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A Methodology for Establishing Conditioning Requirements for Building Materials and Composites

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Structures, Materials and Safety Division
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Washington, D. C. 20234

October 1975

Interim Report

Prepared for
Division of Energy, Building Technology and Standards
Office of Policy Development and Research
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U.S. DEPARTMENT OF COMMERCE, Rogers C.B. Morton, *Secretary*
James A. Baker, III, *Under Secretary*
Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

TABLE OF CONTENTS

TABLE OF CONTENTS - continued

Definitions*

Building Material - Any of the different substances of which a composite is comprised. A (chemically and physically) distinct form of matter intentionally present within a building element.

Building Composite - An intimate combination of two or more building materials designed to perform a specific function more efficiently than any one of the materials.

Sample - A portion of a building element selected to provide specimens of a material or composite.

Specimen - A part of a sample selected to determine the characteristics of the sample by testing.

Optimum Condition - A condition in which the material or composite under study is least sensitive to minor changes in the test environment.

*Definitions relating to conditioning are included in Table 3.

A Methodology for Establishing Conditioning Requirements
for Building Materials and Composites

Abstract

The measured properties of building materials and their composites sometimes reflect the conditions to which they have been exposed while being prepared for test. Conditioning these materials to some standard reference state may be used to minimize such effects.

A methodology for establishing conditioning requirements for building materials and composites is presented and its use illustrated by applying it to two building composites.

The composites to which the methodology is applied are: 1) gypsum wallboard and 2) a structural sandwich wall panel.

Key words: Building composite; building material; conditioning; equilibration; gypsum wallboard; methodology; relative humidity; structural sandwich panel; temperature; testing.

1. INTRODUCTION

The Department of Housing and Urban Development (HUD), in a continuing effort to develop improved standards for evaluating building materials and composites, is sponsoring a research project at the National Bureau of Standards, to study structural test methods. One task of the project is to develop a methodology for establishing conditioning requirements for building materials and composites. The results of the task are included in this report.

An important step in the process of evaluating building materials and composites is "conditioning". Conditioning is defined in ASTM E41-63 (1971) [1][1/] as, "The exposure of a material to the influence of a prescribed atmosphere for a stipulated period of time or until a stipulated relation is reached between material and atmosphere." In addition, ASTM E41 defines preconditioning as "any preliminary exposure of a material to the influence of specified atmospheric conditions for the purpose of favorably approaching equilibrium with a prescribed atmosphere".

The purpose of conditioning is to ensure that all specimens are evaluated under comparable conditions, which are appropriate for the intended purpose. However, the term conditioning is sometimes used in the literature to describe exposure to environmental factors for the purpose of inducing degradation. To avoid ambiguity, it is necessary to define the terms conditioning and preconditioning more explicity. The flow chart in figure 1 will be referred to in clarifying the terms.

Figure 1 outlines the basic steps in tests to determine both short-term and long-term properties of building materials and composites. The type 1 test is used to determine properties of a specimen under selected conditions. It contains three basic steps: specimen preparation, conditioning and the evaluative procedure. The evaluative procedure is the procedure used to measure the property of interest. For example, it may be a procedure to measure a strength property such as tensile or shear strength or one to measure an appearance property such as color or gloss. The type 2 test is used to determine the effects on a specimen of exposure to various environmental factors. The type 2 test contains four basic steps: specimen preparation, exposure to the chosen environment, conditioning and the evaluative procedure. The exposure step consists of exposing the specimen to the environmental factors whose effect on the specimen is to be determined. The exposure conditions can be natural or they may be specially produced in the laboratory. Thus, by comparing the results of both type 1 and type 2 tests on identical specimens, the effect of the environmental exposure can be determined. The important point is that there is a difference in purpose between conditioning and environmental exposure.

1/ The numbers in brackets refer to the literature references listed in Section 6, Bibliography.

Environmental exposure is normally used to identify irreversible effects, while conditioning is to ensure that variations in results are not due to reversible effects. Conditioning usually consists of equilibrating test specimens at a fixed relative humidity (r.h.) and temperature, such as 50% r.h. and 23°C, but it can also consist of water soaking, heating to a constant temperature, etc. For example, let us assume there is a need to determine the effect of heat aging on the wet strength of a material. Test specimens would be wetted and the strength measured to obtain the short term or initial strength of the specimens. Replicate specimens would be heat aged, prior to wetting and strength testing. The two wet strength values could be compared to determine the effect of the heat aging. The wetting procedure would be conditioning and the heat aging would be exposure to the chosen environment. Some of the terminology confusion may be avoided by changing the ASTM definition of conditioning to read: "The exposure of a material to the influence of a prescribed atmosphere for a stipulated period of time or until a stipulated relation is reached between material and atmosphere to ensure that all specimens will be tested under comparable conditions."

To minimize variations between property measurements of replicate specimens or between the results obtained by different laboratories, it is necessary that an appropriate conditioning procedure be specified and utilized in tests of building materials and composites. The use of such a procedure ensures that all specimens are tested under comparable conditions. This is particularly important when the properties of interest are significantly affected by the conditions (e.g. temperature) at which the tests are carried out. However, not all existing test procedures contain conditioning procedures. Often this does not matter since the sensitivity of the specimens to possible changes in conditions is small. However, for new materials and composites, appropriate conditioning procedures should be specified. Thus, there is a need to develop a methodology (guidelines) for selecting conditioning procedures. The purpose of this report is to outline a methodology and to illustrate its use by applying it to selected building composites.

2. CONSIDERATIONS IN SELECTING CONDITIONING REQUIREMENTS

Conditioning procedures for building materials and composites should be chosen so as to contain requirements for temperature, humidity and time of exposure to the required atmosphere. It should be noted that the time of exposure may be specified definitely (i.e. in a specific period) or indefinitely in terms of the requirement that equilibrium be obtained with the surrounding atmosphere.

Table 1 summarizes the conditioning requirements in a number of standard tests for building materials. In addition to the reference designation and the material description, this table presents a description of the test (i.e. evaluative procedure) and the specific conditioning requirements, if any.

There are a number of general requirements that can be stipulated for any conditioning procedure. Seven of these are listed. An acceptable conditoning procedure should:

1) ensure that the history of the preparation of supposedly identical specimens does not contribute to the experimental error or has a minimal effect

2) be as simple as possible

3) be as rapid as possible

4) minimize irreversible changes (or the possiblity of irreversible changes)

5) ensure that the evaluative procedure gives results which indicate the properties of the specimens in the most appropriate condition and, particularly, do not cause the performance to be overestimated

6) be as generally useful as possible

7) be as close to common practice as possible.

The wide variety of materials used in the building industry precludes any single absolute set of conditioning requirements. Temperature and relative humidity (r.h.) might well be selected and standardized but the time for the specimen to reach equilibrium at these conditions would vary considerably depending on the material, the shape and size of the specimen, the construction details and the previous history. For example, a large cross-section, pre-cast concrete beam stored outside during the winter, and covered with snow, may require a much longer time to come to equilibrium at 25°C and 50% r.h. than a section of 4 inch DWV-ABS schedule 40 plastic pipe brought in from a warehouse at 28°C and 75% r.h. Hence, the requirement that equilibrium conditions be obtained places the obligation on the testing facility to assure that all the conditioning requirements are met before the evaluative procedure begins regardless of construction, materials or exposure history.

The factors which govern the selection of conditioning requirements are temperature, humidity and equilibration. These are discussed individually below.

2.1 Temperature

The conditioning temperature might be critical if the composite or single material property being measured in the evaluative procedure is temperature sensitive. Thus, once the testing laboratory has determined the temperature sensitivity of the property, the temperature to be used in a conditioning procedure must be selected so that composites or single materials conditioned by the procedure will reach a common temperature in a reasonable length of time, regardless of the past exposure history.

In selecting a conditioning temperature, the effect of temperature on the chemical and physical properties of the component or material must be considered. For example, Table 2 shows that tests for time of setting for gypsum products in ASTM C 472-73 [2] use a conditioning temperature of 113°F (45°C) for conditioning of the original powdered material, gypsum plaster, which is predominately $CaSO_4 \cdot 1/2\ H_2O$. One purpose of the gypsum plaster conditioning is to ensure freedom from free water. Thus, the 113°F (45°C) conditioning temperature probably was selected as the highest temperature at which the plaster would be dried without dehydrating the gypsum ($CaSO_4 \cdot 2H_2O$) in it to $CaSO_4 \cdot 1/2\ H_2O$. Figure 2, for example, is a phase diagram showing that conditioning at a temperature of 113°F (45°C) and very low r.h., as specified in ASTM C472, should result in hemihydrate formation. The figure also shows that the cure conditions for the time-of-wetting test samples described in ASTM C472, 68 to 72°F (20 to 22°C) and >85% r.h., are well within the $CaSO_4 \cdot 2H_2O$ region.

The selection of a conditioning temperature must also be based upon the type of information desired from the test. For example, the measurement of a dimensional change of a material may require rigid temperature control whereas, for other property measurements, such as strength, less rigid temperature control may be acceptable. If possible, the specified temperature should also be one which is readily obtainable in the laboratory.

Other factors influencing the selection of conditioning requirements, include the intended use of the material, its size, weight, conformation and exposure history. For example, a material to be used in extreme environments may be best conditioned and evaluated in that environment. The size, weight and conformation of the test specimen may limit somewhat the possible range of the conditioning temperature because of the type of conditioning facilities available. The exposure history of the test specimen may have considerable effect on the choice of conditions needed to bring it to equilibrium. For example, a specimen of wood that has been water soaked may require considerable time to equilibrate with a 40% r.h. atmosphere, particulary if the wood is not to warp in the drying process.

Table 1 shows that many standard test procedures specify a conditioning temperature of 25°C with a range of ±1 to ±2°C. The table further shows that temperatures for conditionining are not always specified. The broad usage of 23°C (73.4°F) is oriented to the practical aspects of conditioning: namely, that 23°C, commonly termed "room temperature", is convenient and obviates the need for numerous conditioning rooms or chambers, maintained at different temperatures.

2.2 Humidity

Table 3, on definition of terms relating to conditioning, shows that several descriptions involving the term "humidity" exist. For this report, the discussion will be centered on relative humidity (r.h.) since this is the quantity normally measured in the test laboratory.

As was the case with temperature, the r.h. for conditioning procedures can be critical if the property to be measured in the evaluative procedure is moisture sensitive. The testing laboratory must determine this sensitivity for each component or material to be tested whether by professional judgment and experience or by experiment. For example, strength properties of porous or hygroscopic materials might well be sensitive to moisture. The r.h. must also be selected based upon the effect of moisture on all other chemical and physical properties of the material or component. Table 1, for example, shows that the specified r. h. for conditioning many wood-based products is 65 ± 1% r. h. This r.h. selection is probably dependent upon the fact that the properties of wood are greatly affected by humidity and this value of r. h. has been applied to wood and textiles over the entire world by consensus. Table 1 also shows that a number of tests for concrete use 100% r.h. One of these is ASTM C39-72 [3] for compressive strength. The high r.h. is used in this test to assure suitable conditions for the hydration of the cement. Non-reversible reaction effects, such as mentioned in Section 2.1, may also be important for properties changed by the r.h. of conditioning.

Consideration must also be given to the practical aspects of maintaining rooms for conditioning at various r.h. levels as well as the use of the material and its size, weight and conformation. Table 1 shows that many standard test procedures specify r.h. values of about 50% for the conditioning procedures. The table also illustrates the fact that values are not always specified. As was the case with the widespread use of 23°C as a conditioning temperature, 50% r.h. has frequently been selected for convenience.

2.3 Equilibration

The term equilibration is defined in Chamber's Technical Dictionary as "the production of balance or equilibrium". Further, a definition of equilibrium is included in Table 3 (under moisture equilibrium) as "the condition reached by a sample when the net difference between the amount of moisture absorbed and the amount desorbed, as shown by change in weight, shows no trend and becomes insignificant". Applying this same concept to temperature equilibrium would require reaching a temperature balance so that the temperature difference between any two points in the test specimen would show no trend and become insignificant (i.e. was constant or zero).

Once a temperature and r.h. for conditioning have been chosen, consideration must be given to ensuring that test specimens reach a state of equilibrium under the prescribed conditions. Because of the dependence of the equilibration time on the characteristics of the material or composite under test, no single time, applicable to a broad range of products, can be given. Equilibration time must be determined experimentally for each type of material or composite. A common method for simplifying this determination in the case of specimens which can absorb significant quantities of water is to specify that the material or composite be conditioned to constant weight. A specimen conditioned to constant weight will have equilibrated in terms of moisture content but constant weight does not ensure equilibration with temperature. However, temperature equilibration will generally occur in less time than moisture equilibration.

Depending on the exposure history of the specimen, the requirement for equilibration may necessitate some change in the temperature or r.h. that has been previously identified as being desirable. Preconditioning, defined in Table 3 as "any preliminary exposure of a material to the influence of specified atmospheric conditions for the purpose of accelerating the approach to equilibrium with a prescribed atmosphere", may be desirable in some cases. For example, large test specimens, such as composite sandwich panels or beams, which have been water soaked may require very long times to equilibrate at 23°C and 50% r.h. In such circumstances, the equilibration time may be reduced somewhat by preconditioning at elevated temperatures - as long as irreversible reaction effects are not a factor - and then conditioning can be completed under the previously identified atmospheric conditions.

Table 1 shows that nearly all test methods for plastics specify an equilibration time of 40 hours at 23 ± 2°C and 50 ± 5% r.h. Many wood-based products and the gypsum products in Table 2 use the constant weight criterion for equilibration.

3. METHODOLOGY FOR SELECTING CONDITIONING REQUIREMENTS

The previous sections of this report indicate that detailed requirements for conditioning cannot be specified unless the material or composite is characterized in terms of properties to be measured, physical or chemical changes which might be induced by the conditioning, use of the material or composite, general size of the specimen, weight and conformation of the specimen, and its exposure history. The characterization is often based on the experience and judgment of the individual or group selecting the conditions with input from laboratory studies as needed. Complications arise in selecting conditioning requirements for composites or complex combinations of materials because of possible interactions between adjoining materials. In particular, conditioning procedures for innovative materials and composites may be difficult to establish because of the lack of prior knowledge of the properties of the products.

To help overcome the difficulties in selecting conditioning requirements, this section of the report presents a methodology for their selection. Figure 3 outlines the methodology. The methodology is divided into seven parts:

1. Characterize the Material or Composite

2. Establish a Suitable Temperature Range Based on the Characterization of the Material or Composite

3. Establish a Suitable Relative Humidity Range Based on the Characterization of the Material or Composite

4. Establish Suitable Temperature and Relative Humidity Ranges Based on the Available Facilities in the Testing Laboratory and on the Results of Parts 2 and 3

5. Establish the Equilibration Requirements (Time, Constant Weight, etc.)

6. Select a Specific Temperature Range, Relative Humidity Range and Equilibration Time Based on the Characterization of the Material or Composite and the Facilities Available for Conditioning

7. Prepare a Report Summarizing the Final Results for Conditioning Requirements.

Part 1 of the methodology, "Characterize the Material or Composite", consists of analyzing the factors involved so that decisions regarding the ranges of acceptable conditions may be made.

The steps in characterizing the test specimen are:

a) identify how the material or composite will be used in buildings

b) identify the properties of the specimens to be measured in the evaluation procedure

c) identify the expected normal range of exposure conditions (temperature and moisture) in the field

d) determine the sensitivity of the properties to be measured to the expected temperature and moisture conditions

e) identify if the test specimen is a material or a composite

f) if it is a composite, identify the material or interfaces in the composite which are likely to be most sensitive to conditioning

g) identify desirable conditions for the material or the most sensitive material in a composite based upon steps a through f (however, it must be determined or judged from experience or previous knowledge if the desirable considering the most sensitive material(s) in a composite will adversely affect the evaluation procedure for the composite)

h) identify the effect of temperature and moisture on the chemical and physical properties of the test specimen (for example, if free water is to be released, hydrogen bonding promoted, shrinkage induced etc., during the conditioning, these changes must be known either from experience or experiment)

i) identify desirable conditions to optimize the desired changes in chemical and physical properties that were identified in step h

j) identify the effect of other factors including size, weight, conformation and exposure history of test specimens on conditioning requirements

k) identify desirable conditions based on the information obtained in step j.

As a result of the steps listed in Part 1, three ranges of conditions, identified in steps g, i and k, will have been identified.

Part 2, "Establish a Suitable Temperature Range Based on the Characterization of the Material or Composite", and Part 3, "Establish a Suitable Relative Humidity Range Based on the Characterization of the Material or Composite", must then be completed based upon the ranges identified in Part 1. This consists of analyzing the data from Part 1 and identifying a single desirable range for both temperature and relative humidity.

Part 4, "Establish Suitable Temperature and Relative Humidity Ranges Based on the Available Facilities in the Testing Laboratory and on the Results of Parts 2 and 3", consists of moderating the conditioning range in the testing laboratory. Although conditions based on the characterization of the material or composite ideally should be used, it must be realized that it may not be practicable for a testing laboratory to maintain conditioning facilities that would achieve all the desired conditioning ranges. Thus, it is necessary to provide in the methodology a step which combines the idealized conditions with those which can actually be achieved. In identifying suitable temperature and r.h. ranges in this Part, primary emphasis should be placed on the critical factors identified in characterizing the specimen in Part 1 so that these factors are not exceeded to the detriment of the test sample.

Part 5, "Establish the Equilibration Requirements", consists of experimentally determining the time required for the material or composite to equilibrate with the temperature and r.h. values identified in Part 4.

Part 6, "Select a Specific Temperature Range, Relative Humidity Range and Equilibration Time", involves analyzing the data obtained in the first five parts of the methodology and selecting specific conditioning requirements.

Part 7, "Prepare a Report Summarizing the Final Results for Conditioning Requirements", involves preparing a report summarizing the final results for conditioning requirements giving temperature, r.h. and equilibrium decisions (e.g. time, constant weight, etc.). The basis for the selection of the conditioning requirements should be stated in the report. This summary should also be included with the report on the final tests conducted on the sample.

The methodology outlined in this section for selecting conditioning requirements is primarily intended for use by a standards organization, committee or task group or regulatory body in establishing recommendations for a variety of materials and composites.

4. ILLUSTRATION OF THE METHODOLOGY FOR SELECTING CONDITIONING REQUIREMENTS

The use of the methodology presented in the previous section for establishing conditioning requirements will be illustrated in this section by applying it to 1) a flexural test for gypsum wallboard which is described in ASTM C473-70 [4] and 2) a racking test for a structural sandwich wall panel which is described in ASTM E72-74 [5]. The methodology application will follow the format of the first six parts outlined in figure 3 and, for the purpose of illustration, will include comments which may seem elementary and repetitious. Many of the criteria used in illustrating the methodology are hypothetical. Actual laboratory tests were not conducted for either of the composites.

4.1 Application of the Methodology to a Flexural Test for Gypsum Wallboard

4.1.1 Part 1 - Characterize the Material or Composite

Step a - Identify how the material or composite will be used in buildings.

Gypsum wallboard is normally used as the interior wall or ceiling of buildings and is fastened to framing members either mechanically or adhesively or by a combination of the two. Wallboard is not used as a primary element in transferring structural loads.

Step b - Identify the properties of the specimens to be measured in the evaluative procedure.

The flexural strength of the wallboard will be measured according to standard test procedures.

Step c - Identify the expected normal range of exposure conditions in the field.

The temperature on the interior of buildings is unlikely to fall below -23°C (-10°F), even in an unheated building in winter, or to rise above 43°C (110°F) in a non-airconditioned building in summer. It is expected, however, that a more usual range for most building interior walls would, under normal conditions, be from 16°C (60°F) to 35°C (95°F). The r.h. is unlikely to be less than 10% in building interiors and it cannot exceed 100%. Most building interior walls, however, are expected, under normal conditions, to have a r.h. between 30 and 80% though a cold exterior wall may have a surface with a local r.h. of 100%.

Step d - Determine the sensitivity of the properties to be measured to the expected temperature and moisture conditions.

This step of the methodology generally requires laboratory data. For the purpose of this demonstration, let us assume that laboratory tests have been performed and that the data show that the flexural strength of gypsum wallboard is not temperature sensitive within the ranges mentioned above, but that the flexural strength decreases with r.h. above 90%.

Step e - Identify if the test specimen is a material or a composite.

Gypsum wallboard is a composite comprised of a core of gypsum and various additives with paper firmly bonded to both faces of the core. The final chemical form of gypsum used in wallboard is calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$).

Step f - Identify the material or interfaces in the composite which are likely to be most sensitive to conditioning.

The gypsum (dihydrate) in the core undergoes a dehydration at 120-130°C and ambient r.h. which results in removal of combined water. The reaction is as follows:

$$CaSO_4 \cdot 2H_2O \xrightarrow{\sim 120°C} CaSO_4 \cdot 1/2H_2O + 1\text{-}1/2\ H_2O.$$

(dihydrate) Heat (hemihydrate)

The product of dehydration has a different volume and is somewhat softer than the dihydrate so that debonding of the paper may occur as a result of this reaction.

The paper is sensitive to moisture in that wetted paper may debond from the core. Gypsum that has been exposed to liquid water can lose its continuity and thus its strength.

Since the maximum temperature expected in buildings, 43°C, is well below the dehydration temperature, temperature is not critical at this point in the analysis. High moisture content, however, is known to affect both the gypsum and the paper. It is not apparent if gypsum or the paper is more moisture sensitive. Figure 2 contains the necessary information to determine the conditions under which the proper form of the gypsum can be maintained. This is an example of the type of laboratory information that is important to the selection of proper conditioning requirements. In the absence of such technical data, it is necessary to utilize sound technical judgment in selecting the boundary conditions.

Step g - Identify desirable conditions based on the information obtained in steps a through f.

The temperature range expected in most building interiors was estimated to range from 16 to 35°C and the extreme temperatures expected were estimated to range from -23 to 43°C. Since it was determined that flexural strength is not very sensitive to temperature in these ranges, and since the dehydration process does not occur at the maximum temperature mentioned above, an acceptable temperature range for conditioning, based on the information analyzed thus far, would be -23 to 43°C.

It was assumed for purpose of illustration that an r.h. of 90% and greater, results in a decrease of flexural strength. Thus, the conditioning r.h. should be below 90%. It was estimated that most building interior walls, under normal conditions, would have r.h. values between 30 and 80% and that 10% would be the lowest r.h. expected in a building. Based on these estimates, an r.h. range of 10-80% would appear reasonable.

Step h - Identify the effect of temperature and moisture on the chemical and physical properties of the test specimens.

As mentioned previously, the gypsum ($CaSO_4 \cdot 2H_2O$) undergoes a dehydration reaction at about 120°C which results in the removal of combined water. Thus, the conditioning temperature must remain well below 120°C because the dehydration reaction may occur at slower rates at temperatures somewhat less than 120°C. But the temperature must, if possible, be sufficiently high for the free water (water not combined with gypsum) to be removed at an acceptably high rate.

The r.h. must be high enough to prevent loss of the combined water but low enough to permit free water to escape and thus dry the specimen. Conditions that satisfy these requirements can be selected from figure 2. The r.h., as previously mentioned, will, if high enough, also affect the paper of the wallboard in that wetted paper may debond from the gypsum.

Step i - Identify desirable conditions to optimize the desired changes in chemical and physical properties that were identified in Step h.

Since gypsum wallboard will be used quite often at temperatures close to 23°C in the field, 23°C would be an acceptable conditioning temperature. To provide for more rapid drying of the specimen, by releasing free water, a high temperature may also be needed. The upper temperature limit, however, must be well below 120°C. A conditioning temperature range of 23 to 50°C would appear to satisfy these criteria as long as the r.h. is above 55% as shown in figure 2.

Step j - Identify the effect of other factors including size, weight, conformation and exposure history of test specimens on conditioning requirements.

The specimen size as required in ASTM C473-70 [4] is 30.5 by 40.6 cm (12 by 16 in). This specimen size is convenient for the use of humidity cabinets and ovens commonly found in testing labs. Also, the thickness of the test specimen is the same as that of the test sample so that drying or wetting times for the specimen will be comparable to those for the larger sample.

The specimen weight is dependent upon the thickness of the sample but the size indicates that the weight will not present a problem in handling the test specimen.

The specimen conformation is comparable to the conformation to be found in-service. Thus, it is concluded that the above factors will have little effect in establishing the desired conditions.

The specimen exposure history may have a significant effect on the conditions selected. For example, it would be reasonable to assume that there might be cases when a specimen will be tested after exposure to high temperature or high r.h. Thus, the conditions should, if possible, be such that equilibration of a specimen exposed to these conditions can be brought about in a reasonable time period so that the evaluative procedure results can be compared to those for a specimen exposed under controlled laboratory conditions.

Step k - Identify desirable conditions based on information obtained in Step j.

An r.h. of no less than 55% and a temperature of 23-50°C would be reasonable based on consideration of the factors mentioned in Step j.

4.1.2 Part 2 - Establish a Suitable Temperature Range Based on the Characterization of the Material or Composite

In Step g of Part 1, a temperature range of -23 to 43°C was judged to be acceptable because these were expected extremes in the field. Later considerations, however, established that the release of free water must be accomplished by the conditioning and that a temperaature range of 23 to 50°C meets this requirement. Since the rate of drying will be lower, the lower the temperature, there would be no benefit from using a temperature less than 23°C. Thus, a conditioning temperatue range of 23 to 50°C would be acceptable based on the complete analysis of Part 1.

4.1.3 Part 3 - Establish a Suitable Relative Humidity Range Based on the Characterization of the Material or Composite

In Step g of Part 1, an r.h. range of 10-80% was judged to be acceptable. The analysis in Step i, however, determined that an r.h. above 55% would be needed to prevent dehydration but, at the same time, permit free water volatilization over the temperature range of 23-50°C. It was also judged in Step k that an r.h. of 55% would be desirable to permit drying of specimens that may have been exposed to high humidities prior to conditioning. But it is also very important that loss of combined water not occur. Thus, an r.h. range of 55-60% would be acceptable based on the complete analysis in Part 1.

4.1.4 Part 4 - Establish Suitable Temperature and Relative Humidity Ranges Based on the Available Facilities in the Testing Laboratory and on the Results of Parts 2 and 3

In view of the specimen size, weight and conformation, the specimen can be conditioned in a commercially available humidity cabinet that is commonly available in testing laboratories. The temperature and humidity ranges identified in Parts 2 and 3 are well within the ranges of such cabinets. Assuming a humidity cabinet is available, the temperature and humidity conditions identified in Parts 2 and 3 are attainable for conditioning specimens of gypsum wallboard.

4.1.5 Part 5 - Establish the Equilibration Requirements

This part of the methodology requires experimentation to determine the time to establish temperature and r.h. equilibrium. The temperature and r.h. ranges used in the experiments will be those established in Part 4 of the methodology; namely, 23-50°C and 55-60% r.h.

The initial temperature and r.h. of test specimens prior to conditioning will range from 10 to 70°C and 10 to 90% to duplicate the estimated ranges at which test specimens would be received for test (see rectangle ABCD in figure 2).

Let us assume that the experiments show that conditioning temperatures of 30-40°C and r.h. values of 48-55% result in constant weight in an acceptable period of time (less than fourteen days).

4.1.6 Part 6 - Select a Specific Temperature Range, Relative Humidity Range and Equilibration Time

Based on the "experimental" findings in Part 5 and the acceptable ranges established in Part 4, the temperature of the conditioning should be 30-40°C and the r.h. of the conditioning should be 48-55%. The test specimen should be conditioned to constant weight (less than fourteen days). Rectangle EFGH in figure 2 shows that these conditions should yield the dihydrate form of calcium sulfate.

4.2 Application of the Methodology to a Racking Test for a Structural Sandwich Wall Panel

A cross-section of the structural sandwich wall panel, to which the conditioning methodology will be applied, is shown in figure 4. The core is polyurethane foam that is foamed-in-place during fabrication between skins consisting of 0.3175 cm (1/8 in) asbestos cement board and 0.9525 cm (3/8 in) plywood. The polyurethane, upon curing, bonds to the skins. The exterior side of the panel (the side with the asbestos cement skin) is coated with an 0.3175 cm (1/8 in) epoxy coating. The panel is fabricated to a nominal 1.22 x 2.44 m (4 x 8 ft) size for use in buildings.

4.2.1 Part 1 - Characterize the Material or Composite

Step a - Identify how the material or composite will be used in buildings.

The structural sandwich panel will be joined with other identical panels to form the exterior walls of buildings. Horizontal and vertical loads will be transferred through these panels into the building's foundation.

Step b - Identify the properties of the specimen to be measured in the evaluative procedure.

The inherent capability of the structural sandwich wall panel to resist horizontally-applied in-plane forces (i.e., racking forces) is to be determined by a standardized procedure.

Step c - Identify the expected normal range of exposure conditions in the field.

The air temperature on the interior of buildings is unlikely to fall below -23°C (-10°F) in an unheated building in the winter or rise above 43°C (110°F) in a non-airconditioned building in summer. It is expected, however, that under normal use conditions, most building interiors would be at temperatures between 16°C (60°F) to 35°C (95°F). The exterior air temperature is expected to fall in the range from -46°C (-50°F) to 49°C (120°F) for all U.S. climates. The exterior surface temperature of the panel in the field will differ from the ambient air temperature due to solar factors.

The r. h. might be expected to vary from 10 to 100% in both the interior and exterior of buildings.

Step d - Determine the sensitivity of the properties to be measured to expected temperature and moisture conditions.

This step of the methodology would require laboratory data. For the purpose of this illustration, let us assume that laboratory tests have been performed and that the data show that the racking strength of the panel is not temperature sensitive within the ranges mentioned above if the r.h. is less than 85%. Let us further assume that, at temperatures greater than 49°C and at r.h. values greater than 85%, the racking strength decreases.

Step e - Identify if the test specimen is a material or a composite.

The structural sandwich wall panel is a composite comprised of a polyurethane foam core, skins of asbestos cement board and plywood, and an epoxy coating on the exterior surface (over the asbestos cement).

Step f - Identify the material or interfaces in the composite which are likely to be most sensitive to conditioning.

The epoxy coating is sensitive to temperature, within the range of -46 to 49°C, in that at temperatures below -10°C, it tends to increase in brittleness. The coating is not sensitive to moisture.

The tensile strength of asbestos cement board is not temperature sensitive within the range of -46° to 49°C. High moisture content, however, reduces its strength.

The polyurethane core tensile and shear properties are not temperature sensitive within the range of -46° to 49°C. However, the cells of the core can trap water and water vapor. If the vapor condenses and is then vaporized by increasing the temperature, the core cells can rupture and the core expands considerably. Also, the bond between the urethane and the asbestos cement board and the plywood may be degraded by high moisture exposure.

The tensile strength of plywood is not temperature sensitive but the moisture content of the wood is important and must be controlled. Comparison of results for other wood products would be difficult if a r.h. very different from the standard for wood products were used.

Temperature does not appear to be a major factor at this point in the analysis except for the problems of differential expansion between these materials. Hence, temperature uniformity is important. Relative humidity, however, is important and is probably most important for the plywood because the wood is used such that it is exposed directly to humidity in the air. Relative humidity is also very important for the core but the core is protected somewhat from direct moisture exposure by the design of the panel.

Step g - Identify desirable conditions based on the information obtained in Steps a through f.

The temperature range to which the panel might be exposed in service was estimated to be between -46° and 49°C. It was assumed for illustration, that the racking strength is not temperature sensitive within this range if the r.h. is less than 85% and that the epoxy coating increases in brittleness below -10°C. An acceptable temperature range for conditioning, based on the information considered thus far, would be -10° to 49°C.

The r.h. was found to be most critical for the plywood. However, it must remain below 85% because it is assumed that panel strength decreases rapidly with r.h. for r.h. greater than 85% and with temperatures greater than 49°C. It has been established by consensus that an r.h. of about 65% is the r.h. of choice for wood products, cellulosics, and textiles [7]. Thus, based on the most sensitive material, an r.h. of 65% would be optimal.

But, the adverse effects of a 65% r.h. on the core and the core bond to the skins must be considered. In the absence of actual experimental data, it is judged that an r.h. of 50% or less would prevent weakening of the bonding and would minimize vapor absorption in the core cells. A compromise of 55 to 60% r.h. would appear to be reasonable.

Step h - Identify the effects of temperature and moisture on the chemical and physical properites of the test specimens.

The discussion in Step f pointed out that the epoxy is sensitive to temperatures below -10°C but that other materials in the sandwich panel are not significantly temperature sensitive within the range considered. Temperatures from -10°C to 49°C would also not be expected to cause incompatibility problems (e.g. differential thermal expansion) between the materials in the panel.

The discussion in Step f also mentioned some of the critical factors with regard to moisture; namely, that 1) the properties of the plywood are very r.h. sensitive, 2) the r.h. should not be so high as to cause extensive penetration and accumulation of moisture in the core cells, 3) the r.h. should not be high enough to reduce the asbestos cement board strength, and 4) the r.h. should not be high enough to reduce the bonding of the core to the skins.

The integrity of the bond between the core and the skins is particularly critical because stresses must be transferred through the bonding interface in service. An evaluation of the panel would certainly involve extensive consideration of the bonds. Therefore, it is very important that the conditioning not alter the core-skin bonds.

The bond between the epoxy coating and the asbestos cement is also important. The coating forms a moisture barrier to protect the skins and core from excessive exterior moisture exposure. Failure of the coating bond could lead to complete delamination of the coating and subsequent exposure of the asbestos cement board and core to exterior moisture. One way this bond could be deteriorated would be through asbestos cement board deterioration by water vapor absorption from the interior side of the panel. Thus, the r.h. of the conditioning must be such that coating debonding is not promoted.

Step i - Identify desirable conditions to optimize the desired changes in chemical and physical properties that were identified in Step h.

Since the materials in the panel are not temperature sensitive between -10°C and 49°C and since this temperature range is not expected to produce physical or chemical incompatibility between adjoining materials, a temperature range of -10° to 49°C would appear to be acceptable.

Although an r.h. of 65% is the standard for conditioning wood products, this r.h. may cause problems with the structural bonds or with vapor being absorbed by the core cells. Based on the discussion in Step h, an r.h. of 55 to 60% would appear to be acceptable.

Step j - Identify the effect of other factors including size, weight, conformation and exposure history of test specimens on conditioning requirements.

The size of the panel to be evaluated is 1.22 x 2.44 m (4 x 8 ft). Thus, a relatively large conditioning chamber may be required. The size, however, has no major effect on the selection of conditioning requirements.

The weight of the panel is such that it can be handled easily by two men. This also does not have a major effect on the selection of conditioning requirements.

The specimen design or (conformation), as illustrated in figure 4, is complex in that a number of distinct materials are used. To bring each material to equilibrium may require a substantial time period. An elevated conditioning temperature, for example, may help in promoting drying provided a temperature differential between the core and walls does not become high enough to lead to warping or damage due to differential expansion.

The specimen's exposure history may have a significant effect on the conditions selected. For example, it would be reasonable to assume that in some cases, a specimen will be tested after exposure to extreme temperature or high r.h. Thus, the conditions must be such that equilibration of the specimen exposed to these conditions can be brought about in a reasonable time period so that the evaluative procedure results can be compared to those for a specimen exposed under controlled laboratory conditions. Also, it is reasonable to assume that a specimen may be evaluated after exposure that results in significant degradation. The conditioning must be such that the degradation is not knowingly increased during conditioning.

Step k - Identify desirable conditions based on the information obtained in Step j.

It is reasonable to assume that, to promote drying of the specimen, a temperature of 35°C or higher might be useful. It has been determined that the materials comprising the panel are not temperature sensitive up to 49°C. Thus, a reasonable temperature range would be 35° to 49°C.

An r.h. of 55 to 60% is reasonable based on the discussion in Step j and the information from previous discussions.

4.2.2 Part 2 - Establish a Suitable Temperature Range Based on the Characterization of the Material or Composite

In Steps g and i, a temperature range of -10° to 49°C was estimated to be acceptable. However, in Step k, a range of 35° to 49°C was selected to allow for drying of the specimen. It is not expected that temperatures of -10° to 35°C would dry the specimen at an appreciable rate unless an extremely low r.h. is used. A low r.h. should not be used for the reasons previously mentioned in Step g. Thus, a conditioning temperature range of 35° to 49°C would be acceptable based on the complete analysis in Part 1.

4.2.3 Part 3 - Establish a Suitable Relative Humidity Range Based on the Characterization of the Material or Composite

In Steps g, i and k, an r.h. of 55-60% was judged to be reasonable. An r.h. range of 55-60% should be an acceptable compromise between the accepted standard for wood products and the selection of an r.h. low enough to prevent core-skin bond degradation, coating to skin and degradation and vapor absorption in core lattices.

4.2.4 Part 4 - Establish Suitable Temperatue and Relative Humidity Ranges Based on the Available Facilities in the Testing Laboratory and on the Results of Parts 2 and 3

In view of the specimen size and weight, a relatively large chamber may be needed to perform the conditioning. Let us assume the testing laboratory has no large chamber for conditioning but that rooms at 23°C and 50% r.h. are available. As was pointed out, the specific temperature in the range that has been discussed is not critical to conditioning. Thus, conditioning at 23°C (ambient lab conditions) would be acceptable except that a longer time for drying of the specimen may be needed. The r.h. range of 55-60% is important, however, for the reasons discussed in Step g. Thus, it may be advantageous to construct a temporary "tent-type" chamber in which a humidifier could be placed to maintain the desired r.h. if no special chamber was available.

4.2.5 Part 5 - Establish the Equilibration Requirements

This part of the methodology requires experimentation to determine the time to establish temperature and r.h. equilibrium. The temperature and r.h. ranges used in the experiments will be those established in Part 4 of the methodology; namely, 23°C and 55-60%.

To simulate the established ranges at which test specimens would be received for test, the initial temperature and r.h. of the test specimens, prior to conditioning, may range from -10° to 49°C and 10 to 85%.

Let us assume the experiments show that conditioning temperatures of 35° to 49°C and r.h. values of 55 to 60% result in constant weight being reached in an acceptable period of time.

4.2.6 Part 6 - Select a Specific Temperature Range, Relative Humidity Range and Equilibration Time

Based on the "experimental findings" in Part 5 and the acceptable ranges established in Part 4, the temperature of the conditioning should be 35° to 49°C and the r.h. of the conditioning should be 55 to 60%. The test specimen should be conditioned to constant weight.

It was previously suggested that, in the absence of a special conditioning chamber, a temporary chamber be constructed to maintain the desired r.h. Since the temperature must also be greater than 23°C to permit equilibration in an acceptable time, the chamber must also be heated slightly with thermostatically controlled portable heaters.

5. CONCLUSIONS

Based on an analysis of the effects of temperature and moisture on the chemical and physical properties of two building composites, as well as other factors outlined in the methodology for establishing conditioning requirements, it has been shown how a range of acceptable temperatures and r.h. values for conditioning can be established for conditioning the composites prior to conducting the evaluative procedure. Values for gypsum wallboard, obtained on the basis of the analysis, include a conditioning temperature range of 30° to 49°C and a conditioning relative humidity range of 48 to 55%. The values for the structural sandwich wall panel include a conditioning temperature range of 35° to 49°C and a conditioning r.h. range of 55 to 60%. These examples are not intended to be recommendations for actual practice but serve merely as illustrations of the methodology.

ASTM C473-70 [4], Standard Methods for Physical Testing of Gypsum Board Products and Gypsum Partition Tile or Block, specifies conditioning requirements of 21-38°C and 25-50% r.h. That the acceptable temperature and r.h. values suggested by the use of the methodology are somewhat higher than those in existing standard test for gypsum wallboard is not significant since they are only intended as an illustration of the methodology. In any case, they do overlap the range given in the standards. In demonstrating the methodology in this report, experiments were not actually performed to determine the time to equilibrium. Thus, the conditioning requirements established by the methodology in this report are estimates, based on assumptions of experimental results. The higher temperature for conditioning gypsum wallboard was selected, in this analysis, to permit more rapid drying of wet specimens without altering the composition of the gypsum core.

The important point, however, is that by applying the methodology, outlined in Section 3, a consistent approach to the selection of conditioning requirements <u>can</u> be established.

6. BIBLIOGRAPHY

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TABLE 1. Summary of Conditioning Requirements in Tests for Various Building Components and Materials

MATERIAL	TEST	REFERENCE		TEMP. °C	CONDITIONING R.H., %	TIME
Plastics	Impact Resistance	ASTM(1)	D256-72a	23±2	50±5	40 hr.
	Tensile	ASTM	D638-71a	23±2	50±5	40 hr.
	Def. under Load	ASTM	D621-64A	23±2	50±5	40 hr.
			B	--	desiccator	24 hr.
	Resist. to Chemicals	ASTM	D543-67	23±2	50±5	40 hr.
	Elect. Prop.	ASTM	D618-61	23±2	50±5	40 hr.
Transparent Plastic	Refractive Index	ASTM	D542-50	23±2	50±5	40 hr.
Non-Metallics	Specular Gloss	ASTM	D523-67	--	—	—
Plastic Pipe	All Tests	VPS(2)	18-69	23±2	50±5	40 hr.
			19-69	23±2	50±5	40 hr.
			21-70	23±2	50±5	40 hr.
			22-70	23±2	50±5	40 hr.
PVC-Siding, Rigid	All Tests/VPS-P555-72	ASTM	D618-61	23±2	50±5	40 hr.
Vinyl-Metal Laminates	All Tests/CS(3) 245-62	ASTM	D618-61	23±2	50±5	40 hr.
Plywood	Dimensions	VPS-PS		--	—	—
	Shear	VPS-PS		--	—	—
	Heat-Durability	VPS-PS		--	—	—
	Joint Strength	VPS-PS		--	—	—
	Joint Durability	VPS-PS		--	—	—
Hardwood Plywood	All Tests.	ASTM	D906-64	23±2	50±5	7 d.
Mosaic-Parquet Flooring	All Specs.	VPS-PS		—	—	—
Interior Wood Doors	All Specs.	VPS-PS		--	—	—

(1) Numbers in parenthesis refer to Standards Setting Agencies listed at the end of this table.

TABLE 1. Summary of Conditioning Requirements in Tests for Various Building Components and Materials - continued

MATERIAL	TEST	REFERENCE		TEMP. °C	CONDITIONING R.H., %	TIME
Pine Doors	All Specs.	CS [3]		—	—	—
Wood Shingles	All Specs.	CS		—	—	—
Wood for Structural Laminated-Wood Products	Shear Strength	ASTM	D2559-72	23±2	50-70 [5]	to 8-14% [6] moisture content
	Creep Under Static Load	ASTM	D2559-72	23±2	50-70	
Plywood	Shear Modulus	ASTM	D3044-73	20±3	65±1	to constant mass
Veneer, Plywood, and other Glued Veneer Construction	Compression	ASTM	D805-72	20±3	65±1	to constant mass
	Tension	ASTM	D805-72	20±3	65±1	to constant mass
	Toughness	ASTM	D805-72	20±3	65±1	to constant mass
Wood-Base Fiber and Particle Panel Matls.	Strength Props. Dry	ASTM	D1037-72a	20±3	65±1	to constant mass
	Soaked	ASTM	D1037-72a	20±3	100% submerged in water	24 hr.
Hardboard	Modulus of Rupture	ASTM	D1037-72a	22±1	50±2	to constant wt.
	Tensile Strength	ASTM	D1037-72a	22±1	50±2	to constant wt.
	Water Absorption	ASTM	D1037-72a	22±1	50±2	to constant wt.
	Thickness	ASTM	D1037-72a	22±1	50±2	to constant wt.
Hardboard Siding	All Specs.	VPS-PS		—	—	—
Glass Fiber Reinforced Polyester Panel	All Specs/VPS-P553-72	ASTM	D618-61	23±2	50±5	40 hr.
Paper, Paper Products (Paperboard, Fiberboard)	All Tests	TAPPI [4]		Precond. 22-40	10-35	24 hr.
				23±1	50±2	4-8 hr.

TABLE 1. Summary of Conditioning Requirements in Tests for Various Building Components and Materials - continued

MATERIALS	TEST	REFERENCE		TEMP. °C	CONDITIONING R.H., %	TIME
Concrete	Flex. Strength	ASTM	C78-64	—	—	—
	Compressive Strength	ASTM	C39-66	—	keep moist	0 hr.
	Length Change	ASTM	C157-69T air	23.0±1.1	50±4	min. 4 d.
			water	23.0±1.7	(100)	min. 6.3 wks.
	Young's Modulus	ASTM	C469-65	—	(100)	within 1 hr.
	Freeze Thaw	ASTM	C290-67	—	wet (100)	—
	Fund. Frequencies	ASTM	C215-60	—	—	—
	Creep	ASTM	C512-69	23.0±1.1	50±4	21 d.
Concrete Block	Compression	ASTM	C140-70	"Normal"	room air	72 hr.
Masonry Cement Mortar	Compression	ASTM	C91-71	23±1.7	wet (100)	28 d.
Masonry Mortar	Compression	ASTM	C270-73	23±1.7	90+	28 d.
				21±2.8	lab air	28 d.
Cement Mortar	Compression	ASTM	C109-73	23±1.7	wet (100)	28 d.
Lime Mortar	Compression	ASTM	C141-67	23±1.7	wet	21 d.
Masonry Assemblages	Compression	ASTM	E447-72	24±8	30-70	28 d.
Concrete Block Couplets	Bond	ASTM	E149-66	—	50	28 d.
Brick Couplets	Bond	ASTM	E149-66	—	≥50	28 d.
Brick	Flexure	ASTM	C67-73	100-115	oven dry	≥24 hr.
	Compression	ASTM	C67-73	100-115	oven dry	≥24 hr.
Structural Clay Tile	Compression	ASTM	C112-60	—	oven dry	—

TABLE 1. Summary of Conditioning Requirements in Tests for Various Building Components and Materials - continued

MATERIALS	TEST		REFERENCE		TEMP. °C	CONTITIONING R.H., %	TIME
Building Stone	Flexure	dry	ASTM	C99-52	105±2	oven dry	24 hr.
		wet			25±2	wet	48 hr.
	Compression	dry	ASTM	C170-50	105±2	oven dry	24 hr.
		wet			25±2	wet	48 hr.
Asbestos-Cement Sheets	Flex. Strength		ASTM	C459-63	100-104.4 room temp.	oven dry desiccator	to constant weight
Sandwich Panel of Asbestos-Cement Facing with Fiberboard Core	Flex. Strength		ASTM	C551-67	71.1±2.8 room temp.	oven desiccator	-- --
Steel	Tension		ASTM	A370-68	room temp.	--	24-48 hr.
	Bend Test		ASTM	A370-68	room temp.	--	24-48 hr.
	Hardness		ASTM	A370-68	room temp.	--	24-48 hr.
Steel Bi-Fold Door Units	All Specs.				--	--	--
Porcelain-Enamel Steel Plumbing Fixtures	Acid Resistance/ VPS-PS 5-66		ASTM	C282-67	26±1	--	--
Vitreous China Plumbing Fixtures	All Specs.		CS		--	--	--
Metal Fasteners, Wood	Nail or Screw Withdrawal		ASTM	D1761-68	20±3	65±3	until equilibrium
	Lateral Nail or Screw Resis.		ASTM	D1761-68	20±3	65±3	until equilibrium
	Bolted & Timber Connections		ASTM	D1761-68	20±3	65±3	until equilibrium
	Tension Tests of Plate-Type		ASTM	D1761-68	20±3	65±3	until equilibrium
	Connector Joints		ASTM	D1761-68	20±3	65±3	until equilibrium

TABLE 1. Summary of Conditioning Requirements in Tests for Various Building Components and Materials - continued

MATERIALS	TEST	REFERENCE		TEMP. °C	CONDITIONING R.H., %	TIME
Metallic and Non-Metallic Adherends	Atmospheric Exposure	ASTM	D1828-70	23±1	50±2	40 hr.
Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet Use) Exposure Conditions	Shear Strength Creep Under Static Load	ASTM ASTM	D2559-72 D2559-72	23±2	50-70 (5)	min time recommended by manu-facturer
Gypsum and Gypsum Products		SEE TABLE 2				

(1) American Society for Testing and Materials.
(2) Voluntary Product Standard.
(3) Commercial Standard.
(4) Technical Association of the Pulp and Paper Industry.
(5) Preferably 65%.
(6) Preferably 9-12%.

TABLE 2. ASTM Tests for Gypsum

Test	Reference	Conditioning Temperature (°F)	Conditioning Time	RH (%)
free water	C472-73 Std. Methods for Physical Testing of Gypsum Plasters and Gypsum Concrete	--	--	--
		113	2 hrs. then cool in moisture-free atmosphere	dry atmosphere
normal consistency of gypsum plaster		--	--	--
normal consistency of gypsum concrete		--	--	--
time of setting		113	2 hrs. then cool in moisture-free atmosphere	--
compressive strength		90-110	<7 days to const. weight	<50%
		then store in desiccator over magnesium perchlorate for 24 hrs.		
density		same as for compressive strength		

TABLE 2. ASTM Tests for Gypsum - continued

Test	Reference	Temperature (°F)	Conditioning Time	RH (%)
compressive strength of gypsum partition	C473-70 Std. Methods for Physical Testing of Gypsum Board Products & Gypsum Partition Tile or Block	70-100	to constant wt.	<50%
flexural strength of gypsum boards		70-100	to constant wt. within 0.1%	25-50%
weight and thickness of paper surfacing		60-85	overnight	25-60%
flexural strength of precast reinforced gypsum slabs		70-100	to constant wt.	<50%
nail retention of precast reinforced gypsum slabs		70-100	to constant wt.	<50%
thickness of edge of recessed or tapered - edge gypsum wallboard		--	--	--
water resistance of core-treated water repellent gypsum sheathing		60-85	to constant wt. within 0.1%	25-60%
type X lath and wallboard		--	--	--

TABLE 2. ASTM Tests for Gypsum - continued

Test	Reference	Conditioning Temperature (°F)	Time	RH (%)
chemical analysis	C22-50 (1974) Std. Spec. for Gypsum	refers to C471		
physical properties		refers to C472		
chemical anslysis	C28-68 (1973) Std. Spec. for Gypsum Plasters	refers to C471		
physical properties		refers to C472		
type X	C36-73 Std. Spec. for Gypsum Wallboard	refers to C473		
flexural strength		refers to C473		
thickness		refers to C473		
width, length, weight		--	--	--
flexural strength	C37-69 Std. Spec. for Gypsum Lath	refers to C473		
type X		refers to C473		
thickness, width, length, weight		--	--	--
physical properties	C317-64 (1970) Std. Spec. for Gypsum Concrete	refers to C472		

TABLE 3. Definitions of Terms Relating to Conditioning

(Reference: ASTM E41-63(71), "Standard Definitions of Terms Relating to Conditioning").

1. air, dry -- air containing no water vapor.

2. air, saturated -- a mixture of dry air and water.

3. atmospheric pressure -- the pressure due to the weight of the atmosphere. It is the pressure indicated by a barometer. Standard atmospheric pressure is a pressure of 76 cm Hg having a density of 13.5951 g/cm^3, under standard gravity of 980.665 cm/s^2.

4. atmosphere, standard -- air maintained at a specified temperature, relative humidity, and standard atmospheric pressure. (See Specification E171).

5. conditioning -- the exposure of a material to the influence of a prescribed atmosphere for a stipulated period of time or until a stipulated relation is reached between material and atmosphere.

6. dew point[a] -- the temperature to which water vapor must be reduced to obtain saturation vapor pressure, that is, 100 percent relative humidity.

7. humidity -- the condition of the atmosphere in respect to water vapor. (See also humidity, absolute; humidity, relative.)

8. humidity, absolute -- the weight of water vapor present in a unit volume of air, for example, grains per cubic foot, or grams per cubic meter.

9. humidity, relative -- the ratio of the actual pressure of existing water vapor to the maximum possible (saturation) pressure of water vapor in the atmosphere at the same temperature, expressed as a percentage.

10. moisture equilibrium -- the condition reached by a sample when the net difference between the amount of moisture absorbed and the amount desorbed, as shown by a change in weight, shows no trend and becomes insignificant.

11. preconditioning -- any preliminary exposure of a material to the influence of specified atmospheric conditions for the purpose of favorably approaching equilibrium with a prescribed atmosphere.

12. pressure, saturation -- the pressure, for a pure substance at any given temperature, at which vapor and liquid, or vapor and solid, coexist in stable equilibrium.

13. pressure, vapor[b] -- the pressure exerted by a vapor.

14. pressure, water vapor -- the component of atmospheric pressure caused by the presence of water vapor, usually expressed in millimeters or inches of mercury.

15. room temperature[c] -- a temperature in the range to 20° to 30°C (68° to 85°F).

16. saturation -- the condition of coexistence in stable equilibrium of a vapor and a liquid or a vapor and solid phase of the same substance at the same temperature.

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[a]As air is cooled, the amount of water vapor that it can hold decreases. If air is cooled sufficiently, the actual water vapor pressure becomes equal to the saturation water-vapor pressure and any further cooling beyond this point will normally result in the condensation of moisture.

[b]If a vapor is kept in confinement over its source so that the vapor can accumulate, the temperature being held constant as the vapor pressure approaches a fixed limit is called the maximum, or saturated, vapor pressure, dependent only on the temperature and the liquid.

[c]The term "room temperature" is usually applied to an atmosphere of unspecified relative humidity.

17. saturation, degree of -- the ratio of the weight of water vapor associated with a pound of dry air to the weight of water vapor associated with a pound of dry air saturated at the same temperature.

18. standard laboratory atmosphere -- an atmosphere, the temperature and relative humidity of which is specified, with tolerances on each. (See Specification E171.)[d]

19. temperature -- the thermal state of matter as measured on a definite scale.

20. temperature, dew point -- see dew point.

21. temperature, dry-bulb -- the temperature of the air as indicated by an accurate thermometer, corrected for radiation if significant.

22. temperature, wet-bulb -- wet-bulb temperature (without qualification) is the temperature indicated by a wet-bulb psychrometer constructed and used according to specifications. (see Method E337.)[e]

23. vapor -- the gaseous form of substances that are normally in the solid or liquid state, and that can be changed to these states either by increasing the pressure or decreasing the temperature.

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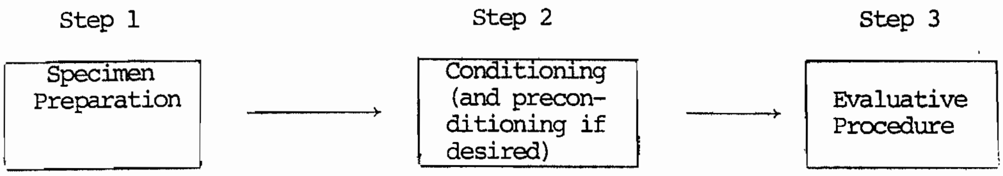
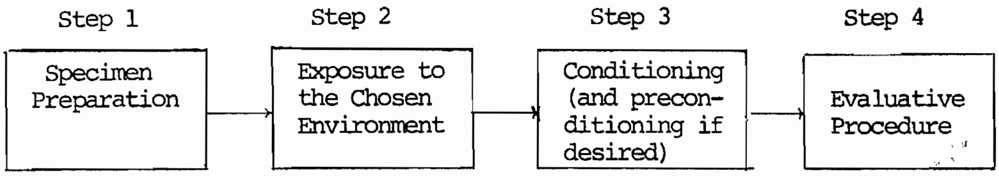
[d]ASTM Specification E171-63 L972), for Standard Atmospheres for Conditioning and Testing Materials which appears in the Annual Book of ASTM Standards, Parts 35 and 41 (1974).

[e]ASTM Method E337-62 (1972), Determining Relative Humidity by Wet- and Dry-Bulb psychrometer, which appears in the Annual Book of ASTM Standards, Parts 20, 32, and 41 (1974).

*Type 1 - Test used to determine the short-term or initial properties of a specimen



*Type 2 - Test used to determine the long-term properties of a specimen following exposure to induce degradation



*The results of the evaluative procedure in the type 2 test must be compared with the results of the same evaluative procedure using the type 1 test to determine the effect of the simulated or natural aging.

FIGURE 1. Outline of the Steps in Tests in which Conditioning is Used

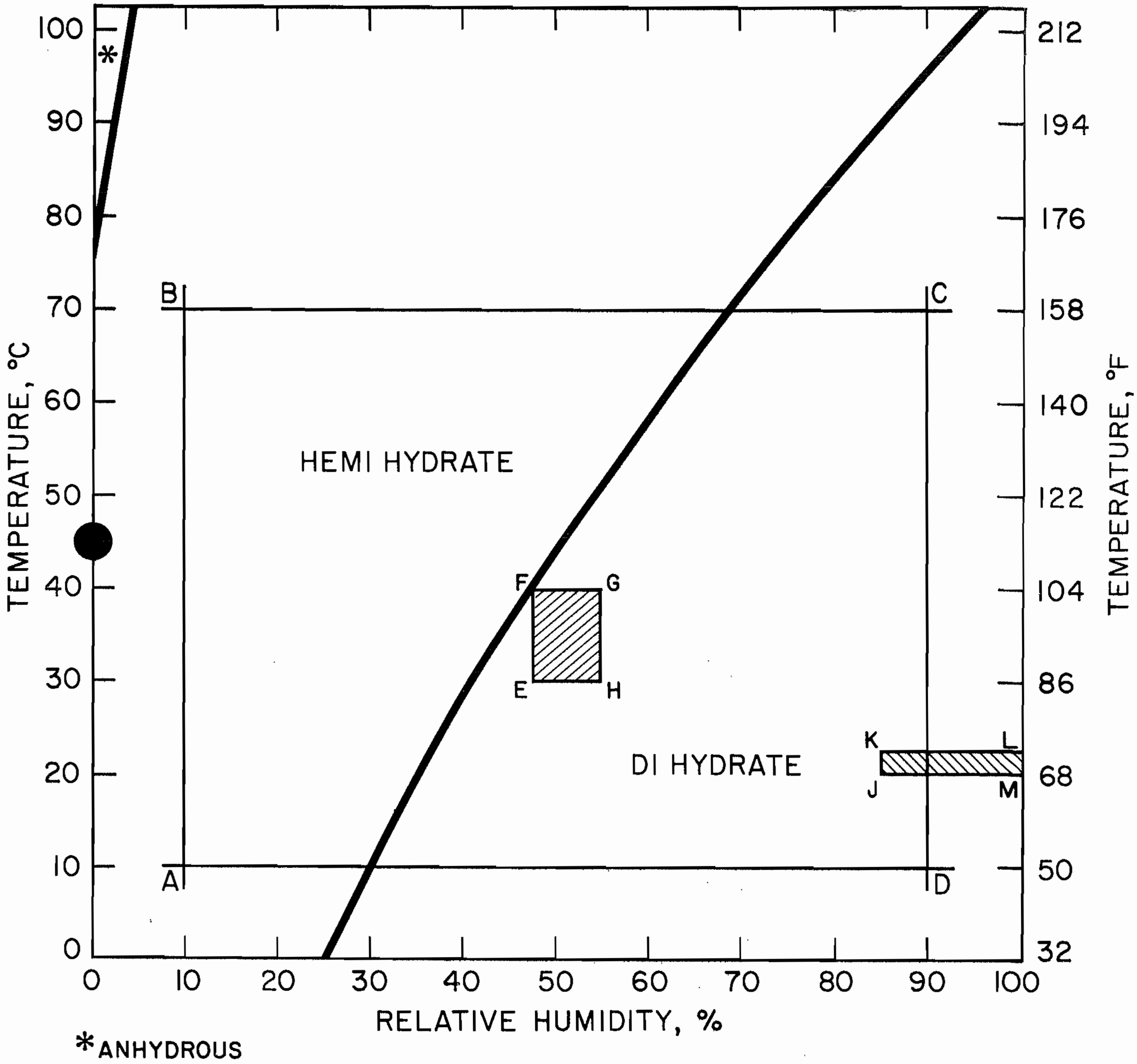


FIGURE 2. Phase Diagram for Calcium Sulfate in the Anhydrous, Hemi-Hydrate and Di-Hydrate Forms. (Date extracted from references 6 and 8.)

*Refer to legend explaining this figure.

Legend for Figure 2
Partial Phase Diagram for Calcium Sulfate-Water

1. The curve from 25% to 97.5% r.h. represents the relative humidity-temperature relationship describing the equilibrium between calcium sulfate dihydrate and calcium sulfate hemihydrate.

$$CaSO_4 \cdot 2H_2O \longleftrightarrow CaSO_4 \cdot 1/2\ H_2O + 1\ 1/2\ H_2O$$

2. The curve from 0% to 3.5% r.h. represents the relative humidity-temperature relationship describing the equilibrium between calcium sulfate hemihydrate and anhydrous calcium sulfate.

$$CaSO_4 \cdot 1/2\ H_2O \longleftrightarrow CaSO_4 + 1/2\ H_2O$$

3. The region bounded by the retangle ABCD represents the estimated possible temperature-humidity conditions in which a gypsum wallboard test specimen may be found.

4. The temperature and humidity represented by the solid circle are the conditions given in ASTM C472 for preparing gypsum plaster for the time of setting measurement. Under these conditions, the major form is the hemihydrate form.

5. The rectangle bounded by JKLM represents the temperature-humidity region specified for curing gypsum in ASTM C472. Under the conditions, the major form is the dihydrate.

6. The region bounded by the rectangle EFGH represents the temperature and r.h. range decided upon in the methodology illustration using gypsum wallboard (Section 4.1).

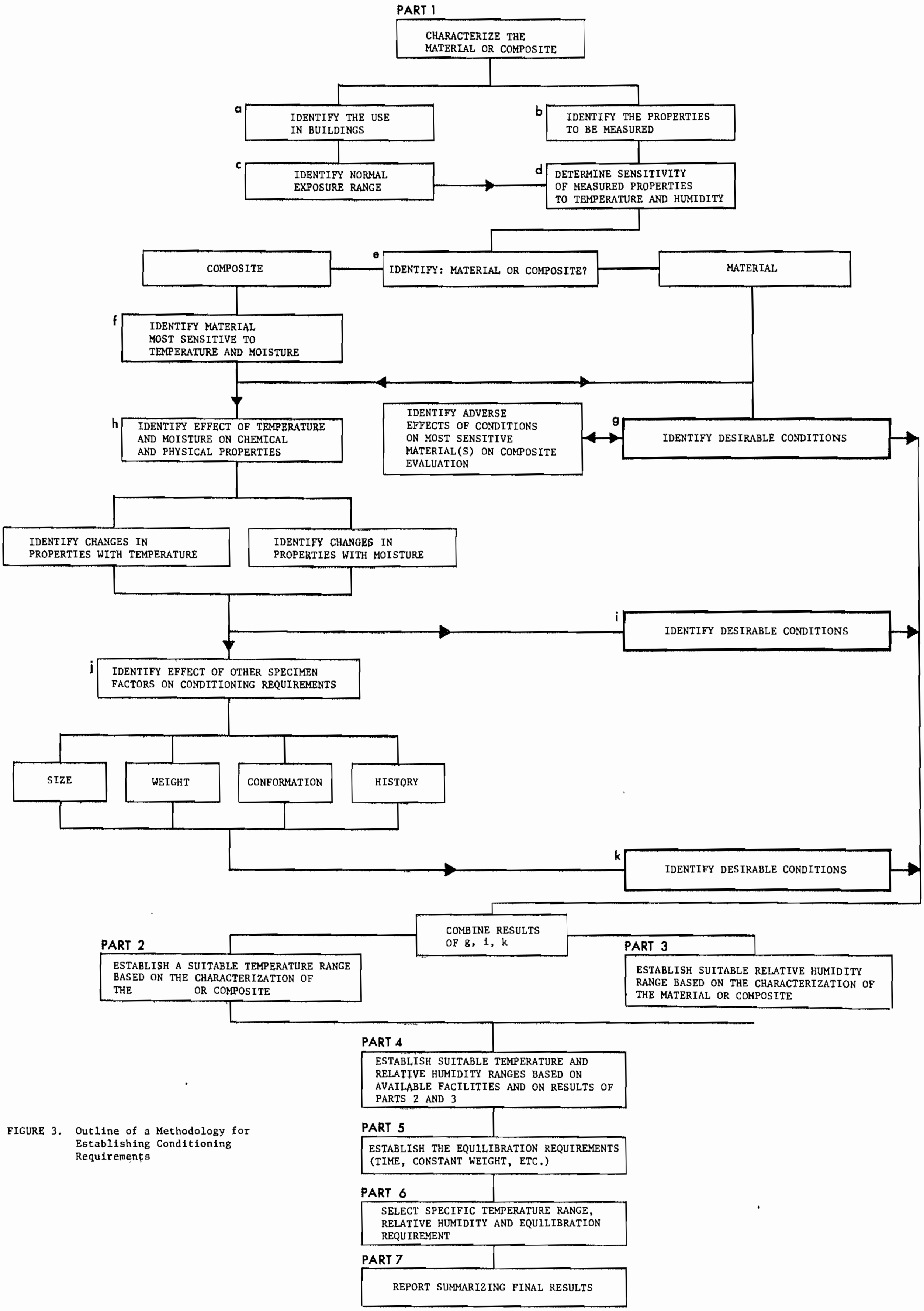


FIGURE 3. Outline of a Methodology for Establishing Conditioning Requirements

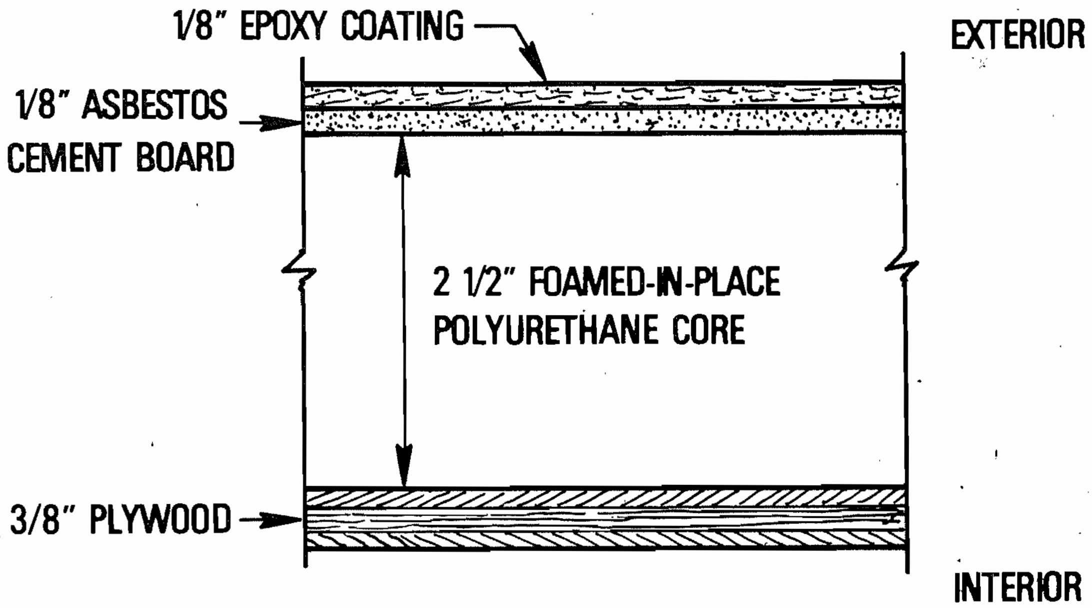


FIGURE 4. Cross-Section of the Structural Sandwich Panel to which the Conditioning Methodology is Applied

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The measured properties of building materials and their composites sometimes reflect the conditions to which they have been exposed while being prepared for test. Conditioning these materials to some standard reference state is stometimes used to minimize this effect.

A methodology for establishing conditioning requirements for building composites and materials is presented and its use illustrated by applying it to two building composites.

The composites to which the methodology is applied are: 1) gypsum wallboard and 2) a structural sandwich wall panel.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Building composite; building material; conditioning; equilibration; gypsum wallboard; methodology; relative humidity; structural sandwich panel; temperature; testing.

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