CHAPTER 24

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 pulp and paper.

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 capable of maintaining 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 of 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).

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 with reheat and/or heating with humidification.

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 the

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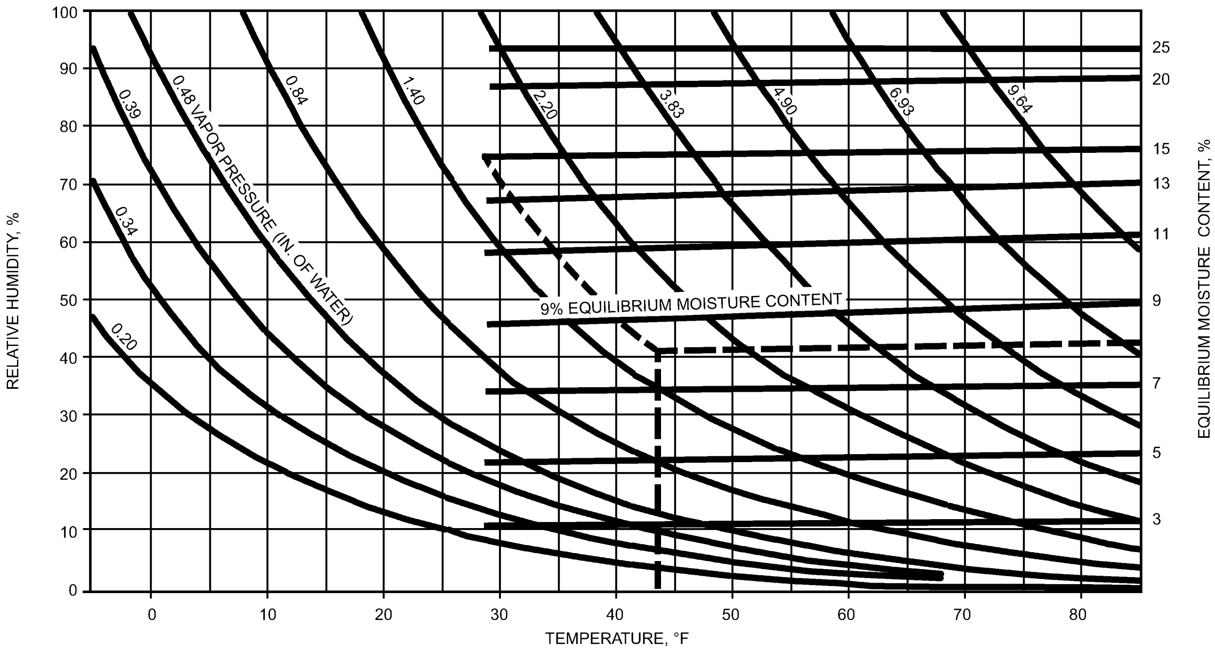

Fig. 1 Relationship of Temperature, Relative Humidity, and Vapor Pressure of Air and Equilibrium Moisture Content of Wood

humidity and temperature to avoid a temperature near the ignition point. Any process involving the 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

Design engineers should be familiar with the client's entire operation and should be aware of the potential for moisture regain. Finished lumber products manufactured from predried stock (moisture content of 10% or less) regain moisture if exposed to a high relative humidity for an extended period. All storage areas housing finished products such as furniture and musical instruments should be conditioned to avoid moisture regain.

PULP AND PAPER OPERATIONS

The papermaking process comprises two basic steps: (1) wood is reduced to pulp, that is, 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 and 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 in the machine room as high as 120°F. 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.

Outside air makeup units and process exhausts absorb and remove room heat and water vapor released from the paper as it is dried (Figure 2). The makeup air is distributed to the 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.

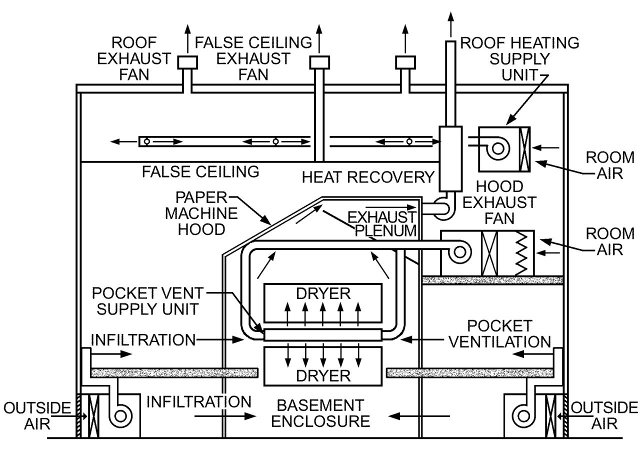

Fig. 2 Paper Machine Area

Wet and basement exhaust should be installed inside the room. Outside 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, a 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, outside 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 section and press section 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 section and press section. The wet end is very humid due to the evaporation of moisture and the 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 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 dewpoint. 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 = outside air temperature, °F
R_{r-is} = heat transfer resistance from room air to roof interior surface. In winter, R_{r-is} = 0.61 ft²·°F·h/Btu
R_{is-o} = required total R-value from roof interior surface to outside air, ft²·°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

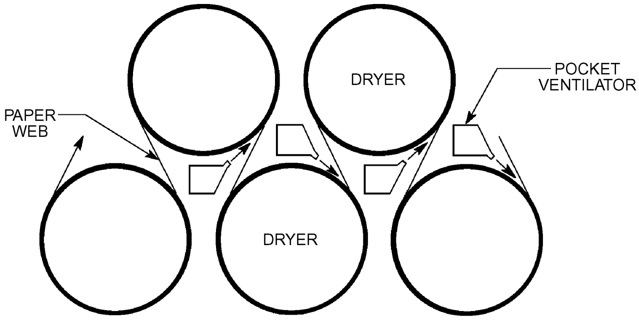

Fig. 3 Pocket Ventilation

the hood exhaust plenum at 70 to 90% rh, with an exhaust rate generally ranging from 300,000 to 400,000 cfm.

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 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.

The potential for heat recovery from the hood exhaust air should be evaluated. Most of the energy in the steam supplied to the paper dryers is converted to latent heat in the hood exhaust as water is evaporated 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 outside air temperature to optimize the 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 will stabilize 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. The rooms should be maintained within reasonably close limits of the selected conditions. Without precise environmental control, the paper equilibrium moisture content will vary, 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 17 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.

Electrical control rooms for distributed control and process 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 the 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.

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, outside 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, Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products. Other standards include ASTM E171, Standard Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials, and ISO/TC 125, Enclosures and Conditions for Testing.

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 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.

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