37.2	−17	13.0	SW
	COLUMBUS	39.9	−20	12.0	SW
OKLA.	OKLAHOMA CITY	47.9	−17	12.0	N
OREG.	BAKER	35.2	−24	6.9	SE
	PORTLAND	46.1	−2	7.5	S
PA.	PHILADELPHIA	42.7	−6	11.0	NW
	PITTSBURGH	41.0	−20	11.7	W
R. I.	PROVIDENCE	37.2	−17	12.8	NW
S. C.	CHARLESTON	57.4	7	10.6	SW
	COLUMBIA	54.0	−2	8.1	NE
S. DAK.	HURON	28.2	−43	10.6	NW
	RAPID CITY	33.4	−34	8.2	W
TENN.	KNOXVILLE	47.9	−16	7.8	SW
	MEMPHIS	51.1	−9	9.7	S
TEXAS	EL PASO	53.5	−5	10.4	NW
	FORT WORTH	55.2	−8	10.4	NW
	SAN ANTONIO	60.6	4	8.0	NE
UTAH	MODENA	36.3	−24	8.8	W
	SALT LAKE CITY	40.0	−20	6.7	SE
VT.	BURLINGTON	31.5	−29	11.8	S
VA.	LYNCHBURG	46.8	−7	7.1	NW
	NORFOLK	49.3	2	12.5	N
	RICHMOND	47.0	−3	7.9	SW
WASH.	SEATTLE	44.8	3	11.3	SE
	SPOKANE	37.7	−30	7.1	SW
W. VA.	ELKINS	39.4	−28	6.6	W
	PARKERSBURG	42.6	−27	7.5	SW
WIS.	GREEN BAY	30.0	−36	10.4	SW
	LA CROSSE	31.7	−43	7.3	S
	MILWAUKEE	33.4	−25	11.5	W
WYO.	LANDER	30.0	−40	5.0	SW
	SHERIDAN	30.7	−41	6.0	NW
ALTA.	EDMONTON	23.0	−57	6.5	SW
B. C.	VANCOUVER	42.0	2	4.5	E
	VICTORIA	43.9	−1.5	12.5	N
MAN.	WINNIPEG	17.5	−47	10.0	NW
N. B.	FREDERICTON	27.0	−35	9.6	NW
N. S.	YARMOUTH	35.0	−12	14.2	NW
ONT.	LONDON	32.6	−27	10.3	SW
	OTTAWA	26.5	−34	8.4	NW
	PORT ARTHUR	22.4	−37	7.8	NW
	TORONTO	32.9	−26.5	13.0	SW
P. E. I.	CHARLOTTETOWN	29.0	−27	9.4	SW
QUEBEC	MONTREAL	27.8	−29	14.3	SW
	QUEBEC	24.2	−34	13.6	SW
SASK.	PRINCE ALBERT	15.8	−70	5.1	W
YUKON	DAWSON	2.1	−68	3.7	S

* United States data from U. S. Weather Bureau.
Canadian data from Meteorological Service of Canada.

SUPPLEMENTARY DATA

TABLE P — HEAT LOSS FACTORS

EXPOSED WALLS

No. 1. Frame, Not Insulated

- (*a*) Clapboards or wood siding, studs, lath and plaster or plaster board (no sheathing) 0.35
- (*b*) Same as (*1a*) with composition siding over wood siding 0.28
- (*c*) Wood siding, paper, sheathing, studs, lath and plaster or plaster board 0.25
- (*d*) Same as (*1c*) with composition siding over wood siding 0.21
- (*e*) Same as (*1c*) substituting asphalt or asbestos shingles for wood siding 0.30

No. 2. Frame, Insulated

- (*a*) Wood siding, paper, sheathing, studs, ½″ rigid insulation, plaster or plaster board 0.19
- (*b*) Wood siding, 25/32″ rigid insulation, studs, lath and plaster or plaster board 0.19
- (*c*) Wood siding, paper, sheathing, ½″ flexible insulation in contact with sheathing, studs, lath and plaster or plaster board 0.17
- (*d*) Same as (*2c*) with air space on both sides of insulation 0.15
- (*e*) Same as (*2c*) substituting 3⅝″ rock wool or equivalent for ½″ flexible insulation 0.08
- (*f*) Same as (*2c*) substituting 2″ rock wool or equivalent for ½″ flexible insulation 0.10

No. 3. Brick, Not Insulated

- (*a*) 8″ Brick, plaster or plaster board one side 0.46
- (*b*) 8″ Brick, furred, lath and plaster or plaster board one side 0.30
- (*c*) 12″ Brick, plaster or plaster board one side 0.35
- (*d*) 12″ Brick, furred, lath and plaster or plaster board one side 0.24
- (*e*) 4″ Brick, 8″ hollow tile, plaster or plaster board one side 0.33
- (*f*) 4″ Brick, 8″ hollow tile or cinder block, furred lath and plaster or plaster board 0.24
- (*g*) 4″ Brick, paper, sheathing, studs, lath and plaster or plaster board 0.27
- (*h*) 4″ Brick, 4″ light weight aggregate block, furred, lath and plaster or plaster board 0.21

No. 4. Brick, Insulated

- (*a*) 8″ Brick, furred, ½″ rigid insulation, plaster or plaster board one side 0.22
- (*b*) 12″ Brick, furred, ½″ rigid insulation, plaster or plaster board one side 0.19
- (*c*) 4″ Brick, 8″ hollow tile, ½″ rigid insulation, plaster or plaster board one side 0.18
- (*d*) 4″ Brick, 4″ light weight aggregate block, ½″ rigid insulation, plaster or plaster board one side 0.16
- (*e*) 4″ Brick, paper, sheathing, studs, rigid insulation, plaster or plaster board 0.20
- (*f*) 4″ Brick, 25/32″ rigid insulation, studs, lath and plaster or plaster board 0.21
- (*g*) 4″ Brick, paper, sheathing, 3⅝″ rock wool or equivalent, studs, lath and plaster or plaster board 0.08
- (*h*) Same as (*4g*) substituting 2″ blanket for 3⅝″ blanket insulation 0.10

EXPOSED WALLS

No. 5. Hollow Tile

- (*a*) 8″ Tile, stucco exterior, furred, lath and plaster or plaster board 0.26
- (*b*) Same as (*5a*) substituting ½″ rigid insulation for lath 0.20

No. 6. Hollow Concrete Block, Gravel Aggregate

- (*a*) 8″ Block, plain, above grade 0.56
- (*b*) Same as (*6a*) plaster or plaster board one side 0.51
- (*c*) Same as (*6a*) furred, lath and plaster or plaster board 0.32
- (*d*) Same as (*6c*) substituting ½″ rigid insulation for lath 0.23
- (*e*) Same as (*6a*) basement wall below grade 0.06
- (*f*) 12″ Block, plain, above grade 0.49
- (*g*) Same as (*6f*) basement wall below grade 0.06

No. 7. Hollow Concrete Block, Cinder Aggregate

- (*a*) 8″ Block, plain 0.42
- (*b*) Same as (*7a*) plaster or plaster board one side 0.39
- (*c*) Same as (*7a*) furred, lath and plaster or plaster board 0.27
- (*d*) Same as (*7c*) substituting ½″ rigid insulation for lath 0.20

No. 8. Hollow Concrete Block, Light Weight Aggregate

- (*a*) 8″ Block, no interior finish 0.37
- (*b*) Same as (*8a*) plaster or plaster board one side 0.35
- (*c*) Same as (*8a*) furred, lath and plaster or plaster board 0.26
- (*d*) Same as (*8c*) substituting ½″ insulating board for lath 0.19
- (*e*) Same as (*8c*) plus 1″ insulating blanket 0.13

No. 9. Poured Concrete

- (*a*) 8″ Wall, above grade 0.69
- (*b*) 8″ Wall, below grade 0.06
- (*c*) 12″ Wall, above grade 0.56
- (*d*) 12″ Wall, below grade 0.06

No. 10. Limestone or Sandstone

- (*a*) 8″ Stone, furred, lath and plaster or plaster board 0.37
- (*b*) Same as (*10a*) substituting ½″ rigid insulation for lath 0.25
- (*c*) 12″ Stone, furred, lath and plaster or plaster board 0.33
- (*d*) Same as (*10c*) substituting ½″ rigid insulation for lath 0.23
- (*e*) 12″ Stone below grade 0.06
- (*f*) 16″ Stone below grade 0.06

No. 11. Glass Block

- (*a*) 3⅝″ Block, corrugated surface 0.49

SUPPLEMENTARY DATA

TABLE P — HEAT LOSS FACTORS

PARTITIONS

No. 12. Frame

(*a*)	With lath and plaster or plaster board one side only	0.31
(*b*)	Same as (*12a*) substituting ½″ rigid insulation for lath	0.18
(*c*)	Same as (*12a*) with ½″ rigid insulation on exposed side	0.13
(*d*)	With lath and plaster or plaster board both sides	0.17
(*e*)	Same as (*12d*) substituting ½″ rigid insulation for lath	0.10
(*f*)	Same as (*12d*) with 3⅝″ rock wool or equivalent	0.04
(*g*)	Same as (*12d*) with 2″ rock wool or equivalent	0.06

CEILINGS

No. 13. Attic Space Above

(*a*)	Lath and plaster or plaster board, no floor above	0.32
(*b*)	Lath and plaster or plaster board, tight floor above	0.20
(*c*)	Same as (*13a*) substituting ½″ rigid insulation for lath	0.23
(*d*)	Same as (*13b*) substituting ½″ rigid insulation for lath	0.16
(*e*)	Same as (*13a*) with ½″ rigid insulation on top of joists	0.18
(*f*)	Same as (*13a*) or (*13b*) with 3⅝″ rock wool or equivalent	0.08
(*g*)	Same as (*13f*) except with 2″ rock wool or equivalent	0.13

No. 14. Part of Single Roof — No Attic Space

(*a*)	Lath and plaster or plaster board, rafter, sheathing, shingles	0.29
(*b*)	Same as (*14a*) substituting ½″ rigid insulation for lath	0.21
(*c*)	Same as (*11a*) with 3⅝″ rock wool or equivalent	0.08
(*d*)	Same as (*11a*) with 2″ rock wool or equivalent	0.10

No. 15. Part of Built-up Roof — No Attic Space

(*a*)	Lath and plaster or plaster board, rafter, sheathing, built-up roofing	0.49
(*b*)	Same as (*15a*) substituting ½″ rigid insulation for lath	0.23
(*c*)	Same as (*15a*) with 3⅝″ rock wool or equivalent	0.08
(*d*)	*Same as* (*15a*) with 2″ rock wool or equivalent	0.13

No. 16. Part of Metal Roof — No Attic Space

(*a*)	Lath and plaster or plaster board, joists, sheathing, metal roof	0.26
(*b*)	Same as (*16a*) substituting ½″ rigid insulation for lath	0.18
(*c*)	Same as (*16a*) with 3⅝″ rock wool or equivalent	0.08
(*d*)	Same as (*16a*) with 2″ rock wool or equivalent	0.10

FLOORS

No. 17. Wood, Over Exposed or Unheated Space

(*a*)	Double floor on joists over enclosed, unheated space	0.17
(*b*)	Same as (*17a*) over exposed space	0.35
(*c*)	Same as (*17a*) with ½″ rigid insulation on bottom of joists	0.10
(*d*)	Same as (*17b*) with ½″ rigid insulation on bottom of joists	0.18
(*e*)	Same as (*17a*) with 2″ rock wool or equivalent between joists	0.06
(*f*)	Same as (*17*b) with 2″ rock wool or equivalent between joists	0.13
(*g*)	Same as (*17a*) with 3⅝″ rock wool or equivalent between joists	0.04
(*h*)	Same as (*17b*) with 3⅝″ rock wool or equivalent between joists	0.08

No. 18. Concrete

(*a*)	4″ thick floor on ground	0.06
(*b*)	4″ thick floor on 3″ cinder fill	0.06
(*c*)	Same as (*18b*) with hardwood floor on pine sub-floor	0.06
(*d*)	Floor on ground, below grade	0.04

WINDOWS

No. 19. Windows

(*a*)	Single (no storm sash)	1.13
(*b*)	With storm sash or double glazed	0.45
(*c*)	Double glazed with ¼″ air space	0.60

EXTERIOR DOORS

No. 20. With or Without Glass

Same as Windows

INFILTRATION

(Based on volume of room in cubic feet)

No. 21. Windows and Doors Without Weather-stripping or Storm Sash

(*a*)	Rooms with windows or exterior doors on one side only	0.017
(*b*)	Rooms with windows or exterior doors on two sides	0.027
(*c*)	Rooms with windows or exterior doors on three sides	0.036
(*d*)	Entrance Halls	0.036
(*e*)	Sun Rooms with many windows on three sides	0.054

No. 22. Windows and Doors Weatherstripped or with Storm Sash

(*a*)	Rooms with windows or exterior doors on one side only	0.011
(*b*)	Rooms with windows or exterior doors on two sides	0.017
(*c*)	Rooms with windows or exterior doors on three sides	0.027
(*d*)	Entrance Halls	0.027
(*e*)	Sun Rooms with many windows on three sides	0.036

SUPPLEMENTARY DATA

TABLE R — BTU/Hr REQUIREMENTS FOR AREAS AND VOLUME

70° F Indoor Minus Outdoor Temperature Difference

Btu/Hr. Required	WINDOW AND DOOR AREAS Sq. Ft.			INFILTRATION Room Volume, Cu. Ft.					WALL, CEILING AND FLOOR AREAS, SQ. FT.										
	FACTORS			FACTORS					FACTORS										
	0.45	0.60	1.13	0.011	0.017	0.027	0.036	0.054	.0.04	0.06	0.08	0.10	0.13	0.15	0.16	0.17	0.18	0.19	0.20
100	3.2	2.4	1.3	130	84	52.9	39.7	26.5	35.7	23.8	17.9	14.3	10.9	9.5	8.9	8.4	7.9	7.5	7.1
200	6.4	4.8	2.5	260	168	106	79.4	52.9	71.4	47.6	35.7	28.6	21.9	19.0	17.8	16.8	15.9	15.0	14.3
300	9.5	7.1	3.8	390	252	159	119	79.4	107	71.4	53.6	42.9	32.9	28.5	26.7	25.2	23.8	22.6	21.4
400	12.7	9.5	5.1	519	336	212	159	106	143	95.2	71.4	57.1	43.9	38.1	35.7	33.6	31.7	30.1	28.6
500	15.9	11.9	6.3	649	420	265	198	132	179	119	89.3	71.4	54.9	47.6	44.6	42.0	39.7	37.6	35.7
600	19.0	14.3	7.6	779	504	317	238	159	214	143	107	85.7	65.9	57.1	53.6	50.4	47.6	45.1	42.9
700	22.2	16.7	8.8	909	588	370	278	185	250	167	125	100	76.9	66.7	62.5	58.8	55.6	52.6	50.0
800	25.4	19.0	10.1	1039	672	423	317	212	286	190	143	114	87.9	76.1	71.4	67.2	63.5	60.1	57.1
900	28.6	21.4	11.4	1169	756	476	352	238	321	214	161	129	98.9	85.7	80.3	75.6	71.4	67.7	64.3
1000	31.7	23.8	12.6	1299	840	529	397	265	357	238	179	143	110	95.2	89.3	84.0	79.4	75.2	71.4
1100	34.9	26.2	13.9	1429	924	582	437	291	393	262	196	157	121	105	98.2	92.4	87.3	82.7	78.6
1200	38.1	28.6	15.1	1558	1008	635	476	317	429	286	214	171	132	114	107	101	95.2	90.2	85.7
1300	41.3	31.0	16.4	1688	1092	688	516	344	464	310	232	186	143	124	116	109	103	97.7	92.8
1400	44.4	33.3	17.7	1818	1176	741	556	370	500	333	250	200	154	133	125	118	111	105	100
1500	47.6	35.7	18.9	1948	1260	794	595	397	536	357	268	214	165	143	134	126	119	113	107
1600	50.8	38.1	20.2	2078	1345	846	635	423	571	381	286	229	176	152	143	134	127	120	114
1700	53.9	40.5	21.5	2208	1429	899	675	450	607	405	304	243	187	162	152	143	135	128	121
1800	57.1	42.9	22.7	2338	1513	952	714	476	643	429	321	257	198	171	161	151	143	135	129
1900	60.3	45.2	24.0	2468	1597	1005	754	503	679	452	339	271	209	181	170	160	151	143	136
2000	63.5	47.6	25.2	2597	1681	1058	794	529	714	476	357	286	220	190	179	168	159	150	143
2100	66.7	50.0	26.5	2727	1765	1111	833	556	750	500	375	300	231	200	187	176	167	158	150
2200	69.8	52.4	27.8	2857	1849	1164	873	582	786	524	393	314	242	210	196	185	175	165	157
2300	73.0	54.8	29.0	2987	1933	1217	913	608	821	548	411	329	253	219	205	193	183	173	164
2400	76.2	57.1	30.3	3117	2017	1270	952	635	857	571	429	343	264	229	214	202	190	180	171
2500	79.4	59.5	31.6	3247	2101	1323	992	661	893	595	446	357	275	238	223	210	198	188	179
2600	82.5	61.9	32.8	3377	2185	1376	1032	688	929	619	464	371	286	248	232	218	206	195	186
2700	85.7	64.3	34.1	3506	2269	1429	1071	714	964	643	482	386	297	257	241	227	214	203	193
2800	88.9	66.7	35.3	3636	2353	1481	1111	741	1000	667	500	400	308	267	250	235	222	211	200
2900	92.0	69.0	36.6	3766	2437	1534	1151	767	1036	690	518	414	319	276	259	244	230	218	207
3000	95.2	71.4	37.9	3896	2521	1587	1190	794	1071	714	536	429	330	286	268	252	238	226	214
3100	98.4	73.8	39.1	4026	2605	1640	1230	820	1107	738	554	443	341	295	277	260	246	233	221
3200	101	76.2	40.4	4156	2689	1693	1270	847	1143	762	571	457	352	305	286	269	254	241	229
3300	105	78.6	41.6	4286	2773	1746	1310	873	1179	786	589	471	363	314	295	277	262	248	236
3400	108	81.0	42.9	4416	2857	1799	1349	899	1214	810	607	486	374	324	304	286	270	256	243
3500	111	83.3	44.2	4545	2941	1852	1389	926	1250	833	625	500	385	333	312	294	278	263	250
3600	114	85.7	45.4	4675	3025	1905	1429	952	1286	857	643	514	396	343	321	303	286	271	257
3700	117	88.1	46.7	4805	3109	1958	1468	979	1321	881	661	529	407	352	330	311	294	278	264
3800	121	90.5	48.0	4935	3193	2011	1509	1005	1357	905	679	543	418	362	339	319	302	286	271
3900	124	92.9	49.2	5065	3277	2063	1548	1032	1393	929	696	557	429	371	348	328	310	293	279
4000	127	95.2	50.5	5195	3361	2116	1587	1058	1429	952	714	571	440	381	357	336	317	301	286
4100	130	97.6	51.7	5325	3445	2169	1627	1085	1464	976	732	586	451	390	366	345	325	308	293
4200	133	100	53.0	5455	3529	2222	1667	1111	1500	1000	750	600	461	400	375	353	333	316	300
4300	136	102	54.2	5584	3613	2275	1706	1138	1536	1024	768	614	472	409	384	361	341	323	307
4400	140	105	55.5	5714	3697	2328	1746	1164	1571	1048	786	629	483	419	393	370	349	331	314
4500	143	107	56.7	5844	3781	2381	1786	1190	1607	1071	804	643	494	429	402	378	357	338	321
4600	146	110	58.1	5974	3866	2434	1825	1217	1643	1095	821	657	505	438	411	387	365	346	329
4700	149	112	59.3	6104	3950	2487	1865	1243	1679	1119	839	671	516	448	420	395	373	353	336
4800	152	114	60.6	6234	4034	2540	1905	1270	1714	1143	857	686	527	457	429	403	381	361	343
4900	156	117	61.8	6364	4118	2593	1944	1296	1750	1167	875	700	538	467	437	412	389	368	350
5000	159	119	63.1	6494	4202	2645	1984	1323	1786	1190	893	714	549	476	446	420	397	376	357

TO USE THIS TABLE Enter at top under factor determined from Table P.
Read down to nearest value in sq. ft. or cu. ft.
Read to left to determine the BTU/Hr required.

SUPPLEMENTARY DATA

TABLE R BTU/Hr REQUIREMENTS FOR AREAS AND VOLUME
70° F Indoor Minus Outdoor Temperature Difference

Btu/Hr. Required	WALL, CEILING AND FLOOR AREAS, SQ. FT. — FACTORS																					
	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.35	0.37	0.39	0.42	0.46	0.49	0.51	0.56	0.69
100	6.8	6.5	6.2	5.9	5.7	5.5	5.3	5.1	4.9	4.8	4.6	4.5	4.3	4.1	3.9	3.7	3.4	3.1	2.9	2.8	2.6	2.1
200	13.6	12.9	12.4	11.9	11.4	10.9	10.5	10.2	9.9	9.5	9.2	8.9	8.7	8.2	7.7	7.3	6.8	6.2	5.8	5.6	5.1	4.1
300	20.4	19.5	18.6	17.9	17.1	16.5	15.8	15.3	14.8	14.3	13.8	13.4	13.0	12.2	11.6	10.9	10.2	9.3	8.7	8.4	7.7	6.2
400	27.2	25.9	24.8	23.8	22.8	21.9	21.1	20.4	19.7	19.0	18.4	17.9	17.3	16.3	15.4	14.7	13.6	12.4	11.7	11.2	10.2	8.3
500	34.0	32.4	31.0	29.7	28.5	27.5	26.4	25.5	24.6	23.8	23.0	22.3	21.6	20.4	19.3	18.3	17.0	15.5	14.6	14.0	12.8	10.4
600	40.8	38.9	37.2	35.7	34.2	32.9	31.7	30.6	29.6	28.6	27.6	26.8	26.0	24.5	23.1	22.0	20.4	18.6	17.5	16.8	15.3	12.4
700	47.6	45.4	43.4	41.6	39.9	38.5	37.0	35.7	34.5	33.3	32.3	31.2	30.3	28.6	27.0	25.6	23.8	21.7	20.4	19.6	17.9	14.5
800	54.4	51.9	49.6	47.6	45.7	43.9	42.3	40.8	39.4	38.1	36.9	35.7	34.6	32.6	30.9	29.3	27.2	24.8	23.3	22.4	20.4	16.6
900	61.2	58.4	55.8	53.5	51.4	49.4	47.6	45.9	44.3	42.8	41.5	40.2	39.0	36.7	34.7	33.0	30.6	27.9	26.2	25.2	23.0	18.6
1000	68.0	64.9	62.1	59.5	57.1	54.9	52.9	51.0	49.3	47.6	46.1	44.6	43.3	40.8	38.6	36.6	34.0	31.1	29.1	28.0	26.0	20.7
1100	74.8	71.4	68.3	65.4	62.8	60.4	58.2	56.1	54.2	52.4	50.7	49.1	47.6	44.9	42.5	40.3	37.4	34.2	32.1	30.8	28.1	22.8
1200	81.6	77.9	74.5	71.4	68.5	65.9	63.5	61.2	59.1	57.1	55.3	53.6	52.0	49.0	46.3	44.0	40.8	37.3	35.0	33.6	30.6	24.8
1300	88.4	84.4	80.7	77.3	74.2	71.4	68.9	66.3	64.0	61.9	59.9	58.0	56.3	53.1	50.2	47.6	44.2	40.4	37.9	36.4	33.2	26.9
1400	95.2	90.9	86.9	83.3	79.9	76.9	74.1	71.4	69.0	66.7	64.5	62.5	60.6	57.1	54.0	51.3	47.6	43.5	40.8	39.2	35.7	29.0
1500	102	97.3	93.1	89.2	85.7	82.4	79.4	76.5	73.9	71.4	69.1	67.0	65.0	61.2	57.9	54.9	51.0	46.6	43.7	42.0	38.3	31.0
1600	109	104	99.3	95.2	91.4	87.9	84.7	81.6	78.8	76.2	73.7	71.4	69.3	65.3	61.8	58.6	54.4	49.7	46.6	44.8	40.8	33.1
1700	116	110	106	101	97.1	93.3	89.9	86.7	83.7	80.9	78.3	75.9	73.6	69.4	65.6	62.3	57.8	52.8	49.5	47.6	43.4	35.2
1800	122	117	112	107	103	98.8	95.2	91.8	88.7	85.7	82.9	80.4	77.9	73.5	69.5	65.9	61.2	55.9	52.5	50.4	45.9	37.3
1900	129	123	118	113	109	104	100	96.9	93.6	90.5	87.6	84.8	82.3	77.5	73.3	69.6	64.6	59.0	55.4	53.2	48.5	39.3
2000	136	130	124	119	114	110	106	102	98.5	95.2	92.1	89.3	86.6	81.6	77.2	73.3	68.0	62.1	58.3	56.0	51.0	41.4
2100	143	136	130	125	120	115	111	107	103	100	96.8	93.7	90.9	85.7	81.1	76.9	71.4	65.2	61.2	58.8	53.6	43.5
2200	150	143	137	131	126	121	116	112	108	105	101	98.2	95.2	89.8	84.9	80.6	74.8	68.3	64.1	61.6	58.7	45.5
2300	156	149	143	137	131	126	122	117	113	110	106	103	99.6	93.8	88.8	84.2	78.2	71.4	67.0	64.4	61.2	47.6
2400	163	156	149	143	137	132	127	122	118	114	111	107	104	97.9	92.6	87.9	81.6	74.5	69.9	67.2	63.8	49.7
2500	170	162	155	149	143	137	132	127	123	119	115	112	108	102	96.5	91.6	85.0	77.6	72.9	70.0	66.3	51.8
2600	177	169	161	155	149	143	138	133	128	124	120	116	113	106	100	95.2	88.4	80.7	75.8	72.8	68.9	53.8
2700	184	175	168	161	154	148	143	138	133	129	124	121	117	110	104	98.9	91.8	83.8	78.7	75.6	71.4	55.9
2800	190	182	174	167	160	154	148	143	138	133	129	125	121	114	108	103	95.2	86.9	81.6	78.4	74.0	58.0
2900	197	188	180	173	166	159	153	148	143	138	134	129	126	118	112	106	98.6	90.0	84.5	81.2	76.5	60.0
3000	204	195	186	179	171	165	159	153	148	143	138	134	130	122	116	110	102	93.2	87.4	84.0	79.1	62.1
3100	211	201	193	185	177	170	164	158	153	148	143	138	134	127	120	114	105	96.3	90.3	86.8	81.6	64.2
3200	218	208	199	190	183	176	169	163	158	152	147	143	139	131	124	117	109	99.4	93.2	89.6	84.2	66.2
3300	224	214	205	196	189	181	175	168	163	157	152	147	143	135	127	121	112	102	96.2	92.4	86.7	68.3
3400	231	221	211	202	194	187	180	173	167	162	157	152	147	139	131	125	116	106	99.1	95.2	89.3	70.4
3500	238	227	217	208	200	192	185	179	172	167	161	156	152	143	135	128	119	109	102	98.0	91.8	72.5
3600	245	234	223	214	206	198	190	184	177	171	166	161	156	147	139	132	122	112	105	101	94.4	74.5
3700	252	240	230	220	211	203	196	189	182	176	170	165	160	151	143	136	126	115	108	104	96.9	76.6
3800	258	247	236	226	217	209	201	194	187	181	175	170	165	155	147	139	129	118	111	106	99.5	78.7
3900	265	253	242	232	223	214	206	199	192	186	180	174	169	159	151	143	133	121	114	109	102	80.7
4000	272	260	248	238	229	220	212	204	197	190	184	179	173	163	154	147	136	124	117	112	105	82.8
4100	279	266	255	244	234	225	217	209	202	195	189	183	177	167	158	150	139	127	119	115	107	84.9
4200	286	273	261	250	240	231	222	214	207	200	194	187	182	171	162	154	143	130	122	118	110	86.9
4300	292	279	267	256	246	236	228	219	212	205	198	192	186	175	166	158	146	134	125	120	112	89.0
4400	299	286	273	262	251	242	233	224	217	209	203	196	190	180	170	161	150	137	128	123	115	91.1
4500	306	292	279	268	257	247	238	230	222	214	207	201	195	184	174	165	153	140	131	126	117	93.2
4600	313	299	286	274	263	253	243	235	227	219	212	205	199	188	178	168	156	143	134	129	120	95.2
4700	320	305	292	280	269	258	249	240	232	224	217	210	203	192	181	172	160	146	137	132	122	97.3
4800	326	312	298	286	274	264	254	245	236	229	221	214	208	196	185	176	163	149	140	134	125	99.4
4900	333	318	304	292	280	269	259	250	241	233	226	219	212	200	189	179	167	152	143	137	128	101
5000	340	325	311	298	286	275	265	255	246	238	230	223	216	204	193	183	170	155	146	140	130	104

TO USE THIS TABLE Enter at top under factor determined from Table P.
Read down to nearest value in sq. ft. or cu. ft.
Read to left to determine the BTU/Hr required.

SUPPLEMENTARY DATA

TABLE S — **EQUIVALENT BTU/Hr HEAT LOSS**

For Various Indoor Minus Outdoor Temperature Difference

70 F	50 F	55 F	60 F	65 F	75 F	80 F	85 F	90 F
1000	710	790	860	930	1070	1140	1210	1290
1100	790	860	940	1020	1180	1260	1340	1410
1200	860	940	1030	1110	1290	1370	1460	1540
1300	930	1020	1110	1210	1390	1490	1580	1670
1400	1000	1100	1200	1300	1500	1600	1700	1800
1500	1070	1180	1290	1390	1610	1710	1820	1930
1600	1140	1260	1370	1490	1710	1830	1940	2060
1700	1210	1340	1460	1580	1820	1940	2060	2190
1800	1290	1410	1540	1670	1930	2060	2190	2310
1900	1360	1490	1630	1760	2040	2170	2310	2440
2000	1430	1570	1720	1860	2140	2290	2430	2570
2100	1500	1650	1800	1950	2250	2400	2550	2700
2200	1570	1730	1890	2040	2360	2510	2670	2830
2300	1640	1810	1970	2140	2460	2630	2790	2960
2400	1710	1890	2060	2230	2570	2740	2910	3090
2500	1790	1960	2140	2320	2680	2860	3040	3210
2600	1860	2040	2230	2410	2790	2970	3160	3340
2700	1930	2120	2310	2510	2890	3090	3280	3470
2800	2000	2200	2400	2600	3000	3200	3400	3600
2900	2070	2280	2490	2690	3110	3310	3520	3730
3000	2140	2360	2570	2790	3210	3430	3640	3860
3100	2210	2440	2660	2800	3320	3540	3760	3990
3200	2290	2510	2740	2970	3430	3660	3890	4110
3300	2350	2590	2830	3060	3540	3770	4010	4240
3400	2430	2670	2910	3160	3640	3890	4130	4370
3500	2500	2750	3000	3250	3750	4000	4250	4500
3600	2570	2830	3090	3340	3860	4110	4370	4630
3700	2640	2910	3170	3440	3960	4230	4490	4760
3800	2710	2990	3260	3530	4070	4340	4610	4890
3900	2790	3060	3340	3620	4180	4460	4740	5010
4000	2860	3140	3430	3710	4290	4570	4860	5140
4100	2930	3220	3510	3810	4390	4690	4980	5270
4200	3000	3300	3600	3900	4500	4800	5100	5400
4300	3070	3380	3690	3990	4610	4910	5220	5530
4400	3140	3460	3770	4090	4710	5030	5340	5660
4500	3210	3540	3860	4180	4820	5140	5460	5790
4600	3290	3610	3940	4270	4930	5260	5590	5910
4700	3360	3690	4030	4360	5040	5370	5710	6040
4800	3430	3770	4110	4460	5140	5490	5830	6170
4900	3500	3850	4200	4550	5250	5600	5950	6300
5000	3570	3930	4290	4640	5360	5720	6070	6430
5100	3640	4010	4370	4740	5460	5830	6190	6560
5200	3710	4090	4460	4830	5570	5940	6310	6690
5300	3790	4160	4540	4920	5680	6060	6440	6810
5400	3860	4240	4630	5010	5790	6170	6560	6940
5500	3930	4320	4710	5110	5890	6290	6680	7070
5600	4000	4400	4800	5200	6000	6400	6800	7200
5700	4070	4480	4890	5290	6110	6520	6920	7340
5800	4140	4560	4970	5390	6210	6630	7040	7460
5900	4210	4640	5060	5480	6320	6740	7160	7590
6000	4290	4710	5140	5570	6430	6860	7290	7710
6100	4360	4790	5230	5670	6540	6970	7410	7840
6200	4430	4870	5310	5760	6640	7090	7530	7970
6300	4500	4950	5400	5850	6750	7200	7650	8100
6400	4570	5030	5490	5940	6860	7320	7770	8230
6500	4640	5110	5570	6040	6960	7430	7890	8360
6600	4710	5190	5660	6130	7070	7540	8010	8490
6700	4790	5260	5740	6220	7180	7660	8140	8610
6800	4860	5340	5830	6310	7290	7770	8260	8740
6900	4930	5420	5910	6410	7390	7890	8380	8870

70 F	50 F	55 F	60 F	65 F	75 F	80 F	85 F	90 F
7000	5000	5500	6000	6500	7500	8000	8500	9000
7100	5070	5580	6090	6600	7610	8120	8620	9130
7200	5140	5660	6170	6690	7710	8230	8740	9260
7300	5210	5740	6260	6780	7820	8340	8860	9390
7400	5290	5810	6340	6870	7930	8460	8990	9510
7500	5360	5890	6430	6960	8040	8570	9100	9640
7600	5430	5970	6510	7060	8140	8690	9230	9770
7700	5500	6050	6600	7150	8250	8800	9350	9900
7800	5570	6130	6690	7240	8360	8920	9470	10030
7900	5640	6210	6770	7340	8460	9030	9590	10160
8000	5710	6290	6860	7430	8570	9140	9710	10290
8100	5790	6360	6940	7520	8680	9260	9840	10410
8200	5860	6440	7030	7610	8790	9370	9960	10540
8300	5930	6520	7110	7710	8890	9490	10080	10670
8400	6000	6600	7200	7800	9000	9600	10200	10800
8500	6070	6680	7290	7890	9110	9720	10320	10930
8600	6140	6760	7370	7990	9210	9830	10440	11060
8700	6210	6840	7460	8080	9320	9940	10560	11190
8800	6290	6910	7540	8170	9430	10060	10690	11310
8900	6360	6990	7630	8260	9540	10170	10810	11440
9000	6430	7070	7710	8360	9640	10290	10930	11570
9100	6500	7150	7800	8450	9750	10400	11050	11700
9200	6570	7230	7890	8540	9850	10520	11170	11830
9300	6640	7310	7970	8640	9960	10630	11290	11960
9400	6710	7390	8060	8730	10070	10740	11420	12090
9500	6790	7460	8140	8820	10180	10860	11540	12210
9600	6860	7540	8230	8910	10290	10970	11660	12340
9700	6930	7620	8310	9010	10390	11090	11780	12470
9800	7000	7700	8400	9100	10500	11200	11900	12600
9900	7070	7780	8490	9190	10610	11320	12020	12730
10000	7140	7860	8570	9290	10710	11430	12140	12860
10100	7210	7940	8660	9380	10820	11540	12260	12990
10200	7290	8010	8740	9470	10930	11660	12390	13110
10300	7360	8090	8830	9560	11040	11770	12510	13240
10400	7430	8170	8910	9660	11140	11890	12630	13370
10500	7500	8250	9000	9750	11250	12000	12750	13500
10600	7570	8330	9090	9840	11360	12120	12870	13630
10700	7640	8410	9170	9940	11460	12230	12990	13760
10800	7710	8490	9260	10030	11570	12340	13110	13890
10900	7790	8560	9340	10120	11680	12460	13240	14010
11000	7860	8640	9430	10210	11790	12570	13360	14140
11100	7930	8720	9510	10310	11890	12690	13480	14270
11200	8000	8800	9600	10400	12000	12800	13600	14400
11300	8070	8880	9690	10490	12110	12920	13720	14530
11400	8140	8960	9770	10590	12210	13030	13840	14660
11500	8210	9040	9860	10680	12320	13140	13960	14790
11600	8290	9110	9940	10770	12430	13260	14090	14910
11700	8360	9190	10030	10860	12540	13370	14210	15040
11800	8430	9270	10110	10960	12640	13490	14330	15170
11900	8500	9350	10200	11000	12750	13600	14450	15300
12000	8570	9430	10290	11140	12860	13720	14570	15430
12100	8640	9510	10370	11240	12960	13840	14690	15560
12200	8710	9590	10460	11330	13070	13940	14810	15690
12300	8790	9670	10540	11420	13180	14060	14940	15810
12400	8860	9740	10630	11510	13290	14170	15060	15940
12500	8930	9820	10710	11610	13390	14290	15180	16070
12600	9000	9900	10800	11700	13500	14400	15300	16200
12700	9070	9980	10890	11790	13620	14520	15420	16320
12800	9140	10060	10970	11890	13710	14630	15540	16460
12900	9210	10140	11060	11980	13820	14740	15660	16590

TO USE THIS TABLE Enter under column headed 70° F.
Read down to BTU/Hr determined from Table R.
Read across to the column which represents the indoor minus outdoor temperature difference for which the system is designed.

DEGREE-DAYS FOR CITIES IN THE UNITED STATES AND CANADA*

State	City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Ala.	Birmingham	589	521	260	69							318	595	2352
	Mobile	428	311	152								186	394	1471
Ariz.	Flagstaff	1153	969	896	654	465	171		40	252	577	840	1128	7145
	Tucson	459	325	257	87							252	465	1845
Ark.	Little Rock	719	582	353	78						47	381	651	2811
Calif.	Los Angeles	326	266	239	159	90						123	301	1504
	San Francisco	465	356	353	294	264	195	202	186	114	146	261	428	3264
Colo.	Col. Springs	1085	991	852	612	369	90			162	502	789	1066	6518
	Denver	1079	918	800	534	267				72	428	759	1017	5874
Conn.	New Haven	1110	1011	899	543	223				39	360	693	1017	5895
D. C.	Washington	970	848	694	348	25					251	594	896	4626
Fla.	Jacksonville	285	207	56								75	267	890
Ga.	Atlanta	682	557	388	132						96	396	639	2890
	Savannah	409	316	167								201	397	1490
Idaho	Boise	1097	848	651	435	236				102	434	738	1011	5552
Ill.	Chicago	1262	1095	911	549	248				3	353	756	1113	6290
	Springfield	1181	1008	760	366	56					282	681	1039	5373
Ind.	Evansville	949	854	620	276						155	528	862	4244
	Indianapolis	1128	969	756	384	59					298	687	1017	5298
Iowa	Des Moines	1392	1173	890	441	118					357	798	1215	6384
	Sioux City	1435	1260	967	489	164				33	415	870	1265	6898
Kans.	Dodge City	1116	890	688	342	47					276	672	1104	5035
	Topeka	1221	980	747	339						270	699	1051	5307
Ky.	Lexington	973	868	648	342	25					245	612	905	4618
	Louisville	939	801	589	264						186	552	849	4180
La.	New Orleans	332	230	59								102	301	1024
Me.	Eastport	1380	1232	1110	786	543	300	143	136	276	543	843	1228	8520
	Portland	1321	1168	1017	642	329	39			120	443	780	1153	7012
Md.	Baltimore	955	843	701	348	22					223	567	874	4533
Mass.	Boston	1150	1042	908	570	245				48	363	693	1026	6045
Mich.	Detroit	1252	1134	973	573	226				42	400	777	1113	6490
	Marquette	1500	1361	1249	804	496	186		43	225	567	960	1302	8693
Minn.	Duluth	1727	1473	1277	810	524	198		37	261	620	1062	1491	9480
	Minneapolis	1609	1400	1094	570	236				93	481	963	1404	7850
Miss.	Vicksburg	521	384	195								252	471	1823
Mo.	Kansas City	1094	958	676	303	12					214	612	983	4852
	St. Louis	1060	854	657	276						205	597	936	4585
Mont.	Billings	1318	1120	955	534	316	60			189	524	909	1194	7119
	Havre	1624	1450	1169	630	369	144			270	620	1041	1383	8700
Nebr.	Lincoln	1311	1131	840	417	99					316	753	1132	5999
	Omaha	1355	1126	868	414	84					329	780	1175	6131
Nev.	Reno	1042	823	753	534	366	90			144	453	714	973	5892
N. H.	Concord	1349	1240	1011	669	298	54			168	484	846	1234	7353
N. J.	Atlantic City	992	904	806	519	220					254	588	893	5176
	Trenton	1014	941	735	402	81					242	588	930	4933
N. M.	Santa Fe	1110	902	775	543	298	3			120	459	780	1073	6063
N. Y.	Albany	1287	1142	980	549	183				72	446	774	1147	6580
	Buffalo	1240	1156	1032	675	335	12			75	419	774	1104	6822
	New York	1060	960	837	486	155					276	618	955	5347
	Utica	1248	1181	989	588	253				182	430	781	1144	6796
N. C.	Raleigh	722	630	446	183						130	429	694	3234
	Wilmington	555	468	322	108						19	303	527	2302
N. D.	Bismarck	1807	1548	1283	657	338	45			222	626	1113	1553	9192

DEGREE-DAYS FOR CITIES IN THE UNITED STATES AND CANADA* (continued)

State	City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Ohio	Cincinnati	1011	871	679	339	19					248	615	921	4703
	Cleveland	1181	1075	930	564	220				27	366	732	1060	6155
	Columbus	1113	980	778	420	87					313	690	1017	5398
Okla.	Oklahoma City	865	742	465	162						105	459	815	3613
Ore.	Portland	806	644	558	402	245	90			105	332	558	729	4469
	Salem	778	633	586	426	285	111			102	350	600	747	4618
Pa.	Philadelphia	1001	893	756	402	68					242	588	905	4855
	Pittsburgh	1054	944	787	423	78					313	669	967	5235
R. I.	Providence	1116	1070	890	558	251				63	348	693	1026	6015
S. C.	Charleston	487	372	242	36							207	425	1769
	Spartanburg	725	622	431	147						121	429	716	3191
S. D.	Sioux Falls	1547	1358	1045	564	217				93	484	945	1404	7657
Tenn.	Memphis	744	599	384	96						62	402	663	2950
	Nashville	812	675	477	180						136	483	744	3507
Texas	Austin	487	330	133								201	434	1585
	Dallas	617	493	267	9							303	567	2256
	Houston	366	277	65								114	335	1157
	San Antonio	381	274	74								126	347	1202
Utah	Logan	1262	1072	893	525	329	48			114	468	819	1218	6748
	Salt Lake City	1110	885	722	453	236				18	388	723	1020	5555
Vt.	Burlington	1429	1294	1088	654	273	3			144	481	861	1287	7514
Va.	Fredericksburg	887	820	583	303						223	549	877	4242
	Norfolk	738	650	521	246						99	411	685	3350
	Richmond	825	703	552	240						158	483	766	3727
Wash.	Seattle	775	652	623	465	319	168	40	43	192	403	570	716	4966
	Spokane	1172	952	778	504	285	81			192	515	819	1057	6355
W. Va.	Morgantown	1026	944	713	414	78					295	648	977	5095
	Parkersburg	995	907	679	360	47					282	630	1048	4948
Wis.	Fond du Lac	1507	1322	1048	603	276				117	493	921	1330	7617
	Green Bay	1538	1358	1125	600	322				132	505	921	1324	7825
	LaCrosse	1535	1265	1033	528	183				96	462	909	1311	7322
	Milwaukee	1383	1201	1023	648	350	39			84	450	846	1221	7245
Wyo.	Cheyenne	1215	1075	995	720	446	126			240	605	900	1144	7463

CANADA

Province	City	Jan.	Feb.	Mar.	Apr.	May	Sept.	Oct.	Nov.	Dec.	Total
B. C.	Victoria										5777
	Vancouver										5976
	Kamloops										6724
Alb.	Medicine Hat										8152
Sask.	Qu'Appelle										11,261
Man.	Winnipeg										11,166
Ont.	Port Arthur										10,803
	Toronto										7732
Que.	Montreal	1615	1409	1219	720	309	190	372	961	1422	8417
	Quebec										8628
N. B.	Fredericton										9099
N. S.	Yarmouth										7694
P. E. I.	Charlottetown										8485

* Figures for United States cities abstracted by permission from *Degree Day Hand Book* (Second Edition, 1937), by Clifford Strock and C. H. B. Hotchkiss. Figures for Canadian cities abstracted from Heating and Ventilating, October, 1939.

PRESSURE DROP TABLES

FOR WATER

Pressure Drop in Pounds per Square Inch at Various Deliveries Per 100 Equivalent Feet of Pipe Run

PIPE SIZE	DELIVERIES IN GALLONS PER MINUTE													
	1	2	3	4	5	10	20	30	40	50	75	100	125	150
¾"	.02	.06	1.0	2.0	3.0	12.0								
1"	.05	.20	.42	.73	1.1	4.0	14.5							
1¼"		.05	.11	.19	.28	1.0	3.7	7.9						
1½"			.05	.09	.13	.47	1.7	3.6	6.2	9.4				
2"					.03	.13	.48	1.0	1.8	2.7	5.9	9.7		
2½"						.05	.20	.43	.73	1.1	2.4	4.0		
3"							.07	.14	.24	.37	.83	1.3	2.0	2.9

FOR STEAM

Steam Deliveries in MBH at Various Pressure Drops Per 100 Equivalent Feet of Pipe Run

PIPE SIZE	1 OZ. PRESSURE	2 OZ. PRESSURE	4 OZ. PRESSURE	8 OZ. PRESSURE
1"	13.5	19	26.6	37.7
1¼"	29.3	41.5	58.8	83
1½"	45.5	64.5	91	129
2"	92.5	131	185	262
2½"	152.5	215.8	304.5	430
3"	279	395	559	790
4"	587	834	1180	1670
5"	1190	1541	2180	3080
6"	1790	2532	3600	5060

WATER CAPACITY PER FOOT OF PIPE

Pipe Size	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	3½"	4"	5"	6"
Gallons Per Foot	.016	.023	.040	.063	.102	.17	.275	.39	.53	.69	1.1	1.5

HEAT EMISSION OF PIPE COILS INSTALLED HORIZONTALLY ON SAME PLANE

HEAT LOSSES FROM HORIZONTAL BARE STEEL PIPE

B.T.U. PER HOUR PER LINEAL FOOT IN STILL AIR AT 70° FAHRENHEIT

	AVERAGE WATER TEMPERATURE °F. IN PIPE					
Pipe Size	120°	150°	180°	200°	210°	227°
½"	22.8	39.6	60	74	82	97
¾"	27.8	48.5	73	90	100	117
1"	34.2	59.4	90	111	123	144
1¼"	42.4	73.0	111	138	152	178
1½"	47.8	83.0	126	155	172	202
2"	59.0	103.0	155	192	212	248

CORRECTION FACTORS FOR DIRECT CAST-IRON RADIATORS*

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STEAM PRESS. APPROX.		Heating Medium Temp. F Steam or Water	FACTORS FOR DIRECT CAST-IRON RADIATORS						
			Room Temperature F						
Gage Vacuum In. Hg.	Abs. Lb. per Sq. In.		80	75	70	65	60	55	50
22.4	3.7	150	2.58	2.36	2.17	2.00	1.86	1.73	1.62
20.3	4.7	160	2.17	2.00	1.86	1.73	1.62	1.52	1.44
17.7	6.0	170	1.86	1.73	1.62	1.52	1.44	1.35	1.28
14.6	7.5	180	1.62	1.52	1.44	1.35	1.28	1.21	1.15
10.9	9.3	190	1.44	1.35	1.28	1.21	1.15	1.10	1.05
6.5	11.5	200	1.28	1.21	1.15	1.10	1.05	1.00	0.96
Lb. per Sq. In.									
1	15.6	215	1.10	1.05	1.00	0.96	0.92	0.88	0.85
6	21	230	0.96	0.92	0.88	0.85	0.81	0.78	0.76
15	30	250	0.81	0.78	0.76	0.73	0.70	0.68	0.66
27	42	270	0.70	0.68	0.66	0.64	0.62	0.60	0.58
52	67	300	0.58	0.57	0.55	0.53	0.52	0.51	0.49

*To determine the size of a radiator for a given space, divide the heat loss in Btu per hour by 240 and multiply the result by the proper factor from the above table.

To determine the heating capacity of a radiator under conditions other than the basic ones with the heating medium at a temperature of 215 F, and the room temperature at 70 F, divide the heating capacities at the basic conditions by the proper factor from the above table.

WEIGHT & HEAT CONTENT OF WATER AT VARIOUS TEMPERATURES*

TEMPERATURE °F	WT. PER CU. FT. POUNDS	BTU PER POUND	TEMPERATURE °F	WT. PER CU. FT. POUNDS	BTU PER POUND
32	62.42	0.	215	59.76	183.11
35	62.42	3.02	220	59.63	188.13
40	62.42	8.05	225	59.52	193.18
45	62.42	13.06	230	59.36	198.23
50	62.38	18.07	235	59.22	203.28
55	62.38	23.07	240	59.10	208.34
60	62.35	28.06	245	58.95	213.40
65	62.31	33.05	250	58.82	218.45
70	62.27	38.04	255	58.67	223.56
75	62.23	43.03	260	58.52	228.64
80	62.19	48.02	265	58.38	233.74
85	62.15	53.0	270	58.24	238.84
90	62.10	57.99	275	58.08	243.94
95	62.05	62.98	280	57.94	249.06
100	62.0	67.97	285	57.77	254.18
105	61.92	72.95	290	57.64	259.31
110	61.84	77.94	295	57.47	264.45
115	61.8	82.93	300	57.29	269.59
120	61.73	87.92	305	57.14	274.75
125	61.65	92.91	310	56.98	279.92
130	61.54	97.3	315	56.82	285.1
135	61.46	102.9	320	56.66	290.28
140	61.39	107.89	325	56.46	295.49
145	61.28	112.89	330	56.31	300.68
150	61.2	117.81	335	56.12	305.91
155	61.09	122.89	340	55.95	311.13
160	61.01	127.89	345	55.77	316.38
165	60.94	132.89	350	55.59	321.63
170	60.83	137.9	355	55.40	326.91
175	60.68	142.91	360	55.22	332.18
180	60.6	147.92	365	55.04	337.48
185	60.46	152.93	370	54.85	342.79
190	60.35	157.95	375	54.65	348.11
195	60.24	162.97	380	54.46	353.45
200	60.13	167.99	385	54.26	358.8
205	60.01	173.03	390	54.05	364.17
210	59.88	178.05	395	53.87	369.56
212	59.81	180.07	400	53.65	374.97

*DATA TAKEN FROM KENNAN & KEYS

PROPERTIES OF SATURATED STEAM

	VACUUM IN INCHES OF MERCURY OR GAGE PRESS. IN LBS. PER SQUARE INCH	TEMPERATURE IN DEGREE FAHRENHEIT	TOTAL HEAT ABOVE 32° F.		LATENT HEAT OF STEAM B.T.U.	VOLUME OF 1 LB. STEAM CU. FT.
			B.T.U. IN WATER	B.T.U. IN STEAM		
VACUUM	29	79	47	1095	1048	652
	28	101	69	1105	1036	339
	27	115	83	1111	1028	231
	26	125	93	1116	1022	176
	25	134	111	1120	1018	143
	21.9	153	121	1128	1007	91
	20	161	129	1131	1002	75
	17.8	170	138	1135	997	62
	15	179	147	1139	992	51
	11.7	188	156	1142	986	42
	10	192	160	1144	984	39
	7.6	198	166	1146	980	35
	5	203	170	1148	977	32
	3.5	206	174	1149	976	30
	1.5	210	178	1151	973	28
	0	212	180	1152	972	27
PRESSURE	0.3	213	181	1151	970	26
	1.3	216	184	1152	967	25
	2.3	219	167	1153	965	23
	3.3	222	190	1154	963	22
	4.3	225	193	1155	962	21
	5.3	228	196	1156	960	20
	6.3	231	199	1157	958	19
	7.3	233	201	1158	957	18
	8.3	235	204	1159	955	18
	9.3	238	206	1159	953	17
	10.3	240	208	1160	952	16
	15.3	250	219	1164	945	14
	20.3	259	228	1167	939	12
	25.3	267	236	1169	933	10
	31.3	276	245	1172	927	9
	35.3	281	250	1173	923	9
	41.3	288	257	1176	918	8
	45.3	293	262	1177	915	7
	51.3	299	268	1179	910	7
	61.3	308	278	1181	903	6
	71.3	317	267	1184	897	5
	81.3	325	295	1186	891	5
	91.3	332	303	1188	885	4
	101.3	339	310	1189	879	4
	125.3	353	325	1192	868	3
	141.3	362	334	1194	860	3
	151.3	366	339	1195	856	3
	165.3	373	346	1196	850	3
	175.3	378	351	1197	846	2
	200.3	388	362	1199	837	2

SUPPLEMENTARY DATA

CHART FOR SIZING STEAM PIPING CONNECTIONS TO WATER HEATERS AND CONVERTORS (based on 8000 feet per minute steam velocity)

Pipe Size	Thousands of BTU's for Various Steam Pressures (Lbs. per Square Inch Atmospheric)										
	0 Lbs.	2 Lbs.	5 Lbs.	8 Lbs.	10 Lbs.	15 Lbs.	25 Lbs.	50 Lbs.	75 Lbs.	100 Lbs.	125 Lbs.
½	36.4	41.5	48.	54.5	59.	69.2	89.5	138.	183.5	226.	267.
¾	63.8	72.5	84.	95.5	103.	121.	157.	241.	322.	396.	474.
1	104.5	119.	137.	156 5	169.	198.	257.	396.	527.	648.	777.
1¼	181.	206.	238.	270	292.	342.	445.	683.	910.	1120.	1340.
1½	246.	280.	324.	368.	396.	465.	605.	930.	1235.	1520.	1820.
2	405.	460.	535.	605.	654.	768.	995.	1530.	2040.	2510.	3000.
2½	580.	650.	764.	865.	934.	1095.	1410.	2180.	2910.	3590.	4300
3	894.	1020.	1180.	1340.	1440.	1690.	2200.	3380.	4500.	5550.	6640.
3½	1190.	1360.	1575.	1785.	1925.	2260.	2930.	4510.	6020.	7400.	8875.
4	1540.	1755.	2035.	2305.	2480.	2920.	3780.	5820.	7750.	9550.	11450
5	2415.	2750.	3190.	3620.	3900.	4580.	5940.	9125.	12180.	15000.	17900.
6	3500.	3980.	4600.	5225.	5640.	6625.	8580.	13200.	17600.	21600.	25950.
8	6190.	7040.	8150.	9250	10000.	11700.	15200.	23400.	31150.	38250.	46000.

To use above chart—

(1) Multiply gallons of water required by the temperature rise of the water passing through the heater. Multiply the result by 8.3 to determine the BTU required per hour. Then divide by 1000.

THUS —

G.P.H. X TEMPERATURE RISE X 8.3 = BTU

$$\frac{\text{BTU}}{1000} = \text{MBH (THOUSANDS OF BTU)}$$

(2) Locate the column in the above chart which corresponds to the steam pressure in the casing of the heater. Read down in this column until you reach the figure equal to or above the M.B.H. value estimated above. Reading to the left from this figure will give you the size of piping connection to the regulating valve.

(3) The steam regulating valve should be sized according to the recommendations of the valve manufacturer. If the supply line is reduced in size at the valve, it should be increased again just beyond the valve.

Sizing Condensate Connection from Heater

The approximate number of *pounds* of condensate per hour can be considered the same as the number of *gallons* of water heated from 40°-140° per hour. Use a trap of sufficient capacity and size the connections the full size of its opening.

CAPACITIES OF CYLINDRICAL TANKS IN U. S. GALLONS

Length in Feet	Diameter in Inches																
	12"	18"	24"	30"	36"	42"	48"	54"	60"	66"	72"	78"	84"	90"	96"	102"	108"
1	6	13	24	37	53	72	94	120	145	180	210	250	290	330	375	425	475
2	12	28	48	74	108	144	188	240	290	360	420	500	580	660	750	850	950
3	18	39	72	111	159	218	282	360	435	540	630	750	870	990	1125	1275	1425
4	24	52	96	148	212	288	376	480	580	720	840	1000	1160	1320	1500	1700	1900
5	30	65	120	185	265	360	470	600	725	900	1050	1250	1450	1650	1875	2125	2375
6	36	78	144	222	318	432	564	720	870	1080	1260	1500	1740	1980	2250	2550	2850
7	42	91	168	259	371	504	658	840	1015	1260	1470	1750	2030	2310	2625	2975	3325
8	48	104	192	296	424	576	752	960	1160	1440	1680	2000	2320	2840	3000	3400	3800
9	54	117	216	333	477	648	646	1080	1305	1620	1890	2250	2610	2970	3375	3825	4275
10	60	130	240	370	530	720	940	1200	1450	1800	2100	2500	2900	3300	3750	4250	4750
11	66	143	264	407	583	792	1034	1320	1595	1980	2310	2750	3190	3630	4125	4675	5225
12	72	156	288	444	636	864	1128	1440	1740	2160	2520	3000	3480	3960	4500	5100	5700
13	78	169	312	481	689	936	1222	1560	1885	2340	2730	3250	3770	4290	4875	5525	6175
14	84	182	336	518	742	1008	1316	1680	2030	2520	2940	3500	4060	4620	5250	5950	6650
15	90	195	360	555	795	1080	1410	1800	2175	2700	3150	3750	4350	4950	5625	6375	7125
16	96	208	384	592	848	1152	1504	1920	2320	2880	3360	4000	4640	5280	6000	6800	7600

To find the capacity in gallons of rectangular tanks, reduce all dimensions to inches, then multiply the length by the width by the height and divide the product by 231.

CONVERSION FACTORS

WATER

U. S. GALLONS	X	8.33	=	POUNDS
U. S. GALLONS	X	0.13368	=	CUBIC FEET
U. S. GALLONS	X	231.00	=	CUBIC INCHES
U. S. GALLONS	X	3.78	=	LITRES
IMPERIAL GALLONS	=	277.3 CUBIC INCHES		
IMPERIAL GALLONS AT 62° F.	=	10.0 POUNDS		
CUBIC INCHES OF WATER (39.2°)	X	0.036130	=	POUNDS
CUBIC INCHES OF WATER (39.2°)	X	0.004329	=	U. S. GALLONS
CUBIC INCHES OF WATER (39.2°)	X	0.576384	=	OUNCES
CUBIC FEET OF WATER (39.2°)	X	62.427	=	POUNDS
CUBIC FEET OF WATER (39.2°)	X	7.48	=	U. S. GALLONS
CUBIC FEET OF WATER (39.2°)	X	0.028	=	TONS
POUNDS OF WATER	X	27.72	=	CUBIC INCHES
POUNDS OF WATER	X	0.01602	=	CUBIC FEET
POUNDS OF WATER	X	0.12	=	U. S. GALLONS

PRESSURE

1 POUND PER SQUARE INCH =
- 144 POUNDS PER SQUARE FOOT
- 2.0355 INCHES OF MERCURY AT 32° F.
- 2.0416 INCHES OF MERCURY AT 62° F.
- 2.309 FEET OF WATER AT 62° F.
- 27.71 INCHES OF WATER AT 62° F.

1 OUNCE PER SQUARE INCH =
- 0.1276 INCHES OF MERCURY AT 62° F.
- 1.732 INCHES OF WATER AT 62° F.

1 ATMOSPHERE (14.7 LBS. PER SQ. IN.) =
- 2116.3 POUNDS PER SQUARE FOOT
- 33.947 FEET OF WATER AT 62° F.
- 30 INCHES OF MERCURY AT 62° F.
- 29.922 INCHES OF MERCURY AT 32° F.
- 760 MILLIMETERS OF MERCURY AT 32° F

1 INCH WATER (AT 62° FAHRENHEIT) =
- 0.03609 LBS. OR 0.5774 OZ. PER SQ. IN
- 5.196 POUNDS PER SQUARE FOOT

1 FOOT WATER (AT 62° FAHRENHEIT) =
- 0.433 POUNDS PER SQUARE INCH
- 62.355 POUNDS PER SQUARE FOOT

1 INCH MERCURY (AT 62° FAHRENHEIT) =
- 0.491 LBS. OR 7.86 OZ. PER SQ. IN.
- 1.132 FEET WATER AT 62° FAHRENHEIT
- 13.58 INCHES WATER AT 62° FAHRENHEIT

FAHRENHEIT - CENTIGRADE CONVERSION TABLE

Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade
−20	−28.9	88	31.1	196	91.1
−18	−27.8	90	32.2	198	92.2
−16	−26.7	92	33.3	200	93.3
−14	−25.6	94	34.4	202	94.4
−12	−24.4	96	35.6	204	95.6
−10	−23.3	98	36.7	206	96.7
−8	−22.2	100	37.8	208	97.8
−6	−21.1	102	38.9	210	98.9
−4	−20.	104	40.	212	100.
−2	−18.9	106	41.1	214	101.1
0	−17.8	108	42.2	216	102.2
2	−16.7	110	43.3	218	103.3
4	−15.6	112	44.4	220	104.4
6	−14.4	114	45.6	222	105.6
8	−13.3	116	46.7	224	106.7
10	−12.2	118	47.8	226	107.8
12	−11.1	120	48.9	228	108.9
14	−10.	122	50.	230	110.
16	−8.9	124	51.1	232	111.1
18	−7.8	126	52.2	234	112.2
20	−6.7	128	53.3	236	113.3
22	−5.6	130	54.4	238	114.4
24	−4.4	132	55.6	240	115.6
26	−3.3	134	56.7	242	116.7
28	−2.2	136	57.8	244	117.8
30	−1.1	138	58.9	246	118.9
32	0.	140	60.	248	120.
34	1.1	142	61.1	250	121.1
36	2.2	144	62.2	252	122.2
38	3.3	146	63.3	254	123.3
40	4.4	148	64.4	256	124.4
42	5.6	150	65.6	258	125.6
44	6.7	152	66.7	260	126.7
46	7.8	154	67.8	262	127.8
48	8.9	156	68.9	264	128.9
50	10.	158	70.	266	130.
52	11.1	160	71.1	268	131.1
54	12.2	162	72.2	270	132.2
56	13.3	164	73.3	272	133.3
58	14.4	166	74.4	274	134.4
60	15.6	168	75.6	276	135.6
62	16.7	170	76.7	278	136.7
64	17.8	172	77.8	280	137.8
66	18.9	174	78.9	282	138.9
68	20.	176	80.	284	140.
70	21.1	178	81.1	286	141.1
72	22.2	180	82.2	288	142.2
74	23.3	182	83.3	290	143.3
76	24.4	184	84.4	292	144.4
78	25.6	186	85.6	294	145.6
80	26.7	188	86.7	296	146.7
82	27.8	190	87.8	298	147.8
84	28.9	192	88.9	300	148.9
86	30.	194	90.		

SUPPLEMENTARY DATA

AREAS OF CIRCLES

Diameter	Area	Diameter	Area	Diameter	Area
1/64	.00019	12	113.09	51	2042.8
1/32	.00077	12½	122.71	52	2123.7
1/16	.00307	13	132.73	53	2206.1
3/32	.00690	13½	143.13	54	2290.2
1/8	.01227	14	153.93	55	2375.8
5/32	.01917	14½	165.13	56	2463.0
3/16	.02761	15	176.71	57	2551.7
7/32	.03758	15½	188.69	58	2642.0
1/4	.04909	16	201.06	59	2733.9
5/16	.07670	16½	216.82	60	2827.4
3/8	.11045	17	226.98	61	2922.4
7/16	.15033	17½	240.52	62	3019.0
1/2	.19635	18	254.46	63	3117.2
9/16	.24850	18½	268.80	64	3216.9
5/8	.30680	19	283.52	65	3318.3
11/16	.37122	19½	298.64	66	3421.2
3/4	.44179	20	314.16	67	3525.6
13/16	.51849	20½	330.06	68	3631.6
7/8	.60132	21	346.36	69	3739.2
15/16	.69029	21½	363.05	70	3848.4
1	.7854	22	380.13	71	3959.2
1⅛	.9940	22½	397.60	72	4071.5
1¼	1.227	23	415.47	73	4185.3
1⅜	1.484	23½	433.73	74	4300.8
1½	1.767	24	452.39	75	4417.8
1⅝	2.073	24½	471.43	76	4536.4
1¾	2.405	25	490.87	77	4656.0
1⅞	2.761	26	530.93	78	4778.3
2	3.141	27	572.55	79	4901.6
2¼	3.976	28	615.75	80	5026.5
2½	4.908	29	660.52	81	5153.0
2¾	5.939	30	706.86	82	5281.0
3	7.068	31	754.76	83	5410.6
3¼	8.295	32	804.24	84	5541.7
3½	9.621	33	855.30	85	5674.5
3¾	11.044	34	907.92	86	5808.8
4	12.566	35	962.11	87	5944.6
4½	15.904	36	1017.8	88	6082.1
5	19.635	37	1075.2	89	6221.1
5½	23.758	38	1134.1	90	6361.7
6	28.274	39	1194.5	91	6503.8
6½	33.183	40	1256.6	92	6647.6
7	38.484	41	1320.2	93	6792.9
7½	44.178	42	1385.4	94	6939.7
8	50.265	43	1452.2	95	7088.2
8½	56.745	44	1520.5	96	7238.2
9	63.617	45	1590.4	97	7389.8
9½	70.882	46	1661.9	98	7542.9
10	78.54	47	1734.9	99	7697.7
10½	86.59	48	1809.5	100	7854.0
11	95.03	49	1885.7		
11½	103.86	50	1963.5		

To find the circumference of a circle when diameter is known:—
DIAMETER X 3.1416 = CIRCUMFERENCE

To find the diameter when circumference is known:—
CIRCUMFERENCE X .31831 = DIAMETER

DECIMAL EQUIVALENTS OF PARTS OF AN INCH

Fraction	Decimal	Fraction	Decimal
1/64	.01563	33/64	.51563
1/32	.03125	17/32	.53125
3/64	.04688	35/64	.54688
1/16	.0625	9/16	.5625
5/64	.07813	37/64	.57813
3/32	.09375	19/32	.59375
7/64	.10938	39/64	.60938
1/8	.125	5/8	.625
9/64	.14063	41/64	.64063
5/32	.15625	21/32	.65625
11/64	.17188	43/64	.67188
3/16	.1875	11/16	.6875
13/64	.20313	45/64	.70313
7/32	.21875	23/32	.71875
15/64	.23438	47/64	.73438
1/4	.25	3/4	.75
17/64	.26563	49/64	.76563
9/32	.28125	25/32	.78125
19/64	.29688	51/64	.79688
5/16	.3125	13/16	.8125
21/64	.32813	53/64	.82813
11/32	.34375	27/32	.84375
23/64	.35938	55/64	.85938
3/8	.375	7/8	.875
25/64	.39063	57/64	.89063
13/32	.40625	29/32	.90625
27/64	.42188	59/64	.92188
7/16	.4375	15/16	.9375
29/64	.45313	61/64	.95313
15/32	.46875	31/32	.96875
31/64	.48438	63/64	.98438
1/2	.5	1	1.00000

METRIC AND ENGLISH MEASURES

MEASURES OF LENGTH

	Metric			English
1	metre	=	39.37 3.28	inches feet
.3048	metre	=	1	foot
1	centimetre	=	.3937	inch
2.54	centimetres	=	1	inch
1	millimetre	=	.03937	in. (1-25 in., nearly)
25.4	millimetres	=	1	inch
1	kilometre	=	1093.61	yards

MEASURES OF SURFACE

1	square metre	=	10.764	square feet
.0929	square metre	=	1	square foot
1	square centimetre	=	.155	square inch
6.452	square centimetres	=	1	square inch
1	square millimetre	=	.00155	square inch
645.2	square millimetres	=	1	square inch

MEASURES OF VOLUME

1	cubic metre	=	35.314	cubic feet
.02832	cubic metre	=	1	cubic foot
1	cubic decimetre	=	61.023 .0353	cubic inches cubic foot
28.32	cubic decimetres	=	1	cubic foot
16.387	cubic centimetres	=	1	cubic inch
1	cubic centimetre	=	1 .061	millimetre cubic inch

MEASURES OF CAPACITY

1	litre=1 cu. decimetre	=	61.023 .0353 .2642 2.202	cubic inches cubic foot gallon (U.S.) lbs. of water at 62° F.
28.317	litres	=	1	cubic foot (7.481 U. S. gallons)
4.543	litres	=	1	gallon (Imperial)
3.785	litres	=	1	gallon (U.S.)

MEASURES OF WEIGHT

28.35	grammes	=	1	ounce avoirdupois
1	kilogramme	=	2.2046	pounds
.4536	kilogramme	=	1	pound
1 1000	metric ton kilogrammes	=	.9842 19.68	ton of 2240 lbs., or cwts. of 2204.6 lbs.
1.016 1016	metric ton kilogrammes	=	1	ton of 2240 lbs.

MISCELLANEOUS

1	gramme per sq. millimetre	=	1.422	lb per square inch
1	kilogramme per sq. millimetre	=	1422.32	lb per square inch
1	kilogramme per sq. centimetre	=	14.223	lb per square inch
1.0335	kilogramme per sq. centimetre 1 atmosphere	=	14.7	lb per square inch
0.070308	kilogramme per sq. centimetre	=	1	lb per square inch

METRIC AND ENGLISH MEASURES

MEASURES OF PRESSURE AND WEIGHT

1 lb per square inch	=	144 2.0355 2.0416 2.309 27.71	lb per square foot in. of mercury at 32° F. in. of mercury at 62° F. ft. of water at 62° F. in. of water at 62° F
1 Atmospheric (14.7 lb per sq. inch)	=	2116.3 33.947 30 29.922 760	lb per square foot ft. of water at 62° F in. of mercury at 62° F. in. of mercury at 32° F. millimetres of mercury at 32 degrees F.
1 Foot of Water at 62 degrees F.	=	.433 62.355	lb per square inch lb per square foot
1 Inch of Mercury at 62 degrees F.	=	.491 1.132 13.58	lb or 7.86 oz. per sq. in. ft. of water at 62° F. in. of water at 62° F.

WEIGHT OF ONE CUBIC FOOT OF PURE WATER

At 32 degrees Fahr. (freezing point)	62.418	lb
At 39.1 degrees Fahr. (maximum density)	62.425	lb
At 62 degrees Fahr. (standard temperature)	62.355	lb
At 212 degrees Fahr. (boiling point, under 1 atmosphere)	59.76	lb
Imperial gallon=277.274 cubic in. of water at 62° Fahr.	10	lb
American gallon=231 cubic in. of water at 62° Fahr.	8.3356	lb

MISCELLANEOUS DATA

1 Calorie	=	3.968	Btu
1 Btu	=	0.252	calorie
1 lb per sq. in.	=	703.08	kilogrammes per m²
1 Kilogramme per m²	=	.00142	lb per sq. in.
1 Calorie per m²	=	.3687	Btu per sq. ft.
1 Btu per sq. ft.	=	2.712	calories per m²
1 Calorie per m² per degree difference Cent.	=	.2048	Btu per sq. ft. per degree difference Fahr.
1 Btu per sq. ft. per degree difference Fahr.	=	4.882	calories per m² per degree difference Cent.
1 Btu per lb	=	.556	calories per kilog.
1 Calorie per kilog.	=	1.8	Btu per lb
1 Litre of Coke at 26.3 lb per cubic foot	=	.93	lb
1 lb. of Coke at 26.3 lb per cu. ft.	=	1.076	litres
Water expands in bulk from 40° to 212°	=	One twenty-third	

A cubic inch of water evaporated under ordinary atmospheric pressure is converted into 1 cubic foot of steam (approximately).

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