CHAPTER 26

AIR-HEATING COILS

AIR-HEATING coils are used to heat air under forced convection. The total coil surface may consist of a single coil section or several coil sections assembled into a bank. The coils described in this chapter apply primarily to comfort heating and air conditioning using steam, hot water, refrigerant vapor heat reclaim (including heat pumps), and electricity. The choice between the various methods of heating depends greatly on the cost of the various available energy sources. For instance, in areas where electric power is cheaply available and heating requirements are limited, heat pumps are a very viable option. With available power and higher heat requirements, electric heat is used. If electric power is considerably expensive, steam or hot water generated using gas-fired sources is used in larger buildings and district cooling. In smaller buildings, heat is supplied using gas furnaces, which are covered in Chapters 32 and 33. Water and steam heating are also widely used where process waste heat is available.

COIL CONSTRUCTION AND DESIGN

Extended-surface coils consist of a primary and a secondary heat-transfer surface. The primary surface is the external surface of the tubes, generally consisting of rows of round tubes or pipes that may be staggered or parallel (in-line) with respect to the airflow. Flattened tubes or tubes with other nonround internal passageways are sometimes used. The inside of the tube is usually smooth and plain, but some coil designs feature various forms of internal fins or turbulence promoters (either fabricated and then inserted, or extruded) to enhance fluid coil performance. The secondary surface is the fins' external surface, which consists of thin metal plates or a spiral ribbon uniformly spaced or wound along the length of the primary surface. The intimate contact with the primary surface provides good heat transfer. Air-heating fluid and steam coils are generally available with different circuit arrangements and combinations that offer varying numbers of parallel water flow passes in the tube core.

Copper and aluminum are the materials most commonly used for extended-surface coils. Tubing made of steel or various copper alloys is used in applications where corrosive forces might attack the coils from inside or outside. The most common combination for low-pressure applications is aluminum fins on copper tubes. Low-pressure steam coils are usually designed to operate up to 50 psig. Higher-strength tube materials such as red brass, admiralty brass, or cupronickel assembled by brazed construction are usable up to 366°F water or 150 psig saturated steam. Higher operating conditions call for electric welded stainless steel construction, designed to meet Section II and Section VIII requirements of the ASME *Boiler and Pressure Vessel Code*.

Customarily, the coil casing consists of a top and bottom channel (also known as baffles or side sheets), two end supports (also known as end plates or tube sheets), and, on longer coils, intermediate supports (also known as center supports or tube sheets). Designs vary, but most are mounted on ducts or built-up systems. Most often, casing material is spangled zinc-coated (galvanized) steel with a minimum coating designation of G90-U. Some corrosive air conditions may require stainless steel casings or corrosive-resistant coating, such as a baked phenolic applied by the manufacturer to the entire coil surface. Steam coil casings should be designed to accommodate thermal expansion of the tube core during operation (a *floating core* arrangement).

Common core tube diameters vary from 5/16 up to 1 in. outside diameter (OD) and fin spacings from 4 to 18 fins per inch. Fluid heating coils have a tube spacing from 3/4 to 1 3/4 in. and tube diameters from 5/16 to 5/8 in. OD. Steam coils have tube spacing from 1 1/4 to 3 in. and tube diameters from 0.5 to 1 in. OD. The most common arrangements are one- or two-row steam coils and two- to four-row hot-water coils. Fins should be spaced according to the application requirements, with particular attention given to any severe duty conditions, such as inlet temperatures and contaminants in the airstream.

Tube wall thickness and the required use of alloys other than (standard) copper are determined primarily by the coil's specified maximum allowable working pressure (MAWP) requirements. A secondary consideration is expected coil service life. Fin type, header, and connection construction also play a large part in this determination. All applicable local job site codes and national safety standards should be followed in the design and application of heating coils.

Flow direction can strongly affect heat transfer surface performance. In air-heating coils with only one row of tubes, the air flows at right angles to the heating medium. Such a cross-flow arrangement is common in steam heating coils. The steam temperature in the tubes remains uniform, and the mean temperature difference is the same regardless of the direction of flow relative to the air. The steam supply connection is located either in the center or at the top of the inlet header. The steam condensate outlet (return connection) is always at the lowest point in the return header.

When coils have two or more tube rows in the direction of airflow, such as hot-water coils, the heating medium in the tubes may be circuited in various parallel-flow and counterflow arrangements. Counterflow is the arrangement most preferred to obtain the highest possible mean temperature difference, which determines the heat transfer of the coil. The greater this temperature difference, the greater the coil's heat transfer capacity. In multirow coils circuited for counterflow, water enters the tube row on the leaving air side of the coil.

Steam Coils

Steam coils are generally classified, similarly to boilers, by operating pressure: low (≤15 psi) or high (>15 psi). However, various organizations use other pressure classification schemes with differing divisions [e.g., low (≤15 psi), medium (15 to 100 psi), or high (>100 psi)]. Steam coils can also be categorized by operating limits of the tube materials:

Standard steam	≤150 psi	366°F	copper tube
High-pressure steam	≤236 psi	400°F	special material [e.g., cupronickel (CuNi)]

The preparation of this chapter is assigned to TC 8.4, Air-to-Refrigerant Heat Transfer Equipment.

Table 1 Preferred Operating Limits for Continuous-Duty Steam Coil Materials in Commercial and Institutional Applications

Pressure, psi	Material	Tube Wall Thickness, in.
≤5	Copper	0.020
5 to 15		0.025
15 to 30		0.035
30 to 50		0.049
50 to 75	Red brass	0.025
75 to 100		0.035
100 to 150	90/10 CuNi	0.035
150 to 200		0.049

Note: Red brass and CuNi may be interchanged, depending on coil manufacturer's specifications.

Although these operating conditions are allowed by code, long exposures to them will shorten coil tube life. Leaks are less likely when the coil tube core has thicker walls of higher-strength materials. Operational experience suggests preferred limits for continuous-duty steam coils (tube OD ranging from 5/8 to 1 in.) in commercial and institutional applications, as shown in Table 1.

Steam coils also can be categorized by type as basic steam, steam-distributing, or face-and-bypass.

Basic steam coils generally have smooth tubes with fins on the air side. The steam supply connection is at one end and the tubes are pitched toward the condensate return, which is usually at the opposite end. For horizontal airflow, the tubes can be either vertical or horizontal. Horizontal tubes should be pitched within the casing toward the condensate return to facilitate condensate removal. Uniform steam distribution to all tubes is accomplished by careful selection of header size, its connection locations, and positioning of inlet connection distributor plates. Orifices also may be used at the core tube entrances in the supply header.

Steam-distributing coils most often incorporate perforated inner tubes that distribute steam evenly along the entire coil. The perforations perform like small steam ejector jets that, when angled in the inner tube, help remove condensate from the outer tube. An alternative design for short coils is an inner tube with no distribution holes, but with an open end. On all coils, supply and return connections can be at the same end or at opposite ends of the coil. For long, low-pressure coils, supply is usually at both ends and the condensate return on one end only.

Face-and-bypass steam coils have short sections of steam coils separated by air bypass openings. Airflow through the coil or bypass section is controlled by coil face-and-bypass dampers linked together. As a freeze protection measure, large installations use face-and-bypass steam coils with vertical tubes.

For proper performance of all types of steam heating coils, air or other noncondensables in the steam supply must be eliminated. Equally important, condensate from the steam must easily drain from inside the coil. Air vents are located at a high point of the piping and at the coil's inlet steam header. Whether airflow is horizontal or vertical, the coil's finned section is pitched toward the condensate return connection end of the coil. Installers must give particular care in the selection and installation of piping, controls, and insulation necessary to protect the coil from freeze-up caused by incomplete condensate drainage.

When entering air is at or below 32°F, the steam supply to the coil should not be modulated, but controlled as full on or full off. Coils located in series in the airstream, with each coil sized and controlled to be full on or completely off (in a specific sequence, depending on the entering air temperature), are not as likely to freeze. Temperature control with face-and-bypass dampers is also common. During part-load conditions, air is bypassed around the steam coil with full steam flow to the coil. In a face-and-bypass arrangement, high-velocity streams of freezing air must not impinge on the coil when the face dampers are partially closed. The section on Overall Requirements in this chapter and the section on Control of HVAC Elements (Heating Coils) in Chapter 46 of the 2007 *ASHRAE Handbook—HVAC Applications* have more details.

Water/Aqueous Glycol Heating Coils

Normal-temperature hot-water heating coils can be categorized as booster coils or standard heating coils. Booster (duct-mounted or reheat) coils are commonly found in variable-air-volume systems. They are one or two rows deep, have minimal water flow, and provide a small air temperature rise. Casings can be either flanged or slip-and-drive construction. Standard heating coils are used in runaround systems, makeup air units, and heating and ventilating systems. All use standard construction materials of copper tube and aluminum fins.

High-temperature water coils may operate with up to 400°F water, with pressures comparable or somewhat higher than the saturated vapor temperature of the water supply. The temperature drop across the coil may be as high as 150°F. To safely accommodate these fluid temperatures and thermal stresses, the coil requires industrial-grade construction that conforms to applicable boiler and safety codes. These requirements should be listed in detail by the specifying engineer, along with the inspection and certification requirements and a compliance check before coil installation and operation.

Proper water coil performance depends on eliminating air and on good water distribution in the coil and its interconnecting piping. Unless properly vented, air may accumulate in the coil circuits, which reduces heat transfer and possibly causes noise and vibration in the pipes. For this reason, water coils should be constructed with self-venting, drainable circuits. The self-venting design is maintained by field-connecting the water supply connection to the bottom and the water return connection to the top of the coil. Ideally, water is supplied at the bottom, flows upward through the coil, and forces any air out the return connection. Complete fluid draining at the supply connection indicates that coils are self-draining and without air or water traps. Such a design ensures that the coil is always filled with water, and it should completely drain when it is required to be empty. Most manufacturers provide vent and drain fittings on the supply and return headers of each water coil.

When water does get trapped in the coil core, it is usually caused by a sag in the coil core or by a nondraining circuit design. During freezing periods, even a small amount of water in the coil core can rupture a tube. Also, such a static accumulation of either water or glycol can corrode the tube over an extended period. Large multirow, multicircuited coils may not drain rapidly, even with self-draining circuitry; if they are not installed level, complete self draining will not take place. This problem can be prevented by including intermediate drain headers and installing the coil so that it is pitched toward the connections.

To produce desired ratings without excessive water pressure drop, manufacturers use various circuit arrangements. A single-feed serpentine circuit is commonly used on booster coils with low water flows. With this arrangement, a single feed carrying the entire water flow makes a number of passes across the airstream. The more common circuit arrangement is called a **full row feed** or **standard circuit**. With this design, all the core tubes of a row are fed with an equal amount of water from the supply header. Others, such as quarter, half, and double-row feed circuit arrangements, may be available, depending on the total number of tubes and rows of the coil. Uniform flow in each water circuit is obtained by designing each circuit's length as equal to the other as possible.

Generally, higher velocity provides greater capacity and more even discharge air temperature across the coil face, but with diminishing returns. To prevent erosion, 6 fps should not be exceeded for copper coils. At higher velocities, only modest gains in capacity can be achieved at increasingly higher pumping power penalties. Above 8 fps, any gain is negligible.

Velocities with fluid flow Reynolds numbers (Re) between 2000 and 10,000 fall into a transition range where heat transfer capacity predictions are less likely to be accurately computed. Below Re = 2000, flow is laminar, where heat transfer prediction is again reliable, but coil capacity is greatly diminished and tube fouling can become a problem. For further insight on the transition flow effect on capacity, refer to Figure 16 of Air-Conditioning and Refrigeration Institute (ARI) *Standard* 410. Methods of controlling water coils to produce a uniform exit air temperature are discussed in Chapter 46 of the 2007 *ASHRAE Handbook—HVAC Applications*.

In some cases, the hot water circulated may contain a considerable amount of sand and other foreign matter such as minerals. This matter should be filtered from the water circuit. Additionally, some coil manufacturers offer removable water header boxes (some are plates), or a removable plug at the return bends of each tube, allowing the tubes to be rodded clean. In an area where build-up of scale or other deposits is expected, include a fouling factor when computing heating coil performance. Hot-water coil ratings (ARI *Standard* 410) include a 0.00025 $h \cdot ft^2 \cdot °F/Btu$ fouling factor. Cupronickel, red brass, admiralty, stainless steel, and other tube alloys are usable to protect against corrosion and erosion, which can be common in hot-water/glycol systems.

Volatile Refrigerant Heat Reclaim Coils

A heat reclaim coil with a volatile refrigerant can function as a condenser either in series or parallel with the primary condenser of a refrigeration system. Heat from condensing or desuperheating vapor warms the airstream. It can be used as a primary source of heat or to assist some other form of heating, such as reheat for humidity control. In the broad sense, a heat reclaim coil functions at half the heat-dissipating capacity of its close-coupled refrigerant system's condenser. Thus, a heat reclaim coil should be (1) piped to be upstream from the condenser and (2) designed with the assumption that some condensate must be removed from the coil. For these reasons, the coil outlet should be located at the lowest point of the coil and trapped if this location is lower than the inlet of the condenser.

Heat reclaim coils are normally circuited for counterflow of air and refrigerant. However, most supermarket heat reclaim coils are two rows deep and use a crossflow design. The section on Air-Cooled Condensers in Chapter 38 has additional information on this topic. Also, because refrigerant heat reclaim involves specialized heating coil design, a refrigerant equipment manufacturer is the best source for information on the topic.

Electric Heating Coils

An electric heating coil consists of a length of resistance wire (commonly nickel/chromium) to which a voltage is applied. The resistance wire may be bare or sheathed in an electrically insulating layer, such as magnesium oxide, and compacted inside a finned steel tube. Sheathed coils are more expensive, have a higher air-side pressure drop, and require more space. A useful comparison for sizing is a heat transfer capacity of 41,000 $Btu/h \cdot ft^2$ of face area compared to 100,000 $Btu/h \cdot ft^2$ for bare resistance wire coils. However, the outer surface temperature of sheathed coils is lower, the coils are mechanically stronger, and contact with personnel or housing is not as dangerous. Coils with sheathed heating elements having an extended finned surface are generally preferred (1) for dust-laden atmospheres, (2) where there is a high probability of maintenance personnel contact, or (3) downstream from a dehumidifying coil that might have moisture carryover. Manufacturers can provide further information, including selection recommendations, applications, and maintenance instructions.

COIL SELECTION

The following factors should be considered in coil selection:

- Required duty or capacity considering other components
- Temperature of air entering the coil and air temperature rise
- Available heating media's operating and maximum pressure(s) and temperature(s)
- Space and dimensional limitations
- Air volume, speed, distribution, and limitations
- Heating media volume, flow speed, distribution, and limitations
- Permissible flow resistances for both the air and heating media
- Characteristics of individual designs and circuit possibilities
- Individual installation requirements, such as type of control and material compatibility
- Specified and applicable codes and standards regulating the design and installation.

Load requirements are discussed in Chapters 29 and 30 of the 2005 *ASHRAE Handbook—Fundamentals*. Much is based on the choice of heating medium, as well as operating temperatures and core tube diameter. Also, proper selection depends on whether the installation is new, being modified, or a replacement. Dimensional fit is usually the primary concern of modified and replacement coils; heating capacity is often unknown.

Air quantity is regulated by factors such as design parameters, codes, space, and size of the components. Resistance through the air circuit influences fan power and speed. This resistance may be limited to allow use of a given size fan motor or to keep operating expenses low, or because of sound level requirements. All of these factors affect coil selection. The air friction loss across the heating coil (summed with other series air pressure drops for system component such as air filters, cooling coils, grilles, and ductwork) determines the static pressure requirements of the complete air system. See Chapter 20 for selecting the fan component.

Permissible resistance through the water or glycol coil circuitry may be dictated by the available pressure from a given size pump and motor. This is usually controlled within limits by careful selection of coil header size and the number of tube circuits. Additionally, the adverse effect of high fluid velocity in contributing to erosion/corrosion of the tube wall is a major factor in selecting tube diameter and the circuit. Heating coil performance depends on the correct choice of original equipment and proper application and installation. For steam coils, proper performance relies first on selecting the correct type of steam coil, and then the proper size and type of steam trap. Properly sized connecting refrigerant lines, risers, and traps are critical to heat reclaim coils.

Heating coil thermal performance is relatively simple to derive. It only involves a dry-bulb temperature and sensible heat, without the complications of latent load and wet-bulb temperature for dehumidifying cooling performance. Even simpler, consult coil manufacturers' catalogs for ratings and selection. Most manufacturers provide computerized coil selection and rating programs on request; some are certified accurate within 5% of an application parameter, representative of a normal application range. Many manufacturers participate in the ARI Coil Certification Program, which approves application ratings that conform to all ARI *Standard* 410 requirements, based on qualifying testing to ASHRAE *Standard* 33.

Coil Ratings

Coil ratings are based on uniform face velocity. Nonuniform airflow may be caused by the system, such as air entering at odd angles, or by inadvertent blocking of part of the coil face. To obtain rated performance, the airflow quantity in the field must correspond to the design requirements and the velocity vary no greater than 20% at any point across the coil face.

The industry-accepted method of coil rating is outlined in ARI *Standard* 410. The test requirements for determining standard coil ratings are specified in ASHRAE *Standard* 33. ARI application ratings are derived by extending the ASHRAE standard rating test results for other operating conditions, coil sizes, row depths, and fin count for a particular coil design and arrangement. Steam, water, and glycol heating coils are rated within the following limits (listed in ARI *Standard* 410), which may be exceeded for special applications.

Air face velocity. 200 to 1500 fpm, based on air density of 0.075 lb/ft^3

Entering air temperature. Steam coils: −20 to 100°F
Water coils: 0 to 100°F

Steam pressure. 2 to 250 psig at coil steam supply connection (pressure drop through steam control valve must be considered)

Fluid temperatures. Water: 120 to 250°F
Ethylene glycol: 0 to 200°F

Fluid velocities. Water: 0.5 to 8 fps
Ethylene glycol: 0.5 to 6 fps

Overall Requirements

Individual installations vary widely, but the following values can be used as a guide. The air face velocity is usually between 500 and 1000 fpm. Delivered air temperature varies from about 72°F for ventilation only to about 150°F for complete heating. Steam pressure typically varies from 2 to 15 psig, with 5 psig being the most common. A minimum steam pressure of 5 psig is recommended for systems with entering air temperatures below freezing. Hot-water (or glycol) temperature for comfort heating is commonly between 180 and 200°F, with water velocities between 4 and 6 fps. For high-temperature water, water temperatures can be over 400°F with operating pressures of 15 to 25 psi over saturated water temperature.

Water quantity is usually based on about 20°F temperature drop through the coil. Air resistance is usually limited to 0.4 to 0.6 in. of water for commercial buildings and to about 1 in. for industrial buildings. High-temperature water systems commonly have a water temperature between 300 and 400°F, with up to 150°F drop through the coil.

Steam coils are selected with dry steam velocities not exceeding 6000 fpm and with acceptable condensate loading per coil core tube depending on the type of steam coil. Table 2 shows some typical maximum condensate loads.

Steam coil performance is maximized when the supply is dry, saturated steam, and condensate is adequately removed from the coil and continually returned to the boiler.

Although steam quality may not significantly affect the heat transfer of the coil, the back-up effect of too rapid a condensate rate, augmented by a wet supply stream, can cause a slug of condensate to travel through the coil and condensate return. This situation can result in noise and possible damage.

Complete mixing of return and outdoor air is essential to proper coil operation. The design of the air mixing damper or ductwork connection section is critical to the proper operation of a system and its air temperature delivery. Systems in which the air passes through a fan before flowing through a coil do not ensure proper air mixing. Dampers at the inlet air face of a steam coil should be the opposed-blade type, which are better than in-line blades for controlling air volume and reducing individual blade-directed cold airstreams when modulating in low-heat mode.

Table 2 Typical Maximum Condensate Loads

Tube Outside Diameter	Maximum Allowable Condensate Load, lb/h	
	Basic Coil	Steam Distributing Coil
5/8 in.	68	40
1 in.	168	95

Heat Transfer and Pressure Drops. For air-side heat transfer and pressure drop, the information given in Chapter 22 for sensible cooling coils is applicable. For water (or glycol) coils, the information given in Chapter 22 for water-side heat transfer and pressure drop also applies here. For steam coils, the heat transfer coefficient of condensing steam must be calculated (see Chapter 3 of the 2005 *ASHRAE Handbook—Fundamentals*). For estimating the pressure drop of condensing steam, see Chapter 5 of the 2005 *ASHRAE Handbook—Fundamentals*.

Parametric Effects. The heat transfer performance of a given coil can be changed by varying the airflow rate and/or the temperature of the heating medium, both of which are relatively linear. Understanding the interaction of these parameters is necessary for designing satisfactory coil capacity and control. A review of manufacturers' catalogs and selection programs, many of which are listed in ARI's *Applied Directory of Certified Products* and *Forced-Circulation Air-Cooling and Air-Heating Coils*, shows the effects of varying these parameters.

INSTALLATION GUIDELINES

Steam systems designed to operate at outdoor air temperatures below 32°F should be different from those designed to operate above it. Below 32°F, the steam air-heating system should be designed as a preheat and reheat pair of coils. The preheat coil functions as a nonmodulating basic steam coil, which requires full steam pressure whenever the outdoor temperature is below freezing. The reheat coil, typically a modulated steam-distributing coil, provides the heating required to reach the design air temperature. Above 32°F, the heating coil can be either a basic or steam-distributing type as needed for the duty.

When the leaving air temperature is controlled by modulating steam supply to the coil, steam-distributing tube coils provide the most uniform exit air temperature (see the section on Steam Coils). Correctly designed steam-distributing tube coils can limit the exit air temperature stratification to a maximum of 6°F over the entire length of the coil, even when steam supply is modulated to a fraction of full-load capacity.

Low-pressure steam systems and coils controlled by modulating steam supply should have a vacuum breaker or be drained through a vacuum-return system to ensure proper condensate drainage. It is good practice to install a closed vacuum breaker (where required) connected to the condensate return line through a check valve. This unit breaks the vacuum by equalizing the pressure, yet minimizes the possibility of air bleeding into the system. Steam traps should be located at least 12 in. below the condensate outlet to allow the coil to drain properly. Also, coils supplied with low-pressure steam or controlled by modulating steam supply should not be trapped directly to an overhead return line. Condensate can be lifted to overhead returns only when enough pressure is available to overcome the condensate head and any return line pressure. If overhead returns are necessary, the condensate must be pumped to the higher elevation (see Chapter 10).

Water coils for air heating generally have horizontal tubes to avoid air pockets. Where water or glycol coils may be exposed to a freezing condition, drainability must be considered. If a coil is to be drained and then exposed to below-freezing temperatures, it should first be flushed with a nonfreeze solution.

To minimize the danger of freezing in both steam and water-heating coils, the outside air inlet dampers usually close automatically when the fan is stopped (system shutdown). In steam systems with very cold outside air conditions (e.g., –20°F or below), it is desirable to fully open the steam valve when the system is shut down. If outside air is used for proportioning building makeup air, the outside air damper should be an opposed-blade design.

Heating coils are designed to allow for expansion and contraction resulting from the temperature ranges in which they operate.

Care must be taken to prevent imposing strains from the piping to the coil connections, particularly on high-temperature hot-water applications. Expansion loops, expansion or three-elbow swing joints, or flexible connections usually provide the needed protection (see Chapter 10).

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

Heat reclaim coils depend on a closely located, readily available source of high-side refrigerant vapor. For example, supermarket rack compressors and the air handler's coil section should be installed close to the store's motor room. Most commonly, the heat reclaim coil section is piped in series with the rack's condenser and sized for 50% heat extraction. Heat reclaim in supermarkets is discussed in Chapter 2 of the 2007 *ASHRAE Handbook—HVAC Applications*; also see Chapter 46 of the 2006 *ASHRAE Handbook—Refrigeration*.

In heat pump applications, the heating coil is usually the indoor coil that is used for cooling in the summer. The heat pump system is normally optimized for cooling load and efficiency. Heating performance is a by-product of cooling performance, and any unsatisfied heating requirement is met using electric heating coils. The refrigerant circuiting is also specialized and involves driving the refrigerant in the reverse direction from the cooling mode. Heat pump coils also have an additional check valve bypass to the expansion device for operating in heat pump mode. For additional details about heat pump coil design and operation, see Chapters 8 and 48.

COIL MAINTENANCE

Both internal and external surfaces must be clean for coils to deliver their full rated capacity. The tubes generally stay clean in glycol systems and in adequately maintained water systems. Should scale be detected in the piping where untreated water is used, chemical or mechanical cleaning of the internal tube surfaces is required. The need for periodic descaling can be minimized by proper boiler water treatment and deaeration.

Internal coil maintenance consists primarily of preventing scale and corrosion in the coil core tubes and piping of potable-water-heating (including steam) systems. In its simplest form, this involves removing dissolved oxygen, maintaining deionized water, and controlling boiler water pH. Boiler water can be deaerated mechanically. Vacuum deaerating simultaneously removes oxygen and carbon dioxide. The last traces of oxygen can be removed chemically by adding sodium sulfide. For steam coils, 100% dry steam contains 0% air. Good boiler water results in the absence of oxygen and a pH maintained at 10.5. If this is not practicable, a pH of 7 to 9 with a corrosion inhibitor is recommended. Because calcium carbonate is less soluble in water at higher pH, the inhibitor most often used for this purpose is sodium nitrate. Usually, the requirements for chemical treatment increase as the temperature of the coil's return flow drops. With few exceptions, boiler water chemical treatment programs use only proportional feeding, which is the recommended way of maintaining a constant concentration at all times. Periodic batch or slug feeding of water treatment chemicals is not an accurate way to treat boiler water, particularly if the system has a high water makeup rate. Only use chemicals known to be compatible with the coil's tube and connection metal(s). Chemical treatment of boiler water is complicated and has environmental effects. For this reason, it is important to consult a water treatment specialist to establish a proper boiler water treatment program. For further information on boilers, see Chapter 31.

The finned surface of heating coils can sometimes be brushed and cleaned with a vacuum cleaner. Coils are commonly surface-cleaned annually using pressurized hot water containing a mild detergent. Reheat coils that contain their refrigerant charge should never be cleaned with a spray above 150°F. In extreme cases of neglect, especially in restaurants where grease and dirt have accumulated, coil(s) may need to be removed to completely clean off the accumulation with steam, compressed air and water, or hot water containing a suitable detergent. Pressurized cleaning is more thorough if first done from the coil's air leaving side, before cleaning from the coil's air entry side. Often, outside makeup air coils have no upstream air filters, so they should be visually checked on a frequent schedule. Overall, coils should be inspected and serviced regularly. Visual observation should not be relied on to judge cleaning requirements for coils greater than three rows deep because airborne dirt tends to pack midway through the depth of the coil.

REFERENCES

ARI. 2001. Forced-circulation air-cooling and air-heating coils. *Standard* 410-2001. Air-Conditioning and Refrigeration Institute, Arlington, VA.

ARI. 2008. *CHC: Certified air-cooling and air-heating coils*. Air-Conditioning and Refrigeration Institute, Arlington, VA. http://www.ahridirectory.org.

ARI. Semiannually. *Applied directory of certified air-conditioning products*. Air-Conditioning and Refrigeration Institute, Arlington, VA. http://www.ahridirectory.org.

ASHRAE. 2000. Methods of testing forced circulation air cooling and air heating coils. *Standard* 33-2000.

ASME. 2001. *Boiler and pressure vessel code*. American Society of Mechanical Engineers, New York.

Related Commercial Resources