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Photography — Photographic films and papers — Determination of the dimensional change characteristics

Photographie — Papiers et films photographiques — Méthode de détermination des caractéristiques de variation dimensionnelle

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Foreword

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Photography — Photographic films and papers — Determination of the dimensional change characteristics

0 Introduction

Photographic films and papers exhibit temporary or reversible dimensional changes as well as permanent dimensional changes. This International Standard is designed to provide uniform methods for treating the samples and for expressing the dimensional changes which occur with changes in atmospheric conditions and those which occur in processing and aging.

Temporary or reversible dimensional changes are the result of changes in moisture content (which is determined by the relative humidity of the surrounding atmosphere) or changes in temperature. Permanent dimensional changes occur as the result of processing and aging. The rate of permanent shrinkage of film generally increases with temperature but decreases with time. The rate of shrinkage may also be greatest at either high or low relative humidity, depending on the type of film. Some materials, particularly photographic film on polyester base, can show a swelling after a high humidity exposure.

The increasing use of photographic films in recent years, in applications where dimensional stability is critical, has emphasized the importance of an accurate measure of dimensional properties. For example, in photomechanical reproductions, a dimensional change of as little as 0,01 % may be of practical importance. In the case of aerial mapping, uniform shrinkage is not serious since it can be easily corrected by a change in magnification, but any difference in shrinkage in the two principal directions is a source of error. Any localized or non-uniform changes in dimension are of particular concern.

The dimensional change properties of any film or paper depend not only on their composition and method of manufacture but also on their thermal and moisture history. Accurate evaluation of such properties requires some control over the sample history as well as very precise control over the conditioning and measuring procedures. Film and paper dimensions are also subject to hysteresis effects. These are relatively more important with the more stable materials, such as hydrophobic resin-base films.

Additional information on the dimensional characteristics of photographic films and papers and on methods of measurement may be found in the literature listed in annex C.

1 Scope and field of application

This International Standard gives a method for determining the dimensional change of photographic films and papers caused by :

a) variations in moisture content due to change in the relative humidity of the atmosphere (humidity coefficient of expansion);

b) change in temperature (thermal coefficient of expansion);

c) processing;

d) aging.

This International Standard deals with the humidity and thermal history of the samples before measurement, the atmospheric conditions during measurement and the treatment of the data. This International Standard does not describe the various experimental techniques used to make the measurements.

2 Definitions

2.1 humidity expansion (or contraction) : The dimensional change caused by the gain (or loss) of moisture following changes in the relative humidity of the ambient air at constant temperature.

2.2 humidity coefficient of expansion : The average change in dimension per unit length per 1 % change in relative humidity.

2.3 thermal expansion (or contraction) : The dimensional change caused by a rise (or fall) of temperature at constant relative humidity[1].

2.4 thermal coefficient of expansion : The average change in dimension per unit length per 1 °C change in temperature.

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[1] This is, more correctly, an apparent thermal expansion, since the moisture content of film varies slightly with temperature at constant relative humidity. Thermal expansion is less important for paper because of the small changes involved, particularly compared to humidity effects.

2.5 dimensional change due to processing : The permanent dimensional change caused by photographic processing. This may be the conventional wet chemical processing, vapour processing or heat processing. It is measured after conditioning at the same relative humidity and temperature as used for the original measurement and is expressed as a percentage.

2.6 dimensional change due to processing plus aging : The permanent dimensional change which occurs as a result of processing plus aging of the processed material. It is measured after conditioning of the processed, aged film or paper at the same relative humidity and temperature as used for the original measurement and is expressed as a percentage.

2.7 length direction : The direction of the film or paper parallel to its forward movement in the film- or paper-making machine. This is also termed "grain" (in the case of papers) or "machine direction".

2.8 width direction : The direction of the film or paper at right angles to the length direction.This is also termed "cross direction".

2.9 differential dimensional change : The difference between the dimensional changes of the material in the two principal directions (length and width).[1]

2.10 conditioning : The exposure of a sample to air at a given relative humidity and temperature until equilibrium is reached.

2.11 preconditioning : The establishment of a moisture history by conditioning the sample at a relative humidity above or below the conditioning relative humidity used for measurement. The purpose of preconditioning is to control the effects of hysteresis (see 2.12).

2.12 dimensional hysteresis : The difference in the absolute dimensions of a sample in equilibrium with air at a given relative humidity, when conditioned from a higher relative humidity and when conditioned from a lower relative humidity (see annex B).

3 Technique of measurement

There are a number of different techniques used for measuring the dimensional change of sensitized materials. Specification of measuring equipment is beyond the scope of this International Standard but several approaches are described in annex A.

4 Sampling

4.1 Selection of samples

Samples intended for dimensional stability tests should exhibit no obvious physical defects, be representative of the whole of the material being tested, be handled in the same manner as in actual use, and be treated uniformly. When different materials are to be compared, they should preferably have been subjected to the same conditioning history. The length direction should be indicated if known.

4.2 Handling of specimens

Prepare specimens under controlled conditions, and then separate them into groups which are subjected to different atmospheric conditions. Wear moisture resistant gloves while handling the specimens. Moisture from skin may reduce accuracy of test data. The operator shall take care not to breathe on the specimens.

4.3 Processing of specimens

Specimens shall be exposed and processed by methods and equipment normal for the product. When the effects of processing machines, tensions, or drying conditions are being investigated, the film or paper must be processed in the sizes of practical interest. Specimens may be developed as negatives or as positives but this may affect the dimensional change properties of some materials. Silver-gelatin films generally show less dimensional change when they have low density rather than with high density.

5 Conditioning

5.1 Constant humidity chamber

Either a walk-in constant humidity room or a cabinet may be used.

5.1.1 Constant humidity room

The room shall be vapour sealed and insulated on all sides and equipped with an air-lock entrance. The room shall be mechanically air-conditioned and the air circulated at a linear velocity of at least 15 cm/s. The number of personnel permitted in the room at one time during testing shall be limited. The relative humidity of the room shall be checked regularly, preferably by means of a calibrated electric hygrometer or by wet and dry bulb thermometers.

5.1.2 Constant humidity cabinet

A convenient size for a humidity cabinet is approximately 1 m in height, and 0,5 m in width and depth. It should be constructed of materials which will ensure good insulation and it should be lined inside with metal sheeting. Provision shall be made at the bottom of the cabinet for inserting suitable trays, which should hold about 1 l of salt solution for control of humidity. A large surface area is needed and about 1 000 cm^2 is suitable. Suitable provision shall be made for thermostatically controlling the temperature within the cabinet. A fan shall be provided to ensure rapid and complete circulation of air over the salt solution tray and around the specimens. The linear air velocity shall be

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[1] Polyester based films frequently have the maximum and minimum dimensional changes in directions other than the length or width. These can be determined by rotating and viewing uncoated base between a pair of crossed polarizers. When either the maximum or minimum direction is coincident with the optical axis of one polarizer, there is minimum light transmission through the base.

at least 30 cm/s. The cabinet shall be equipped with ports fitted with rubber gloves and sleeves for entrance of the operator's hands. The relative humidity of the cabinet shall be checked regularly, preferably by means of a calibrated electric hygrometer.

5.2 Standard temperature and humidity

The standard temperature shall be 23 ± 0,5 °C except for the test specified in clause 7. The relative humidity is specified in the respective test procedure paragraphs and depends upon the property being measured.

5.3 Conditioning of specimens

The specimen may be suspended in the conditioning atmosphere by means of a hook or a rod through a hole in the middle of one end near the edge of the specimen. The specimens should be separated to prevent contact with each other. An alternative method of conditioning is to place specimens on edge in racks with the long dimension horizontal and spaced so that there is a free circulation of the air. The specimens shall not be removed from the conditioning atmosphere for measuring. Condition specimens until practical moisture equilibrium has been reached.

5.3.1 Film

The conditioning time for film will be about 4 h but will vary according to access of the conditioning air, the film type, base thickness, etc. Conditioning time should not exceed 24 h[1].

5.3.2 Paper

Double weight non-resin coated papers will require about 8 h of conditioning; resin coated papers require up to 5 d depending on resin coverage.

6 Test for humidity coefficient of expansion

6.1 Procedure

Five samples shall be preconditioned[2] at 10 to 15 % RH, then conditioned at 15 to 25 % RH (but at least 5 % RH above the preconditioning relative humidity) and measured. They shall then be conditioned again at 50 to 60 % RH and remeasured[3]. The conditioning temperature shall be constant as specified in 5.2. The two conditioning relative humidities shall be carefully measured. The test may be made on both unprocessed and processed samples depending on the measuring method used (see annex A). The humidity coefficient of expansion of unprocessed and processed film is generally not the same.

6.2 Calculations

Since the dimensions change curve versus relative humidity is not always linear (see annex B), this test method gives only an average coefficient over the range measured. The dimensional change between the two measurements of five samples shall be averaged and the humidity coefficients of expansion shall be calculated according to the following formula :

$$H = \frac{l_2 - l_1}{l_1 \times R}$$

where

H is the humidity coefficient of expansion per 1 % RH;

l_1 is the gauge distance or the dimension measured at the initial conditioning temperature and relative humidity;

l_2 is the gauge distance or the dimension measured at the final conditioning temperature and relative humidity;

R is the difference between the two conditioning relative humidities used, as a percentage.

6.3 Test report

The test report should contain the following :

a) humidity coefficients of expansion for both the length and width directions;

b) two conditioning relative humidities and temperature;

c) a statement as to whether the samples were unprocessed, processed to high density, or processed clear.

7 Test for thermal coefficient of expansion[4]

7.1 Procedure

Five samples shall be conditioned first at 45 to 60 °C and measured, and then conditioned at 10 to 25 °C and remeasured.[5] A conditioning time of from one to four hours at each temperature is recommended. Both the samples and the

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[1] At relative humidities of 60 % and above, films and papers sometimes undergo an irreversible change in size with time. For this reason, the conditioning time must be standardized for comparison purposes.

[2] Preconditioning times of 1 to 2 h are recommended for photographic film.

[3] This range of relative humidity is selected because the dimension versus relative humidity curve for some materials is abnormal above 60 % RH (see annex B).

[4] Dimensional changes of photograhic paper with reasonable changes in temperature (but at the same moisture content) are so small that measurement is very difficult and has little practical significance. This method is of importance for photographic film.

[5] The high-temperature measurement is made first so that any permanent shrinkage which may occur during conditioning will not affect the result.

measuring equipment must be at thermal equilibrium. The relative humidity shall be the same at both temperatures and controlled as specified in 5.1. A low humidity is more practical for laboratory work, but other relative humidities may be used.[1] The test can be made on either unprocessed or processed material depending on the measuring method used (see annex A).

7.2 Calculations

This test method gives only an apparent thermal coefficient of expansion, since the moisture content of film and paper[2] varies slightly with temperature at constant relative humidity. The dimensional change between the two measurements of five samples shall be averaged and the thermal coefficients of expansion shall be calculated according to the following formula :

$$\alpha = \frac{l_2 - l_1}{l_1 \times t}$$

where

α is the thermal coefficient of expansion per 1°C;

l_1 is the gauge distance or the dimension measured at the final conditioning temperature and relative humidity;

l_2 is the gauge distance or the dimension measured at the initial conditioning temperature and relative humidity;

t is the difference between the two conditioning temperatures used, in degrees Celsius.

Depending on the type and composition of the measuring equipment, it may be necessary to correct for the thermal expansion of the gauge or of the reference standard.

7.3 Test report

The test report should contain the following :

a) thermal coefficients of expansion for both the length and width directions;

b) conditioning temperatures and relative humidity;

c) a statement as to whether the samples were unprocessed, processed to high density, or processed clear.

8 Test for dimensional change due to processing

8.1 General

The dimensional change due to processing of photographic films and papers can be markedly affected by the following three variables in the test procedure :

8.1.1 Preconditioning relative humidity of raw sample

The dimension of the unprocessed specimen at a given relative humidity can be dependent to a large extent upon the preconditioning humidity history. This is due to the hysteresis and relaxation effects described in annex B. It is necessary to specify whether the sample had been preconditioned from a lower or from a higher humidity prior to the original measurement on the unprocessed material. This is indicated by the letter "L" for the former and "H" for the latter.

8.1.2 Preconditioning relative humidity of processed sample

The preconditioning humidity history is as important for the dimension of the processed sample as for the raw sample described in 8.1.1. The letters "L" and "H" are also used to indicate the humidity history of the processed material. The letter "H" is also used when the sample is dried after processing at the measuring humidity.

8.1.3 Measuring relative humidity

Samples must be in moisture equilibrium with the same relative humidity for both the raw and processed measurements. Otherwise a reversible humidity expansion will be included in the measured dimensional change. However, the dimensional change due to processing can be very dependent upon the relative humidity at which those measurements are made and this must be indicated when reporting the results.

8.2 Coding system

A wide variety of test procedures can be used for the measurement of dimensional change due to processing by varying the preconditioning history of the raw and processed samples and the humidity at which these measurements are made. To characterize the procedure used, a coding system is used. For example, procedure LH-50 signifies that the raw sample had been preconditioned from a low humidity (L), the processed sample had been preconditioned from a high humidity (H), and all measurements were made at 50 % RH. Likewise, procedure LL-10 indicates that both the raw and processed sample had been preconditioned at a lower humidity than the 10 % RH at which the samples were measured. In practice, the range encompassed by LH-50 (tray processed and air dried) and HL-50 (machine processed and dried) generally reflects the expected variation in processing dimensional change.

8.3 Procedure

Five samples shall be preconditioned[3]. The preconditioning relative humidity shall be chosen to provide the desired low (L) or high (H) humidity history and shall be at least 5 % RH below or above the measuring humidity. The samples shall then be conditioned to the measuring humidity and the sample dimen-

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[1] The thermal coefficient of expansion varies slightly with relative humidity for some materials.

[2] Dimensional changes of photographic paper with reasonable changes in temperature (but at the same moisture content) are so small that measurement is very difficult and has little practical significance . This method is of importance for photographic film.

[3] Preconditioning times of 1 to 2 h are recommended for photographic film and paper.

sions shall be measured (or exposed if a photographic image is to be used for measurement as described in annex A). The samples shall be processed and dried as outlined in 4.3. The samples shall subsequently be preconditioned to the desired low or high preconditioning humidity, conditioned at the measuring humidity and remeasured.[1] The conditioning temperature shall be the same before and after processing and shall be controlled as specified in 5.2; the conditioning time shall be as specified in 5.3.

8.4 Calculations

The dimensional changes between the two measurements of five samples shall be averaged and the processing dimensional change calculated according to the following formula :

$$\% P = \frac{l_2 - l_1}{l_1} \times 100$$

where

$\% P$ is the dimensional change due to processing, as a percentage. A negative sign indicates shrinkage and a positive sign shows expansion.

l_1 is the gauge distance or the dimension measured at the initial conditioning temperature and relative humidity;

l_2 is the gauge distance or the dimension measured at the final conditioning temperature and relative humidity.

8.5 Test report

The test report should contain the following :

a) procedure used (for example LH-50);

b) dimensional changes due to processing for both the length and width directions;

c) processing conditions, including whether processed to a high density or processed clear.

9 Test for dimensional change due to processing plus aging

9.1 Aging conditions

The aging conditions[2] used shall be selected from the following[3] :

a) normal conditions, 23 ± 2 °C and 50 ± 5 % RH,

b) summer conditions, 32 ± 2 °C and 60 ± 5 % RH,

c) moist tropical conditions, 32 ± 2 °C and 90 ± 5 % RH,

d) dry accelerated conditions, 50 ± 2 °C and 20 ± 5 % RH.

9.2 Aging time

The aging times used shall be selected from the following : one week, one month, three months, six months, one year or multiples thereof.

9.3 Procedure

Five samples shall first be subjected to procedure LL-50 in accordance with 8.3. They shall then be placed at least 6 mm apart on racks, or hung from clips, and stored under one or more of the aging conditions listed in 9.1. After the aging time (see 9.2) has elapsed, the samples shall be preconditioned[4] at a low humidity at the standard temperature (see 5.2), then conditioned at 50 % RH, as specified in 5.3, and remeasured. The samples may then be returned to the same aging condition and stored for another time interval if desired.

9.4 Calculations

The dimensional changes between the initial measurement of the raw film and the final measurement of the processed and aged film for the five samples shall be averaged and the dimensional change due to processing plus aging calculated according to the following formula :

$$\% A = \frac{l_2 - l_1}{l_2} \times 100$$

where

$\% A$ is the dimensional change due to processing plus aging, as a percentage. A negative sign indicates shrinkage and a positive sign indicates expansion;

l_1 is the gauge distance or the dimension measured at the initial conditioning temperature and relative humidity;

l_2 is the gauge distance or the dimension measured at the final conditioning temperature and relative humidity.

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[1] When samples are dried at the measuring humidity, the letter "H" is used without the need for a separate preconditioning step.

[2] Moist, accelerated conditions hasten shrinkage caused by loss of residual solvent in solvent-coated film base. Dry, accelerated conditions hasten shrinkage caused by strain relaxation or plastic flow of film base. Photographic paper does not have solvent loss shrinkage but does change dimension with humidity cycling due to strain relaxation.

[3] The tolerances on temperature and relative humidity for aging conditions do not need to be as critical as the tolerances on temperature and relative humidity for conditioning for measuring.

[4] Preconditioning times of 1 to 2 h are recommended for photographic film and paper.

9.5 Test report

The test report should include the following :

a) dimensional change due to processing plus aging for both the length and width directions;

b) processing conditions, including whether processed to a high density or processed clear;

c) aging conditions;

d) aging time.

Annex A

Methods to measure dimensional change

Many different techniques are available today to measure the size change of photographic films and papers. The most suitable method depends upon the accuracy required, the dimensions of the sensitized material available for measurement, the relative importance of measuring the physical dimensions of the material or the displacement of the photographic image, whether dimensions must be measured simultaneously in different directions, and the need to obtain a measure of size change uniformity. Several well-established approaches are briefly reviewed below.

One widely-used technique is the pin gauge method first described by Davis and Stovall [1]. With this technique, the photographic material is punched with two pairs of perforations which are a known distance apart. These perforations fit over corresponding pairs of pins in a mechanical gauge, and the distance between the pins is read on a dial indicator. Repeatability of ± 0,006 % can be obtained. Depending on gauge tension, this equipment may be less satisfactory with some thin photographic papers and thin base films since the perforations may not have sufficient strength to resist distortion. This procedure gives a dimensional change averaged over the gauge length, and localized areas of non-uniform behaviour will not be detected. Moreover, values are determined only in one direction of the test specimen and appropriate specimens must be cut for each direction of interest. Within these limitations, this technique has proved to be extremely useful [2].

Another useful device, which also measures the dimensions of strips, is an electronic gauge [3] using a strain gauge. Again this method is limited to one dimension and a spring-loaded probe tends to deflect thin base materials.

Dimensional changes in several directions of photographic film have been simultaneously studied by exposing a reseau or grid on the film and subsequently comparing the intersections of this grid against those of the original master grid (on a glass plate) using an optical comparator. This approach can yield very precise values [4] [5] [6] and can be made on relatively large sheet sizes. However, the measurements are very laborious. A more sophisticated variation of this technique measures the X and Y coordinates of a rectangular grid pattern [7]. A computer program converts these coordinates into more meaningful data.

Another optical method on large sheet sizes involves the principle of moire interference patterns [8 to 11]. A fine halftone chequered pattern on glass is exposed on the film and registration is subsequently made with the glass master of the chequered pattern. The resulting moire patterns can be used to calculate absolute size change and also to readily illustrate any non-uniformities in size change. Both this moire technique and the grid-comparator method utilize the photographic image for measurement purposes and hence cannot be used on unprocessed materials. Both the grid and the moire methods also provide information on the uniformity of dimensional change.

Annex B

Dimensional hysteresis in photographic film

Careful measurement of the dimensional properties of photographic materials, particularly films on low-shrink, moisture-resistant resin supports, must take into account the phenomenon of dimensional hysteresis. This is the failure of the material to reach the same dimensions when its equilibrium relative humidity is approached from a lower or from a higher relative humidity.

Hydrophilic or moisture absorbing materials exhibit a moisture hysteresis and have a higher moisture content when equilibrium is approached from a higher relative humidity than when it is approached from a lower relative humidity. Paper, cellulose ester, and gelatin are typical of such materials. However, dimensional hysteresis in photographic film is further complicated because mechanical factors, in addition to moisture absorption, are involved.

Dimensional hysteresis curves are shown in figure 1 for an unprocessed cellulose ester base film. Figure 2 shows the dimensional hysteresis for both an unprocessed and processed hydrophobic resin base film. These curves illustrate the dimensional changes that can occur with cycling relative humidity although there can be considerable variation in behaviour for different films. The unprocessed cellulose ester base film illustrated in figure 1 shows the normal type of hysteresis resulting from higher moisture content during desorption than during sorption. The resin base film (see figure 2) on the other hand, shows "hysteresis" but in the reversed direction; that is, the film has a smaller dimension when the relative humidity is approached from above. The reversed hysteresis observed here is due to mechanical and rheological effects related to the gelatin-base interactions [12]. Thus, two competing forces may be present to cause dimensional hysteresis in photographic films, namely, normal moisture hysteresis in the base and a reversed hysteresis due to the mechanical effects of the gelatin. In fact, some types of cellulose ester base film also exhibit reversed hysteresis. In other words, the type of base and emulsion and the base/emulsion thickness ratio determine the dimensional hysteresis characteristics.

It is apparent from the above that the dimensional properties of a piece of film can be accurately determined only by the most careful control of the sample history and the rigid specification of test conditions. In clause 6, measurement is specified over a range below 60 % RH because the curves for resin base films sometimes show an inflection point at high humidity. In clause 8, different procedures may be used to take into account the different combinations of moisture history in the raw and processed films that may occur in practice. This is relatively more important in the more stable resin base films. Figure 2 illustrates the variation in dimensional changes that can be caused by previous moisture history, even when the film is returned to the same relative humidity at the time of printing as existed at the time of camera exposure.

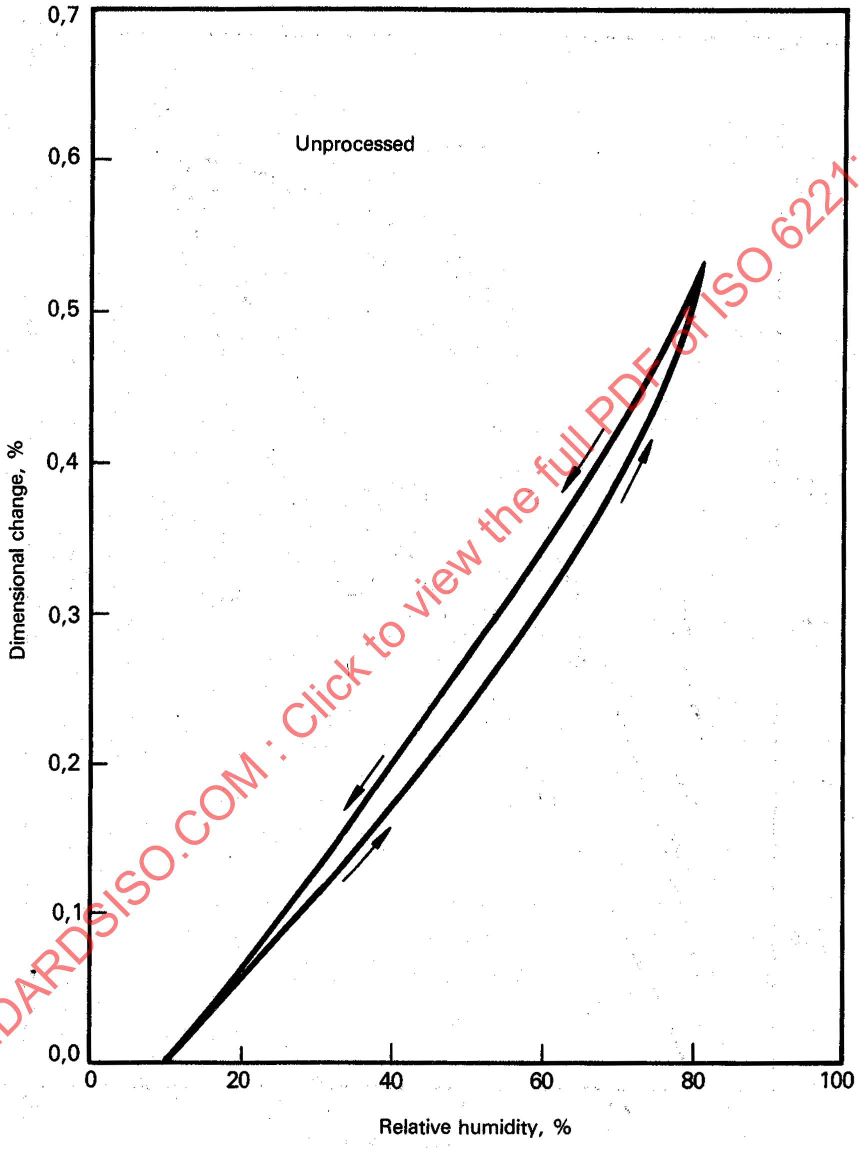

Figure 1 — Dimensional hysteresis curve for a typical cellulose ester base film (gelatin emulsion and backing)

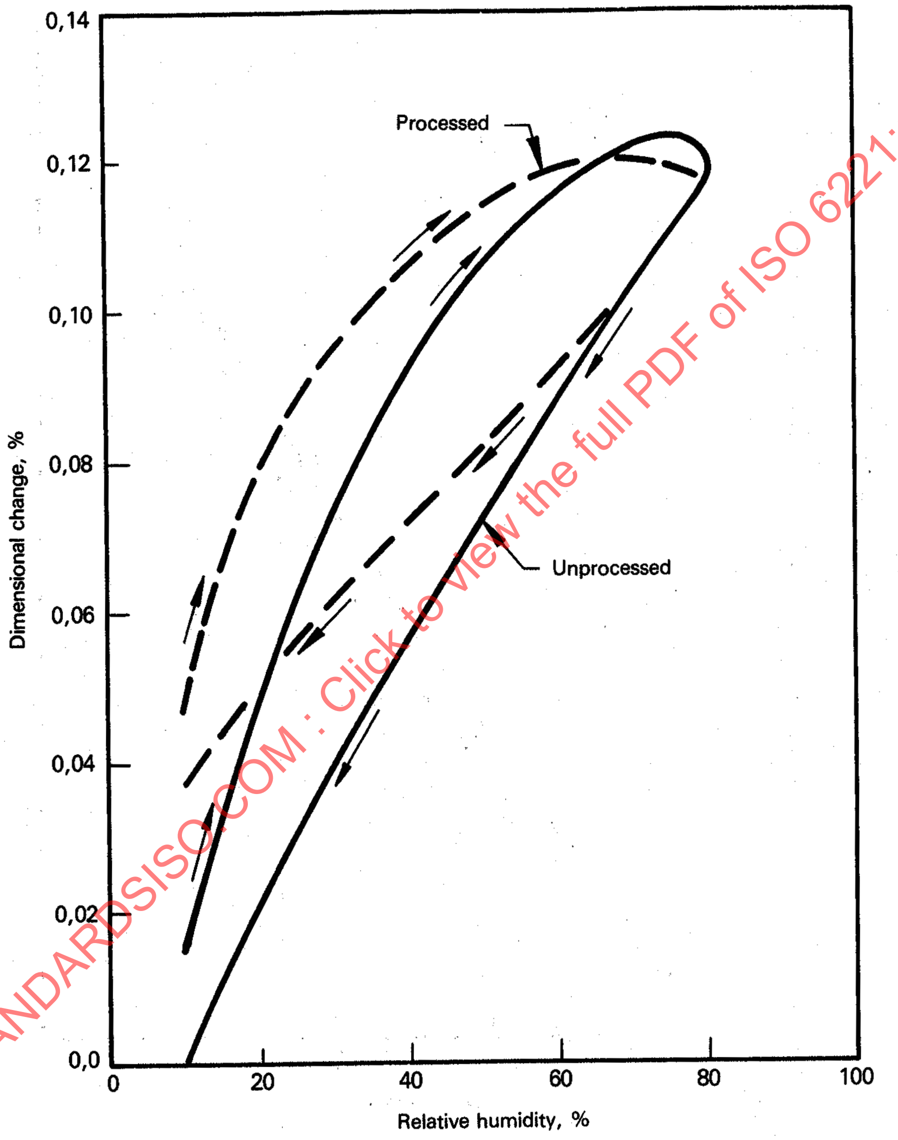

Figure 2 — Dimensional hysteresis curves for a typical resin base film (gelatin emulsion and backing)