Related Commercial Resources

CHAPTER 27. AIR CONDITIONING OF WOOD AND PAPER PRODUCT FACILITIES

THIS chapter covers some of the standard requirements for air conditioning of facilities that manufacture finished wood products as well as for pulp and paper product process operations.

Special Warning: Certain industrial spaces may contain flammable, combustible, and/or toxic concentrations of vapors or dusts under either normal or abnormal conditions. In spaces such as these, there are life-safety issues that this chapter may not completely address. Special precautions must be taken in accordance with requirements of recognized authorities such as the National Fire Protection Association (NFPA), the Occupational Safety and Health Administration (OSHA), and the American National Standards Institute (ANSI). In all situations, engineers, designers, and installers who encounter conflicting codes and standards must defer to the code or standard that best addresses and safeguards life safety.

1. GENERAL WOOD PRODUCT OPERATIONS

In wood product manufacturing facilities, ventilation can be considered a part of the process. Metal ductwork should be used and grounded to prevent a buildup of static electricity. Hoods should be made of spark-free, noncombustible material. A pneumatic conveying system should be furnished to reduce the accumulation of wood dust in the collecting duct system. The airflow rate and velocity should be able to maintain the air-dust mixture below the minimum explosive concentration level. If dampers are unavoidable in the system, they should be firmly fastened after balancing work. Dust collectors should be located outside the building. Fans or blowers should be placed downstream of the dust collector and air-cleaning equipment, and should be interlocked with the wood-processing equipment. When the fan or blower stops, the wood process should stop immediately and forward a signal to the alarm system.

Deflagration venting and suppression should be furnished for wood-processing workshops and wood-processing equipment such as vessels, reactors, mixers, blenders, mills, dryers, ovens, filters, dust collectors, storage equipment, material-handling equipment, and aerosol areas. The deflagration suppression system must be disarmed before performing any maintenance work to avoid possible injury from discharging the suppressant. Warning signs should be displayed prominently at all maintenance access points.

Finished lumber products to be used in heated buildings should be stored in areas that are heated 10 to 20°F above ambient. This provides sufficient protection for furniture stock, interior trim, cabinet material, and stock for products such as ax handles and glue-laminated beams. Air should be circulated within the storage areas. Lumber that is kiln-dried to a moisture content of 12% or less can be kept within a given moisture content range through storage in a heated shed. The moisture content can be regulated either manually or automatically by altering the dry-bulb temperature (Figure 1).

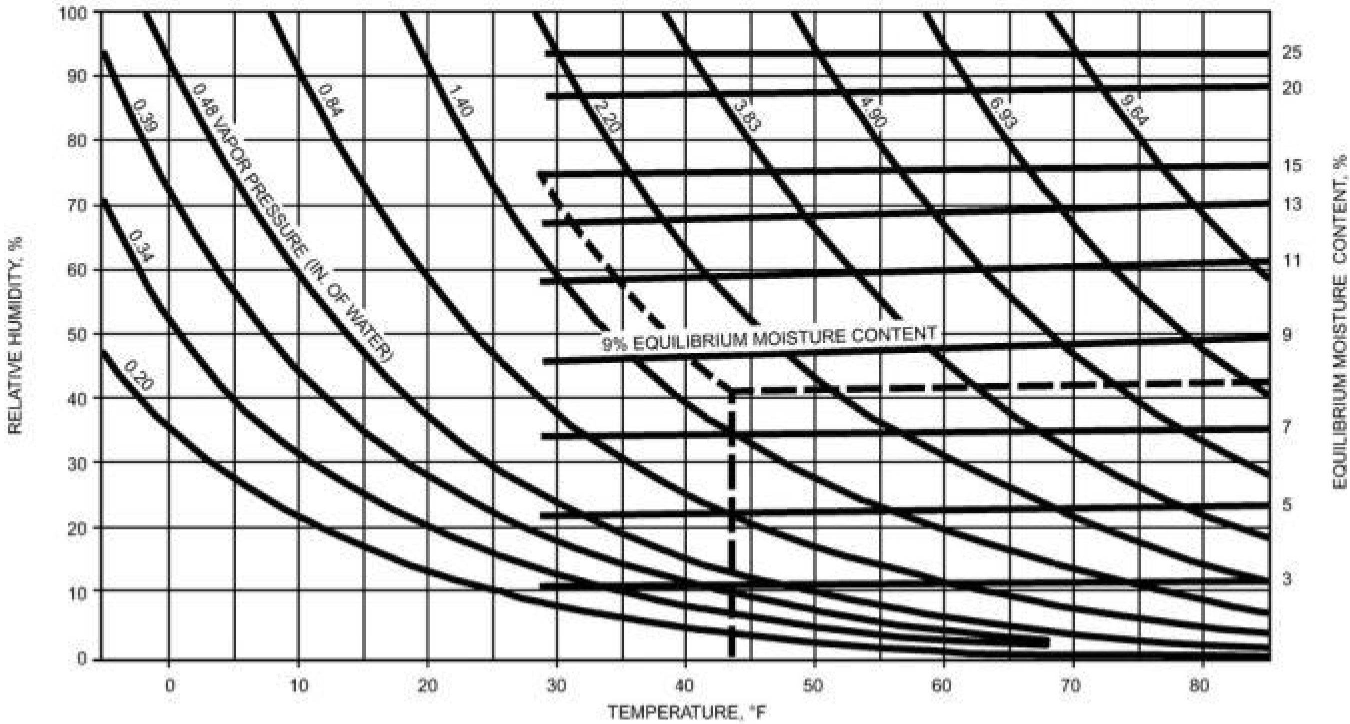

Figure 1. Relationship of Temperature, Relative Humidity, and Vapor Pressure of Air and Equilibrium Moisture Content of Wood

Some special materials require close control of moisture content. For example, musical instrument stock must be dried to a given moisture level and maintained there because the moisture content of the wood affects the harmonics of most stringed wooden instruments. This control may require air conditioning, heating, and/or humidification, with or without reheating.

Process Area Air Conditioning

Temperature and humidity requirements in wood product process areas vary according to product, manufacturer, and governing code. For example, in match manufacturing, the match head must be cured (i.e., dried) after dipping. This requires careful control of humidity and temperature to avoid a temperature near the ignition point. Any process involving application of flammable substances should follow the ventilation recommendations of the National Fire Protection Association, the National Fire Code, and the U.S. Occupational Safety and Health Act.

Finished Product Storage

Finished lumber to be made into furniture, equipment parts, musical instruments, architectural woodwork, or other wood products of value is stored and/or manufactured under controlled temperature and humidity to maintain proper wood dryness. Improper drying can cause laminated or glued joints to fail. Finished wood that has changed dimension because of excess moisture gain or loss can cause fitting problems. Cracking, splitting, checking, warping, and discoloration can also occur in improperly dried and/or stored wood.

Green, rough, cut lumber is stacked end to end in layers, each layer being separated by wood strips to allow air circulation. Lumber can be stacked and left to dry naturally in open-sided sheds. Enclosed, heated kilns with steam coils and/or direct steam injection, forced air circulation, makeup air, and exhaust air vents could be used where faster, controlled drying is preferred. Drying (or addition of moisture) can be accomplished by HVAC systems using dehumidifying coils and/or desiccants, heating/reheat coils, humidifiers, makeup and exhaust air, distribution air ducts, and automatic controls. An insulated dehumidifying/humidifying room could be constructed and finished to minimize moisture migration from higher-humidity areas. Lumber can also be dried by solar kilns, microwaves, dielectric heating, superheated steam, and vacuum.

Wood is composed of natural fibers and moisture content varies according to the environment. Samples from the wood being dried must be tested for moisture content at predetermined time intervals to prevent overdrying and defects. Drying rates are determined by the wood species. Final moisture content depends upon the wood’s ultimate use.

The formula for determining moisture content is

$$\frac{\left[\begin{pmatrix}\text{Weight of sample}\\ \text{when cut}\end{pmatrix} - \begin{pmatrix}\text{Weight of oven-}\\ \text{dried sample}\end{pmatrix}\right] \times 100}{\text{Weight of oven-dried sample}} = \begin{matrix}\text{Moisture}\\ \text{content, \%}\end{matrix}$$

Lumber/wood drying using HVAC systems can be accomplished with factory- or field-assembled systems. The quantity of lumber/wood to be dried, wood species, rate of drying, total moisture removal, drying room construction, economics (cost and rate of return on investment), fire and safety codes, maintenance, and ease of use influence the type of HVAC system to be installed.

2. PULP AND PAPER OPERATIONS

The papermaking process comprises two basic steps: (1) wood is reduced to pulp (i.e., wood fibers), and (2) the pulp is converted to paper. Wood can be pulped by either mechanical action (e.g., grinding in a groundwood mill), chemical action (e.g., kraft pulping), or a combination of both.

Many different types of paper can be produced from pulp, ranging from the finest glossy finish to newsprint to bleached board to fluff pulp for disposable diapers. To make newsprint, a mixture of mechanical and chemical pulps is fed into the paper machine. To make kraft paper (e.g., grocery bags, corrugated containers), however, only unbleached chemical pulp is used. Disposable diaper material and photographic paper require bleached chemical pulp with a very low moisture content of 6 to 9%.

Paper Machine Area

In papermaking, extensive air systems are required to support and enhance the process (e.g., by preventing condensation) and to provide reasonable comfort for operating personnel. Radiant heat from steam and hot-water sources and mechanical energy dissipated as heat can result in summer temperatures as high as 120°Fin the machine room. In addition, high paper machine operating speeds of 2000 to 4500 fpm and a stock temperature near 122°F produce warm vapor in the machine room.

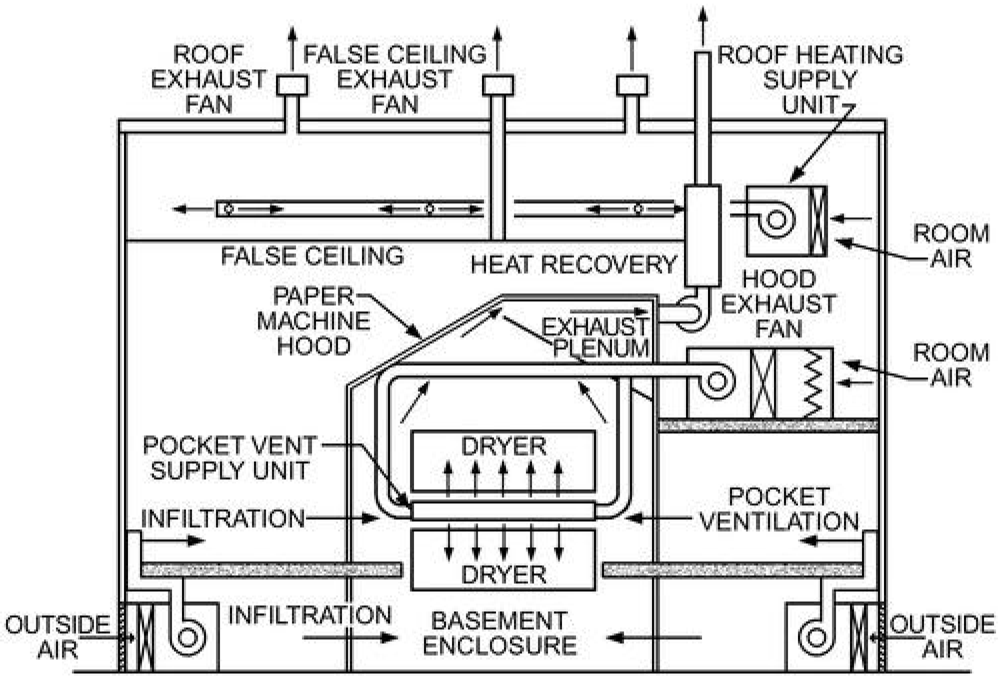

Figure 2. Paper Machine Area

Outdoor air makeup units and process exhausts absorb and remove room heat and water vapor released from the paper as it is dried (Figure 2). Makeup air is distributed to working areas above and below the operating floor. Part of the air delivered to the basement migrates to the operating floor through hatches and stairwells. Motor-cooling equipment distributes cooler basement air to the paper machine drive motors.

Wet and basement exhaust should be installed inside the room. Outdoor air intakes with insulated adjustable louvers should be installed on the outside wall to supplement the mechanical air supply. In facilities with no basement exterior wall, sufficient mechanical air intake should be provided. The exhaust, adjustable louver, or mechanical air intake should be furnished with modulating control. When the ambient temperature drops to near freezing, outdoor airflow must be reduced to a minimum and the appropriate heater started to prevent freezing.

The most severe ventilation demand occurs in the area between the wet-end forming and press sections and the dryer section. In the forming section, the pulp slurry, which contains about 90% water, is deposited on a traveling screen. Gravity, rolls, foils, vacuum, steam boxes, and three or more press roll nips are sequentially used to remove up to 50% of the water in the forming and press sections. The wet end is very humid because of evaporation of moisture and mechanical generation of vapor by turning rolls and cleaning showers. Baffles and a custom-designed exhaust in the forming section help control the vapor. A drive-side exhaust in the wet end removes heat from the motor vent air and removes the process generated vapor.

To prevent condensation or accumulated fiber from falling on the traveling web, a false ceiling is used with ducts connected to roof exhausters that remove humid air not captured at a lower point. At the wet end, heated inside air is usually circulated to scrub the underside of the roof to prevent condensation in cold weather. Additional roof exhaust may also remove accumulated heat from the dryer section and the dry end during warmer periods. Ventilation in the wet end should be predominantly accomplished by roof exhaust.

The large volume of moisture and vapor generated from the wet-end process rises and accumulates under the roof. To keep condensation from forming in winter, the roof is normally exhausted and hot air is distributed under the roof. Sufficient roof insulation should be installed to keep the inside surface temperature above the dew point. Heat transfer from the room to the interior surface is

$$\frac{t_r - t_{is}}{R_{r-is}} = \frac{t_{is} - t_o}{R_{is-o}} \tag{1}$$

where

t_r	=	room air temperature, °F
t_{is}	=	roof interior surface temperature, °F
t_o	=	outdoor air temperature, °F
R_{r-is}	=	heat transfer resistance from room air to roof interior surface. In winter, R_{r-is} = 0.61 ft^2 · °F · h/Btu
R_{is-o}	=	required total R-value from roof interior surface to outdoor air, ft^2 · °F · h/Btu

For a given project, t_o and t_r have been determined and only t_{is} needs to be selected. For wet-end roof insulation and assuming 96% relative humidity, t_{is} can be shown on a psychrometric chart to be

$$t_{is} = t_r - 1.2°\text{F} \tag{2}$$

Then Equation (1) can be simplified to find the required roof R-value as

$$R_{is-o} = \frac{0.61}{1.2}\,(t_r - t_o - 1.2) \tag{3}$$

In the dryer section, the paper web is dried as it travels in a serpentine path around rotating steam-heated drums. Exhaust hoods remove heat from the dryers and moisture evaporated from the paper web. Most modern machines have enclosed hoods, which reduce the airflow required to less than 50% of that required for an open-hood exhaust. The temperature inside an enclosed hood ranges from 130 to 140°F at the operating floor to 180 to 200°F in the hood exhaust plenum at 70 to 90% rh, with an exhaust rate generally ranging from 300,000 to 400,000 cfm per machine.

Where possible, pocket ventilation air (see Figure 3) and hood supply air are drawn from the upper level of the machine room to take advantage of the preheating of makeup air by process heat as it rises. The basement of the dryer section is also enclosed to control infiltration of machine room air to the enclosed hood. The hood supply and the pocket ventilation air typically operate at 200°F; however, some systems run as high as 250°F. Enclosed hood exhaust is typically 300 cfm per ton of machine capacity. The pocket ventilation and hood supply are designed for 75 to 80% of the exhaust, with the balance infiltrated from the basement and machine room. Large volumes of air (500,000 to 800,000 cfm) are required to balance the paper machine’s exhaust with the building air balance.

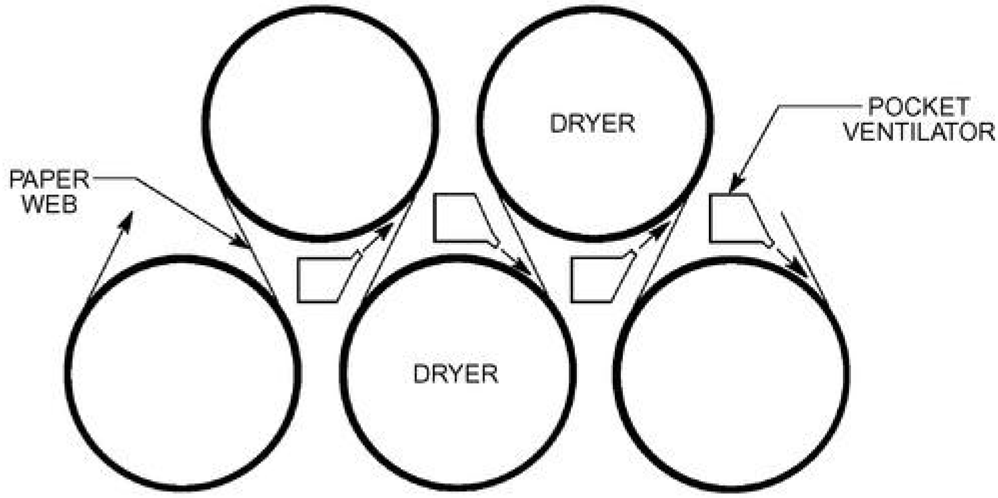

Figure 3. Pocket Ventilation

The potential for heat recovery from hood exhaust air should be evaluated. Most of the energy in steam supplied to the paper dryers is converted to latent heat in the hood exhaust as water evaporates from the paper web. Air-to-air heat exchangers are used where the air supply is located close to the exhaust. Air-to-liquid heat exchangers that recirculate water/glycol to heat remote makeup air units can also be used. Air-to-liquid systems provide more latent heat recovery, resulting in three to four times more total heat recovery than air-to-air units. Some machines use heat recovered from the exhaust air to heat process water. Ventilation in paper machine buildings in the United States ranges from 10 to 25 air changes per hour in northern mills to 20 to 50 in southern mills. In some plants, computers monitor the production rate and outdoor air temperature to optimize operation and conserve energy.

After fine, bond, and cut papers have been bundled and/or packaged, they should be wrapped in a nonpermeable material. Most papers are produced with less than 10% moisture by weight, the average being 7%. Dry paper and pulp are hygroscopic and begin to swell noticeably and deform permanently when the relative humidity exceeds 38%. Therefore, finished products should be stored under controlled conditions to maintain their uniform moisture content.

Finishing Area

To produce a precisely cut paper that stabilizes at a desirable equilibrium moisture content, the finishing areas require temperature and humidity control. Further converting operations such as printing and die cutting require optimum sheet moisture content for efficient processing. Finishing room conditions range from 70 to 75°F db and from 40 to 45% rh. Rooms should be maintained within reasonably close limits of the selected conditions. Without precise environmental control, the paper equilibrium moisture content varies, influencing dimensional stability, the tendency to curl, and further processing.

Process and Motor Control Rooms

In most pulp and paper applications, process control, motor control, and switchgear rooms are separate from the process environment. Air conditioning removes heat generated by equipment, lights, etc., and reduces the air-cleaning requirement. (See Chapter 20 for air conditioning in control rooms that include a computer, a computer terminal, or data processing equipment.) Ceiling grilles or diffusers should be located above access aisles to avoid the risk of condensation on control consoles or electrical equipment during start-up and recovery after an air-conditioning shutdown. Electrical rooms are usually maintained in the range of 75 to 80°F, with control rooms at 73°F; the humidity is maintained in the range of 45 to 55% in process control rooms and is not normally controlled in electrical equipment rooms.

Motor and electrical control rooms for process and electrical distribution control contain electronic equipment that is susceptible to corrosion. The typical pulp and paper mill environment contains both particulate and vapor-phase contaminants with sulfur- and chloride-based compounds. To protect equipment, multistage particulate and adsorbent filters should be used. They should have treated activated charcoal and potassium permanganate-impregnated alumina sections for vapor-phase contaminants, as well as fiberglass and cloth media for particulates.

To ensure normal operation of air-conditioning systems, redundancy of supply fans, fan motors, and fan power supply in air-handling units that serve process control rooms and motor control centers is strongly recommended in new-construction plants.

Switchgear and motor control centers are not as heat-sensitive as control rooms, but the moisture-laden air carries chemical residues onto the contact surfaces. Arcing, corrosion, and general deterioration can result. A minimum amount of filtered, outdoor air and air conditioning is used to protect these areas.

In most projects, the electric distribution control system (DCS) is energized before the room air conditioning is installed and started. If a temporary air conditioner is used in the DCS room, a condensate drain pan and temporary drain pipe should be installed to keep condensate from the cable channel beneath the DCS panels.

Paper Testing Laboratories

Design conditions in paper mill laboratories must be followed rigidly. The most recognized standard for testing environments for paper and paper products (paperboard, fiberboard, and containers) is TAPPI (the Technical Association of the Pulp and Paper Industry) *Standard* T402. ASTM E171 is also relevant.

Standard pulp and paper testing laboratories have three environments: preconditioning, conditioning, and testing. The physical properties of a sample are different if it is brought to the testing humidity from a high humidity than if it is brought from a lower humidity. Preconditioning at lower relative humidity tends to eliminate hysteresis. For a preconditioning atmosphere, TAPPI *Standard* T402 recommends 10 to 35% rh and 72 to 104°F db. Samples are usually conditioned in a controlled, conditioned cabinet.

Conditioning and testing atmospheres should be maintained at 50 ± 2.0% rh and 73 ± 2°F db. However, a change of 2°F db at 73°F without starting a humidifier causes the relative humidity to fluctuate as much as 3%. A dry-bulb temperature tolerance of ±1°F must be held to maintain a ±2% rh. A well-designed temperature and humidity control system should be provided.

Miscellaneous Areas

The pulp digester area contains many components that release heat and contribute to dusty conditions. For batch digesters, the chip feeders are a source of dust and need hooded exhaust and makeup air. The wash and screen areas have numerous components with hooded exhausts that require considerable makeup air. Good ventilation controls fumes and humidity. The lime kiln feed-end releases extremely large amounts of heat and requires high ventilation rates or air conditioning.

Recovery-boiler and power-boiler buildings have conditions similar to those of power plants; the ventilation rates are also similar. The control rooms are generally air conditioned. The grinding motor room, in which groundwood is made, contains many large motors that require ventilation to keep the humidity low.

System Selection

The system and equipment selected for air conditioning a pulp and paper mill depends on many factors, including the plant layout and atmosphere, geographic location, roof and ceiling heights (which can exceed 100 ft), and degree of control desired. Chilled-water systems are economical and practical for most pulp and paper operations, because they have both the large cooling capacity needed by mills and the precision of control to maintain the proper temperature and humidity in laboratories and finishing areas. In the bleach plant, the manufacture of chlorine dioxide is enhanced by using water with a temperature of 45°F or lower; this water is often supplied by the chilled-water system. If clean plant or process water is available, water-cooled chillers are satisfactory and may be supplemented by water-cooled direct-expansion package units for small, remote areas. However, if plant water is not clean enough, a separate cooling tower and condenser water system should be installed for the air conditioning.

Most manufacturers prefer water-cooled over air-cooled systems because of the gases and particulates present in most paper mills. The most prevalent contaminants are chlorine gas, caustic soda, borax, phosphates, and sulfur compounds. With efficient air cleaning, the air quality in and about most mills is adequate for properly placed air-cooled chillers or condensing units that have properly applied coil and housing coatings. Phosphor-free brazed coil joints are recommended in areas where sulfur compounds are present.

Heat is readily available from processing operations and should be recovered whenever possible. Most plants have good-quality hot water and steam, which can be used for unit heater, central station, or reheat quite easily. Evaporative cooling should be considered. Newer plant air-conditioning methods, using energy conservation techniques such as temperature destratification and stratified air conditioning, have application in large structures. Absorption systems should be considered for pulp and paper mills because they provide some degree of energy recovery from the high-temperature steam processes.

BIBLIOGRAPHY

ASHRAE members can access *ASHRAE Journal* articles and ASHRAE research project final reports at technologyportal.ashrae.org. Articles and reports are also available for purchase by nonmembers in the online ASHRAE Bookstore at www.ashrae.org/bookstore.

ACGIH. 2009. *Industrial ventilation: A manual of recommended practice*, 29th ed. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

ASTM. 2015. Standard specification for standard atmospheres for conditioning and testing flexible barrier materials. *Standard* E171-11 (2015). American Society for Testing and Materials, West Conshohocken, PA.

TAPPI. 2009. Conditioning and testing atmospheres for paper, board, pulp handsheets, and related products. ANSI/TAPPI *Test Method* T402. Technical Association of the Pulp and Paper Industry, Norcross, GA.

The preparation of this chapter is assigned to TC 9.2, Industrial Air Conditioning.