while, in general, it is decreased by lower temperature and humidity.

High relative humidities alone are usually more harmful than high temperatures alone. High humidity can accelerate the loss of sensitivity and contrast, increase shrinkage, produce mottle, cause softening of the emulsion and promote fungus growth. Low relative humidity increases the susceptibility of the film to static markings, brittleness and curl. Color films of the modern three-layer subtractive type are more seriously affected than black-and-white because heat and moisture usually affect the three emulsion layers to different degrees, thus causing a change in color balance as well as a change in overall film speed and contrast.

Frequently, film for domestic consumption is packaged in a container sufficiently moisture-resistant for protection in temperate zones only, or in places having the same general atmospheric conditions as prevail in the temperate zones. Photographic film intended for the tropics, or other places of high humidities and temperatures, should be specially packaged to provide extra protection against moisture and harmful gases. The type of packaging used for a particular film product should be determined from the manufacturer and the appropriate storage conditions then maintained.

One film manufacturer, however, is currently packaging its film products for both domestic and tropical consumption in vapor-tight containers suitable for refrigerated storage without any necessity for further humidity control. This film is packaged in equilibrium with air at a relative humidity between 40 to 60 percent, depending on the particular type of film. It should be noted that the relative humidity used while packaging is somewhere within this range, but that the relative humidity chosen depends on the particular product being packaged and is held to approximately ±2 percent.

Film packed in a vapor-tight container maintains its own moisture content within the package and does not require storage in an area with carefully controlled humidity as long as the seal remains unbroken. Films which are not in vapor-tight packaging or are in opened packages should not be stored in damp basements, ice boxes, refrigerators, or other places where the relative humidity is high. The ideal relative humidity for storage of such packages is between 40 and 60 percent, preferably near 40 percent. It should be noted that a moderate temperature with low relative humidity, such as 60 F with 40 percent rh, is better than a lower temperature with high relative humidity such as 40 F with 80 percent rh.

When humid storage conditions cannot be avoided, or when the use of a refrigerator is necessary for cooling, films in opened or non-vapor-tight packages should be given moisture protection by placing them in a can or jar which can be tightly sealed.

During summer months in temperate or tropical zones, refrigerated storage is recommended for keeping films cool, provided they are in vapor-tight packages or are sealed in cans or jars. In general, it is desirable that black-and-white films be stored at least below 70 F for a storage period of up to two months, below 60 F for a storage period up to six months, and below 50 F for a storage period up to twelve months. When color films must be kept for several months, it is recommended that they be stored at 45–55 F in the main compartment of a refrigerator. Storage at temperatures above 70 F for more than four weeks may lead to changes in speed and color balance.

Temperatures below 32 F are not harmful to photographic film. The water content of the film is relatively small and ice crystals do not form inside the film at normal moisture levels no matter how low the temperature or how rapid the cooling. Films which must be stored for more than a year should be kept at 0 to −10 F in a freezing unit. This type of storage arrests changes in film characteristics almost completely for long periods of time. However, the effects of adverse storage conditions between removal from refrigeration and exposure, or between exposure and processing, may cause unsatisfactory results in spite of the previous low-temperature storage.

In locating film storage areas it should be remembered that films not packaged in sealed foil envelopes or screw-cap cans must be kept away from formaldehyde vapor, industrial gases, motor exhausts and vapors of solvents and cleaners. In hospitals, industrial plants and laboratories, all films, regardless of the type of packaging, must be protected from x-rays, radium and other radioactive materials. For example, films stored 25 ft away from 100 mg of radium require the protection of 3½ in. of lead around the radium.

Film stored in a refrigerator or freezing unit should be removed some time before it is used, to allow it to warm up to the outside temperature. Otherwise, moisture may condense on the cold film when the sealed package is opened.

Table 1 .... Suggested Warm-Up Time for Black-and-White and Color Film

Type of Film Package	Warm-Up Time Hr	
	25 F deg Rise	100 F deg Rise
Roll film, including Size 828	½	1
Size 135 magazines	1	1½
Sheet Film, 10 sheet box	1	1½
Sheet Film, 50 sheet box	2	3
Motion Picture Film, 16 mm, any length	1	1½
Motion Picture Film, 35 mm, any length	3	5

Table 1 is based on the time required to reach within 3 F deg of equilibrium; about 50 percent longer times should be allowed for complete equilibrium. These warm-up times are based on individual packages separated from each other. Cold packages stacked on top of each other would require much longer to warm up (proportional to total thickness). The length of film on the roll is not important, only the thickness of the package.

Under extremely humid conditions, film should be both exposed and processed as soon as possible after the package is opened. If exposed film cannot be processed within a few days after it is exposed, it should be kept in a dehumidified cabinet or storeroom, or else desiccated and then resealed in a moistureproof container. Mechanical air conditioning with fully automatic relative humidity control would provide the most desirable storage conditions for exposed but unprocessed film. If this is not available, an electric refrigerating dehumidifier controlled by a humidistat can be used for dehumidifying a storage cabinet or small storeroom. Also suitable is an electrically operated desiccating dehumidifier which makes use of a desiccating agent, such as activated silica gel or alumina, with an automatic reactivation cycle.

PROCESSING AND PRINTING PHOTOGRAPHIC MATERIALS

General Air Conditioning

Satisfactory ventilation of a processing laboratory is more complex than the ventilation of a room for comfort only. Uncovered solutions can increase the humidity in the room, processing solutions create slight odors, and drying cabinets give off heat. Excessive humidity causes the body to perspire and damp fingers will leave marks on dry films. If the air is too dry, film is susceptible to static accumulations which may discharge during handling, leaving streaks on the processed film. In addition to eliminating these problems, adequate temperature and humidity controls can speed up the drying processes, simplify the maintenance of constant temperatures of processing solutions and eliminate dust or other air-borne impurities which can damage the photographic image.

Temperatures of 70–80 F are recommended, but this may be modified, if desirable, for the sake of comfort. Relative humidity should be controlled at about 45–50 percent. This is particularly important in laboratories processing and printing color materials.

Dryers and automatic printers are major sources of heat and humidity which must be considered in designing an air-conditioning system for the processing laboratory. For example, one type of large heated-drum dryer for color prints has an input of 7500 watts, essentially all of which is subsequently given off as heat. The paper prints are dried in contact with the outside of the drum, giving off steam into the atmosphere. An automatic printer used by many color processing laboratories has a variable input of between 200 and 1300 watts during printing operations. As in the case of the dryer, virtually all of this wattage is given off as heat. Much of this heat and humidity can be removed directly through hoods mounted above the equipment to serve as return air ducts or as part of a separate exhaust system.

The air in the laboratory should be maintained at a slight positive pressure to prevent the entrance of dust through doors and windows. Most dirt can be removed sufficiently well from air by means of commercial air filters. However, using the best filters lengthens the time between cleaning periods. Some types of electrostatic filters have proved advantageous in photographic practice. Filters made of bundles or mats of soft crepe paper or cotton pads give good results and require less maintenance. No filter is perfectly efficient and some smoke passes through it and agglomerates later. This agglomerated smoke deposits on walls or ducts and can be dislodged later by vibration or an accidental blow. Showers of such dirt are serious in the photographic industry. They can be prevented in part by putting viscous filters in the ducts at the ends of long runs.

Processing Temperature Control

The density obtained in a developed image on photographic film depends on the nature of the emulsion, the exposure it has received and the degree of development. With any particular emulsion, the degree of development depends on the time of development, the temperature of the developer, the degree of agitation and the activity of the developer.

When the developer temperature is low, the reaction is slow and the development time recommended for the normal temperature would give under-development; when the temperature is high, the reaction is fast, and at the same time of treatment would give over-development. Within certain limits, these changes in the rate of development can be compensated for by increasing or decreasing the development time. Once a temperature for development is determined for many applications, it should be maintained within approximately ±1 F deg for black-and-white film. In some applications the temperature tolerance can vary from this general figure.

Although a minimum of temperature control may be needed in the processing of black-and-white materials, solution temperatures must be kept strictly within the limits specified for processing color materials. In the development of color film composed of three emulsions, changes in the temperature of the developer cannot readily be compensated for by changes in development time. Changes in the temperature of the developer may change the development characteristics of the three emulsions in a different manner and upset the color balance, in addition to changing contrast, speed and fog. Color film is developed at a recommended temperature of 75 F ± ½ deg. The remaining steps of the development process are not as critical to changes in temperature of the processing solutions and they may vary from 73–77 F.

Besides changes in development rate, there are other important effects dependent on the temperature of the processing baths. At high temperature, the gelatin of the emulsion becomes so swollen and tender that it may be easily damaged, and it may even loosen from the support or wrinkle up in a fine network of lines called *reticulation*. The temperature of the developers and other solutions, must, therefore, be kept sufficiently low to avoid danger of damage, but not so low as to decrease too much the chemical activity of the baths. High temperature processes (125 F and higher) have been devised and are in limited use. The temperature tolerance is about the same as for the normal processing temperature.

The most efficient method of temperature control is achieved by placing the tanks of processing solutions in a water jacket supplied by a continuous flow of fresh water or by a recirculating system.

The ideal situation, of course, would be to maintain the air and the tap water at the recommended processing temperature. Under such circumstances the water in the jacket would remain at a constant temperature. However, in many sections of the country the temperature of tap water approaches the freezing point in winter and frequently rises above 80 F in summer. To maintain the desired temperature in such instances, hot or refrigerated water must be added.

The simplest form of temperature regulator is a manually controlled water mixer, such as an ordinary shower valve. Since it does not contain a thermostatic element, any variation in pressure or volume requires manual resetting. Because of the difficulty in maintaining a constant temperature with such a valve, it is not very satisfactory for black-and-white processing operations and is entirely unsatisfactory in color processing.

A great many processing installations utilize a manually operated mixing valve incorporating a thermostatic element which compensates for minor deviations in line pressure and volume. Fig. 1 shows an installation with a self-contained thermostatic mixing valve that controls tap, hot and refrigerated water. In the winter time hot water can be blended with tap water when the latter is below the recommended processing temperature, and refrigerated water can be mixed with tap water for summer use. The change from winter to summer blending is accomplished by means of two 2-port, 3-way cocks. If a pressure equalizing valve is needed, it can be installed. The bulb of a dial thermometer is placed at the outlet of the mixing valve to provide a check on its operation.

Manually controlled thermostatic mixing valves operated at their minimum capacity are not as efficient as those operated at medium or maximum flow. Therefore, careful attention must be given to the flow rate that is required through each valve.

Some idea of the volume required may be gained from the