

of the water to the individual tube circuits. Air elimination in system piping is described in Chapter 10 of the 1964 Guide And Data Book.

Comfort heating systems employing hot water usually require not more than one or two rows of tubes in direction of air flow, in order to produce the desired heating capacity. To produce the most efficient capacity without excessive water pressure drop through the coil, various circuit arrangements are used.

A single-tube serpentine circuit arrangement can be used on small size booster heaters requiring small water quantities up to a maximum of approximately 4 or 5 gpm. With this arrangement, a single-tube handles the entire water quantity, provided the tube is circuited in such a manner that it makes a number of passes across the air stream.

The most common circuiting arrangement is often referred to as single-row serpentine or standard circuiting. With this arrangement all tubes in each coil row are supplied with an equal amount of water through a manifold, commonly called the *coil header*. When the water volume used with this arrangement is small, so that the water flow in the tubes is laminar, some mechanical means, such as mechanical *turbulators* installed in each of the tube circuits, is sometimes provided to produce turbulent water flow.

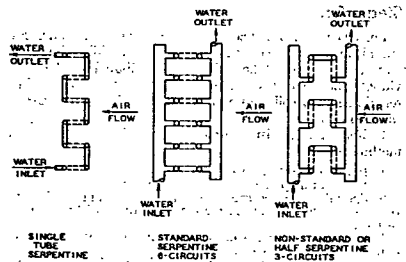


Fig. 1 Water Circuit Arrangements

Special circuiting (serpentine) arrangements accomplish the same effect as mechanical turbulators when the water volume supplied to the coil is small. Serpentine reduce the number of circuits, thus increasing the water velocity in each circuit and creating turbulent flow.

Fig. 1 illustrates commonly used water-circuit arrangements.

Water coils are usually designed to be self-venting. This is accomplished by supplying the water to the coil in such a way that the water flows upward in the coil, forcing air out through the return water connection. This also assures that the coil is always completely filled with water, regardless of the water volume supplied.

Methods for controlling water coils to produce uniform leaving air temperatures are discussed in Chapter 13.

Flow Arrangement

In heat transfer processes, the relative directions of flow of the fluids influence the performance of the heat-transfer surface. In air heating coils with only one row of tubes in the direction of air flow, the relative direction of the air flow to

the heating medium is at right angles. In coils with more than one row of tubes in the direction of air flow, the heating medium in the tubes may be circuited in various ways, as illustrated in Fig. 8 of Chapter 34.

Cross-flow is common in steam heating coils. The steam temperature within the tubes remains substantially uniform; and the mean temperature difference is basically the same, whatever the direction of flow relative to the air.

Parallel-flow and counter-flow arrangements are common in water coils. Counter-flow is the preferred arrangement to obtain the highest possible mean temperature difference. The mean temperature potential determines the *heat-transfer driving force* of the coil. The greater the mean temperature difference, the greater is the capacity of the coil.

Applications

The air flow in heating coils is vertical or horizontal. The latter arrangement is more common.

For steam heating, the coils may be installed with the tubes in vertical or horizontal position. Horizontal coil-tubes should be pitched or inclined toward the return connection to provide for condensate drainage. Water heating coils generally have horizontal tubes to avoid air and water pockets.

When the leaving air temperature is controlled by modulation of the steam supply to the coil, *steam distributing tube type coils* are used to provide the optimum in uniform leaving air temperatures when controlling the coil by modulating the steam supply. (See Section, Steam Coils.) The diameters of the primary-surface tubes of these special coils are larger than those of comparable single-tube steam coils, and commonly are $\frac{1}{2}$ to 1 in. on the outside. The larger the tube diameter, the more uniform will be the temperature distribution. This also offers maximum protection against freezing, even under modulated operating conditions, when the air entering the coil is 32° or lower; and when the coil is properly applied and installed. Correctly designed steam-distributing tube type coils limit the leaving air temperature stratification to a maximum of 5 to 6 F deg over the entire length of the coil, even when the steam supply is modulated to a small fraction of the full load capacity. As an added precaution, with both steam and water heating coils, the outdoor-air inlet dampers usually close automatically when the fan is stopped. This special control arrangement minimizes the danger of freezing, and prevents drafts caused by drifting of cold outdoor air into the system during off periods.

Heating coils are designed to allow for expansion and contraction resulting from the temperature ranges within which they operate. Care must be taken to prevent imposing strains from the piping on the coil connections. This can usually be accomplished by providing expansion loops, expansion or swing joints, or flexible connections. (See Chapter 8 of the 1964 Guide And Data Book.)

It is good practice to support banked coils individually in an angle iron frame or a similar supporting structure. With this arrangement, the lowermost coil is not required to support the weight of the coils stacked above. This design also facilitates the removal of individual coils in a multiple coil bank for repair or replacement.

Low-pressure steam systems and coils controlled by modulating the steam supply, or both, should be provided with a vacuum breaker, or drained through a vacuum return system to assure proper condensate drainage. It is considered good practice to provide a closed vacuum breaker, where one is required, connected to the condensate return line through a check valve. This breaks the vacuum by equalizing the pressure, yet minimizes the possibility of air being bled into the system. Also, coils supplied with low-pressure steam or con-

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trolled by modulating the steam supply, should not be trapped directly to overhead return lines. Condensate can be lifted to overhead returns only, if sufficient pressure is available to overcome the condensate head and any return line pressure that may exist. If, under these conditions, overhead returns are necessary, the condensate should be pumped to the higher elevation.

COIL SELECTION

The following factors should be considered in coil selection:

1. The required duty or capacity considering the other system components.
2. Temperature of the air entering the coil.
3. Available heating media.
4. Space and dimensional limitations.
5. Air quantity.
6. Permissible resistances for both the air and heating media.
7. Characteristics of individual coil designs.
8. Individual installation requirements, such as the type of control to be used.
9. Coil face velocity.

The duties required may be determined from information in Chapters 24, 25, and 26. See also Chapter 1 of the 1964 Guide And Data Book. There may be a choice of heating media, as well as operating temperatures, depending upon whether the installation is new or being modified. Space limitations are dictated by the requirements of individual cases. The air quantity is influenced by a number of considerations. The air handled may be limited by the use of installed ventilating ducts for air distribution, or it may be determined by requirements for satisfactory air distribution or ventilation. The resistance through the air circuit influences the fan horsepower and speed. This resistance may be limited to allow the use of a given size of fan motor, or to keep the operating expense low. It may also be limited because of sound-level requirements. Air resistance can always be kept low by designing for low air face velocities. The *permissible water resistance* of a hot water coil may be dictated by the available pump head from a given size of pump and pump motor. This can usually be controlled within reasonable limits by careful selection of the coil header size and the number of tube circuits. And finally, the *performance* of a heating coil depends upon the correct choice of the original equipment, and proper application and maintenance. For proper steam coil performance, selection of the correct type and size of steam trap is of the utmost importance.

Coil ratings are based on uniform face velocity. Therefore, nonuniform air flow through the coil will affect performance. Nonuniform air flow may be caused by air entrance at odd angles, or by inadvertent blocking of a portion of the coil face. To obtain rated performance, air quantity in the field must correspond with design quantity, and must always be maintained. A common cause in the reduction in air quantity is the fouling of the filters.

When it is necessary to clean coils, a common method is to wash them with water. They can sometimes be brushed and cleaned with a vacuum cleaner. In bad cases of neglect, especially in restaurants where grease and dirt have accumulated, it is sometimes necessary to remove the coils and wash off the accumulation with steam, compressed air and water, or hot water and a suitable detergent. The best practice, however, is to keep the filters serviced, and to inspect and wash the coils at regular intervals.

The proper selection of coils requires an understanding of the special requirements of each installation, and should be based on an economic analysis of the plant design as a whole. While no general rule can be established for the selection of heating coils, it is possible, nevertheless, to point out the

limits of the usual practice and to indicate the influence of the variables involved in coil selection.

Coil Ratings

Steam and hot water coils are usually rated within these limits:

1. Air Face Velocity 300-1500 fpm, based on air at standard density of 0.075 lb per cu ft.
2. Entering Air Temperature Minus 20 F to 80 F for steam coils; 32 F to 80 F for hot water coils.
3. Steam Pressures 2 to 200 psig at the coil steam supply connection (pressure drop through the steam control valve must be considered).
4. Hot Water Temperatures 120 F to 250 F.
5. Water Velocities 1 to 8 fps.

Individual installations vary widely, but the following values can be used as a guide:

The most common air face velocities used are between 500 and 600 fpm. Delivered air temperatures vary from about 72 F for ventilation only, to about 150 F for complete heating. Steam pressures vary from 2 to 10 psig, with 5 psig most common. Water temperatures for comfort heating are commonly between 180 and 200 F with water velocities between 4 and 6 fps.

Water quantity is usually based on about 20 F temperature drop through the coil. Air resistance is usually limited to from $\frac{1}{2}$ to 1 in. of water for commercial buildings, and to about 1 in. of water for industrial buildings.

The selection of heating coils is relatively simple, because it involves dry-bulb temperatures and sensible heat only, without the complication of simultaneous latent heat loads, as in cooling coils. Heating coils are usually selected from charts or tables giving final air temperatures at various air velocities, entering air temperatures, and steam or water temperatures.

The selection of hot water heating coils is slightly more complicated, because of the added water velocity variable and the fact that the water temperature decreases as it flows through the coil circuits. Therefore, in selecting hot water heating coils, the water velocity and the mean temperature difference (between the hot water flowing in the tubes and the air passing over the fins) must be taken into consideration.

Most coil manufacturers have their own methods of producing performance rating tables from a suitable number of duct performance tests. A method of testing coils is given in ASHRAE Standard 33-64, *Method of Testing for Rating Forced-Circulation Air-Cooling and Air-Heating Coils*. A basic method of rating to provide a fundamental means for establishing thermal performance of dehumidifying coils by extension of test data, as determined from laboratory tests on prototypes, to other operating conditions, coil sizes, and row depths of a particular surface design and arrangement, is given in *Air-Conditioning and Refrigeration Institute Standard 410-62 for Forced-Circulation Air-Cooling and Air-Heating Coils*.

HEAT TRANSFER

The transfer of heat between the heating medium and the air stream is influenced by several variables:

1. The temperature difference between the heating medium and the air stream.
 2. The design and surface characteristics of the coil.
 3. The velocity and character of the air stream.
 4. The velocity and character of the heating medium flowing in the tubes.
 5. Fluid flow arrangement: counter-flow, parallel-flow, or cross-flow.
- The heat transfer driving force is usually expressed as the logarithmic mean temperature difference between the heating medium and the air.