CHAPTER 2

RETAIL FACILITIES

THIS chapter covers design and application of air-conditioning and heating systems for various retail merchandising facilities. Load calculations, systems, and equipment are covered elsewhere in the Handbook series.

GENERAL CRITERIA

To apply equipment properly, the construction of the space to be conditioned, its use and occupancy, the time of day in which greatest occupancy occurs, physical building characteristics, and lighting layout must be known.

The following must also be considered:

- Electric power—size of service
- Heating—availability of steam, hot water, gas, oil, or electricity
- Cooling—availability of chilled water, well water, city water, and water conservation equipment
- Internal heat gains
- Rigging and delivery of equipment
- Structural considerations
- Obstructions
- Ventilation—opening through roof or wall for outside air duct, number of doors to sales area, and exposures
- Orientation of store
- Code requirements
- Utility rates and regulations
- Building standards

Specific design requirements, such as the increase in outside air required for exhaust where lunch counters exist, must be considered. The requirements of ASHRAE ventilation standards must be followed. Heavy smoking and objectionable odors may necessitate special filtering in conjunction with outside air intake and exhaust. Load calculations should be made using the procedure outlined in Chapter 29 of the 2001 *ASHRAE Handbook—Fundamentals.*

Almost all localities have some form of energy code in effect that establishes strict requirements for insulation, equipment efficiencies, system designs, etc., and places strict limits on fenestration and lighting. The requirements of ASHRAE *Standard* 90 should be met as a minimum guideline for retail facilities.

HVAC system selection and design for retail facilities are normally determined by economics. First cost is usually the determining factor for small stores; for large retail facilities, operating and maintenance costs are also considered. Generally, decisions about mechanical systems for retail facilities are based on a cash flow analysis rather than on a full life-cycle analysis.

SMALL STORES

Large glass areas found at the front of many small stores may cause high peak solar heat gain unless they have northern exposures. High heat loss may be experienced on cold, cloudy days. The HVAC system for this portion of the small store should be designed to offset the greater cooling and heating requirements. Entrance vestibules and heaters may be needed in cold climates.

Many new small stores are part of a shopping center. Although exterior loads will differ between stores, internal loads will be similar; proper design is important.

Design Considerations

System Design. Single-zone unitary rooftop equipment is common in store air conditioning. Using multiple units to condition the store involves less ductwork and can maintain comfort in the event of partial equipment failure. Prefabricated and matching curbs simplify installation and ensure compatibility with roof materials.

Heat pumps, offered as packaged equipment, are readily adaptable to small-store applications and have a low first cost. Winter design conditions, utility rates, and operating cost should be compared to those for conventional heating systems before this type of equipment is chosen.

Water-cooled unitary equipment is available for small-store air conditioning, but many U.S. communities restrict the use of city water and groundwater for condensing purposes and require installation of a cooling tower. Water-cooled equipment generally operates efficiently and economically.

Retail facilities often have a high sensible heat gain relative to the total heat gain. Unitary HVAC equipment should be designed and selected to provide the necessary sensible heat removal.

Air Distribution. External static pressures available in small-store air-conditioning units are limited, and ducts should be designed to keep duct resistances low. Duct velocities should not exceed 1200 fpm and pressure drop should not exceed 0.10 in. of water per 100 ft. Average air quantities range from 350 to 450 cfm per ton of cooling in accordance with the calculated internal sensible heat load.

Attention should be paid to suspended obstacles, such as lights and displays, that interfere with proper air distribution.

The duct system should contain enough dampers for air balancing. Dampers should be installed in the return and outside air duct for proper outside air/return air balance. Volume dampers should be installed in takeoffs from the main supply duct to balance air to the branch ducts.

Control. Controls for small stores should be kept as simple as possible while still able to perform required functions. Unitary equipment is typically available with manufacturer-supplied controls for easy installation and operation.

Automatic dampers should be placed in the outside air intake to prevent outside air from entering when the fan is turned off.

Heating controls vary with the nature of the heating medium. Duct heaters are generally furnished with manufacturer-installed safety controls. Steam or hot-water heating coils require a motorized valve for heating control.

Time clock control can limit unnecessary HVAC operation. Unoccupied reset controls should be provided in conjunction with timed control.

Maintenance. To protect the initial investment and ensure maximum efficiency, maintenance of air-conditioning units in small

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The preparation of this chapter is assigned to TC 9.8, Large Building Air-Conditioning Applications.

stores should be contracted out to a reliable service company on a yearly basis. The contract should clearly specify responsibility for filter replacements, lubrication, belts, coil cleaning, adjustment of controls, compressor maintenance, replacement of refrigerant, pump repairs, electrical maintenance, winterizing, system start-up, and extra labor required for repairs.

Improving Operating Cost. Outside air economizers can reduce the operating cost of cooling in most climates. They are generally available as factory options or accessories with roof-mounted units. Increased exterior insulation generally reduces operating energy requirements and may in some cases allow the size of installed equipment to be reduced. Many codes now include minimum requirements for insulation and fenestration materials.

DISCOUNT, BIG-BOX, AND SUPERCENTER STORES

Large warehouse or big-box stores attract customers with discount prices when large quantities are purchased. These stores typically have high-bay fixture displays and usually store merchandise in the sales area. They feature a wide range of merchandise and may include such diverse areas as a lunch counter, an auto service area, a supermarket, a pharmacy, and a garden shop. Some stores sell pets, including fish and birds. This variety of merchandise must be considered in designing air conditioning. The design and application suggestions for small stores also apply to discount stores.

Another type of big-box facility provides both dry good and grocery areas. The grocery area is typically treated as a traditional stand-alone grocery (see the section on Supermarkets). Conditioning outside air for the dry goods areas must be considered to limit the introduction of excess moisture that will migrate to the freezer aisles.

Hardware, lumber, furniture, etc., is also sold in big-box facilities. A particular concern in this type of facility is ventilation for material-handling equipment, such as forklift trucks.

In addition, areas such as stockrooms, rest rooms, offices, and special storage rooms for perishable merchandise may require air conditioning or refrigeration.

Load Determination

Operating economics and the spaces served often dictate inside design conditions. Some stores may base summer load calculations on a higher inside temperature (e.g., 80°F db) but then set the thermostats to control at 72 to 75°F db. This reduces the installed equipment size while providing the desired inside temperature most of the time.

Special rooms for storage of perishable goods are usually designed with separate unitary air conditioners.

The heat gain from lighting will not be uniform throughout the entire area. For example, jewelry and other specialty displays typically have lighting heat gains of 6 to 8 W per square foot of floor area, whereas the typical sales area has an average value of 2 to 4 W/ft^2. For stockrooms and receiving, marking, toilet, and rest room areas, a value of 2 W/ft^2 may be used. When available, actual lighting layouts rather than average values should be used for load computation.

The store owner usually determines the population density for a store based on its location, size, and past experience.

Food preparation and service areas in discount and outlet stores range from small lunch counters with heat-producing equipment (ranges, griddles, ovens, coffee urns, toasters) in the conditioned space to large deluxe installations with kitchens separate from the conditioned space. Chapter 31 has specific information on HVAC systems for kitchen and eating spaces.

Data on the heat released by special merchandising equipment, such as amusement rides for children or equipment used for preparing speciality food items (e.g., popcorn, pizza, frankfurters, hamburgers, doughnuts, roasted chickens, cooked nuts, etc.), should be obtained from the equipment manufacturers.

Ventilation and outside air must be provided as required in ASHRAE *Standard* 62 and local codes.

Design Considerations

Heat released by installed lighting is usually sufficient to offset the design roof heat loss. Therefore, interior areas of these stores need cooling during business hours throughout the year. Perimeter areas, especially the storefront and entrance areas, may have highly variable heating and cooling requirements. Proper zone control and HVAC design are essential. The location of checkout lanes in this area makes proper environmental control even more important.

System Design. The important factors in selecting discount and outlet store air-conditioning systems are (1) installation costs, (2) floor space required for equipment, (3) maintenance requirements and equipment reliability, and (4) simplicity of control. Roof-mounted units are most commonly used.

Air Distribution. The air supply for large sales areas should generally be designed to satisfy the primary cooling requirement. For perimeter areas, the variable heating and cooling requirements must be considered.

Because these stores require high, clear areas for display and restocking, air is generally distributed from heights of 14 ft and greater. Air distribution at these heights requires high velocities in the heating season to overcome the buoyancy of hot air. The discharge air velocity creates turbulence in the space and induces airflow from the ceiling area to promote complete mixing of the air.

During the cooling season the designer can take advantage of stratification to reduce equipment load. By introducing air near customers at low velocity, the air will stratify during the cooling season. With this method of air distribution, the set-point temperature can be maintained in the occupant zone and the temperature in the upper space can be allowed to rise. However, this strategy requires equipment to destratify the air during the heating season. Space-mounted fans, and radiant heating at the perimeter, entrance, and sales areas may be required.

Control. Because the controls are usually operated by personnel who have little knowledge of air conditioning, systems should be simple, dependable, and fully automatic, as simple to operate as a residential system. Most unitary equipment has automatic electronic controls for ease of operation.

Maintenance. Most stores do not employ trained maintenance personnel; they rely instead on service contracts with either the installer or a local service company. For suggestions on lowering operating costs, see the section on Small Stores.

SUPERMARKETS

Load Determination

Heating and cooling loads should be calculated using the methods outlined in Chapter 29 of the 2001 *ASHRAE Handbook—Fundamentals*. Data for calculating loads caused by people, lights, motors, and heat-producing equipment should be obtained from the store owner or manager or from the equipment manufacturer. In supermarkets, space conditioning is required both for human comfort and for proper operation of refrigerated display cases. The air-conditioning unit should introduce a minimum quantity of outside air, either the volume required for ventilation based on ASHRAE *Standard* 62 or the volume required to maintain slightly positive pressure in the space, whichever is larger.

Many supermarkets are units of a large chain owned or operated by a single company. The standardized construction, layout, and equipment used in designing many similar stores simplify load calculations.

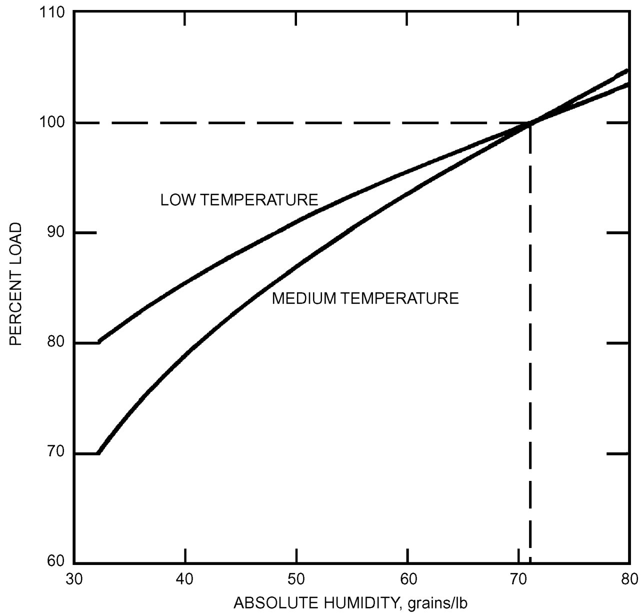

Fig. 1 Refrigerated Case Load Variation with Store Air Humidity

It is important that the final air-conditioning load be correctly determined. Refer to manufacturers' data for information on total heat extraction, sensible heat, latent heat, and percentage of latent to total loadfor display cases. Engineers report considerable fixture heat removal (case load) variation as the relative humidity and temperature vary in comparatively small increments. Relative humidity above 55% (75°F and 72 gr/lb absolute humidity) substantially increases the load; reduced absolute humidity substantially decreases the load, as shown in Figure 1. Trends in store design, which include more food refrigeration and more efficient lighting, reduce the sensible component of the load even further.

To calculate the total load and percentage of latent and sensible heat that the air conditioning must handle, the refrigerating effect imposed by the display fixtures must be subtracted from the building's gross air-conditioning requirements (Table 1).

Modern supermarket designs have a high percentage of closed refrigerated display fixtures. These vertical cases have large glass display doors and greatly reduce the problem of latent and sensible heat removal from the occupied space. The doors do, however, require heaters to minimize condensation and fogging. These heaters should cycle by automatic control.

For more information on supermarkets, see Chapter 47, Retail Food Store Refrigeration and Equipment, in the 2002 *ASHRAE Handbook—Refrigeration*.

Design Considerations

Store owners and operators frequently complain about cold aisles, heaters that operate even when the outside temperature is above 70°F, and air conditioners that operate infrequently. These problems are usually attributed to spillover of cold air from open refrigerated display equipment.

Although refrigerated display equipment may cause cold stores, the problem is not excessive spillover or improperly operating equipment. Heating and air-conditioning systems must compensate for the effects of open refrigerated display equipment. Design considerations include the following:

- Increased heating requirement because of removal of large quantities of heat, even in summer.

Table 1 Refrigerating Effect (RE) Produced by Open Refrigerated Display Fixtures

	RE on Building Per Unit Length of Fixture*			
Display Fixture Types	Latent Heat, Btu/h·ft	% Latent to Total RE	Sensible Heat, Btu/h·ft	Total RE, Btu/h·ft
Low-temperature (frozen food)				
Single-deck	38	15	207	245
Single-deck/double-island	70	15	400	470
2-deck	144	20	576	720
3-deck	322	20	1288	1610
4- or 5-deck	400	20	1600	2000
Ice cream				
Single-deck	64	15	366	430
Single-deck/double-island	70	15	400	470
Standard-treatment				
Meats				
Single-deck	52	15	298	350
Multideck	219	20	876	1095
Dairy, multideck	196	20	784	980
Produce				
Single-deck	36	15	204	240
Multideck	192	20	768	960

*These figures are general magnitudes for fixtures adjusted for average desired product temperatures and apply to store ambients in front of display cases of 72 to 74°F with 50 to 55% rh. Raising the dry bulb only 3 to 5°F and the humidity to 5 to 10% can increase loads (heat removal) 25% or more. Lower temperatures and humidities, as in winter, have an equally marked effect on lowering loads and heat removal from the space. Consult display case manufactuer's data for the particular equipment to be used.

- Net air-conditioning load after deducting the latent and sensible refrigeration effect. The load reduction and change in sensible-latent load ratio have a major effect on equipment selection.
- Need for special air circulation and distribution to offset the heat removed by open refrigerating equipment.
- Need for independent temperature and humidity control.

Each of these problems is present to some degree in every supermarket, although situations vary with climate and store layout. Methods of overcoming these problems are discussed in the following sections. Energy costs may be extremely high if the year-round air-conditioning system has not been designed to compensate for the effects of refrigerated display equipment.

Heat Removed by Refrigerated Displays. The display refrigerator not only cools a displayed product but envelops it in a blanket of cold air that absorbs heat from the room air in contact with it. Approximately 80 to 90% of the heat removed from the room by vertical refrigerators is absorbed through the display opening. Thus, the open refrigerator acts as a large air cooler, absorbing heat from the room and rejecting it via the condensers outside the building. Occasionally, this conditioning effect can be greater than the design air-conditioning capacity of the store. The heat removed by the refrigeration equipment *must* be considered in the design of the air-conditioning and heating systems because this heat is being removed constantly, day and night, summer and winter, regardless of the store temperature.

Display cases increase the building heating requirement such that heat is often required at unexpected times. The following example illustrates the extent of this cooling effect. The desired store temperature is 75°F. Store heat loss or gain is assumed to be 15,000 Btu/h per °F of temperature difference between outside and store temperature. (This value varies with store size, location, and exposure.) The heat removed by refrigeration equipment is 190,000 Btu/h. (This value varies with the number of refrigerators.) The latent heat removed is assumed to be 19% of the total, leaving 81% or 154,000 Btu/h sensible heat removed, which will cool the store 154,000/15,000 = 10°F. By constantly removing sensible heat from its environment, the refrigeration equipment in this store will cool the store 10°F below outside temperature in winter and in summer. Thus, in mild climates, heat must be added to the store to maintain comfort conditions.

The designer can either discard or reclaim the heat removed by refrigeration. If economics and store heat data indicate that the heat should be discarded, heat extraction from the space must be included in the heating load calculation. If this internal heat loss is not included, the heating system may not have sufficient capacity to maintain design temperature under peak conditions.

The additional sensible heat removed by the cases may change the air-conditioning latent load ratio from 32% to as much as 50% of the net heat load. Removing a 50% latent load by refrigeration alone is very difficult. Normally, it requires specially designed equipment with reheat or chemical adsorption.

Multishelf refrigerated display equipment requires 55% rh or less. In the dry-bulb temperature ranges of average stores, humidity in excess of 55% can cause heavy coil frosting, product zone frosting in low-temperature cases, fixture sweating, and substantially increased refrigeration power consumption.

A humidistat can be used during summer cooling to control humidity by transferring heat from the condenser to a heating coil in the airstream. The store thermostat maintains proper summer temperature conditions. Override controls prevent conflict between the humidistat and the thermostat.

The equivalent result can be accomplished with a conventional air-conditioning system by using three- or four-way valves and reheat condensers in the ducts. This system borrows heat from the standard condenser and is controlled by a humidistat. For higher energy efficiency, specially designed equipment should be considered. Desiccant dehumidifiers and heat pipes have also been used.

Humidity. Cooling from refrigeration equipment does not preclude the need for air conditioning. On the contrary, it increases the need for humidity control.

With increases in store humidity, heavier loads are imposed on the refrigeration equipment, operating costs rise, more defrost periods are required, and the display life of products is shortened. The dew point rises with relative humidity, and sweating can become so profuse that even nonrefrigerated items such as shelving superstructures, canned products, mirrors, and walls may sweat.

Lower humidity results in lower operating costs for refrigerated cases. There are three methods to reduce the humidity level: (1) standard air conditioning, which may overcool the space when the latent load is high and sensible load is low; (2) mechanical dehumidification, which removes moisture by lowering the air temperature to its dew point, and uses hot-gas reheat when needed to discharge at any desired temperature; and (3) desiccant dehumidification, which removes moisture independent of temperature, supplying warm air to the space unless postcooling is provided to discharge at any desired temperature.

Each method provides different dew-point temperatures at different energy consumption and capital expenditures. The designer should evaluate and consider all consequential tradeoffs. Standard air conditioning requires no additional investment but reduces the space dew-point temperature only to 60 to 65°F. At 75°F space temperature this results in 60 to 70% rh at best. Mechanical dehumidifiers can provide humidity levels of 40 to 50% at 75°F. Supply air temperature can be controlled with hot-gas reheat between 50 and 90°F. Desiccant dehumidification can provide levels of 35 to 40% rh at 75°F. Postcooling supply air may be required, depending on internal sensible loads. A desiccant is reactivated by passing hot air at 180 to 250°F through the desiccant base.

System Design. The same air-handling equipment and distribution system are generally used for both cooling and heating. The entrance area is the most difficult section to heat. Many supermarkets in the northern United States are built with vestibules provided with separate heating equipment to temper the cold air entering from outside. Auxiliary heat may also be provided at the checkout area, which is usually close to the front entrance. Methods of heating entrance areas include the use of (1) air curtains, (2) gas-fired or electric infrared radiant heaters, and (3) waste heat from the refrigeration condensers.

Air-cooled condensing units are the most commonly used in supermarkets. Typically, a central air handler conditions the entire sales area. Specialty areas like bakeries, computer rooms, or warehouses are better served with a separate air handler because the loads in these areas vary and require different control than the sales area.

Most installations are made on the roof of the supermarket. If air-cooled condensers are located on the ground outside the store, they must be protected against vandalism as well as truck and customer traffic. If water-cooled condensers are used on the air-conditioning equipment and a cooling tower is required, provisions should be made to prevent freezing during winter operation.

Air Distribution. Designers overcome the concentrated load at the front of a supermarket by discharging a large portion of the total air supply into the front third of the sales area.

The air supply to the space with a standard air-conditioning system is typically 1 cfm per square foot of sales area. This value should be calculated based on the sensible and latent internal loads. The desiccant system typically requires less air supply because of its high moisture removal rate, typically 0.5 cfm per square foot. Mechanical dehumidification can fall within these parameters, depending on required dew point and suction pressure limitations.

Being denser, air cooled by the refrigerators settles to the floor and becomes increasingly colder, especially in the first 36 in. above the floor. If this cold air remains still, it causes discomfort and does not help to cool other areas of the store that need more cooling. Cold floors or areas in the store cannot be eliminated by the simple addition of heat. Reduction of air-conditioning capacity without circulation of localized cold air is analogous to installing an air conditioner without a fan. To take advantage of the cooling effect of the refrigerators and provide an even temperature in the store, the cold air must be mixed with the general store air.

To accomplish the necessary mixing, air returns should be located at floor level; they should also be strategically placed to remove the cold air near concentrations of refrigerated fixtures. Returns should be designed and located to avoid creating drafts. There are two general solutions to this problem:

- **Return Ducts in Floor.** This is the preferred method and can be accomplished in two ways. The floor area in front of the refrigerated display cases is the coolest area. Refrigerant lines are run to all of these cases, usually in tubes or trenches. If the trenches or tubes are enlarged and made to open under the cases for air return, air can be drawn in from the cold area (Figure 2). The air is returned to the air-handling unit through a tee connection to the trench before it enters the back room area. The opening through which the refrigerant lines enter the back room should be sealed.

  If refrigerant line conduits are not used, air can be returned through inexpensive underfloor ducts. If refrigerators have insufficient undercase air passage, the manufacturer should be consulted. Often they can be raised off the floor approximately 1.5 in. Floor trenches can also be used as ducts for tubing, electrical supply, and so forth.

  Floor-level return relieves the problem of localized cold areas and cold aisles and uses the cooling effect for store cooling, or increases the heating efficiency by distributing the air to areas that need it most.
- **Fans Behind Cases.** If ducts cannot be placed in the floor, circulating fans can draw air from the floor and discharge it above

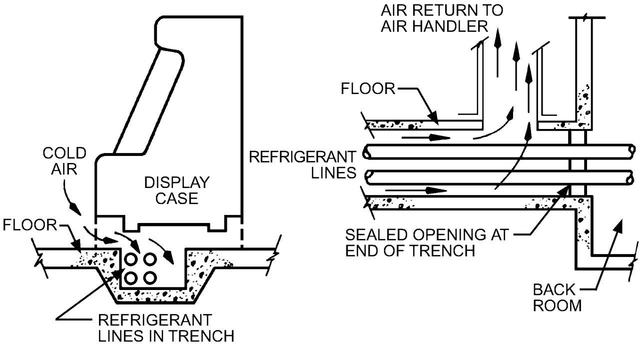

Fig. 2 Floor Return Ducts

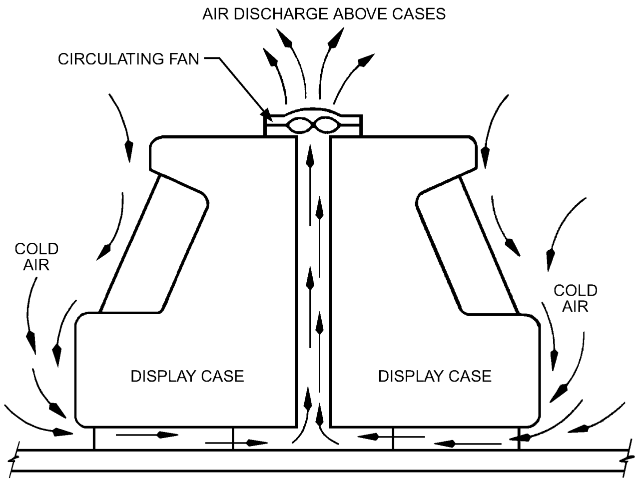

Fig. 3 Air Mixing Using Fans Behind Cases

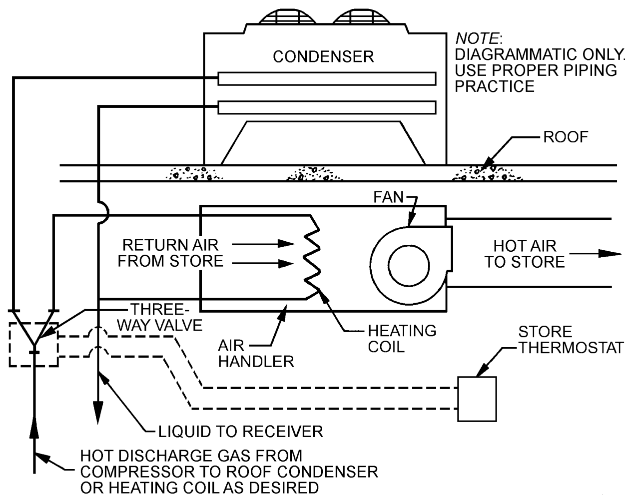

Fig. 4 Heat Reclaiming Systems

the cases (Figure 3). Although this approach prevents objectionable cold aisles in front of the refrigerated display cases, it does not prevent an area with a concentration of refrigerated fixtures from remaining colder than the rest of the store.

Control. Store personnel should only be required to change the position of a selector switch to start or stop the system or to change from heating to cooling or from cooling to heating. Control systems

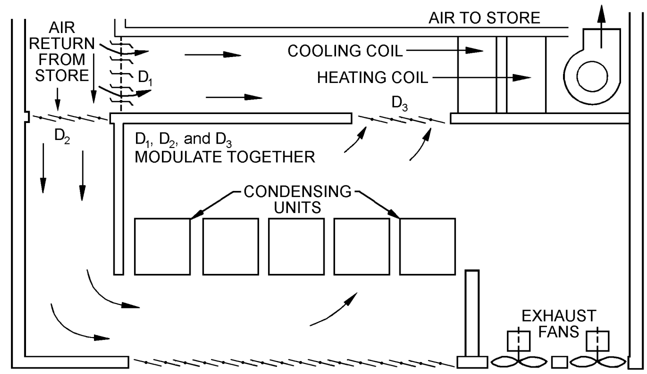

Fig. 5 Machine Room with Automatic Temperature Control Interlocked with Store Temperature Control

for heat recovery applications are more complex and should be coordinated with the equipment manufacturer.

Maintenance and Heat Reclamation. Most supermarkets, except large chains, do not employ trained maintenance personnel, but rather rely on service contracts with either the installer or a local service company. This relieves store management of the responsibility of keeping the air conditioning operating properly.

Heat extracted from the store and heat of compression may be reclaimed for heating cost saving. One method of reclaiming rejected heat is to use a separate condenser coil located in the air conditioner's air handler, either alternately or in conjunction with the main refrigeration condensers, to provide heat as required (Figure 4). Another system uses water-cooled condensers and delivers its rejected heat to a water coil in the air handler.

The heat rejected by conventional machines using air-cooled condensers may be reclaimed by proper duct and damper design (Figure 5). Automatic controls can either reject this heat to the outside or recirculate it through the store.

DEPARTMENT STORES

Department stores vary in size, type, and location, so air-conditioning design should be specific to each store. An ample minimum quantity of outside air reduces or eliminates odor problems. Essential features of a quality system include (1) an automatic control system properly designed to compensate for load fluctuations, (2) zoned air distribution to maintain uniform conditions under shifting loads, and (3) use of outside air for cooling during intermediate seasons and peak sales periods. It is also desirable to adjust inside temperature for variations in the outside temperature. Although close control of humidity is not necessary, a properly designed system should operate to maintain relative humidity at 50% or below with a corresponding dry-bulb temperature of 78°F. This humidity limit eliminates musty odors and retards perspiration, particularly in fitting rooms.

Load Determination

Because the occupancy (except store personnel) is transient, inside conditions are commonly set not to exceed 78°F db and 50% rh at outside summer design conditions, and 70°F db at outside winter design conditions. Winter humidification is seldom used in store air conditioning.

The number of customers and store personnel normally found on each conditioned floor must be ascertained, particularly in specialty departments or other areas having a greater-than-average concentration of occupants. Lights should be checked for wattage and type. Table 2 gives approximate values for lighting in various areas; Table 3 gives approximate occupancies.

Table 2 Approximate Lighting Load for Department Stores

Area	W/ft^2
Basement	3 to 5
First floor	4 to 7
Upper floors, women's wear	3 to 5
Upper floors, house furnishings	2 to 3

Table 3 Approximate Occupancy for Department Stores

Area		ft^2 per person
Basement		25 to 100
First floor		25 to 75
Upper floors,	women's wear	50 to 100
	house furnishings	100 or more

Other loads, such as those from motors, beauty parlor and restaurant equipment, and any special display or merchandising equipment, should be determined.

The minimum outside air requirement should be as defined in ASHRAE *Standard* 62, which is generally acceptable and adequate for removing odors and keeping the building atmosphere fresh. However, local ventilation ordinances may require greater quantities of outside air.

Paint shops, alteration rooms, rest rooms, eating places, and locker rooms should be provided with positive exhaust ventilation, and their requirements must be checked against local codes.

Design Considerations

Before performing load calculations, the designer should examine the store arrangement to determine what will affect the load and the system design. For existing buildings, actual construction, floor arrangement, and load sources can be surveyed. For new buildings, examination of the drawings and discussion with the architect or owner is required.

Larger stores may contain beauty parlors, restaurants, lunch counters, or auditoriums. These special areas may operate during all store hours. If one of these areas has a load that is small in proportion to the total load, the load may be met by the portion of the air conditioning serving that floor. If present or future operation could for any reason be compromised by such a strategy, this space should be served by separate air conditioning. Because of the concentrated load in the beauty parlor, separate air distribution should be provided for this area.

The restaurant, because of its required service facilities, is generally centrally located. It is often used only during lunchtime. For odor control, a separate air-handling system should be considered. Future plans for the store must be ascertained because they can have a great effect on the type of air conditioning and refrigeration to be used.

System Design. Air conditioning for department stores may be unitary or central station. Selection should be based on owning and operating costs as well as special considerations for the particular store, such as store hours, load variations, and size of load.

Large department stores often use central-station systems consisting of air-handling units having chilled-water cooling coils, hot-water heating coils, fans, and filters. Air systems must have adequate zoning for varying loads, occupancy, and usage. Wide variations in people loads may justify considering variable-volume air distribution systems. Water chilling and heating plants distribute water to the various air handlers and zones and may take advantage of some load diversity throughout the building.

Air-conditioning equipment should not be placed in the sales area; instead, it should be located in ceiling, roof, and mechanical equipment room areas whenever practicable. Maintenance and operation after installation should be considered when siting equipment.

Air Distribution. All buildings must be studied for orientation, wind exposure, construction, and floor arrangement. These factors affect not only load calculations, but also zone arrangements and duct locations. In addition to entrances, wall areas with significant glass, roof areas, and population densities, the expected locations of various departments (e.g., the lamp department) should be considered. Flexibility must be left in the duct design to allow for future movement of departments. The preliminary duct layout should also be checked in regard to winter heating to determine any special situations. It is usually necessary to design separate air systems for entrances, particularly in northern areas. This is also true for storage areas where cooling is not contemplated.

Air curtains may be installed at entrance doorways to limit or prevent infiltration of unconditioned air, at the same time providing greater ease of entry compared to a vestibule with a second set of doors.

Control. The necessary extent of automatic control depends on the type of installation and the extent to which it is zoned. Control must be such that correctly conditioned air is delivered to each zone. Outside air intake should be automatically controlled to operate at minimum cost while providing required airflow. Partial or full automatic control should be provided for cooling to compensate for load fluctuations. Completely automatic refrigeration plants should be considered.

Maintenance. Most department stores employ personnel for routine operation and maintenance, but rely on service and preventive maintenance contracts for refrigeration cycles, chemical treatment, central plant systems, and major repairs.

Improving Operating Cost. An outside air economizer can reduce the operating cost of cooling in most climates. These are generally available as factory options or accessories with the air-handling units or control systems. Heat recovery and thermal storage should also be analyzed.

CONVENIENCE CENTERS

Many small stores, discount stores, supermarkets, drugstores, theaters, and even department stores are located in convenience centers. The space for an individual store is usually leased. Arrangements for installing air conditioning in leased space vary. Typically, the developer builds a shell structure and provides the tenant with an allowance for usual heating and cooling and other minimum interior finish work. The tenant must then install an HVAC system. In another arrangement, developers install HVAC units in the small stores with the shell construction, often before the space is leased or the occupancy is known. Larger stores typically provide their own HVAC design and installation.

Design Considerations

The developer or owner may establish standards for typical heating and cooling that may or may not be sufficient for the tenant's specific requirements. The tenant may therefore have to install systems of different sizes and types than originally allowed for by the developer. The tenant must ascertain that power and other services will be available for the total intended requirements.

The use of party walls in convenience centers tends to reduce heating and cooling loads. However, the effect an unoccupied adjacent space has on the partition load must be considered.

REGIONAL SHOPPING CENTERS

Regional shopping centers generally incorporate an enclosed, heated and air-conditioned mall. These centers are normally owned by a developer, who may be an independent party, a financial institution, or one of the major tenants in the center.

Table 4 Typical Installed Cooling Capacity and Lighting Levels—Midwestern United States

Type of Space	Area per Unit of Installed Cooling, ft^2/ton	Installed Cooling per Unit of Area, Btu·h/ft^2	Lighting Density of Area, W/ft^2	Annual Lighting Energy Use,[a] kWh/ft^2
Dry retail[b]	367	33	4.0	16.2
Restaurant	136	88	2.0	8.1
Fast food				
food court tenant area	160	75	3.0	12.2
food court seating area	147	82	3.0	12.2
Mall common area	282	43	3.0	12.2[c]
Total	264	45	3.6	14.6

[a]Hours of operating lighting assumes 12 h/day and 6.5 days/week.
[b]Jewelry, high-end lingerie, and some other lighting levels are typically 6 to 8 W/ft^2 and can range to 11 W/ft^2.
[c]5.8 kWh/ft^2 for centers that shut off lighting during daylight, assuming 6 h/day and 6.2 days/week.

Major department stores are typically considered separate buildings, although they are attached to the mall. The space for individual small stores is usually leased. Arrangements for installing air conditioning in the individually leased spaces vary, but are similar to those for small stores in convenience centers.

Table 4 presents typical data that can be used as check figures and field estimates. However, this table should not be used for final determination of load, because the values are only averages.

Design Considerations

The owner provides the air-conditioning system for the enclosed mall. The mall may use a central plant or unitary equipment. The owner generally requires that the individual tenant stores connect to a central plant and includes charges for heating and cooling in the rent. Where unitary systems are used, the owner generally requires that the individual tenant install a unitary system of similar design.

The owner may establish standards for typical heating and cooling systems that may or may not be sufficient for the tenant's specific requirements. Therefore, the tenant may have to install systems of different sizes than originally allowed for by the developer.

Leasing arrangements may include provisions that have a detrimental effect on conservation (such as allowing excessive lighting and outside air or deleting requirements for economizer systems). The designer of HVAC for tenants in a shopping center must be well aware of the lease requirements and work closely with leasing agents to guide these systems toward better energy efficiency.

Many regional shopping centers contain specialty food court areas that require special considerations for odor control, outside air requirements, kitchen exhaust, heat removal, and refrigeration equipment.

System Design. Regional shopping centers vary widely in physical arrangement and architectural design. Single-level and smaller centers usually use unitary systems for mall and tenant air conditioning; multilevel and larger centers usually use a central plant. The owner sets the design of the mall and generally requires that similar systems be installed for tenant stores.

A typical central plant may distribute chilled air to individual tenant stores and to the mall air-conditioning system and use variable-volume control and electric heating at the local use point. Some plants distribute both hot and chilled water. Some all-air systems also distribute heated air. The central plant provides improved efficiency and better overall economics of operation. Central plants also provide the basic components required for smoke control.

Air Distribution. Air distribution for individual stores should be designed for a particular space occupancy. Some tenant stores maintain a negative pressure relative to the mall for odor control.

Air distribution should maintain a slight positive pressure relative to atmospheric pressure and a neutral pressure relative to most of the individual tenant stores. Exterior entrances should have vestibules with independent heating systems.

Smoke management is required by many building codes, so air distribution should be designed to easily accommodate smoke control requirements.

Maintenance. Methods for ensuring the operation and maintenance of HVAC systems in regional shopping centers are similar to those used in department stores. Individual tenant stores may have to provide their own maintenance.

Improving Operating Cost. Methods for lowering operating costs in shopping centers are similar to those used in department stores. Some shopping centers have successfully used cooling tower heat exchanger economizers.

Central plant systems for regional shopping centers typically have much lower operating costs than unitary systems. However, the initial cost of the central plant system is typically higher.

MULTIPLE-USE COMPLEXES

Multiple-use complexes are being developed in most metropolitan areas. These complexes generally combine retail facilities with other facilities such as offices, hotels, residences, or other commercial space into a single site. This consolidation of facilities into a single site or structure provides benefits such as improved land use; structural savings; more efficient parking; utility savings; and opportunities for more efficient electrical, fire protection, and mechanical systems.

Load Determination

The various occupancies may have peak HVAC demands that occur at different times of the day or even of the year. Therefore, the HVAC loads of these occupancies should be determined independently. Where a combined central plant is considered, a block load should also be determined.

Design Considerations

Retail facilities are generally located on the lower levels of multiple-use complexes, and other commercial facilities are on upper levels. Generally, the perimeter loads of the retail portion differ from those of the other commercial spaces. Greater lighting and population densities also make HVAC demands for the retail space different from those for the other commercial space.

The differences in HVAC characteristics for various occupancies within a multiple-use complex indicate that separate air handling and distribution should be used for the separate spaces. However, combining the heating and cooling requirements of various facilities into a central plant can achieve a substantial saving. A combined central heating and cooling plant for a multiple-use complex also provides good opportunities for heat recovery, thermal storage, and other similar functions that may not be economical in a single-use facility.

Many multiple-use complexes have atriums. The stack effect created by atriums requires special design considerations for tenants and space on the main floor. Areas near entrances require special measures to prevent drafts and accommodate extra heating requirements.

System Design. Individual air-handling and distribution systems should be designed for the various occupancies. The central heating and cooling plant may be sized for the block load requirements, which may be less than the sum of each occupancy's demand.

Control. Multiple-use complexes typically require centralized control. It may be dictated by requirements for fire and smoke control, security, remote monitoring, billing for central facilities use, maintenance control, building operations control, and energy management.