buildings but its comparisons and conclusions are largely applicable to the other types of multiroom buildings.

LOCAL SYSTEM DETAILS

To meet the requirements common to multiroom buildings, all peripheral systems considered must provide wide flexibility and range, to meet individual room requirements. The means for meeting the requirements may be:

1. Controlled mixing of air at two different temperatures.
2. Controlled use of water at two different temperatures.
3. Use of local refrigeration *and* local steam or hot-water heating.
4. Use of air to obtain heating together with water for cooling. Systems of this type require, in many climates, seasonal change-over, so as to reverse operation between summer and winter conditions.

In addition to maintaining acceptable temperatures and humidity, all these systems should:

1. Introduce into each individual space a sufficient amount of filtered and conditioned outdoor air, for satisfactory ventilation.
2. Limit outdoor air to the required amount and thereby reduce *needless* refrigeration or heating demands and costs.
3. Recirculate air, either centrally or locally, and recondition enough *return* air, in addition to the *outdoor* air, so that the *total* air circulated in the occupied spaces will do the necessary cooling and dehumidifying in summer at permissible temperature-differentials, as well as the necessary heating in winter.
4. Distribute and diffuse the air in the occupied spaces, at such temperatures, velocities, and directions as not to cause drafts objectionable to the occupants.
5. Operate without objectionable noise-levels in the occupied spaces.
6. Be easily maintained, kept clean, and adjusted to suit varying tastes of occupants.
7. Automatically differentiate between the cooling and heating requirements of different floors or zones, different *directional exposures*, and different individual rooms (due to sunshine, wind, etc.), as well as the load-variations resulting from occupancy, *lighting, local equipment, etc., and to adjust the performance*, smoothly and rapidly, to compensate for such variations.

Double-Duct Systems (Scheme I)

In the double-duct method of local temperature control, air (previously filtered, and often partly conditioned) is delivered by a single high-pressure fan to *two* sets of coils connected in parallel. One coil *cools* the air in hot weather to a temperature 20 to 25 deg lower than the desired room-condition; the other one *warms* the air (already sufficiently dehumidified, in summer) to a temperature *at* or *above* the room condition. In cold weather the cold air temperature can be secured without using refrigeration. The warm air temperature is raised progressively as the weather becomes colder.

The two coils feed into two parallel high-velocity duct systems; while the cold duct should usually be sized for 100 percent of the total fan-capacity, the hot duct, in most cases, need be sized only for 50, 60, or 70 percent. From the two ducts, a pair of mixing-dampers (or valves) deliver, to each individual room or bay, air at the right (mixed) temperature for the then current cooling or heating demand of that particular space. *A local thermostat controls the setting of the* mixing-valves. Since the pressure drop through these generates *noise*, acoustic attenuation is needed here. Quite often, the valves, the attenuator, and a *constant* air volume regulator are incorporated in a fabricated package or box, which feeds air into the room. An important element in many such systems is static-pressure control to maintain reasonably equal pressures in *both* ducts, at or near the mixing-valves, as the total flow through each duct varies.

Duct sizes usually limit *vertical* distribution (at outside walls) to 3 or 4 floors in height. Beyond this, horizontal distribution is often needed. In long, narrow buildings, it may be the preferred method. Such systems can sometimes be so designed that *the same* duct system serves several, or all, different zones. In this case, and if windows are large, the cold duct may sometimes be smaller than for 100 percent capacity, since not all facades will receive sunshine at the same time. In tropical climates (and even in colder climates if windows are very small and double-glazed) all boxes and outlets may be at the ceiling. Where winters get cold and windows are average or large in size, those for peripheral zones should be under windows.

Radiant Cooling and Heating (Scheme II)

This is accomplished by the circulation of *cooled* water, in summer, through coils, which extract heat from an aluminum ceiling, attached under the coils, and exposed to the room to be thus cooled. The same equipment obtains effective winter heating by *warming* the circulated water. To absorb heat, the ceiling must be appreciably *colder* than the air (or than other surfaces in the room). For example, a suitable surface, about 15 deg cooler than the room-air, will absorb sensible heat of about 20 Btuh per sq ft in a room not receiving sunlight. With solar radiation entering through windows, this value may increase to 25 or more. This is about equal to the differential between typical inside and peripheral zone demands, *if* windows are small or well shaded, and permits a large reduction in the amount of conditioned-air required. It may also make it possible to *combine* outside and inside zones into a single system of fans and ducts, with room and *zone control* only, by varying the water supplied to the radiant ceilings. Small convectors or radiant panels under windows (for winter use only) may be needed as a supplement in *corner* rooms and in colder climates.

In order to apply radiant cooling and heating, careful consideration must be given to fundamentals as follows:

1. To absorb heat adequately, the surface of the ceiling must be materially *colder* than the air.
2. The circulating water must, in turn, be *colder* than the ceiling surface. With well-designed coils, and ceilings of aluminum, the coldest water might be 3 or 4 F deg lower than the average ceiling temperature. With plaster or concrete ceilings which are much poorer heat-conductors this *differential* would have to be several times as great.
3. It is not economical to maintain dew points lower than 54 F to 56 F in midsummer throughout a conditioned building.
4. To avoid any risk of condensation, therefore, *no* indoor air should contact any surfaces at a lower temperature than 58 F. To avoid the high cost of (vapor-tight) heat-insulation for the cooled water system, this implies that the *coldest water in any* part of the system should be little (if any) below about 60 F.
5. Recessed lighting fixtures may be integrated with a radiant ceiling design. They may also be directly connected with the coils, so that much of the heat (emitted by lights) can be removed *directly without first becoming room* load. When thus used, or when the ceiling receives heat from floors directly heated by the sun, the cooling water (at a given temperature) will absorb much more heat than from the room air alone.
6. In very low dew point climates, such as deserts, lower water and ceiling temperatures may be used to increase capacity.
7. Where an ample supply of natural 60 F, or lower, water is available, radiant cooling plus chemical-adsorption dehumidification may eliminate the need for mechanical refrigeration.

For further information on panel cooling see Chapter 3.

Aluminum is advantageous for radiant-cooling ceiling material, because:

1. It is the best heat conductor (except silver or copper).
2. It is easily formed and worked and comparatively inexpensive.
3. It is not subject to corrosion which would interfere seriously with heat conduction from ceiling to coils. Steel coils should be well galvanized, to avoid reduction of heat transfer due to rusting.
4. It can be coated with a wide variety of finishes, and seldom needs refinishing. A flat finish which may be painted, anodized, etc., is essential for good thermal performance.

Sectional aluminum radiant-cooling ceiling panels (usually 12×12 in. or 12×24 in. are advantageously used for modular layouts consistent with spacing of windows, lights, and partitions and can also serve for acoustic treatment. Acoustic perforations represent a negligible percentage of the heat-absorbing surface, while the acoustic blanket of fiberglass or the like above the ceiling, is also efficient thermal insulation against reverse loss above the ceiling, and thereby improves performance and control of cooling panels.

While radiant cooling, where *applicable, eliminates* the space occupied by unit enclosures and primary-air conduits, and greatly reduces the amount of air handled as well as the size and space for fan-rooms and ducts, etc., it cannot eliminate *fans and ducts*. It can only *reduce* their size, cost, and complexity. It is still necessary to introduce enough outdoor air for:

1. Ventilation.
2. Comfortable air-motion.
3. Removal of most of the sensible cooling load due to people and lights.
4. Removal of latent load due to people and to obtain dehumidification to a point where the internal dew point will be low enough to avoid condensation on cooled pipes or surfaces.

Fan-Coil Units (Scheme III)

These systems make use of package fan-and-coil units, located under windows and supplied with circulating water which is chilled in summer or heated in winter. Good design includes:

1. Operating the fan-coil unit with *only* recirculation, to control the temperature of each room separately.
2. Controlling water flow by a room thermostat.
3. Providing a *separate* central fan-room and duct system (high or low velocity) of capacity *only* great enough to provide each room with proper ventilation and humidity control. The air may enter the room either through a branch duct connecting into the unit, or through a *separate* ceiling *outlet*.

The former arrangement has been successfully used in tropical hotels, where the conditioning unit was located overhead on the corridor side of the room. The latter arrangement may be advantageous for apartment houses. It may be noted that air quantities supplied through ducts will be ample with only 15 to 20 percent of that required for an all air system for peripheral zones so that the central fan-and-duct system becomes quite low in cost, and simple in design.

These systems are applicable to buildings having almost no interior zone space, or to the peripheral zones of those in which a *separate* conditioning system is provided for the interior zones. (See also Chapter 2.)

A variation is to let the interior zone all-air system deliver *ventilating* air to rooms in peripheral zones. This is not an efficient method, because (a) the interior zone supply (much of the time) may be about 75 percent *recirculated* air. To supply the same outdoor air ventilation, about 4 times as much air must be blown into peripheral spaces, and (b) the interior zones nearly always require *cooling*. In cold weather, then, the fan coil unit must supply *extra* heat. This causes a waste in both heating and cooling effect.

Zoned All-Water Systems (Scheme IIIA)

This is a scheme in which each room has *its own* fan-and-coil conditioning unit, with no ductwork. For adequate conditioning, each unit should have an outdoor-air intake under a window, or through the wall or roof, so as to deliver a mixture (fixed or variable) of outdoor and locally recirculated air.

Water-circulating piping *is zoned* by *direction* of the facades—or otherwise, to suit the particular building. Chilled water may thus be pumped to areas that require cooling, and, at the same time, warmed water to areas that require heating. Such systems are being used for apartment houses; they are materially less costly to install than what would be considered good practice for an office building or hotel, but decidedly better than the self-contained units formerly mostly used for apartments. They are suitable only where no large *interior* spaces require cooling and ventilation, since they have no central air supply system.

A variation of this scheme accomplishes heating, when needed, by *separate* coils, connected to a separate steam or hot water circulating system. Such an installation will be somewhat more costly and will have more complications. Its one major advantage *is the ability to control, separately*, the temperature *and* humidity (in climates where this may be essential), by cooling humid air as necessary to take out enough moisture, and then *reheating* it to the correct delivery *temperature*.

Induction Systems (Scheme IV)

In this scheme, now widely used in large office buildings, hotels, and the like, the peripheral zones (areas extending about 12 to 18 ft inward from the windows) are cooled or heated by means of compact local units, enclosed in metal cabinets under the windows or in a continuous metal sill construction. Each unit circulates, locally, as much conditioned air as will properly serve the peripheral zone space bounded by one window or by one small group of windows, while the inner zones of the building are conditioned by *separate* air duct supply systems. In the most usual method, the units under the windows receive as primary air about 15 to 20 percent of the total to be circulated in the room from a remote fan-room, through small high-velocity conduit ducts which are run *vertically* whenever possible, near each outside wall. The primary air *(largely or entirely outdoor) is filtered, humidified*, or dehumidified as necessary, cooled or heated at different seasons, and delivered at considerable pressure to the under-window units in which, by means of ejector-nozzles, the *primary air* aspirates or induces several times its own volume of air to flow *from* the room *into* the unit, mixes with it, and delivers the mixture back into the room in such a manner as to give good local distribution. The aspirated room-air passes into the unit through a finned-coil where it is cooled in summer or heated in winter by *water* circulated from a piping system connecting to each unit, and distributed much as is the primary-air ductwork. Preferably, the flow of water (or in some models, the flow of air) through the coil is controlled by a room thermostat responding to the temperature of the room air entering the unit. (See also Chapter 2.)

Many available combinations of nozzles, coils, operating pressures, etc., can produce units of many capacities, having several different ratios of primary-air to total thermal capacity, and having various heights, and thicknesses, etc. Generally speaking, the more liberal the proportions of the unit, for a given capacity, the quieter is its operation; but all units include careful acoustic treatment.

Two-Pipe Secondary Water. The majority of installations have employed a two-pipe water-circulating system, often zoned by facades, so that water at different temperatures could be supplied as required to compensate for sunshine, wind, and outdoor temperature effects. Whether or not water is zoned, good practice is to zone the primary air, because the local damper, after it has been adjusted for the correct amount of aspiration, maintains a fixed quantity of flow and there-