

This can be accomplished with a mechanical humidifying unit operating in conjunction with a controlling humidistat set at 40 percent to prevent overhumidification.

For commercial storage, approximate room temperatures of 74 F are recommended. Temperatures over 80 F should be avoided, if possible, because shrinkage and distortion are more likely to occur. However, two or three weeks a year at 90-100 F should not be serious, provided that this is not combined with relative humidities higher than those recommended. Low storage temperatures are not harmful unless the resulting relative humidity is above 60 percent. Films stored below the ambient dew point should be allowed to warm up before opening to prevent moisture condensation (see Table 1).

An oxidizing or reducing atmosphere may cause deterioration of film base or paper and gradual fading of the photographic image. Typical examples are fumes of hydrogen sulfide and sulfur dioxide (usually present in coal-burning regions) and paint fumes. When it is known that such fumes are present in the intended storage space, steps should be taken to eliminate the fumes or to protect the film from contact with the atmosphere.

Archival Storage of Safety Base Film

For archival records which have great historical value and are to be preserved indefinitely, only black-and-white silver images on safety base should be used. However, since color films and nitrate films of archival value are already in existence, means of preserving these materials are described later in this chapter.

Film of archival value should be kept in a fireproof storage vault located and constructed in accordance with the local building code, the *Fire Underwriter's Regulations*, and the requirements of the National Fire Protection Association¹ for a valuable record room, except that an approved controlled air-conditioning installation should be permitted.

Films should be stored in metal cabinets with adjustable shelves or drawers, depending on the filing requirements. The walls of the cabinets should have louvers or openings located so as to facilitate the circulation of conditioned air through the cabinets, and the cabinets should be spaced in the room so as to permit the free circulation of air around them.

As with commercial films, archival films should be protected from water damage, whether from leaks, fire sprinkler discharge, or flooding. Drains should be provided that have sufficient capacity to keep the water from sprinkler discharge from reaching a depth of three in. The storage cabinets should be raised so that the lowest shelf or drawer is at least six in. off the floor, and should be constructed so that water can not splash through the ventilating louvers onto the records.

It is realized that the National Fire Protection Association advises against the use of air conditioning in valuable-paper record rooms because of the possible fire hazard from outside. However, properly controlled air conditioning is considered essential for the long-term preservation of archival films. The fire hazard introduced by the openings in the room for air-conditioning ducts may be overcome by the use of automatic fire-control dampers approved by Underwriters' Laboratories installed in the ducts in accordance with recommendations of the National Fire Protection Association² and the National Board of Fire Underwriters.

The storage space should be conditioned and controlled automatically at 40 to 50 percent rh and between 60-80 F dry bulb preferably near 70 F, depending on the dew point of the outdoor air. Low temperature aids preservation, but if the storage space is below the dew point of the outdoor air, the

records must be allowed to warm up in a closed container before they are used, to prevent condensation of moisture.

The air conditioner must be capable of maintaining the temperature and humidity conditions within the limits specified at all seasons of the year. One system may supply several film vaults if desired.

The type of air conditioner that should be used will depend upon local conditions. A spray-chamber type of air conditioner is suggested. Sufficient outdoor air should be provided to keep the room under a slight positive pressure for ventilation purposes and to prevent the entrance of untreated air. The conditioner should preferably be located outside the vault for ease of maintenance, and precautions should be taken to prevent leakage of water into the vault in case of a breakdown. The conditioner casing and all duct work should be well insulated. Control of room conditions may be by means of a dry-bulb thermostat and either a wet-bulb thermostat, a hygrometer, or a dew-point controller.

A refrigeration unit, usually a unit-type reciprocating compressor-condenser machine using Refrigerant 12, should be furnished to provide the necessary refrigeration needs of the unit air conditioner. The refrigeration condenser may be of either the air-cooled or water-cooled type, depending in some cases on the services available.

It is possible in some climates to do a reasonably good job without a spray chamber by passing air through cooling coils to remove excess moisture and then reheating the air. This will prevent high humidity but will not prevent low humidity in dry seasons. It is also permissible to allow temperatures to rise up to 10 F deg above the recommended level on occasional hot days in summer. This allows the use of a lower capacity cooling system than one required to handle all peak loads. The temperature and relative humidity should be checked daily with a wet- and dry-bulb psychrometer equipped with means for providing the required air velocity over the thermometer bulbs as approved by the National Bureau of Standards.

The vault should be cleaned frequently to prevent the accumulation of lint from clothing, dirt from shoes, and other contaminants. If a spray chamber is used in the air conditioner, and the water is recirculated, it should be kept clean to prevent the formation of biological slime which eventually decomposes to give off hydrogen sulfide. Safeguards should be set up to prevent condensation of moisture on objects in the vault whenever the refrigeration or dehumidification unit is shut off for a clean-up or is otherwise out of order.

All air being supplied to the room should be filtered to remove dust regardless of whether a spray-chamber type of unit air conditioner is employed. Sufficient fresh air should be supplied to provide for personnel working in the room. Atmospheric contaminants, such as paint fumes, hydrogen sulfide, sulfur dioxide and similar gases may cause slow deterioration of film base and gradual fading of the photographic image. The removal of such gases from the air requires special consideration. These contaminants, which can come from illuminating gas, coal gas, and certain chemical plants, are present in harmful concentrations in most industrial and urban areas. When a contaminated atmosphere cannot be avoided, engineering advice may be required to select the air scrubber, activated charcoal adsorber, or other purification method which should be employed. Reference might also be made to the facilities installed in the Harvard University Rare Book Library.³

Because all dyes, including those used in color films, fade somewhat in time, the *American Standard Specifications for*

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Films for Permanent Records, PH 1.28-1957, specifically excludes the use of color images for archival purposes. However, many valuable color films exist and it may be desirable to preserve them as long as possible.

The factors which contribute to fading of color films are light, heat, and moisture. Optimum storage conditions for the preservation of the dyes in color films are as cold and dry as possible. For maximum permanence, the films should be stored in sealed containers at a temperature below 0 F and relative humidity of 15 to 25 percent. Conditioning to the recommended humidity can be accomplished by passing the film through a conditioning cabinet with air circulating at about 15 percent rh. Each strand or sheet of film should spend about 15 min in the cabinet. If a conditioning unit is not available, the air may be heated the correct amount to maintain 15 percent relative humidity.

Accurate control of the moisture content of films requires some analytical facilities and technical supervision. No collection of color films of appreciable size and value to be preserved indefinitely should be desiccated without such facilities.

When removed from cold storage, the film container must not be opened until it has been allowed to warm up to room temperature. If the desiccated film is to be printed or projected, it should first be reconditioned by passing it through the conditioning cabinet again for 15 min at 40 to 50 percent rh, or allowing it to stand several days uncovered in a room at this condition. This will minimize the chance of breakage from excessive dryness. It will then have to be desiccated again before returning to storage.

Storage of Nitrate Base Film

The chemical stability of cellulose nitrate, from which nitrate film base is made, is relatively poor. It is chemically similar to gun cotton, but is not explosive, although it is highly flammable. This type of base decomposes slowly but continuously even under normal room conditions. The decomposition produces small amounts of gases such as nitric oxide, nitrogen dioxide, and others. Unless the nitrogen dioxide can escape readily, it reacts with the film base, speeding up the decomposition as time goes on. The rate of decomposition is greatly accelerated by moisture in the film and is approximately doubled with every 10 F increase in temperature. This process ends only with complete decomposition of the film or, under certain conditions, spontaneous combustion.

The effects of nitrogen dioxide gas produced by the decomposition of nitrate film base are more widespread than so far indicated. In addition to accelerating further decomposition of the base, nitrogen dioxide attacks the image of photographic film. The silver image in black-and-white film is faded or bleached until it disappears and the dye images in color film are affected so that severe discoloration is produced followed by complete bleaching. This fading of the image is often the first sign of nitrate film decomposition. Nitrogen dioxide from nitrate base also attacks the gelatin in the emulsion layer breaking it down chemically until it becomes either very brittle, or sticky and readily soluble in water.

Although nitrate motion-picture film is no longer manufactured in the United States, considerable quantities remain in storage. Some of this film is in the form of duplicates of prints of commercial or short-term value. There are also many pictures on nitrate base which are considered of great historical or archival value. These are often in the possession of libraries and museums, and the cost of duplication on safety base film is prohibitive. Therefore, it is necessary to con-

sider the best way to preserve such records, even though nitrate base film should not have been used for this purpose.

All nitrate film of either commercial or archival value must be stored in an approved vented cabinet or vault. Nitrate films should never be stored in the same vault with safety base films, because any decomposition of the nitrate film is quite likely to cause decomposition of the safety film. Cans in which the film is stored should never be sealed, as this would prevent the escape of nitrogen oxide gases which accelerate the decomposition of the film. Standards for the design, construction, and use of storage cabinets and vaults for both commercial and archival nitrate films have been established by the National Board of Fire Underwriters.⁴ These standards have been developed over a period of many years and are the result of a great deal of experience with nitrate film fires. Important revisions were made in these standards in the 1953 edition, which should be carefully followed. Details of construction and diagrams are given for cabinets, non-archival vaults, and archival vaults. Investigations have also been made by the National Archives and the National Bureau of Standards on the effect of a number of factors on fires in nitrate film vaults.⁵

Air-conditioning systems in film vaults should be installed according to regulations of the National Fire Protection Association and the National Board of Fire Underwriters.⁶ Automatic fire dampers should be installed in the air ducts so that a fire in one vault will not spread to another, and so that the toxic gases given off will not be distributed to other rooms but will be vented outside.

The Underwriters' regulations make no provision for control of air temperature and relative humidity in the storage of nitrate film other than that temperatures must not exceed 70 F, as a safety precaution. Additional precautions are required from the standpoint of film preservation.

For commercial storage, temperatures up to 70 F and relative humidities between 25 and 60 percent are considered satisfactory. Where complete air conditioning is unavailable, dehumidification by machine without cooling is less expensive and would offer some advantage. Cooling alone without automatic relative humidity control is also beneficial, since a considerable amount of moisture can be condensed out of the air on cooling coils. Nitrate film should not be conditioned or desiccated and then sealed in air-tight containers, because decomposition products could not escape.

Nitrate black-and-white films of archival value should be stored below 50 F at 40 to 50 percent rh and color films below 0 F at 40 to 50 percent rh for maximum life. Lower relative humidities would retard decomposition of nitrate film and fading of color images, but it is felt that the risk of brittleness with old nitrate film is too great.

REFERENCES

- ¹ *Protection of Records* (Consolidated Reports of the Committee on Protection of Records, National Fire Protection Association, 1947).
- ² *Standards for the Installation of Air Conditioning and Ventilating Systems of Other than Residential Type* (National Fire Protection Association Pamphlet No. 90A, May 1961. Also published by National Board of Fire Underwriters).
- ³ G. K. Sourwein: Air conditioning for protection (*Heating, Piping and Air Conditioning*, May 1941, p. 311).
- ⁴ *Standards of the National Board of Fire Underwriters for Storage and Handling of Cellulose Nitrate Motion Picture Film as Recommended by the National Fire Protection Association* (NBFU Pamphlet No. 40, November 1953).
- ⁵ J. V. Ryan, J. W. Cummings, and A. C. Hutton: *Fire Effects and Fire Control in Nitro Cellulose Photographic-Film Storage*