titled *Joint ASRE-ASHAE Standard Method of Testing and Rating Forced-Circulation Air-Cooling and Air-Heating Coils*, has been adopted (1958).

DETERMINING REFRIGERATION LOAD

The following determination of the refrigeration load shows a division of the true *sensible* and *latent heat* loss of the air, which is accurate within the limitations of the data. These divisions will not correspond to load determination obtained from approximate factors or constants.

The total refrigeration load q_t of a cooling and dehumidifying coil (or air washer) is indicated on Fig. 13 and consists of the following components:

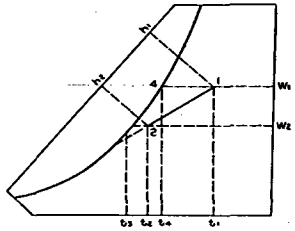

Fig. 13 . . . . Psychrometric Performance of Cooling Coil in Central System

1. The *sensible heat* q_s removed from the dry air and moisture in cooling from entering temperature t_1 to leaving temperature t_2.
2. The *latent heat* q_s removed to condense the moisture at the dew-point temperature t_4 of the entering air.
3. The heat of *subcooling* q_w removed from the condensate in cooling it from the condensing temperature t_4 to the leaving condensate temperature t_3.

Items 1, 2, and 3 may be related by

$$q_t = q_s + q_s + q_w \tag{5}$$

If only the *total heat* value is desired, it may be computed by

$$q_t = (h_1 - h_2) - (w_1 - w_2)h_{w3} \tag{6}$$

where

h_1 and h_2 = enthalpy at points 1 and 2 respectively.
w_1 and w_2 = humidity ratio at points 1 and 2 respectively.
h_{w3} = enthalpy of saturated liquid at the final temperature, t_3.

If a breakdown into *latent* and *sensible heat* components is desired, the following relations may be used:

The *latent heat* may be found from

$$q_s = (w_1 - w_2)h_{fs4} \tag{7}$$

where

h_{fs4} = enthalpy at the condensing temperature, t_4.

The *sensible heat* may be shown to be

$$q_s + q_w = (h_1 - h_2) - (w_1 - w_2)h_{s4} + (w_1 - w_2)(h_{w4} - h_{w3}) \tag{8}$$

where

h_{s4} = enthalpy at the condensing temperature, t_4.
h_{w4} = enthalpy of saturated liquid at condensing temperature, t_4.

The last term in Equation 8 is the heat of *subcooling* the condensate from the condensing temperature t_4 to its final temperature t_3. Then,

$$q_w = (w_1 - w_2)(h_{w4} - h_{w3}) \tag{9}$$

All values for solving the foregoing equations may be found on the ASHAE Psychrometric Chart and Tables 2 and 3 of Chapter 3.

Example 1: Air enters a coil at 90 F dry-bulb, 75 F wet-bulb; it leaves at 61 F dry-bulb, 58 F wet-bulb; leaving water is assumed to leave at a temperature between the leaving air dew point and coil surface temperature of 54 F. Find the total, latent, and sensible cooling loads on the coil.

Solution: From the ASHAE Psychrometric Chart, find the following:

h_1 = 38.42 Btu per lb of dry air.
h_2 = 25.10 Btu per lb of dry air.
t_4 = 69 F wet-bulb of entering air.
w_1 = 0.01525 lb per lb of dry air.
w_2 = 0.00960 lb per lb of dry air.

From Table 3, find:

h_{w4} = 37.11 Btu per lb.
h_{w3} = 22.12 Btu per lb.
h_{fs4} = 1054.27 Btu per lb.
h_{s4} = 1091.34 Btu per lb.

The total heat from Equation 6 is

$$q_t = (38.42 - 25.10) - (0.01525 - 0.00960) \times 22.12$$
$$= 13.32 - (0.00565 \times 22.12)$$
$$= 13.32 - 0.12 = 13.20 \text{ Btu per lb dry air.}$$

The *latent heat* from Equation 7 is

$$q_s = 0.00565 \times 1054.27 = 5.96 \text{ Btu per lb of dry air.}$$

The *sensible heat* by difference, is

$$q_s + q_w = q_t - q_s = 13.20 - 5.96 = 7.24 \text{ Btu per lb of dry air.}$$

Or the *sensible heat* may be computed from Equation 8 as

$$q_s + q_w = (38.42 - 25.10) - (0.00565 \times 1091.34) + 0.00565\,(37.11 - 22.12)$$
$$= 13.32 - 6.16 + 0.00565 \times 14.99$$
$$= 13.32 - 6.16 + 0.08 = 7.24 \text{ Btu per lb of dry air.}$$

The *subcooling* of the condensate as a part of the sensible heat is indicated by the last term of the equation, 0.08 Btu per lb of dry air.

CHAPTER 24

AIR CLEANING

Atmospheric Air Cleaners: Airborne Particulate Matter, Viscous-Impingement Filters, Dry Air Filters, Electronic Air Cleaners, Air Filter Performance, Selection, Maintenance, Installation, Adsorption of Vapors; Industrial Air and Gas Cleaners: Degree of Cleaning, Selection, Types, Application, Inertial Separators, Scrubbers, Wet Collectors, Filters, Electrostatic Precipitators, Adsorbers, Absorbers, Combustion Devices

AIR cleaning devices remove contaminants from an air or gas stream. They are available in a wide range of designs to meet various air cleaning requirements. Degree of removal required, quantity and characteristics of the contaminant to be removed, and conditions of the air or gas stream will have a bearing on the device selected for a given application. Definitions and a discussion of contaminant characteristics are given in Chapter 7, together with some consideration of their origin.

Air cleaning devices are divided in this chapter into two basic groups: Atmospheric Air Cleaners, described in Part I, and Industrial Air and Gas Cleaners, described in Part II.

Atmospheric Air Cleaners are ordinarily used to remove particulates such as are found in outdoor air, and are employed in ventilation, air conditioning, and heating systems where dust content seldom exceeds 4 grains per 1000 cu ft of air.

Industrial Air and Gas Cleaners are ordinarily used for the heavier concentrations encountered in local exhaust ventilation where the particulate content (loading) ranges from 100 to 20,000 grains per 1000 cu ft of air. Because of these heavier loadings, atmospheric air cleaners can seldom be used for the control of process aerosols in industrial applications.

PART I—ATMOSPHERIC AIR CLEANERS

Conventional air filters and electronic air cleaners are installed in air handling systems to remove dusts. These dusts constitute a mixture of particle sizes within the classification of temporary and permanent impurities listed in Fig. 1, Chapter 7, including bacteria, pollens, house dusts, and similar allergens which motivate attacks on persons of allergic sensitivity.[1,2]

Since the purpose of the filter or cleaner is to free the air of as much existing contamination as practicable, the degree of air cleanliness required should influence the choice of apparatus. Atmospheric dusts are mixtures of particles in all sizes. The removal of these particles and fractions becomes progressively difficult as the particle size decreases. Smoke particles are of major importance in many applications. Air cleaners will justify their cost through a reduction in housekeeping expense in the ventilated space, by the protection of the equipment in the ventilation system itself, and by providing relatively dust-free air for critical manufacturing processes.

Cleaning devices for atmospheric air are classified by the principle employed to collect dirt particles such as impingement on viscous coated media, filtration through porous media, or electronic air cleaning. In some cases a filter may display a combination of these principles. Each type of air cleaner has certain advantages. There are applications where it is desirable to pass air through a series of two or more different types to obtain optimum results.

AIRBORNE PARTICULATE MATTER

Suspensions of particulate matter in the air are called aerosols and consist of smokes, dusts, mists, and fumes. The characteristics of the aerosols which affect the performance of an air cleaner include particle size, concentration, shape, density, velocity, and surface characteristics. One of the most important of these is size.

The rate of settling of particles varies approximately as the square of the diameter. Particles larger than 10 microns in diameter settle so rapidly that the concentration of such particles decreases rapidly as the distance from the source increases. Particles less than 1 micron in size settle so slowly that the ordinary convection currents prevent sustained downward motion, and consequently such particles remain in the air for long periods.

If particles could be examined through a super microscope having a magnification of 250,000 diameters, a tobacco smoke particle of 0.1 micron would appear to be 1 in. in diameter, or approximately the size of a golf ball; a soft coal smoke particle 0.3 micron in diameter would appear like a baseball; a ragweed pollen grain of 20 microns in diameter would appear 16.5 ft in diameter, while the 50 micron particle (just visible to the naked eye and able to pass through a 270 mesh screen) would appear to be 50 ft in diameter. Consideration of this range in particle size from a golf ball to a sphere 50 ft in diameter will emphasize the difficulty of devising any single test to measure adequately the performance of air cleaning devices under all conditions of service.

The particles in the atmosphere can range in size from less than 0.01 micron up to things which are caught by an ordinary fly screen, such as lint, feathers, and insects. Almost all conceivable shapes and sizes are represented. The material is very commonly soot, ash, soil, lint, smoke, and fumes, but may include particles of almost any inorganic or organic material and even such living organisms as virus, bacteria,[3] and fungus spores.

This wide variety makes it impossible to design one type of cleaner which will be best for all applications. Mechanical filters of the low-pressure type can remove large particles effectively. Other mechanical filters can remove extremely fine particles, but may be handicapped somewhat by high-pressure drop and cost. Electronic air cleaners have the ability to give high effectiveness on normal atmospheric contamination, with a low operating-pressure drop.

As a general rule, the removal of the coarser dust particles and lint from the ventilating air produces tangible results in