Air discharged toward cold surfaces should be designed for a terminal velocity of 50 fpm at approximately one-quarter the distance from a cold wall. Grille outlet velocities in excess of 600 fpm under 9 and 10 ft ceilings are likely to cause drafts at some points in the occupancy zone.

Forced Air Systems (Central Steam)

In these systems the air supplied for ventilation is tempered by automatically controlled steam coils and the normal heat loss for each room is supplied by direct radiators or convection. Provision is made for exhaust equal to the amount of outdoor air supplied. There are many variations of these systems, and they may include any features of central systems described in Chapter 30. Hot water may also be used as the heating medium.

This type of system can also be designed to provide the entire heating requirement without using any direct radiation. This arrangement is quite satisfactory, but must be controlled for zones of similar occupancy which have exactly the same orientation. Where used as a two-duct system as described under Forced Warm Air Systems in preceding section, much more satisfactory results can be expected.

Unit Ventilator Systems

Unit ventilators are used for supplying heat and ventilation for individual classrooms. These units and their controls are described in Chapters 25 and 39. They can be combined or furnished with storage cabinets, book shelves, extensions for additional direct radiation, and extended grilles to discharge upward along the window sills.

As in previous systems described, the excess air must be provided a means of escape.

Panel Heating Systems

A number of schools have employed panel heating of various designs. It is particularly adaptable in the *slab-on-ground* type of school to overcome the cold floor. It is also quite adaptable to the *open corridor* type of school using natural or window ventilation in the warmer climates. In the cold climates it should be augmented by a tempered-air ventilating system as previously described.

Design data are given in Chapter 24, but the designer must include ample thermostatic control which employs some means of varying the water temperature in inverse ratio to the outside temperature. With well-insulated walls and ceilings this feature usually results in an appreciable anticipation of the heating requirements. Several control systems are outlined in Chapter 39. Individual room control is desirable but not mandatory. A separate zone control for each exposure and for each floor is absolutely necessary for satisfactory results.

When coils are installed in the floor slab, these systems must be operated continuously (day and night). Night setback is not desirable, but when used it must be placed on the room thermostats and the setback must not exceed 10 deg. Generally room temperatures, read on wall thermometers placed 60 in. from the floor, can be one to two deg lower than with other types of systems for equal comfort.

Floor temperature must not exceed 85 F on design days except that a perimeter band, not exceeding 15 in. from the walls, may have a surface temperature of 100 F. Floor panels should not be expected to warm the large volumes of air required for school ventilation, and for this reason a tempered air supply is required in all except mild climates.

MAINTENANCE AND OPERATION

Controls, boilers and combustion equipment, fans and mechanical heating devices, traps and valves, all need attention at least annually. Every designer must use extreme care in selecting equipment that will require a minimum of attention, and see that it is accessible for service.

While school custodial forces may be competent, they frequently have more work than can be handled during normal working hours. Unusual maintenance problems may therefore result in deterioration of equipment and systems. While first cost is important, final selection of equipment should not be made without consideration of the overall cost which includes maintenance and service.

CHAPTER 52

INSTRUMENTS AND MEASUREMENTS

Temperature Measurement, Pressure Measurement, Air Flow Measurement, Air Change Measurement, Humidity Measurement, Heat Transfer Through Building Materials, Evaluation of Thermal Environment, Combustion Analysis, Smoke Density Measurements, Determination of Air Contaminants, Sound and Vibration Measurements

HEATING and air conditioning engineers and technicians require instruments for both laboratory and field use and somewhat more precision is attainable and essential in the laboratory, where research and development are undertaken, than in the field, where acceptance and adjustment tests are conducted. Some instruments have attained an adequate state of development, while others fall far short of the desirable. For instance, temperatures can now be measured readily with ample accuracy for most purposes, while a convenient and precise method for determining or comparing the dustiness of atmospheres is lacking, and improvement in existing hygrometers and humidity controllers is essential.

Codes and standards covering different types of heating and air conditioning devices and apparatus have been promulgated by various authoritative organizations, and instruments essential for performance or compliance testing are enumerated in the relevant publications.[1, 2, 3, 4] The present purpose is to discuss the use and characteristics of the more important instruments.

TEMPERATURE MEASUREMENT[5, 6]

Thermometers

Any device capable of indicating temperature is a thermometer, but in common usage the term *thermometer* without qualification has come to signify the ordinary mercury-in-glass temperature indicating device. This type has a useful range from −40 F, the freezing point of mercury, to about 1000 F, at or near which the glass usually softens. Lower temperatures can be measured with alcohol-filled thermometers for which the range is about −94 F to +248 F. The better thermometers have their scales, either Fahrenheit or Centigrade, etched with acid into the glass which forms their stems. The probable error for etched stem thermometers is plus or minus one scale division, and calibration is desirable for much test work. Thermometers are calibrated during manufacture at not less than two temperatures—the freezing and boiling points of water—and calibration is often accomplished with the instrument completely immersed in a bath at the known temperature. The intervening scale divisions are then applied to the stem. When such a thermometer is used with the stem incompletely immersed, a correction known as the stem correction is necessary for accurate measurements, and its magnitude is usually computed by means of the following formula:

$$K = 0.00009\ D\ (t_1 - t_2) \qquad (1)$$

where

K = correction to be added, Fahrenheit degrees.