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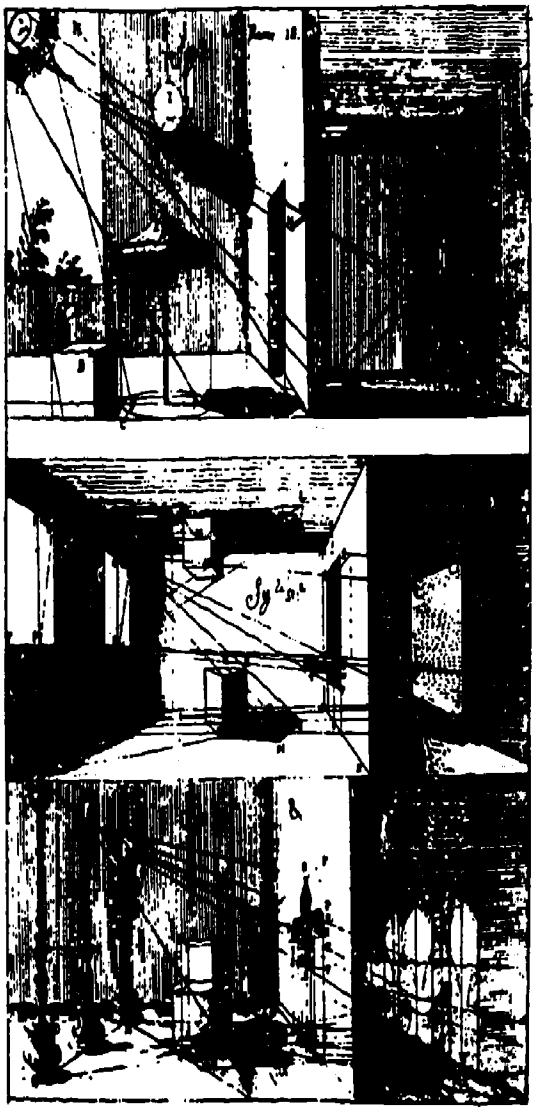
ABSTRACT

This report is one product of the 'Buildings in Use' study. The overall study examines architectural attributes of existing buildings in order to determine how they have performed technically and functionally, and the relationship between the environment of the building and the behavior of its user population. Four elementary schools in Columbus, Indiana, are examined. These schools, designed by nationally prominent architects, were completed in 1962, 1966, 1969, and 1972. The two older schools contain traditional classrooms; the two more recent utilize semi-open (1969) and open (1972) educational and design concepts. The schools are similar in size (500-600 students) and in the social characteristics of their students. Technical studies have been carried out in the following areas: exterior walls; roofs; interior walls; floors; ceilings; acoustics; lighting; and heating, ventilating, and air conditioning. This document presents nearly 100 field tests in these areas with performance objectives, test methods, and descriptions of the conditions each test measures. (Author/MLF)

# buildings in use study



## field tests manual

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# INTRODUCTION

## THE STUDY

Those responsible for building design rarely examine, in a formal and comprehensive manner, the environment they have helped create. We believe that such examination is, however, the primary method through which better buildings can be created. Thus, what we learn from this study can be used--by clients and architects--in the design of future buildings.

This report is one product of the "Buildings in Use" study. The overall study examines architectural characteristics of existing buildings in order to determine how they have performed technically and functionally and the relationship between the environment of the building and the behavior of its user population. This working document specifically addresses the technical aspect of the study. Later reports will include the other aspects.

## TESTING AND MEASURING IN THE FIELD

Technical studies of buildings in use have been rare. Little information exists in this field and therefore, this manual should be of real use. It is truly meant to be a "working" document and suggested modifications will be welcomed - we are already making changes for the next 'edition'.

Although many laboratory tests exist for specific materials, there is a lack of field equivalents of laboratory tests which measure specific performance attributes of assembled components. Our field tests, derived primarily from existing A.S.T.M. and N.B.S. laboratory procedures, attempt to fill this need.

Laboratory procedures provide extreme accuracy by controlling test conditions through the use of apparatus which simulate real usage and actual building conditions. For instance, a standard abrading machine provides a simulation of the abrasion caused by the actions of shoes on a floor surface and the wear on this surface can be measured after a certain exposure to such a machine. Our tests, however, provide no such control and accuracy. For instance, in our field tests, the abrasion of floor surfaces has been provided by non-standard children wearing non-standard shoes carrying all sorts of grit, plus teaching and custodial staffs, over periods of time varying from two to twelve years, and the results must be reported in that context. What we lose in control of the agents of wear, we make up for in the very real nature of our testing situations.

## EVALUATING TECHNICAL PERFORMANCE

Properly evaluating and reporting the results of many field tests is as critical as the effort involved in developing the tests.

After trying various methods, including detailed narrative, ratings, weightings, etc., we have developed a method which links the performance to the nature of the building. There are two assumptions which are the basis of this method.

> ...one generally cannot discuss an entire building, or even a subsystem, in such a technical investigation. There are too many performance characteristics in even the simplest situation. Each must be discussed separately.
>
> ...in terms of technical factors, the building must provide a satisfactory 'background' supportive of the activities in the building. A quite high performance standard for building subsystems is therefore expected so that technical factors will not at all hinder activities in the building.

The method of technical evaluation shown in the final chapter of this report presents many performance characteristics for each subsystem. Each characteristic is evaluated in the following way:

95% Performance Level: very satisfactory performance
85% Performance Level: minor performance problems which do not affect the activities within, or the image of, the building
75% Performance Level: major problems having some detrimental effects on the activities within, or on the iamge of, the building. These are correctable only by means of major repair or replacement procedures.

## CRITERIA FOR EVALUATING PERFORMANCE

This manual does not contain criteria for evaluating the results of the field tests. Many factors outside the realm of this manual will affect the criteria used in individual cases of technical evaluation. Building type, age and the owner's own standards can alter the criteria for each subsystem. Our own study of elementary schools does contain

criteria and an evaluation based on these tests but they are specific to our study, and some criteria even vary between the various school buildings.

## USING THE FIELD TEST MANUAL

The tests in this manual exclude factors concerned with structure, fire safety and certain mechanical subsystems such as plumbing, electricity, etc. These were excluded because the standards in these areas are either so well defined in design, code, manufacture and installation and/or the measurement of these characteristics is beyond the scope of this study.

Interviews and discussions with maintenance personnel are invaluable in determining past performance and critical areas of performance for all subsystems. A careful examination of the working drawings and specifications can help determine areas of the building to be studied in detail and to clarify the reasons for the actual performance characteristics of certain subystems.

This manual should be used as a guide to testing. Good judgement should be used in modifying the tests to conform to the specific conditions encountered in different buildings. Although the manual is written generically, it certainly does not apply to many of the myriad of products and techniques available in construction.

Follow-up procedures for many of the tests can be very useful. The 'USE' part of each test has been performed, as mentioned earlier, by the actual users in uncontrolled circumstances. Because of this anonymous test, it is useful to use follow-up procedures in cases where findings indicate problems. The results of the follow-up tests should reveal a more exact level at which specific characteristics have failed.

The cause of problems revealed in the course of technical testing is also not a part of this manual because of the numerous circumstances which can affect performance. The technical evaluation aspect of our study will deal specifically with causal factors.

## PREVIOUS STUDIES

Though a 'Field Test Manual', per se, was not found in our literature search, some significant examples of technical factors' evaluations were found.

A Study of the Performance of Buildings, K.W. Jaeggin and A.E. Brass, National Research Council of Canada 9352, May 1967.
An excellent outline for technical evaluation, very impressive and useful.

The studies of the Pilkington Research Unit of the Department of Building Science, University of Liverpool, on school, office buildings and factories. Significant research though criteria used are below U.S. levels.

Building Performance, Building Performance Research Unit, Applied Science Publishers, London, England 1972.

In addition:

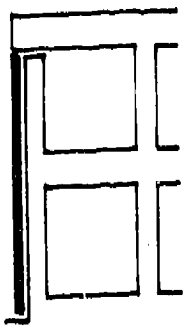
ASTM Standards in Building Codes 9th Edition, 1971.
American Society of Testing and Materials, Phila., Pa..
Contains a large number of laboratory test methods.

"Methodology for Development of Requirements for the Physical Elements of a Dwelling", H. Berger, National Bureau of Standards Report 10575. April, 1971.
Contains comprehensive lists of tests which are applicable to various activities.

Other documents which are specifically related to each subsystem are mentioned at the end of each chapter.

# EXTERIOR WALLS

SUMMARY



The primary objective of the exterior wall is to keep out the weather - heat, cold, rain, snow and wind. In the process of achieving this goal, the wall is exposed to the brunt of these elements. The field tests in this area emphasize these primary objectives and are directed at conditions which impair this performance.

Undue movements of the exterior wall often create openings which will either now or in the future, cause problems. Ascribing the cause of these openings (cracks) is difficult and while they are categorized below in terms of the most likely cause, other factors can generate the same condition.

PERFORMANCE OBJECTIVE: PREVENT ELEMENTS FROM ENTERING BUILDING

TEST # 1: Control Undue Movement of Exterior Walls

Test Method: Determine past performance, if possible. Test by visually examining the complete exterior wall (outside and inside) from a distance of five feet with occasional examination from one foot in critical areas such as parapets, intersections and points of juncture with other subsystems. A vernier calipers, spark plug gapper or ruler calibrated to 1/32 inch should be used to measure separations. Depth of openings can be measured by a Depth Gauge employing a rod for probing (1/16 inch diameter and calibrated to 1/64 inch).

Oftentimes, problems not apparent on the exterior surface will be quite obvious inside because of the monolithic nature of interior materials, and their more uniform texture and color which should result in 'telltale' cracking.

A long level (at least 4 feet) and a simple venier inclinometer (Empire Corporation, Milwaukee, Wis.) reading to 1° is used to determine horizontal and vertical displacement. Data on the location and size of openings is recorded and photographs taken of these conditions.

Measures:

a. Due to thermal expansion and contraction of wall
- Cracking at intersection of walls
- Step cracking and buckling at parapets, especially corners
- Cracks in center of wall
- Cracking at intersection of low and high exterior wall
- Horizontal crack between foundation and exterior wall

b. Due to thermal expansion and contraction of structure
- Vertical or step cracks under points of structural support
- Horizontal crack at wall mid-section; lack of plumbness
- Horizontal crack or lack of plumbness where parapet meets roofline due to expansion of roofdeck
- Vertical cracks at parapet or exterior wall between column lines
- Vertical cracks at wall intersections (due to creep)

c. Due to structural loads
- Vertical crack over mid-section of lintel or step crack at upper ends of lintel
- Vertical cracks at column

d. Due to settlement
- Horizontal crack between wall and foundation
- Random vertical cracks in wall
- Step cracks at lower part of openings

TEST # 2: Resist Heat and Moisture Penetration At Openings

Test Method: Use test #1 with emphasis on the examination of caulking, gasketing and tolerances around all openings in wall.

Measures: Tolerance and seal of wall openings

- Missing or deteriorated caulking (caulking cracking, wrinkling, slump, adhesion, shrinkage, oil bleeding, brittleness, peeling)
- Gap between door and threshold (to 1/32 inch)
- Infiltration of air around door and windows
- Discoloration of openings around doors and windows

TEST # 3: Resistance to Moisture Penetration

Test Method: Same as test #2

Measures: Stains, discoloration due to moisture penetration

- Measure to 2 inches

TEST # 4: Control Condensation-Causing Heat Loss

Test Method: Same as test #3

Measures: Stains, discoloration

- Same as test #3

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY

TEST # 5: Resistance to Staining, Discoloration and Deterioration

Test Method: Same as test #1. Wall should be viewed from a distance of 5 feet.

Measures:

- Efflorescence from dissolved salts. Measure extent and severity to 1 inch
- Rust and dirt stains on surface. Measure to 6 inches. Spalling of surface (to 6 inches)
- Cracking, checking, blistering (to 1 inch)
- Fading, chalking
- Ink, pencil, marker paint damage

TEST # 6: Control Deterioration of Appearance

Test Method: Determine past performance if possible. Test by using routine maintenance procedures and commercially available cleaning materials to remove stains; discoloration; graffiti; etc., which is easily visible from 5 feet. The removal procedure should not exceed 15 minutes of application, scrubbing, etc.

Measures: Stain removal

- Completely removed (not visible from 2 feet)
- Trace remaining (just visible from 5 feet)
- Most removed (visible from 5 feet)
- Partially or not removed (easily visible from 5 feet)

## REFERENCES

The most significant sources for development of these field tests were:

Performance Criteria for Exterior Wall Systems, National Bureau of Standards Report 9817. 4.25.68
This includes test descriptions in some detail and their background. Very comprehensive document on performance characteristics and the results of testing some typical specimans.

The Weathering and Performance of Building Materials, J.W. Simpson and P.J. Horrobin. Wiley, 1970.
Exterior materials emphasized. Excellent background for understanding performance, required of various exterior wall materials.

The following were also helpful in test development:

The Contemporary Curtain Wall, W.H. Hunt, Jr., F.W. Dodge, N.Y., 1958

ASTM C509-66T, Cellular elastomeric, Performed Gasket and Sealing Material, Test #2,3

ASTM E283-65T & E331 Test for Air Leakage through Windows, Test for Water Resistance of Windows, Test #2,3

ASTM C67-66. Sampling and Testing Brick, Test #5

Fed. Standard #141a, method 6141. Gardner Washability Test, Test #6

SUMMARY OF EXTERIOR WALLS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PREVENT ELEMENTS FROM ENTERING BUILDING

TEST # 1: Control Undue Movement of Exterior Walls

TEST # 2: Resist Heat and Moisture Penetrations at Openings

TEST # 3: Resistance to Moisture Penetration

TEST # 4: Control Condensation-Causing Heat Loss

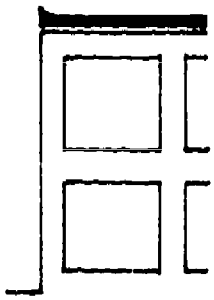
PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY

TEST # 5: Resistance to Staining, Discoloration and Deterioration

TEST # 6: Control Deterioration of Appearance

# ROOFS

SUMMARY

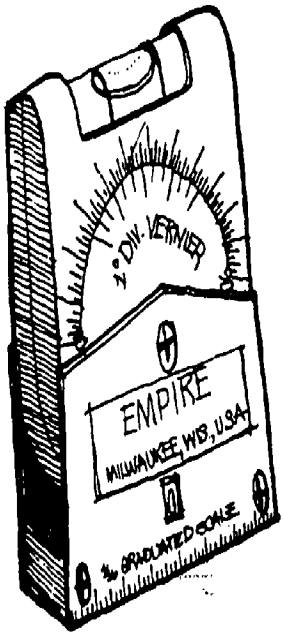


The primary objective of the roofing membrane is to absolutely keep out weather - principally moisture. In the process of achieving this goal, the roofing membrane is directly exposed to the brunt of the elements. The field tests in this area emphasize the primary objectives and are directed at conditions which impair this performance.

Small openings in the impervious roof surface cause leaks. Field tests in this area examine potential and actual openings and attempt to attribute their cause. The flat roofs are typical for the building type studied and are the only type examined by the B.I.U. Project.

PERFORMANCE OBJECTIVE: KEEP MOISTURE FROM ENTERING BUILDING

TEST # 1: Minimize Standing Water on Roof Surface




Test Method: Determine past performance, if possible. It is necessary that the field test should occur within four days of a moderate to heavy rain. Test by visually examining the entire roof to determine overall drainage patterns, standing water and obstacles to proper drainage. A long level (four feet or longer) used with a vernier inclinometer reading $1^0$ accuracy should be used to determine slopes. Approximately five measures in each direction at equal intervals should be made for every 1000 sq. ft. of roof surface. A metal ruler can be used to measure the depth of standing water. Data is recorded and unusual conditions are photographed. Wear waterproof boots.

Measures: Ponding (standing water)

-Slopes of roof to $1^0$ accuracy
-Extent (to two feet) and depth (to 1/4 inch) of standing water

measure with the ruler on membrane surface below aggregate level (on top of membrane).
- Obstacles in gutters and drains
- Comparison between the level of roof drain (lip) and roof three feet from drain (to 1/4 inch).

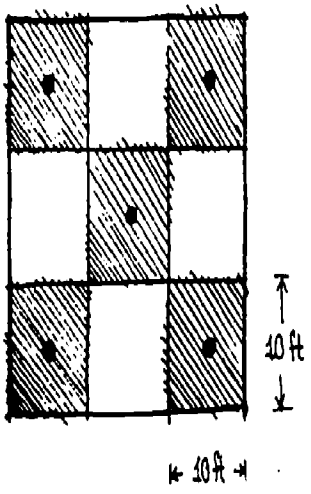
## TEST # 2: Proper Detailing of Roof Penetrations

Test Method: Determine past performance if possible. Test by close examination of the working drawings and specifications to determine conditions which are not consistent with good practice and may cause potential leaks. These conditions bear careful examination in the field.

All penetrations through the roof membrane, including level changes, the roof edge, ducts, piping, skylights, etc., should be examined from a distance of one foot with a concentration on the interior of the building around these joints. Data is recorded and photographs are taken of unusual conditions.

Measures: Proper roof detailing

- Adequate flashing above roof level (to 1/2 inch)
- Membrane carried up around penetration (to 1/2 inch)
- Exposed flashing
- Evidence of leakage around penetrations




## TEST # 3: Resistance to Movement

Test Method: Determine past performance if possible. Test by making a detailed visual examination of the roof from a few inches. Approximately five observations are made per 1000 sq. ft. on alternate ten foot squares. Data is recorded and unusual conditions are photographed.

Measures: Deterioration due to movement

- Tears and splits caused by moisture or temperature expansion and contraction (length to 1 inch: width and depth to 1/32 inch)
- Alligatoring around standing water due to temperature differentials or by enbrittlement (extent to 6 inches: width and depth to 1/32 inch)
- Blisters and buckles due to trapped air within membrane (to 1 inch)
- Holes (to 1/32 inch)
- Extent and quality of aggregate coverage

## TEST # 4: Proper Installation of Roofing Membrane

Test Method: Same as Test #3

Measures: Roof construction

- Exposed laps of roofing membrane (to 1 inch)
- Fishmouthing (to 1 inch)

## REFERENCES

Material on roofing performance which helped develop our field tests was plentiful. Manufacturers literature (Johns-Manville; Pittsburgh-Corning) and reports by institutions (National Research Council, Canada; Small Homes Council, University of Illinois; U.S. National Bureau of Standards) are all useful. The book, Manual of Built-Up Roof Systems, C.W. Griffin, McGraw Hill, 1970, was especially comprehensive. Though there is no lack of material in this area it remains, in general, an area of poor performance in practice. Reasons for this are discussed in detail in the Technical Factors Report.

In Addition:

ASTM D-1709 Impact Resistance for Film and Sheet-Type Materials

ASTM D-781 Sudden Application of Puncture

ASTM D-471 Absorption by hydroscopic Roof Covering Materials

"Flat Roof Failures" in Architects' Journal, 30 June 1971

A roofing contractor can be used to take a core sample of a roof which reveals problems in cross section. This is easily patched.

SUMMARY OF ROOFS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: KEEP MOISTURE FROM ENTERING BUILDING

TEST # 1: Minimize Standing Water on Roof Surface

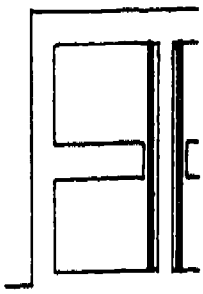
TEST # 2: Proper Detailing of Roof Penetrations

TEST # 3: Resistance to Movement

TEST # 4: Proper Installation of Roofing Membrane

# INTERIOR WALLS

SUMMARY



Interior walls constitute the means for separating the various activities occurring simultaneously within the building. In fulfilling this principal separating function, such interior partitions must meet criteria of structural soundness, physical durability and present an acceptable appearance. The field tests in this area emphasize these performance objectives and are directed at conditions which impair this performance.

PERFORMANCE OBJECTIVE: PROVIDE STRUCTURAL STABILITY

TEST # 1: Resistance to Loads

Test Method: Determine past performance, if possible. Test by examining each interior wall from a distance of five feet. Cracks, splits or any other discrepancies should be carefully located and recorded in terms of position, length, depth, width, direction and described in detail in regard to special relationships, such as to beams, corners, wall openings, etc. Photograph any unusual conditions observed.

Deflections in any direction, as indicated by measurements taken with a plumb line and level, should also be noted, recorded and photographed.

Measures: Cracks, splits

- Record length, depth, width to 1/32 inch

Measures: Deflection

- Record to 1/32 inch

## TEST # 2: Resistance to Impact

Test Methods: Determine past performance, if possible. Test by observing from a distance of one foot areas of high impact loads, such as around doorways, and note any instances of either cracking or splitting. Record and photograph.

Measures: Cracking, splitting, crushing, indentation
- Record to 1/32 inch

## TEST # 3: Support for Attached Loads

Test Method: Determine past performance, if possible. Test by examining the wall at points of support for attached loads, from a distance of one foot, noting any damage to the wall, its surface or any other subsystems as a result of attached loads (e.g., clothes racks, blackboards, hung shelves, etc.). Record and photograph any instances of damage.

Measures: Cracking, splitting, deflection, permanent set
- Record to 1/32 inch

## TEST # 4: Proper Installation of Nonsystem Elements

Test Methods: Determine past performance, if possible. Test by examining the interior walls, from a distance of one foot, at the interface with nonsystem elements. Door and window tolerances should be checked for loose fit or tight fit. Door jams and window frames should be checked for cracks and spaces where they meet the wall. Bulletin boards, blackboards and other fastened objects should be checked for looseness and broken surfaces around their fasteners. Any broken or loose hardware should be noted by location and type of damage, recorded and photographed.

Measures: Looseness, tightness

- Record according to the amount of or resistance to movement as extensive, moderate or slight

Measures: Cracks, splits

- Record to 1/32 inch

PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE

TEST # 5: Durability of Surfaces

Test Method: Determine past performance, if possible. Test by observing all wall surfaces from a distance of four feet. Cohesion/adhesion of surfaces can be checked by noting instances of buckling, peeling, delamination and the extent and location of each. Delamination of surface or residual adhesive which may occur due to removal of adhesive tape. Record and photograph.

Durability of the surfaces is tested by locating concentrations of dents, scratches, gouges and punctures. Such concentrations may be expected to occur around doors and the lower ten inches of doors. Observe from a distance of one foot. Measure the depth and width of these, if possible. Note their location, severity and photograph.

Test for color fastness to light, evenness of color and abrasion by visual comparison between an unused sample and a sample area of the material in use. Record and photograph any deterioration observed. Short descriptions of certain special instances where damage seems extreme or out of the ordinary should be written. Record and photograph.

Measures: Record the incidence, location, severity and extent of buckling, peeling, delamination, cracking, crazing, splitting, blistering (to 1/2 inch); indentation, punctures, scratching and gouging (to 1/32 inch).

## TEST # 6: Resistance to Scratching and Abrasion

Test Method: Determine past performance, if possible. Test by locating, from a distance of four feet, concentrations of damage due to scratching or abrasion. Note any relationship to openings in the wall (e.g., windows, doors, etc.) and describe according to location, type, severity and extent of damage. Record and photograph.

Measures: Scratches, gouges, punctures, indentation, chipping

- Record to 1/32 inch

## TEST # 7: Water Absorption and Retention

Test Method: Determine past performance, if possible. Test by comparing, from a distance of two feet, an unused sample with the material in use on the surface of the wall. Note instances of water-related deterioration, and such relationships to windows, doors, elements of the water system, the roof system and exterior walls as may exist. Record instances of damage by noting location, type, extent and severity of damage. Photograph.

Measures: Color change, staining, cracking, blistering, swelling

- Record by location, severity and extent of damage

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY

TEST # 8: Cleanability and Resistance to Stains

Test Method: Determine past performance, if possible. Test by visually locating, from a distance of five feet, stains and other areas which need cleaning. List the stains and note the locations. Attempt to remove the existing stains with cleansors and methods used by the maintenance staff. Record the results and any effects on wall materials.

Observe, from a distance of three feet, areas which have been cleaned and note any loss of gloss value in comparison to an unused sample of the same material, and any other cleaning-related deterioration.

Measures: Cleanability

- Record the change in the stain after cleaning as:
  - completely removed (not visible from two feet)
  - trace remaining (just visible from five feet)
  - mostly removed (visible from five feet)
  - partially or not removed (easily visible from five feet)

TEST # 9: Dust Accumulation

Test Method: Determine past performance, if possible. Test by visually comparing an unused sample with the material in use on the wall. Note any graying which might indicate dust retention on or within the surface of the material.

Measures: Color change (graying)

- Record color change as slight, moderate or severe.

In recent years some excellent work has been done in collecting performance data on interior finishes-interior walls, floors and ceilings. Two documents which contain excellent information are:

"The PBS Performance Specification for Office Buildings", by D. Hattis and T. Ware, et. al., National Bureau of Standards Report, 10 527, Jan. 1971

"The Performance Concept", V.I. by Staff, National Bureau of Standards Report, 9849, June 1968

SUMMARY OF INTERIOR WALLS PERFORMANCE TESTS

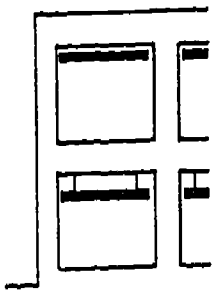
PERFORMANCE OBJECTIVE: PROVIDE STRUCTURAL STABILITY
- TEST # 1: Resistance to Loads
- TEST # 2: Resistance to Impact
- TEST # 3: Support for Attached Loads
- TEST # 4: Proper Installation of Nonsystem Elements

PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE
- TEST # 5: Durability of Surfaces
- TEST # 6: Resistance to Scratching and Abrasion
- TEST # 7: Water Absorption and Retention

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY
- TEST # 8: Cleanability and Resistance to Stains
- TEST # 9: Dust Accumulation

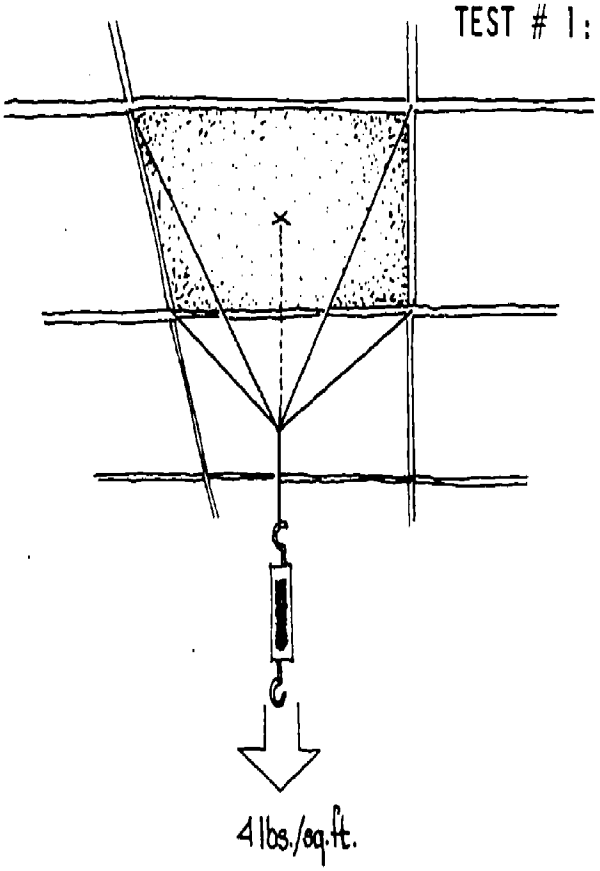
# CEILINGS

SUMMARY



The ceiling subsystem refers to the finished ceiling surface (i.e., that which is visible to the users of the building). As such, its satisfactory appearance is its primary function, and success or failure in this regard essentially derives from its initial design. This being the case, the principal concerns with the ceiling are that it retain its satisfactory appearance, that it be structurally sound, and that it not interfere with the normal activities of the space it encloses. The field tests in this area emphasize these primary objectives and are directed at conditions which cause deterioration in appearance and function.

PERFORMANCE OBJECTIVE: PROVIDE STABLE STRUCTURAL SUPPORT



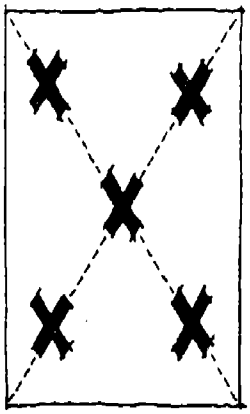

TEST # 1: Resistance to Loads

Test Method: Determine past performance, if possible. Test by constructing a simple apparatus consisting of a wire, run from each of the four corners of the ceiling grid, suspending a tension scale (see diagram). Apply downward pressure and observe any deflection which occurs as a result. The ceiling support system should be able to resist up to four pounds per square foot of ceiling area (see diagram). (Refers to suspended ceilings only.)

Measures: Deflection

- Record the pull in points, necessary to induce noticeable deflection (i.e., greater than 1/16 inch) in the ceiling grid.

TEST # 2: Parallel to Floor



Test Method: Determine past performance, if possible, Test, with a plumbline and a tape graduated to 1/16 inch, by measuring the floor to ceiling height at the one-fifth points of both room diagonals and at the crossing of the diagonals (see diagram). Record each height to 1/16 inch accuracy. Record and photograph.

Measures: Floor to ceiling distance

- Record differring in inches between the lowest and highest floor to ceiling distance
- Record inches deviation from the average floor to ceiling height

TEST # 3: Resistance to Ascending Forces

Test Method: Determine past performance, if possible. Test by slamming a door forcefully fifty times in succession, and observe, from a distance of two feet, any displacement or damage to the ceiling. Record and photograph.

Measures: Damage and displacement in ceiling

- Record type and extent of damage

PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE

TEST # 4: Cohesive Strength

Test Method: Determine past performance, if possible. Test by observing, from a distance of one foot, all coatings on exposed areas of the ceiling (one observation per 100 square feet of ceiling area). Locate and record areas of possible problems.

Measures: Crumbling, flaking, breaking, discoloration

## TEST # 5: Adhesive Strength

Test Method: Determine past performance, if possible. Test by observing the entire ceiling from eye level to determine if any area has been sagging or pulling away from its support system. Check to see if any tiles have been replaced. Record and photograph problems and problem areas.

Measures: Delamination

- Record as severe, moderate or slight

## TEST # 6: Resistance to Impact

Test Method: Determine past performance, if possible. Test by gently tapping the ceiling with the end of a broom handle, observing any damage from a distance of two feet. Tap again, harder, and observe. Finally, give it a very hard poke and observe, the indentation caused by even the hardest impact should not be greater than 1/16 inch deep. Record and photograph any damage. (This test should be run only once for each type of ceiling material in use.)

Measures: Indentation

- Record depth to 1/16 inch

TEST # 7: Resistance to Scratching

Test Method: Determine past performance, if possible. Test by obtaining samples of each type ot ceiling material in use. Using 6B, 2B, and 2H pencil leads of medium sharpness, make a scratch in the surface with each, using a force not quite sufficient to break the lead point. Note the apparent depth of the resulting scratches and record. (This need be done only once for each type of ceiling material in use.)

Observe the ceiling from eye level, noting any scratches and the areas in which they occur. Record and photograph, if possible.

Measures: Scratching

- Record depth as heavy, medium or trace
- Record areas of scratching by extent, severity and location of damage

TEST # 8: Resistance to Water

Test Method: Determine past performance, if possible. Test by observing the entire ceiling from eye level. Note any staining or discoloration from elements, such as rust, that may be present in water. Record and photograph any damage, and indicate the probable source of the leakage.

Measures: Staining

- Record areas of staining by extent, severity and location of damage.

PERFORMANCE OBJECTIVE: PROVIDE A SAFE SURFACE

TEST # 9: Anthropometric Fit

Test Method: Determine past performance, if possible. Test by determining, through observation and from the results of Ceiling Test #2, that it is possible for the average person to walk under the ceiling without it or any other subsystem causing personal injury or presenting a potential danger. Record and photograph any potentially dangerous situations.

Measures: Ability to walk under the ceiling

- Minimum ceiling height: 6 feet, 8 inches

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY

TEST #10: Color Homogeneity

Test Method: Determine past performance, if possible. Test by scoring, on a sample of each type of material in use on the ceilings, a grid of 1/16 inch squares on an area of the surface 1/2 inch by 1/2 inch. Press and smooth on firmly a piece of 3M Company "Scotch" brand magic transparent tape over the scored lines and lift off sharply. Record the results, noting depth of color.

Observe the entire ceiling from eye level, noting any areas of flaking, peeling, any chips or dents, Record and photograph. Identify probable cause.

Measures: Depth of color on surface

- Linear depth to the nearest 1/32 inch, or as an approximate percentage of total thickness of ceiling material

Measures: Flaking and peeling

- Record the number of 1/16 inch squares that tear away during the testing procedure
- Record any damage observed by type, location, severity and extent

## TEST #11: Resistance to Fading

Test Method: Determine past performance, if possible. Test by obtaining an unused sample of each material in use on the ceilings. Compare these samples with the installed ceiling for instances of fading. Record and photograph.

Measures: Fading

- Record as severe, moderate or slight

## TEST #12: Resistance to Dust Accumulation

Test Method: Determine past performance, if possible. Test by examining the ceiling from eye level, noting any instances of trapped dirt or dust, especially around HVAC equipment and outlets, windows, doors, etc. Record and photograph.

Measures: Dust accumulation

- Record by location, extent and severity of damage

TEST #13: Cleanability

Test Method: Determine past performance, if possible. Test by washing a one foot square sample area of the ceiling surface with a mild detergent solution. Allow it to dry. From a distance of one foot, examine the cleaned surface for any cracking, splitting, spalling, blisters, delaminations or breaks in the surface. Record and photograph. Repeat test for each ceiling material.

Measures: Surface deterioration due to cleaning

- Record the type, extent and severity of damage

TEST #14: Access to Plenum

Test Method: Determine past performance, if possible. Test by removing the panels that provide access to the plenum. The opening provided must be large enough to permit access for servicing. Record the size of the panels and photograph.

Remove and replace the access panel twenty times. Examine from a distance of one foot, record and photograph any damage.

Measures: Accessibility

- Access panels should measure not less than 20 inches square.

Measures: Visual appearance

- Record any damage resulting from removing and replacing of the access panels by type, severity and extent of damage.

## TEST #15: Accommodation for Out-of-System Hardware

Test Method: Determine past performance, if possible. Test by determining if the ceiling system is capable of accommodating other subsystems or out-of-system built elements in the typical enclosed space at all points where maintenance or adjustment of these built elements may be required. Record and photograph.

Measures: Adaptability to out-of-system hardware.

-Record as adequate or inadequate (and explain).

See interior wall notes P. C-6. The reports mentioned contain excellent documentation of performance and tests in the areas of interior walls, ceilings and floors.

SUMMARY OF CEILINGS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PROVIDE STABLE STRUCTURAL SUPPORT

TEST # 1: Resistance to Loads

TEST # 2: Parallel to Floor

TEST # 3: Resistance to Ascending Forces

PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE

TEST # 4: Cohesive Strength

TEST # 5: Adhesive Strength

TEST # 6: Resistance to Impact

TEST # 7: Resistance to Scratching

TEST # 8: Resistance to Water

PERFORMANCE OBJECTIVE: PROVIDE A SAFE SURFACE

TEST # 9: Anthropometric Fit

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY

TEST #10: Color Homogeneity

TEST #11: Resistance to Fading

TEST #12: Resistance to Dust Accumulation

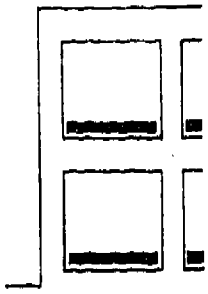
TEST #13: Cleanability

TEST #14: Access to Plenum

TEST #15: Accommodation for Out-of-System Hardware

# FLOORS

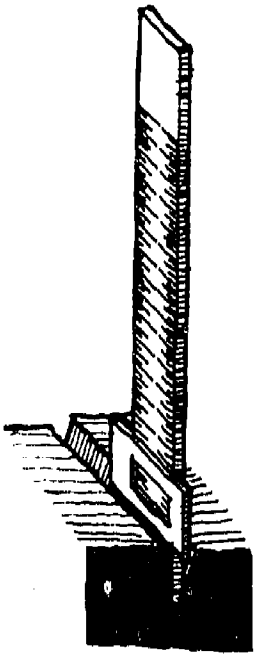
SUMMARY



The primary objective of the floor system is to provide a structurally stable plane for the activities occurring within the building and the equipment which supports these activities. The floor system should also be physically durable, maintainable, hygienic, safely usable and present a satisfactory appearance. The field tests in this area emphasize these primary objectives and are directed at conditions which impair this performance.

## PERFORMANCE OBJECTIVE: PROVIDE STRUCTURAL STABILITY

### TEST # 1: Resistance to Static Loads

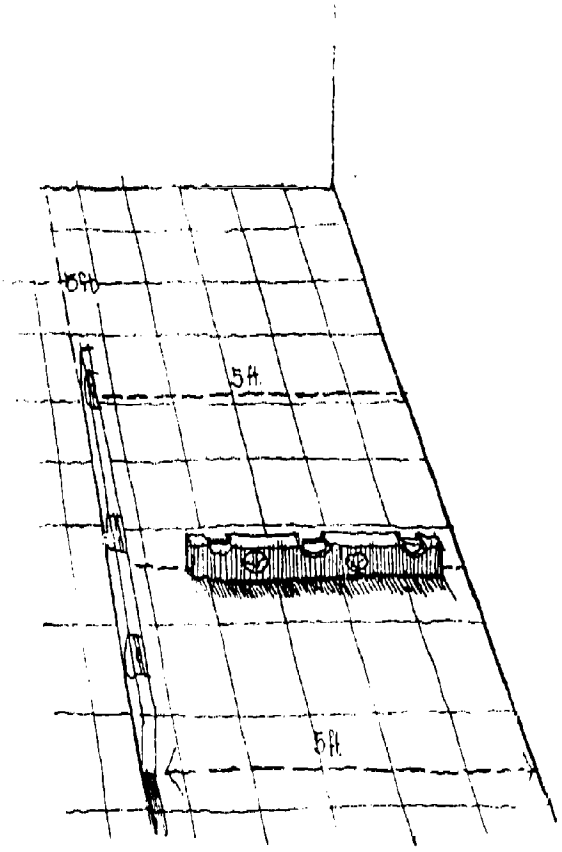


Test Method: Determine past performance, if possible. Test by locating at least one heavy load in the room (e.g. a desk, bookcase, file cabinet, etc.). Observe the floor around the legs from a distance of one foot noting any change in physical condition. If possible, shift the load and observe an indentation in the flooring. Measure this with a depth gauge.

Observe the floor from a distance of three feet, at any angle, with the floor illuminated. Record the number of indentations, and photograph.

Measure: Indentation, cracking, splitting
-Based on depth, record as slight (less than 1/16 inch), moderate (1/16 to 1/8 inch), or severe (greater than 1/8 inch).
-Based on width, record as slight (less than 1/32 inch), moderate (1/32 to 1/16 inch), or severe (greater than 1/16 inch).
Measure: Checking
-Record as slight, moderate or severe based on areal extent and depth of cracking.

## TEST # 2: Levelness of Surface



Test Method: Determine past performance, if possible. Test by sweeping the floor clean of all particulate matter which might interfere with the testing procedures. Rolling a spherical object such as a ball bearing to observe deviation from a straight line path, or observing flow or ponding of water during cleaning operations can be used as gross indicators of a general or localized non-level condition which can then be verified by more precise measurement using long levels.

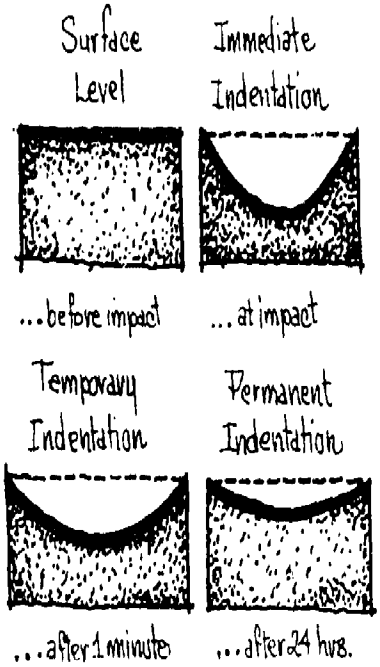
Place a four foot level on the floor parallel to, and within five feet of, a wall to determine whether or not the floor is indeed level. Determine if the level rests evenly on the surface along its entire length. Light penetration under the level from the opposite side will indicate deviations from a level condition. Repeat the test in the same location but with the level perpendicular to the wall. (Test should be conducted once for every 500 square feet of floor area.) Record the results.

Measure: Significant problems with an unlevel condition may be said to exist when such a floor is measurably and/or noticably sloped, either in general or in any small area such that it interferes with normal activities, routine maintenance, the stability of objects resting on it, or produces psychological discomfort for its occupants. Visually note and describe instances of cupping, bulging or slope as slight, moderate or severe.

## PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE

## TEST # 3: Resistance to Point Impact

Test Method: Determine past performance, if possible. Test by visually evaluating the result of impacting, with reasonable force, a conventional 3/4 inch diameter hammer head on the floor sur-




face. It should withstand any reasonable impact without damage. Record and photograph.

Measure: Determine the depth of any indentation, to the nearest 1/64 inch, with the aid of a level and any standard linear measuring device applicable to the situation. Note the occurrence of any splitting, cracking or crazing. Measures should be made at the time of the test and again after 24 hours. Note the permanence of the damage.

## TEST # 4: Resistance to Abrasion and Scratching

Test Method: Determine past performance, if possible. Test by locating areas of heavy use (e.g. doorways, aisles between desks, under desks, in front of sinks, etc.). Place a four foot level over the area with each end of the level supported by an area of less hard use. Measure the depth of the wear with a ruler. If the test for color homogeneity (Floor Test #15) yields the fact that the surface color does not fully penetrate the material, observe and note any areas where the subsurface color of the material shows through.

For scratching, observe the flooring from a distance of three feet, at various angles, and note any areas of scratching or ground-in dirt. Clean a sample scratched area with a damp sponge passed vigorously over the area ten times. Rinse with one pass of a clean sponge. Observe the area again from a distance of one foot, recording the extent and severity of the damage from scratching and ground-in dirt. Photograph.

Measure: Abrasion
-For large area abrasion, note change in depth to 1/64 inch
-For abrasion with wear of the top surface color layer, note extent to 1 inch and depth to 1/16 inch.

Measure: Scratching
-Record depth of scratches to 1/64 inch and length to 1 inch

TEST # 5: Cohesive Strength

Test Method: Determine past performance, if possible. Test by visually locating areas of hard use (i.e. possible areas of crumbling or breaking) or areas subject to standing water. Observe from a distance of three feet. Record and photograph any deterioration.

For carpeting, test by running a common nail through a loop of the carpet. Holding the nail in the hand, exert a pressure increasing to about seven pounds. Record any yielding in the carpet, such as snagging or running, and photograph.

Measure: Crumbling, breaking
-Record as extensive, moderate or slight
Measure: Snagging, running
-Record the amount of pressure necessary to cause damage as heavy, moderate or light

TEST # 6: Adhesive Strength

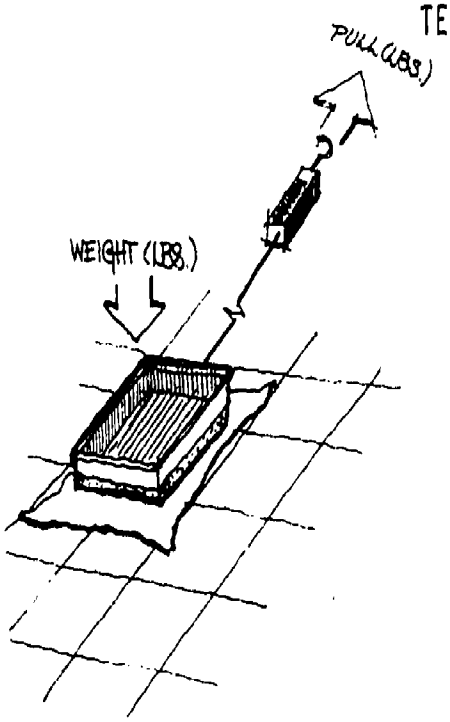
Test Method: Determine past performance, if possible. Test by visually examining the entire floor from eye level for bulges or loose tile. Test these areas by pulling upward on exposed edges to see if delamination has actually occurred.

For carpeting, test by running a common nail through about five loops and exerting a quick pull of about seven pounds to determine any yielding of the adhesive has occurred. Record and photograph.

Measure: Bulges, delamination
-Note existing bulges or delaminations to 1/32 inch
-Note any test-induced bulges or delaminations to 1/32 inch

PERFORMANCE OBJECTIVE: PROVIDE A SAFE SURFACE

TEST # 7: Resistance to Slip




Test Method: Determine past performance, if possible. Test by using a slip meter to determine the coefficient of slip of hard, smooth surfaces (not to be used on carpeting or on heavily-textured surfaces). The slip meter is a weighted cloth bag which is pulled and the force necessary to cause the device to begin moving across a surface is noted on a tension scale. This test need be performed only once for each flooring material in use. Record the results for each surface, wet and dry.

Measure: Coefficient of slip
-Note the force necessary to move the testing equipment, under both wet and dry conditions, to the nearest pound. Determine the coefficient of slip.

TEST # 8: Control of Static Discharge

Test Method: Determine past performance, if possible. Test by walking several paces on the carpet or other flooring material. Touch a grounded conductor (e.g. another person or a light switch) noting the general force of any static discharge which occurs.

This test can also be performed using a voltmeter, by rubbing the surface of the floor and measuring the voltage at which a shock is received when turning on a piece of electrical equipment such as a light switch or electric typewriter. Use this measurement as a criterion for measuring other areas. (This test may not be reliable on days of high humidity.) Record.

Measure: Static discharge
-Record voltage generated during static discharge
-Indicate the severity of the discharge generally as severe, moderate or slight.

TEST # 9: Anthropometric Fit

Test Method: Determine past performance, if possible. Test by visually observing possible anthropometric problems in the course of performing other testing procedures. Record and photograph.

Measure: Anthropometric fit
-Measure to 1/2 inch

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY

TEST #10: Resistance to Chemical Cleansers

Test Method: Determine past performance, if possible. Test by exposing the floor surface, for sixty minutes, to each of the following: distilled water, a detergent solution, sodium hydroxide and a 1% soap solution. Compare the exposed surface to an unexposed sample of the same material. Record and photograph the results.

Measure: Changes in color, dimension, deterioration
-Record the type of damage and note its extent as either slight, moderate or severe.

## TEST #11: Water Permeability

Test Method: Determine past performance, if possible. Test by submerging a flat sample of flooring (not to include carpeting) in water for a period of three hours. Test, by weighing, the amount of water absorbed during the test period. Absorption should not exceed 15%, by weight. Note any other deterioration of the sample as a result of the testing procedure. Record and photograph. (Test need be run only once for each type of material in use.)

Measure: Water absorption
- Record weight of the sample, before and immediately after the test, to the nearest gram. Difference should not exceed 15% of the pretest weight.
- Note any other test-related deterioration, recording its type and severity as either slight, moderate or severe.

## TEST #12: Dust Accumulation

Test Method: Determine past performance, if possible. Test by collecting a sample of retained dust from a one foot square area of each type of flooring material in use by means of a baster (a tube device in which a rubber bulb is depressed to provide suction). The flooring surface (except carpeting) should not allow more than 1/4 gram of dust to be retained per square foot. Record the results.

The floor should also be checked by close visual observation, from a distance of three feet, to determine if there are any areas in which dust and other particulate matter can concentrate out of the reach of normal cleaning operations. Record and photograph any such areas.

Measure: Dust retention
- Record the weight of the retained dust sample to 1/2 gram
- Record the location of any uncleaned accumulations of dust or other particulate matter.

## TEST #13: Economic Washability and Scrubability

Test Method: Determine past performance, if possible. Test by visually comparing an unused sample with each type of flooring material in use. Routine cleaning procedures should provide an 85% retention of the original appearance of the material. Record and photograph results.

Measure: Retention of original appearance
-For resilient floors, note the retention of marks and the level of gloss remaining
-For carpeting, observe pile height and record.

## TEST #14: Convenient Repair and Replacement

Test Method: Determine past performance, if possible. Test by examining the entire floor, from eye level, noting areas where the flooring material has been repaired or replaced. New material should be of the same type as the original flooring. Record any significant discrepancies (other than those related to age and wear) and photograph.

Measure: Replaceability
-Record differences in material types

## TEST #15: Color Homogeneity and Stability

Test Method: Determine past performance, if possible. Test by visually comparing the color of unused samples with each flooring material in use. Record and photograph any significant changes. Measure the depth of the surface color on an edge of each flooring sample. Such colored material should constitute not less than 50% of the thickness of the sample. Record the results.

Measure: Color stability
-Record any significant changes in color
Measure: Color homogeneity
- Measure depth of surface color to 1/32 inch

TEST #16: Resistance to Fading

Test Method: Determine past performance, if possible. Test by obtaining an unused sample of each type of flooring material in use. Locate possible areas of natural fading (e.g. areas near windows, areas subjected to standing water, etc.) and compare the flooring with the unused sample of the same material. Note any instances of fading. Record and photograph.

Measure: Fading
- Record as severe, moderate or slight

TEST #17: Resistance to Staining

Test Method: Determine past performance, if possible. Test by exposing each type of flooring material in use (except carpet) to the following stain-causing materials: pencil, orange juice, coffee, tea, milk, cold drinks, residue of cigarette snuffed out rapidly with the foot, chalk, grease, permanent inks, ball point, alcohol-based marker, lipstick, nail polish, heel marks, paint, etc. Exposure for 15 minutes and a subsequent use of a stain remover or cleansing agent tests the resistance to the material to each of these agents. Observe, from a distance of one foot, any change in the appearance of the tested areas. Record and photograph.

Measure: Stain resistance
-Record each agent tested as staining or non-staining

See interior wall notes P. C-6. The reports mentioned contain excellent documentation of performance and tests in the areas of interior walls, ceilings and floors.

SUMMARY OF FLOORS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PROVIDE STRUCTURAL STABILITY
- TEST # 1: Resistance to Static Loads
- TEST # 2: Levelness of Surface

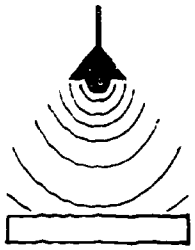
PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE
- TEST # 3: Resistance to Point impact
- TEST # 4: Resistance to Abrasion and Scratching
- TEST # 5: Cohesive Strength
- TEST # 6: Adhesive Strength

PERFORMANCE OBJECTIVE: PROVIDE A SAFE SURFACE
- TEST # 7: Resistance to Slip
- TEST # 8: Control of Static Discharge
- TEST # 9: Anthropometric Fit

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY
- TEST #10: Resistance to Chemical Cleansors
- TEST #11: Water Permeability
- TEST #12: Dust Accumulation
- TEST #13: Economic Washability and Scrubability
- TEST #14: Convenient Repair and Replacement
- TEST #15 Color Homogeneity and Stability
- TEST # Resistance to Fading
- TEST #17: Resistance to Staining

# LIGHTING

SUMMARY

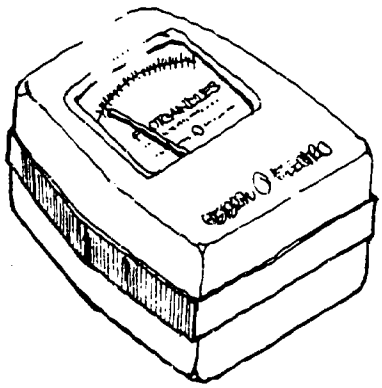


The primary objective of the lighting subsystem is to provide a satisfactory quantity and quality of illumination for the activities in the building.

Though specifying the quantity of illumination is now standard operating procedure in almost all environments, the quality of the illumination provided has not been considered in most cases. This includes direct and indirect glare, contrast rendition and contrast ratios.

PERFORMANCE OBJECTIVE: PROVIDE SUFFICIENT QUANTITY AND QUALITY OF LIGHT

TEST # 1: Provide Sufficient Quantity of Light

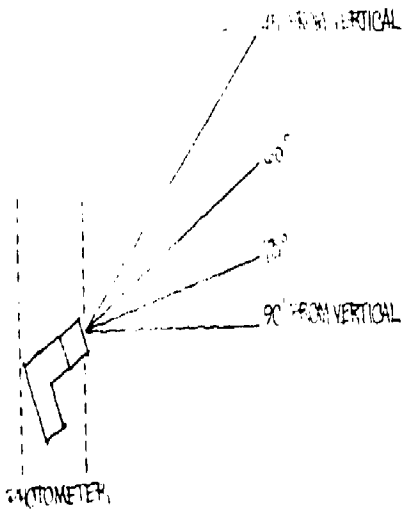


Test Method: Determine past performance, if possible. Use a footcandle meter which reads from 3-8000 footcandles. Multiple readings are taken in each room under luminaires, between luminaires, in the center of the room, at the edge of the room and at the windows. Readings are made under the following conditions - daylight only (between 9 a.m. & 3 p.m.), artificial illumination only (nighttime is best) and a combination of the two. All readings are taken 30 inches above the floor (table height).

Measures: Natural light, artificial light, combined natural and artificial light

- Artificial illumination only (nighttime) under luminaires, between luminaires, at walls
- Natural illumination only, at windows, at 5 feet intervals from windows to opposite wall
- Combination of artificial and natural illumination, at all of the above locations.

## TEST # 2: Minimize Direct Glare




Test Method: Determine past performance, if possible. Use a spectra photometer reading in footlamberts or a (Minolta, Honeywell, etc.) lightmeter whose readings can be converted to footlamberts. Readings are taken with a 1° spot.

Readings are taken at eye level directly under and perpendicular to lighting fixtures in the viewing directions most frequently used. Readings are taken from 45 - 90° from the vertical. Use artificial lighting only.

Measures: Footlamberts of illumination

- Footlambert measurements parallel and percendicular to fixtures at the following angles - 45°, 60°, 75°, 90°, and graphed on a I.E.S. scissors curve.

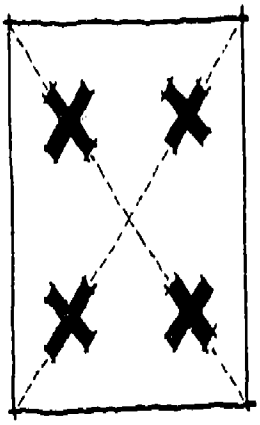
## TEST # 3: Control Brightness Contrast Ratios

Test Method: Determine past performance, if possible. Use a photometer as in Test #2. This test is made under artificial light only, daylight only, and combinations of the two with window shades open and closed. Readings are taken from most of the work surfaces in the room.

Measures: Brightness contrast ratios

- Measures are taken on the ceiling on and between lighting fixtures, on upper wall(s), wall at eye level on various surfaces, on task, immediate task surround, window, wall adjacent to window, floor.
- Measures are taken under the following conditions: artificial light only, daylight only, combination artificial and daylight with shades open and closed.

## TEST # 4: Eliminate Shadows on Task Surfaces



Test Method: The following test is made at the fourth points of both room diagonals. These are used as task locations and the footcandle level is read with and without a user at the task location to compare the possible effects of shadow on the task.

Measure: Task illumination

- The footcandles on the task with and without the seated user.

## TEST # 5: Maintain Quantity and Quality of Illumination

Test Method: Using a photometer as described in Test #2, measure the luminaire brightness from seated eye level on the diffuser and/or bulb before and after cleaning a diffuser and bulb with a dry rag. Install a new bulb and again measure luminaire brightness.

Measure: Luminaire brightness

- Luminaire brightness, diffuser and/or lamp under three conditions - actual usage; bulb and diffuser cleaned; new bulb (diffuser cleaned).

REFERENCES

"I.E.S. Handbook", Illuminating Engineering Society, 1966.
This contains almost all standard tests. A standard text.

"Contrast Rendition in School Lighting", Foster Sampson, Educational Facility Laboratories, N.Y., 1970.
This is very significant and goes far beyond the I.E.S. Handbook.

SUMMARY OF LIGHTING PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PROVIDE SUFFICIENT QUANTITY AND QUALITY OF LIGHT

TEST # 1: Provide sufficient Quantity of Light

TEST # 2: Minimize Direct Glare

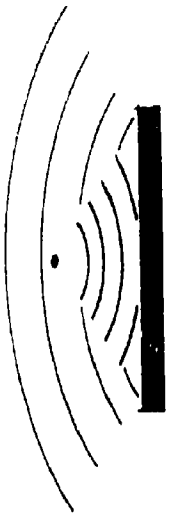
TEST # 3: Control Brightness Contrast Ratios

TEST # 4: Eliminate Shadows on Task Surfaces

TEST # 5: Maintain Quantity and Quality of Illumination

# ACOUSTICS

SUMMARY

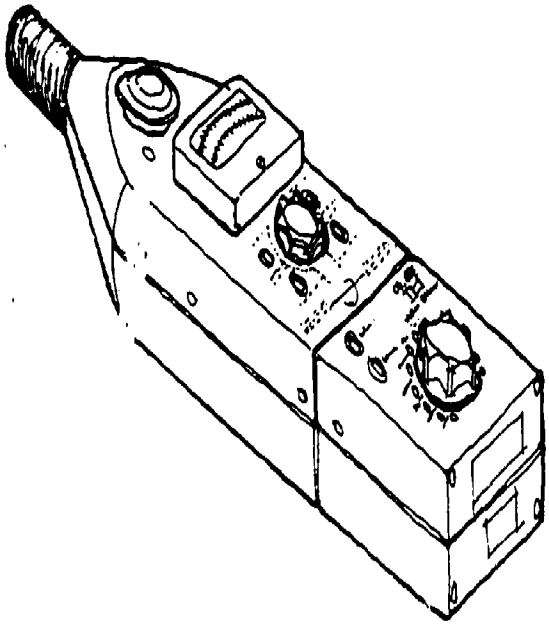


The primary objective of the acoustical environment is to be responsive to the activities within the building. To support clear communications and to provide privacy and a lack of acoustical interference. Field tests in this area emphasize these primary objectives and are directed at conditions which impair this performance.

The transmission of interfering sound between adjacent activities is a major characteristic to be tested although in large spaces the background or ambient sound level and the 'echo' effects can also be potential problems.

## PERFORMANCE OBJECTIVE: PROVIDE AN ACCEPTABLE ACOUSTICAL ENVIRONMENT

### TEST # 1: Correct Ambient Sound Level

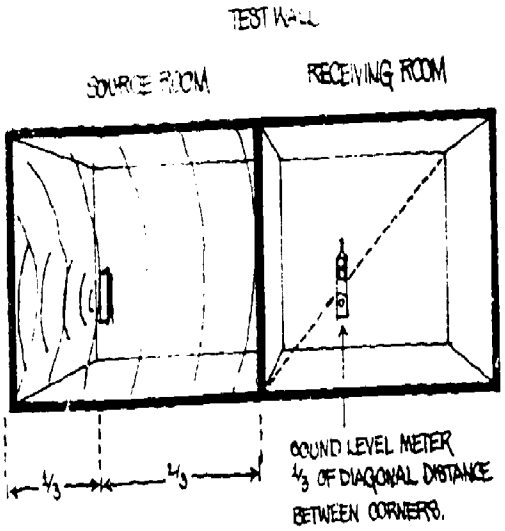


Test Method: Determine past performance if possible. Test by using a sound level meter with an 'A' scale and preferably a reading to 30 decibels. If possible, a meter with an octave band analyzer should be used. Sound level readings are taken within the area to be tested with and without normal activities present in the space. These readings should be taken on both the 'A' scale and at various frequencies. The meter should be used in an upright position and readings taken at the center of the room.

Measures: Ambient sound level

- In empty room: 'A' scale ± 1 db.
- Multiple readings with space in use: 'A' scale ± 3 db.
- Frequency distribution in empty room at 125, ± 50, 500, 1,000, and 2,000 HZ ± 1 db.

## TEST # 2: Control Sound Transmission Between Spaces




Test Method: Determine past performance if possible. Test by using two rooms. One room contains a sound source and a sound level meter in the second room determines the amount of the transmitted sound. A good quality cassette recorder playing prerecorded 'white' noise at a level of 75 db. or more is a suitable source. A sound level meter with an 'A' scale is used as a receiver. Note #1

The cassette recorder is placed 2/3 of the distance from the wall being tested and facing away from the wall. The preferred placement of the sound level meter in the receiving room is 1/3 along one of the diagonals from the lowest corner of the room near the wall being tested to the far opposite upper corner of the room. Since there are four such diagonals, choose the one closest to non-sound absorbent surfaces. Measurements should be taken at least 30" from reflective surfaces.

A measurement is made in the source room with the source on and in the receiving room with the source off. A second reading in the receiving room with the source on will complete the test.

Note: The ambient sound level in the receiving room should be at least 10 dbA below the source level in the adjacent room. The test should simulate normal conditions. For example, if a door to the corridor connecting the two rooms if usually left open, the test should be done with the door open (and closed too!)

Measures: Ambient sound level

- Ambient sound level, ± 1 dbA, in receiving room without source on;

- Ambient sound level, ± dbA, in source room with source on;
- Ambient sound level, ± dbA, in receiving room with source on.

## TEST # 3: Control Reverberation Within Spaces

Test Method: Determine past performance if possible. Test by using 18 inch diameter balloons to provide an instantaneous and loud sound source. A tape recorder specifically modified for the purpose records the reverberation test. Two trials are recorded in each space. The tape is analyzed in a laboratory to determine the reverberation time. Measurement is made at least 30 inches from any reflecting surface.

Since the equipment used in this test is quite expensive and sophisticated and since reverberation detrimental to normal speech should be heard using the balloons, it is possible to burst balloons and simply note the discernible reverberation if any.

Measures: Reverberation times

- Reverberation times for the following frequencies: 125, 250, 500, 1,000, and 2,000 HZ.

## TEST # 4: Control Mechanical Systems Noise

Test Method: Determine past performance if possible. Same as test #1. Readings are taken with lighting and mechanical systems turned off and turned on.

Measures: Mechanical systems noise

- anical systems on dbA and 60, 125, 250, 500, 1,000, ,000 HZ
- hanical systems off dbA and 25, 250, 500, 1,000, ,000 HZ
- Lighting on only dbA and 60, , 250, 500, 1,000, 2,000 HZ
- Mechanical on only dbA and 60, 125, 250, 500, 1,000, 2,000 HZ

## TEST # 5: Control Impact-Generated Sound Transmission

Test Method: Test by using on typical sounds generated by impact such as footfalls or desk and chair movement. A 35 dbA white noise is used as background to determine if it masks the impact noises.

Measures: Impact noise

- Easily discernible noise from 20 feet
- Easily discernible noise from 15 feet
- Easily discernible noise from 10 feet
- Easily discernible noise from 5 feet

## REFERENCES

ASTM E 90-66T, ASTM E 336-67T Transmission of sound through partitions

ASTM C423-66 Sound absorption of acoustical materials (reverberation)

"A Simplified Field Transmission Test", Siekman and Yerges, Sound and Vibration, V.5, #10

NOTE #1: White noise can be found in a telephone dial tone, T.V. station signal before programming begins, interstation hum on radios, etc.

SUMMARY OF ACOUSTICS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PROVIDE AN ACCEPTABLE ACOUSTICAL ENVIRONMENT

TEST # 1: Correct Ambient Sound Level

TEST # 2: Control Sound Transmission Between Spaces

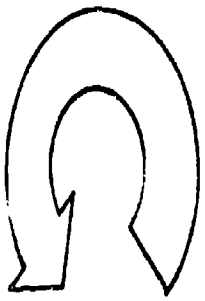
TEST # 3: Control Reverberation Within Spaces

TEST # 4: Control Mechanical Systems' Noise

TEST # 5: Control Impact-Generated Sound Transmission

# HVAC

SUMMARY



The primary objective of the HVAC system is to provide an atmospheric environment including proper thermal conditions, air movement and humidity, responsive to the activities within the building.

Although excellent control of the above attributes is now standard practice in terms of design and installation, the actual operational effect of these attributes has been less studied especially in terms of relationships with other factors such as orientation, windows and performance over time.

## PERFORMANCE OBJECTIVE: PROVIDE PROPER THERMAL ENVIRONMENT

### TEST # 1: Control Dry Bulb Temperature

Test Method: Use a recording thermometer. Long term measurements are made during all seasons of the year in all space types and orientations of the building. Measurements are made at the 5 foot level in the center of the area.

Measures: Dry bulb temperature

- Dry bulb temperature in major spaces during all seasons
- Outside dry bulb temperature during the same period
- Inside dry bulb temperatures for different orientations
- Weather colorations, strong sun, partly cloudy, overcast, storm

## TEST # 2: Control Dry Bulb Temperature

Test Method: Use Test Method #1.

Measure: Thermostat temperature.

-Record thermostat thermometer reading and thermostat setting at the time the dry bulb measurement is made with the recording thermometer.

## TEST # 3: Provide Proper Dry Bulb Temperature in Occupied Zone

Test Method: Same as Test #1. Additional measurements are made five feet above floor level.

Measure: Dry bulb temperature

-Dry bulb temperature at one inch and six feet five inches above floor level.

## TEST # 4: Control Radiant Temperature

Test Method: Use a surface thermometer (Pacific Transducer Corporation, Model 309F: about $10). Measurements are made directly on outside walls and windows.

Measure: Radiant temperature

-Mean radiant temperatures on room surfaces exposed to outdoor environment.

## TEST # 5: Control Humidity

Test Method: Using a Whirling Psychrometer or equivalent gauges, record dry bulb and wet bulb temperatures. Use the same schedule as provided on Test #1.

Measures: Dry bulb, wet bulb temperatures

- Dry bulb and wet bulb temperatures
- Relative humidity using psychrometer chart
- Outdoor relative humidity

## TEST # 6: Control Air Circulation

Test Method: Use either a deflecting air anemometer or smoke from titanium tetrachloride to measure air velocities in occupied zone. Measurements should be made at ankle and neck regions - 2 inches and 5 feet above floor at 1/3 points on both diagonals of the room.

Measure: Air velocity

- Record air velocity in feet per minute

## PERFORMANCE OBJECTIVE: MAINTAIN HEALTH AND SAFETY STANDARDS IN HVAC SYSTEM

## TEST # 7: Control Safety Hazards to Maintenance Staff and Users

Test Method: Interviews with maintenance staff and inspection of facilities and equipment.

Measure: Safety hazards

- Uninsulated 'hot' piping
- Unshielded moving equipment
- Adequate guards and barriers
- Adequate monitoring equipment

Test Method: Same as Test #6

Measure: Frequency of repairs

- Note quantity and quality of unusual maintenance and repairs

REFERENCES

ASHRAE Standard 55-66 Thermal Environment Standards were helpful as well as:

"The Performance Concept", VI., Staff of the National Bureau of Standards, Report 9849, June 1968

'Equipment Test Code 106ZR3", Air Diffusion Council, Chicago, 1972
Another excellent source of HVAC Test Procedures

SUMMARY OF HVAC PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PROVIDE PROPER THERMAL ENVIRONMENT

TEST # 1: Control Dry Bulb Temperature

TEST # 2: Control Dry Bulb Temperature

TEST # 3: Provide Proper Dry Bulb Temperature in Occupied Zone

TEST # 4: Control Radiant Temperature

TEST # 5: Control Humidity

TEST # 6: Control Air Circulation

PERFORMANCE OBJECTIVE: MAINTAIN HEALTH AND SAFETY STANDARDS IN HVAC SYSTEM

TEST # 7: Control Safety Hazards to Maintenance Staff and Users

# TECHNICAL PERFORMANCE FACTORS

| PERFORMANCE TEST | | | | |
|---|---|---|---|---|
| stability | | | | |
| movement | | | | |
| -structural loading | | | | |
| -thermal movement | | | | |
| -setting | | | | |
| impact | | | | |
| air infiltration | | | | |
| moisture infiltration | | | | |
| thermal conductivity | | | | |
| staining | | | | |
| discoloration | | | | |
| delamination | | | | |
| deterioration | | | | |
| aesthetics | | | | |

| PERFORMANCE TEST | | | | |
|---|---|---|---|---|
| drainage (ponding) . . . . . | | | | |
| moisture penetration . . . . . | | | | |
| sag. . . . . | | | | |
| movement . . . . . | | | | |
| deterioration. . . . . | | | | |
| erosion. . . . . | | | | |
| impact . . . . . | | | | |
| indentation. . . . . | | | | |
| brittleness. . . . . | | | | |

| PERFORMANCE TEST | | | | |
|---|---|---|---|---|
| structural stability. . . . . | | | | |
| impact. . . . . | | | | |
| attached loads. . . . . | | | | |
| cohesion. . . . . | | | | |
| delamination. . . . . | | | | |
| wearability . . . . . | | | | |
| indentation . . . . . | | | | |
| abrasion. . . . . | | | | |
| scratch . . . . . | | | | |
| water absorption. . . . . | | | | |
| stain . . . . . | | | | |
| cleanability. . . . . | | | | |
| dust accumulation . . . . . | | | | |
| replacement/repair. . . . . | | | | |
| aesthetics. . . . . | | | | |

| PERFORMANCE TEST | | | | |
|---|---|---|---|---|
| deflection. . . . . | | | | |
| parallel to floor . . . . . | | | | |
| displacement. . . . . | | | | |
| cohesion. . . . . | | | | |
| adhesion. . . . . | | | | |
| indentation (impact). . . . . | | | | |
| scratch . . . . . | | | | |
| staining. . . . . | | | | |
| anthropometric fit. . . . . | | | | |
| color homogeneity . . . . . | | | | |
| flaking/peeling . . . . . | | | | |
| fading. . . . . | | | | |
| dust accumulation . . . . . | | | | |
| cleanability. . . . . | | | | |
| access to plenum. . . . . | | | | |
| replacement/repair. . . . . | | | | |
| out-of-system hardware. . . . . | | | | |
| aesthetics. . . . . | | | | |

| PERFORMANCE TEST | | | | |
|---|---|---|---|---|
| indentation | | | | |
| impact | | | | |
| resiliency | | | | |
| brittleness | | | | |
| cohesion | | | | |
| adhesion | | | | |
| levelness | | | | |
| abrasion | | | | |
| scratch | | | | |
| wear | | | | |
| slip resistance | | | | |
| static discharge | | | | |
| cleanability | | | | |
| dust accumulation | | | | |
| water absorption | | | | |
| delamination | | | | |
| replacement/repair | | | | |
| cigarette burn | | | | |
| color fastness (fading) | | | | |

| | | | | |
|---|---|---|---|---|
| color homogeneity . . . . . | | | | |
| aesthetics. . . . . | | | | |

| PERFORMANCE TEST | | | | |
|---|---|---|---|---|
| illumination - natural . . . . . (footcandles $f_c$) | | | | |
| illumination - artificial . . . . (footcandles $f_c$) | | | | |
| illumination - combined . . . . . (footcandles $f_c$) | | | | |
| shade fully drawn . . . . . (footcandles) | | | | |
| luminaire luminance . . . . . (footlamberts) | | | | |
| room contrast . . . . . ratio | | | | |
| glare . . . . . | | | | |
| task/surround . . . . . contrast ratio | | | | |
| illumination. . . . . | | | | |
| luminance gain (cleaning) . . . . | | | | |

| PERFORMANCE TEST | | | | |
|---|---|---|---|---|
| ambient, sound level: db. . . . . (w/children, lights) | | | | |
| ambient, sound level: db. . . . . (w/o children) | | | | |
| ambient, sound level: db. . . . . (w/o children, lights) | | | | |
| attenuation, db . . . . . (classroom-classroom) | | | | |
| attenuation, db . . . . . (classroom-hall) | | | | |
| reverberation 500hz . . . . . (seconds) 1000hz 2000hz | | | | |
| mechanical systems noise: db. . . | | | | |
| impact-generated noise: db . . . | | | | |

| PERFORMANCE TEST | | | | |
|---|---|---|---|---|
| ambient temp. . . . . | | | | |
| temp. gradient. . . . . | | | | |
| humidity. . . . . | | | | |
| air movement. . . . . | | | | |
| safety hazards. . . . . | | | | |

## FUTURE TEST DEVELOPMENT

The next step in development of field testing will attempt to investigate and develop additional tests in the eight areas of subsystems and attributes.

This will include:

| | |
|---|---|
| Exterior walls | Measurement of movement through the use of gauges |
| | Testing samples for compliance with specifications |
| Roofs | Core sampling |
| Floors | Testing samples for compliance with specifications |
| Lighting | Compatibility of existing tests with visual comfort index (VCI) |
| Acoustics | Articulation index test development for 'open' situations |
| | Use of recording long term ambient levels |
| HVAC | Room air velocity test |
| | Radiant effects measurement building |

| | |
|---|---|
| | Surface/volume and operating costs |
| Economics | A study of the relations between architectural decisions, building costs and life cycle costs. |