reduces the capacity, but can be largely avoided by proper layout or by the use of directing baffles.

The heat transfer depends also upon the velocity of the medium in the tubes and upon its character, whether flowing water, condensing steam or evaporating volatile refrigerant. Heat transfer rates expressed as Btu per square foot of internal surface per degree logarithmic mean effective temperature difference between the fluid and tube wall are, for example, about 150 to 300 for evaporating dichlorodifluoromethane, about 350 to 1200 for water at 2 and 6 fps and about 1200 for condensing steam. The influence of the medium in the tubes on the overall heat transfer rate is, therefore, apparent.

Because of these variables, reliable rating and performance information for any design of coil must be based on actual tests on that coil under the expected conditions of operation. A comparison between the performance of two designs, unless based on such tests on each, may lead to entirely erroneous conclusions.

PERFORMANCE OF HEATING AND COOLING COILS

Heating and cooling coils are essentially heat exchangers and as such their performance depends in general upon:

1. The overall coefficient of heat transfer from the fluid within the coil to the air it heats or cools.
2. The mean temperature difference between the fluid within the coil and the air flowing over the coil.
3. The physical dimensions of the coil.

Thus, for any one definite operating condition, the heating or cooling capacity of a given coil is expressed by the following basic formula:

$$Q = U \times MTD \times A \tag{1}$$

where

Q = total heat transferred by the coil, Btu per hour.

U = overall coefficient of heat transfer, Btu per hour per square foot of external coil surface per degree Fahrenheit temperature difference between the fluid within the coil and the air flowing over the coil.

MTD = mean temperature difference, degrees Fahrenheit between the fluid within the coil and the air passing over it. (This is commonly taken as the logarithmic mean temperature difference.)

A = external surface area of the given coil, square feet.

The performances of heating and cooling coils are influenced by the same factors in all but one very important exception, that is, when cooling coils operate wet or act as dehumidifying coils. For this reason, in the later discussion, heating and dry cooling coils are treated as one group and dehumidifying coils as another.

OVERALL COEFFICIENT OF HEAT TRANSFER

Of all factors affecting the performance of heating or cooling coils, the overall coefficient of heat transfer is the most difficult to determine as it is influenced by several factors which depend upon coil design and conditions of operation.

Considering any coil, whether of bare pipe or of finned type, the overall heat transfer coefficient for a given size and design of coil can always be considered as a combined effect of three individual heat transfer coefficients, namely:

1. The film coefficient of heat transfer between air and the external surface of the coil, usually given in Btu per hour per square foot external surface per degree Fahrenheit mean temperature difference.
2. The coefficient of heat transfer through the coil material—tube wall, fins, ribs, etc.
3. The film coefficient of heat transfer between the internal surface of the coil and the fluid flowing within the coil, usually given in Btu per hour per square foot internal surface per degree Fahrenheit mean temperature difference.

These three individual coefficients acting in series result in an overall coefficient of heat transfer in accordance with the basic laws. For a *bare pipe* coil the overall coefficient of heat transfer, whether for heating or for cooling (dry), can be expressed by a simplified basic formula as follows:

$$U = \frac{1}{\frac{R}{f_r} + \frac{X}{k} + \frac{1}{f_a}} \tag{2}$$

where

U = overall coefficient of heat transfer, Btu per hour per square foot external surface per degree Fahrenheit mean temperature difference between air and fluid within the coil.

f_r = film coefficient of heat transfer between the internal surface of the coil and the fluid flowing within the coil, Btu per hour per square foot internal surface per degree Fahrenheit mean temperature difference between that surface and the average fluid temperature.

f_a = film coefficient of heat transfer between air and the external surface of the coil, Btu per hour per square foot external surface per degree Fahrenheit mean temperature difference between the mass of air and the external surface.

k = conductivity of material from which the bare pipe is constructed, Btu per hour per square foot per degree Fahrenheit per inch thickness.

X = thickness of tube wall, inches.

R = ratio between external and internal surface of the bare tube, usually varying from 1.03 to 1.15 for the tube used in typical heating or cooling coils. This ratio R is inserted in the formula in order to place internal fluid coefficient of heat transfer on the basis of external surface.

Frequently, when pipe or tube walls are thin and of material having high conductivity (as is the case in construction of typical heating and cooling coils) the term X in Equation 2 becomes negligible and is generally disregarded. (The effect of the term X in typical bare pipe heating or cooling coils seldom exceeds 1 to 2 per cent of the overall coefficient). Thus, in its simplest form, for bare pipe:

$$U = \frac{1}{\frac{R}{f_r} + \frac{1}{f_a}} \tag{3}$$

For finned coils the formula[1] for the overall coefficient of heat transfer can be conveniently written:

$$U = \frac{1}{\frac{R}{f_r} + \frac{1}{zf_a}} \tag{4}$$

[1]Rational Development and Rating of Extended Air Cooling Surface, by H. B. Pownall (*Refrigerating Engineering*, October, 1935, p. 211).