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Standard Guide for Evaluating Water Leakage of Building Walls[1]

This standard is issued under the fixed designation E 2128; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes methods for determining and evaluating causes of water leakage of exterior walls. For this purpose, water penetration is considered leakage, and therefore problematic, if it exceeds the planned resistance or temporary retention and drainage capacity of the wall, is causing or is likely to cause premature deterioration of a building or its contents, or is adversely affecting the performance of other components. A wall is considered a system including its exterior and interior finishes, fenestration, structural components and components for maintaining the building interior environment.

1.2 Investigative techniques discussed may be intrusive, disruptive or destructive. It is the responsibility of the investigator to establish the limitations of use, to anticipate and advise of the destructive nature of some procedures, and to plan for patching and selective reconstruction as necessary.

1.3 *This practice does not purport to address all of the safety concerns, if any, associated with its use. Establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Awareness of safety and familiarity with safe procedures are particularly important for above-ground operations on the exterior of a building and destructive investigative procedures which typically are associated with the work described in this guide.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 331 Test Method for Water Penetration of Exterior Windows, Curtain Walls and Doors by Uniform Static Air Pressure Difference[2]

E 514 Test Method for Water Penetration and Leakage Through Masonry[3]

E 547 Test Method for Water Penetration of Exterior Windows, Curtain Walls and Doors by Cyclic Static Air Pressure Differential[2]

E 631 Terminology of Building Construction[2]

E 1105 Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls and Doors by Uniform or Cyclic Static Air Pressure Difference[2]

2.2 *American Architectural Manufacturers Association (AAMA) Standards:*

501.2 Field Check of Metal Storefronts, Curtain Walls and Sloped Glazing Systems for Water Leakage[4]

502 Specification for Field Testing of Windows and Sliding Doors[4]

503 Specification for Field Testing of Metal Storefronts, Curtain Walls and Sloped Glazing Systems[4]

3. Terminology

3.1 Refer to Terminology E 631.

3.2 *Definitions:*

3.2.1 *incidental water*—unplanned water infiltration that penetrates beyond the primary barrier and the flashing or secondary barrier system, of such limited volume that it can escape or evaporate without causing adverse consequences.

3.2.2 *water absorption*—a process in which a material takes in water through its pores and interstices and retains it wholly without transmission.

3.2.3 *water infiltration*—a process in which water passes through a material or between materials in a system and reaches a space that is not directly or intentionally exposed to the water source.

3.2.4 *water leakage*—water that is uncontrolled, exceeds the resistance, retention or discharge capacity of the system, or causes subsequent damage or premature deterioration.

3.2.5 *water penetration*—a process in which water gains access into a material or system by passing through the surface exposed to the water source.

3.2.6 *water permeation*—a process in which water enters, flows and spreads within and discharges from a material.

4. Significance and Use

4.1 This guide is intended to provide building professionals with a comprehensive methodology for evaluating water leakage through walls. It addresses the performance expectations and service history of a wall, the various components of a wall, and the interaction between these components and adjacent construction. It is not intended as a construction quality control procedure, nor as a preconstruction qualification procedure. It is intended for evaluating buildings that exhibit water leakage.

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[1] This guide is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.55 on Exterior Building Wall Systems.

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[2] *Annual Book of ASTM Standards*, Vol 04.11.

[3] *Annual Book of ASTM Standards*, Vol 04.05.

[4] Available from AAMA, 1827 Walden Office Square, Suite 104, Schaumburg, IL 60173–4268.

4.1.1 *Qualifications*—Use of this Guide requires a knowledge of basic physics, and construction and wall design principles and practices.

4.1.2 *Application*—The sequential activities described herein are intended to produce a complete and comprehensive evaluation program, but all activities may not be applicable or necessary for a particular evaluation program. It is the responsibility of the professional using this guide to determine the activities and sequence necessary to properly perform an appropriate leakage evaluation for a specific building.

4.1.3 *Preliminary Assessment*—A preliminary assessment may indicate that water leakage problems are limited to a specific element or portion of a wall. The evaluation of causes may likewise be limited in scope, and the procedures recommended herein abridged according to the professional judgement of the investigator. A statement stipulating the limits of the investigation should be included in the report.

4.1.4 *Expectations*—Expectations about the overall effectiveness of an evaluation program must be reasonable, and in proportion to a defined scope of work and the effort and resources applied to the task. The objective is to be as comprehensive as possible within a defined scope of work. The methodology in this guide is intended to address intrinsic leakage behavior properties of a wall system, leading to conclusions that generally apply to similar locations on the building. Since every possible location is not included in an evaluation program, it is probable that every leak source will not be identified. Leakage sources that are localized and unique may remain, and require additional localized evaluation effort. The potential results and benefits of the evaluation program should not be over-represented.

4.2 This guide is not intended as a design guide or as a guide specification. Reference is made to design features of a wall only for the purpose of identifying items of interest for consideration in the evaluation process.

4.3 This guide does not address leakage through roofs, leakage below grade or water that accumulates due to water vapor migration and condensation. It is not intended for use with structures designed to retain water, such as pools and fountains.

SYSTEMATIC APPROACH TO AN EVALUATION

5. Overview

5.1 The methodology presented in this guide is a systematic approach to evaluating wall leaks, and is applicable to any wall system or material. It differs from other approaches that are material specific or component specific, and which are basically adaptations of quality control procedures. The sequence of activities is intended to lead to an accumulation of information in an orderly and efficient manner, so that each step enhances and supplements the information gathered in the preceding step.

5.1.1 *Sequence of Activities*—The recommended sequence of activities, discussed in individual sections below, are:

5.1.1.1 Review of project documents.

5.1.1.2 Evaluation of design concept.

5.1.1.3 Determination of service history.

5.1.1.4 Inspection.

5.1.1.5 Investigative testing.

5.1.1.6 Analysis.

5.1.1.7 Report preparation.

5.2 *Analysis and Interpretation*—The information systematically gathered during a leakage evaluation is analyzed as it is acquired. The sequential activities described in this guide are not intended to imply that analysis and interpretation of the information occurs only at the completion of all activities.

6. Review of Project Documents

6.1 Ideally, project documents including wall component shop drawings will be available and accessible for review. The discussion in this section assumes that a project was organized on a conventional Owner/Architect/Contractor model. Building projects can be delivered in a variety of ways, and the actual method used will dictate the appropriate organization of the project documents. Regardless of how a project is organized and administered, the information discussed below should be available for review somewhere in the project documents.

6.1.1 *Design, Bidding and Contract Documents*—These documents include architectural and engineering drawings, specifications, and may also include calculations, wind tunnel reports, correspondence, meeting minutes, addenda, substitution proposals, product literature, test reports, etc. They contain the information necessary to understand the performance criteria, the design intent, the required materials, and relationships among wall components.

6.1.1.1 Documents may be revised or supplemented over the course of construction. Revisions to drawings are typically recorded by number and date, with a cross reference to other accompanying documents. Reviewing all revisions and issuances of the documents, and understanding the differences between them and the reason for the differences, is part of a comprehensive evaluation.

6.1.1.2 Documents with the most recent issue date and the highest revision number establish the requirements for the project. Ideally, a set of documents marked "as-built" or "record set" intended to show the actual construction will be available.

6.2 *Referenced Codes and Standards*—Project documents usually contain references to regulatory codes and industry standards. Standards and referenced codes often contain default or minimum criteria that might have been relied upon to establish the performance criteria for the wall. Conflicting requirements between referenced standards and codes, and those explicitly stated in the project documents, should not be assumed to be a cause of leakage without further investigation.

6.2.1 Regulatory codes and industry standards change over time. The version of regulatory codes and industry standards examined as part of the review of project documents should be those listed with dates in the project documents, or if not listed with dates, those in effect when the building permit was issued. Understanding the history and background of referenced codes and standards is part of a comprehensive evaluation.

6.3 *Submittals*—Additional documents are generated after the award of contracts, and are submitted to the design professional for review and inclusion in the project record. The submittals usually apply to a specific material, component, assembly or installation method, and the information contained will augment the project documents. There are often a number of revisions to submittals prior to final approval. The standard for the project is set by the submittals approved by the design professional. Submittals include some or all of the following: shop drawings, test reports, product literature, manufacturers' recommendations, installation and maintenance guidelines, warranties, etc.

6.3.1 Test reports provided by manufacturers and suppliers should have been performed by an independent laboratory or witnessed by an independent agency. Review the test dates and the description of what was tested to determine if and how the information actually applies to the project.

6.3.2 Manufacturers' and suppliers' information, and the exclusionary language in warranties, may suggest circumstances under which a component may not function properly. Project conditions should be evaluated to determine if an appropriate product selection was made.

6.3.3 Submittals should be reviewed for maintenance recommendations and guidelines.

6.4 *Pre-Qualification and Mock-Up Reports*—Compliance with project requirements may have been demonstrated by a mock-up test. Mock-ups of complex wall systems rarely pass all tests on the first attempt. The mock-up report should contain a clear and complete description of changes necessary to pass the test. Project documents should incorporate these changes, and they should be reflected in the actual construction. Failure to incorporate these changes should be considered as a possible cause of water leakage.

6.5 *Additional Construction Documents*—Additional construction documents that record changes, decisions and activities during the construction phase may include bulletins, requests of information (RFI), clarifications, change orders, directives, progress photos, inspection and quality assurance reports, test reports, meeting minutes and correspondence. The information in these documents may augment, modify or supersede the design documents.

6.6 *Local Practices*—Knowledge of local and historical practices will permit a more thorough assessment of the project design and construction. The actual construction may be influenced in an undocumented manner by local practices.

6.7 *Missing Documents*—Project documents may be unavailable or have missing parts. This unfortunate situation will require the determination of existing and as-built conditions. Rather than verifying the information in the project documents, the information may need to be generated from observations and measurements of the building.

7. Evaluation of Design Concept

7.1 *Performance Criteria*—Review of the project documents should reveal what, if any, water resistance performance requirements were specified for the wall. The required water infiltration resistance for manufactured wall components such as windows and curtain walls, expressed as a differential test pressure across the wall to simulate the action of wind-driven rain, is usually stated explicitly in the contract documents. Alternatively, the required resistance may have been implied through references to industry standards or local codes.

7.2 *Efficacy of the Design*—The wall design must be consistent with the performance criteria so that the desired performance can actually be achieved. The design must include properly selected components. The details must provide for the interfacing and integration of components so that each one can perform individually and so that the components can perform collectively as a system. The details must also address issues such as construction tolerances, material compatibilities, volume changes, and movements. A careful evaluation of the efficacy of the design relative to the performance criteria will indicate inconsistencies that may contribute to leakage.

7.2.1 The failure of a single wall component to perform at the specified level does not automatically mean that it was the cause of leakage, particularly if the performance requirements for the component were unnecessarily severe relative to other components. In evaluating the overall wall, it must not be assumed that the cause of leakage is a single component simply because it does not satisfy a performance requirement in the project documents.

7.3 *Exposure*—The performance criteria in the project documents will generally differ from actual exposure conditions. Based on an analysis of local weather conditions, and the location and geometry of the building, identify the actual weather conditions during periods of leakage. These conditions can be correlated with the service history, described in the next section, to help establish a protocol for the evaluation process.

8. Determination of Service History

8.1 Gathering information on the service history related to leakage problems serves several purposes. First, patterns in the observed leakage and visible damage can provide an indication of the cause(s) and where to focus an investigation. Second, and more importantly, the information provides a checklist against which failure theories and conclusions can be evaluated. A comprehensive diagnostic program should result in an explanation for most if not all aspects of the observed leaks and damage.

8.1.1 *Document Physical Symptoms of Leaks*:

8.1.1.1 Make a detailed visual inspection of both the exterior and interior wall surfaces. Locations that should be checked for indications of leakage include but are not limited to:

(a) Intersection of walls with floors and ceilings.

(b) Window, door, vent and louver openings, particularly at corners and mulled joints between units.

(c) Handrail connections.

(d) Intersection of walls with exterior balconies. Balcony features that can contribute to leakage problems are little or no slope away from the wall, absence of a curb under the wall and door, little or no slope to drain grates or scuppers, or handrail base which obstructs drainage.

(e) Utility and building services penetrations.

(f) Below setbacks, where an exterior wall on one floor is above an interior space of the floor below.

(g) Intersection of an exterior wall and a roof plane.

8.1.1.2 Note all indications of past and existing water damage including, but not limited to, the following:

(a) Wet, damp or water-saturated surfaces.

(b) Color differences caused by organic growth, staining, or corrosion.

(c) Surface deposits associated with recrystallization of dissolved materials from within the walls. In masonry construction this is commonly called efflorescence, but it can also occur in other wall types.

(d) Staining indicating the flow or accumulation of water.

(e) Areas repaired or patched due to prior leakage.

(f) Blistering surface finishes that can indicate subsurface wetting.

8.2 *Interviews*—Interview occupants, maintenance personnel, subcontractors, tradesmen or other first-hand observers. Obtain information that will help correlate leakage with building features and other events, such as:

8.2.1 The apparent origination point of a leak.

8.2.2 The exterior environmental conditions under which the leak occurs.

8.2.3 The frequency of occurrence. Is the leak a one-time occurrence under exceptional or extreme conditions, or is it a recurring problem? When was the leak first observed?

8.2.4 For leaks that occur during rains, ascertain if a leak:

8.2.4.1 Occurs immediately after the onset of rain or after a period of time.

8.2.4.2 Stops immediately when the rain stops, or continues for a period of time after the rain ends.

8.2.4.3 Occurs during every rain regardless of severity.

8.2.4.4 Occurs during every, rain regardless of wind direction, or only with wind from a certain directions.

8.2.5 Whether the leak occurs during or immediately after cold weather, with or without accompanying rain. If a leak occurs during cold weather without accompanying rain, it might be due to condensation rather than rain infiltration.

8.2.6 The interior environmental conditions and the building operating conditions under which the leak occurs. Weekend and evening operating conditions may differ from weekday business hour conditions.

8.2.7 Whether the leak appears to be related only to a particular feature or detail.

8.2.8 The performance of the building piping system, including water supply and drainage, heating and air conditioning supply and return, and roof drains. Leaks from the piping system might be misinterpreted as wall leakage.

8.3 *Maintenance and Repair Records*—Buildings with chronic leakage problems are often subjected to several attempts at remediation before a comprehensive evaluation is made. An effort should be made to understand the earlier attempts at repairs because: (*1*) they may indicate a pattern of leakage; (*2*) although well-intended, repairs may be causing or contributing to current leakage; and (*3*) it will be necessary to distinguish between original construction and attempted repairs during the inspection and testing phases of a systematic evaluation. Where appropriate and possible:

8.3.1 Review the original project close-out comments or "punch list" if available. Water infiltration problems often occur early in a building's life, and stop-gap repairs might have been made in an effort to close out the project.

8.3.2 Review purchase orders and/or contracts for building maintenance and repair. Consider roofing, caulking and sealants, painting, waterproofing, removing efflorescence or staining, and other activities that may relate to water leakage problems.

8.3.3 Review maintenance work orders that deal repeatedly with the same leakage problem.

8.3.4 Evaluate the success of previous repair attempts.

8.3.5 Compare original details to actual conditions observed to determine deviations from original construction intent or undocumented repair attempts.

8.3.6 Identify repairs that inadvertently seal weep holes or other openings and paths which are intended to dissipate or weep entrapped water. These might have been sealed in an attempt to stop leaks.

8.3.7 Evaluate the effect of attempted repairs on the original design intent. Common but often ineffective repairs made to leaking walls include the application of additional sealant, and coating of exterior surfaces with clear water repellents or elastomeric coatings. Inappropriate use of these procedures can cause additional problems, for example:

8.3.7.1 Sealant installed at weep holes and other drainage paths can entrap water within the wall assembly. The application of additional sealant should not be made prior to evaluation of the total wall assembly except to correct obvious omissions.

8.3.7.2 Water repellents can affect the performances of future repairs, such as the adhesion of sealants or the bond of repointing mortar. These materials can also reduce the water vapor transmission rate of a wall assembly.

8.3.7.3 Low permeance coatings will reduce the water vapor transmission rate of the wall assembly and can increase the time required for water-saturated walls to dry. The application of these materials can increase the amount of entrapped water if any other uncorrected deficiencies exist.

8.4 *Determine Extent of Leakage*—Use the information gained above to determine the extent of leakage.

8.4.1 Attempt to correlate historical leak occurrences with particular building features and details.

8.4.2 A graphical analysis is useful for correlation studies. Leak occurrences can be superimposed on building drawings to help reveal patterns that might be traceable to potential leak sources.

8.4.3 Consider wall components that might act as conduits or channels for infiltrated water, such as furring strips, board joints, shelf angles, etc. They can cause interior manifestations of a leak to occur at a distance from the exterior points of entry.

8.5 *Weather Records for the Vicinity*

8.5.1 Detailed weather data for a specific time period, typically recorded at major airports, can be obtained from the National Weather Service. The data of particular interest for a leakage evaluation are: precipitation rate, wind speed during precipitation, wind direction, and relative humidity.

8.5.2 Unusual events and severe leakage occurrences should be correlated, and may require additional weather data for specific times.

8.6 *Correlations*—Correlate leak occurrence with other factors such as temperature, wind direction and speed, season of year, building operations.

8.6.1 *Temperature*—Ambient air temperature and wall surface temperature can effect water leakage. Building joints and material cracks are most likely at their widest when ambient temperatures are low, and their narrowest when surface temperatures are high.

8.6.2 *Wind Direction and Speed*—A primary driving force for water leakage of walls is wind-driven rain. The severity and location of leakage can often be correlated to the direction and speed of the wind.

8.6.3 *Season of Year*—Some buildings in northern climates only leak during the winter months. The accumulation of ice and snow on horizontal surfaces can feed water into a wall assembly during clear cold sunny days even when the outside temperature stays below freezing.

8.6.4 *Building Operations*—Although most building HVAC systems operate at a positive pressure, parts of the building could be subjected to negative interior pressures when exposed to certain wind conditions. Negative interior pressure might also result from the "stack effect" due to the difference between interior and exterior temperatures. Portions of a wall might also communicate with return air plenums that are operated at a negative pressure. Negative interior pressure can allow water to enter walls through small openings that might otherwise resist leakage. Building operating pressures are usually very small compared to the effect of wind, and are rarely the sole cause of leakage in occupied spaces. However, in the vicinity of louvers and equipment spaces, mechanically induced pressures can be significant.

9. Inspection

9.1 Inspections complement and extend the information gathered from the review of project documents and the service history. The major objectives of an inspection program are: to determine as-built conditions, determine the current condition of the wall including visible and concealed water damage and apparent water paths, and to formulate initial hypotheses about cause.

9.2 *Determine As-Built Conditions*—The various components of the wall system, including the structural support system, utilities within the wall, thermal and condensation control systems, and the finishes, should all work together to provide the desired wall performance. Project drawings rarely depict the relationship between all of these components of a wall completely and accurately. The inspection process should result in a clear understanding of the relationship between all the parts of a wall system.

9.2.1 *Presentation*—Composite large-scale drawings are helpful in gathering and recording information about as-built conditions. A composite drawing can begin with the best available information from the project documents, including pertinent information from the architectural, structural, mechanical and electrical drawings and specifications, as well as the structural and wall component shop drawings. The investigator must correlate information from these sources based on some reference such as the column centerlines or face-of-wall dimensions. The composite drawing can serve as a form for recording actual field conditions. Differences between information in the project documents and the as-built conditions should be anticipated, and discovery of differences does not necessarily mean that a leak source has been identified. The purpose of accurately determining the as-built condition is to provide a rational basis for further inspection, testing, and remedial recommendations.

9.3 *Determine Current Conditions*—The physical condition of wall components, and visible and concealed evidence of water infiltration, should be documented during the inspection process. This information is later correlated with information from the service history of the wall in formulating a hypothesis on the cause(s) of leakage. Examples of information that should be documented include:

9.3.1 Placement, condition, and resilience of sealants and gaskets.

9.3.2 Functional aspects of drainage systems, such as end dams, weeps, lap and splice configurations, placement of the flashing relative to other components, and obstructions.

9.3.3 Interfaces between wall components. Critical interfaces include the integration of walls and windows; locations where wall materials or support conditions change, and where prefabricated units of the wall are joined.

9.3.4 Interface with other building components, such as copings, penetrations by mechanical equipment or structural supports, foundations.

9.3.5 Wall attachments and appurtenances such as signs and canopies, balconies, and handrails.

9.3.6 Location and size of drip grooves or drip edges at the underside of horizontal surfaces.

9.3.7 Other possible mechanisms for water entry into a wall or migration within a wall, such as capillary action or air movements causing percolation.

9.3.8 Material conditions, including symptoms of deterioration, freeze-thaw damage, prolonged saturation, delaminations, adhesive or cohesive material failures, efflorescence and water-related damage to finishes.

9.3.9 Indications of wear and tear, maintenance, attempted repairs, damage from non-weather-related causes such as impacts, unaccommodated volume changes or structural movements.

9.3.10 General assessment of workmanship and compliance with specified installation and execution as it affects water penetration.

9.4 *Determine Water Paths*—Inspections produce information on water paths resulting from the service conditions of the building. The significance of water paths that are induced during testing can not be properly evaluated without information about water paths from service conditions.

9.5 *Planning*—Inspections conducted in a planned and orderly fashion are the most efficient and effective way to produce useful results. Planning is also necessary when concurrent sampling and testing are incorporated in the inspection program. The inspection plan should addresses the following issues:

9.5.1 *Scope*—Both typical and atypical conditions should be included. It is particularly important to include the terminations and interfaces of the components being inspected, such as corners, ends, tops, bottoms, joints, transitions to other materials or changes in geometry. The inspection should also include both non-performing and properly performing locations, if any exist. The differences between non-performing and properly performing locations can provide useful information about the cause(s) of leaks. The objective of the inspection program is to acquire information about the intrinsic properties of the wall system so that conclusions reached are applicable to all similar locations in the wall. A sufficient number of inspection locations must be selected to accomplish this objective. If constraints on the inspection program preclude a sufficient number of locations, the results should be so qualified.

9.5.2 *Selection*—It is normally not necessary to inspect an entire building facade except in special situations such as where safety is an issue. The selection of inspection areas is based primarily on the service history, review of project documents and accessibility. Limitations of resources will often require the selection of inspection areas from seemingly equal choices. A preliminary inspection using rapid methods of limited detail can help in the rational selection of areas where more detailed methods are warranted.

9.5.3 *Access*—Both interior and exterior access for close-up inspection should be pre-arranged with the building owner. Interior access may require temporarily moving furniture, removing interior finish materials, or relocating or suspending the use of a space, and might have a significant temporary impact on use of the space. Exterior access will probably require the assistance of a contractor to erect scaffolding and walkway protection, provide a boom truck or rig a swing stage. Possible damage to the building resulting from the access equipment should also be considered, and either avoided or corrected.

9.5.4 *Organizing Information*—A comprehensive inspection will generate a large amount of data. Determining how the information will be recorded and organized is part of the planning process. Building drawings can be made beforehand and used to record observations, thereby making the location of the information self-evident. Symbols and shorthand notations can be developed and tabulated beforehand. It is sometimes useful to establish a numbering system based on column lines, swing stage drops, floor number, wall component within a typical module, etc., rather than repeating lengthy location identifications using words.

9.6 *Methods*—Inspection methods range from rapid visual inspections using binoculars or a telescope, to close-up observations and inspection openings. The method used depends on the information required. Rapid methods are particularly useful for preliminary inspections and to narrow the scope of more detailed inspections. A comprehensive inspection program will include some method for observing or evaluating concealed conditions, such as inspection openings, borescope probes, moisture meters and detectors, mechanical penetrators or infrared thermography scans.

9.6.1 Inspection openings involve the progressive removal of wall materials to reveal underlying, concealed conditions. Each layer may be changed or destroyed during the process, so it is desirable for the investigator to be present during the operation and to document each step. Possible safety issues such as the presence of asbestos, lead paint and toxins must be considered, and the necessary precautions taken.

9.6.2 An inspection mirror with an adjustable head and a flashlight, are useful tools for viewing concealed conditions through confined openings in much the same way that a dentist uses a mirror.

9.6.3 A fiber-optic borescope makes it possible to observe and photograph concealed conditions while making only a small diameter hole in the outer layers of a wall. It is most useful where there is an empty cavity space in the wall so the light from the scope can disperse, and the field of view can be targeted to items of interest.

9.6.4 Moisture detectors of the capacitance/impedance type and moisture meters of the resistance type make it possible to estimate the moisture content of concealed wall materials. High moisture content can indicate proximity to a water entry point or location along a water migration path. Plotting the measured relative moisture content on a grid superimposed on a building drawing can provide a diagram of wetted area resulting from leak. Care must be taken in interpreting the absolute values of readings reported by these instruments, since calibration and operating technique can affect the readings.

9.6.5 Mechanical penetrators provide an indication of the extent of deterioration caused by prolonged exposure to water by the way some materials, such as wood or gypsum board products, resist penetration by a sharp object. The tactile resistance to penetration decreases as deterioration of these materials increase. Any sharp object, such as a awl, ice pick or nail can be used. Some commercially available devices have a calibrated spring that produces a consistent force at the tip of the penetrator.

9.6.6 Infrared thermography produces an image that, with proper interpretation, can indicate conditions such as air movements through a wall, concealed water within the wall, and saturated wall materials. Infrared thermography is a specialized technology, and should be performed and interpreted with the assistance of a specialist knowledgeable in the technology.

9.7 *Documentation*—Inspection findings should be recorded in writing, with clarifying sketches where appropriate. The documentation should be supplemented graphically with photographs, video or dictated notes, but these should not normally be relied upon as the sole record of the inspection process because of the risk of accidental erasure, undetected camera or recorder malfunctions or processing accidents.

9.7.1 Written documentation should be complete enough for the evaluation process to be repeated, as well as for the information gathered to be interpreted in determining the cause(s) of leaks. In addition to carefully recording observations, the following should be considered in making the written documentation:

9.7.1.1 The location of the observation should be clearly defined. References to column lines and floors can be used.

9.7.1.2 Preliminary opinions formed and interpretations made during the inspection should be recorded separately from the inspection notes, and be distinct from observations of fact and measurements.

9.7.1.3 Keys for codified shorthand notations and symbols should be given. Undefined cryptic shorthand should be avoided.

9.7.1.4 If the procedure used is not self-evident, it should be described in detail.

9.7.1.5 The sequence of the inspection process should be clear from the written documentation.

9.7.1.6 The date, time, and name of the person(s) making the observation, should be recorded for each data sheet.

9.7.2 Supplementary photographs and video are useful for informing others of the inspection procedures and observations, and provide an opportunity to reconsider or check findings at a later date. In making photographs or video recordings, the following should be considered:

9.7.2.1 It should be possible to orient the pictures. This may require a progression of photos from wide to narrow view, or zooming from wide to narrow view with a video camera. Including something of known size in a photograph will help viewers determine the size of the object of interest. For example, a person or a piece of equipment such as a pocket knife can be used. For a more accurate reference, a ruler or an extended length of a carpenter's tape can be included in the picture.

9.7.2.2 The location of a picture should be identified. Labels in the picture, or markings directly on the wall, are useful for this purpose.

9.7.2.3 If the object of interest in a photograph is a crack or a split, it is helpful to add a pointer to focus attention, or to insert a tool in the crack. Cracks with low contrast do not photograph well, and enhancing the path of a crack by drawing a line next to it in a contrasting color can also be helpful. It is also sometimes helpful to intentionally cast a shadow over a small or faint object of interest to reduce the overall contrast of a photograph.

9.7.2.4 Automatically recording a sequential number or the time and date on the film, or including the time and date in the photo label, maybe helpful in organizing the pictures.

10. Investigative Testing

10.1 Testing can be an integral part of the evaluation process, and should be thought of as a means to verify and extend hypotheses arrived at during the document review and inspection phases of the program using controlled and reproducible procedures. Implementing testing before completing the preceding steps in a systematic approach may significantly limit the potential benefits of the test, and more importantly, can lead to incorrect conclusions. At the very least, skipping the preceding steps will reduce the efficiency and effectiveness of on-site testing efforts. Some leakage problems can be diagnosed and corrected with little or no testing.

10.1.1 *Objectives*:

10.1.1.1 *Recreate Leaks*—The primary purpose of investigative testing is to recreate leaks that are known to occur. Investigative testing is not intended to demonstrate code compliance or compliance with project documents unless such deviations are actually related to the leakage problem.

10.1.1.2 *Trace Internal Path of the Leak*—Leakage paths within a wall are difficult to trace during a rain. Testing provides the opportunity to recreate the leakage and water migration paths under controlled and reproducible conditions. The paths observed during testing should be compared to evidence of water paths during actual leaks by assessing existing concealed staining, damage and residue accumulation.

10.1.1.3 *Correlate Test Results with Observed Damage*—The test procedure should reproduce the observed in-service leakage behavior. Creating new leaks during a test may be useful information, but it is not a valid assessment of the existing leakage problem.

10.1.1.4 *Verify Hypothesis*—The controlled conditions during a test are an opportunity to verify hypotheses about the cause of leakage. If a theory on the cause of a leak cannot be demonstrated by a reasonable and appropriate test, the theory is questionable. Remedial recommendations should not be based on unverified theories.

10.2 *Planning*:

10.2.1 *Service History*—The service history of the building and the environmental exposure history of the site must be considered in planning a testing program. To the extent practical, the selected test method should simulate the actual conditions under which leakage has been observed.

10.2.2 Investigative testing is a diagnostic procedure, not a quality assurance procedure. A distinction must be made between leak causation and compliance with design criteria. Focusing on the design criteria may interfere with the diagnostic objectives of testing. Testing at an environmental exposure level that the building has never experienced and has little likelihood of experiencing may lead to incorrect conclusions.

10.2.3 For diagnostic purposes, a wall should be tested in its current as-found condition if the cause of the current leaks is to be determined. Upgrading components of a wall to their original construction condition, or to their original design intent, so that they can "pass the test" and be exonerated prevents the acquisition of important information about current behavior. If original construction conditions or compliance with the original design intent are of interest, those tests can be performed separately after the diagnostic tests.

10.2.4 Previous remedial measures and modifications must be accounted for in the test plan. It may be desirable to undo modifications prior to or during testing to limit confusion, particularly if the modifications can be readily identified and have proven to be ineffective.

10.2.5 Both technical and non-technical constraints can affect the choice of a test method. Testing costs can vary significantly depending on the methods utilized. The evaluation budget and the agreed scope of work can be an important consideration. An owner may establish limitations on access due to cost, safety, security or operational requirements, and may require that disruption of normal building operations be limited.

10.2.6 If repeated modifications and retesting are anticipated, particularly for isolation protocols using selective masking or for the development of repairs, the selected test method must accommodate repeated access to the interior and exterior of the wall without compromising the reproducibility of the test. The selected test method should not require complete disassembly of the test setup for each cycle of access. Gasketed access doors and hatches, and adequate working space within a test chamber, can make repeated removal of the chamber unnecessary.

10.2.7 Diagnostic testing methods can be adapted from standard test methods such as E 331, E 547 and E 514, to meet specific objectives for a particular building, and do not necessarily conform in every way to standard test methods. Diagnostic testing can also be adapted from in-service quality assurance testing procedures such as E 1105, AAMA 502 and AAMA 503. Therefore, agreement on testing methods and interpretation of results should be reached between the interested parties before testing begins. Items that should be addressed by the interested parties include:

10.2.7.1 Test criteria, methods, frequency and location.

10.2.7.2 Participation of interested parties, and opportunity for close-up examination of test location and test set up.

10.2.7.3 Innermost acceptable migration of water.

10.2.7.4 Documentation.

10.2.7.5 Effects of age and use/abuse.

10.2.8 *Testing Duration*—Judgement is needed in determining the duration of water testing, recognizing that the ultimate objective of diagnostic testing is to recreate existing leakage behavior that occurs under in-service conditions. Factors that may influence the test duration required to recreate leakage paths include wall construction details, the potential length of internal leakage paths, the absorption properties of exposed and concealed materials, and internal storage capacity. For example, water may leak more readily and more immediately through a glass and metal curtain wall system than through a thick, multi-wythe masonry wall. Testing durations specified for new construction quality control testing may not be sufficient for a leakage diagnosis if in-service leaks indicated by the service history cannot be recreated within that time. The investigator must analyze the building service history to establish a useful and realistic test duration.

10.3 *Methods and Equipment*—Testing under controlled and reproducible conditions to recreate leaks can be divided into two broad categories: (*1*) methods that simulate surface flow; and (*2*) methods that simulate wind-driven rain.

10.3.1 *Simulating Surface Flow*—Water flows down the face of a wall by gravity. This flow is capable of causing leaks under some circumstances even without wind-induced differential pressure. Surface flow can be simulated by wetting a wall area with a matrix of uniformly spaced spray nozzles that deposit a full film of water. The customary spray rate is between 4 and 10 gallons per square foot per hour, nominally averaging 5 gallons per square foot per hour, and is intended to deliver a continuous water film to the test area, rather than to simulate a particular rain event. Tests to simulate surface flow alone, without differential pressure, are a useful first test. Other methods of depositing a surface film of water for diagnosing leaks include soaker hoses or a trickle of water from an ordinary hose. Soaker hoses or a trickle of water have been particularly useful in diagnosing problems with drip edges and small overhangs.

10.3.2 *Simulating Wind-Driven Rain*—Wind-driven rain produces leaks because of the kinetic energy of the rain drops and the differential pressure caused by the wind. Under some wind conditions, rain water deposited on the face of a building may actually flow upward. Capillary action and absorption may also be operative.

10.3.2.1 The effect of differential air pressure on the leakage mechanism can be simulated with the use of a chamber capable of being pressurized. The chamber is sealed to the wall test area, and a positive pressure is created by blowers if the chamber is on the exterior, or a negative (vacuum) pressure is created if it is on the interior. A matrix of spray nozzles is used to deposit a uniform flow of water onto the exterior surface. The flow rate is customarily between 4 and 10 gallons per square foot per hour with a target average of 5 gallons per square foot per hour. Standard methods using differential pressure are E 1105, AAMA 502 and AAMA 503, each of which include calibration requirements for the water spray rack. The required pressure is differential, meaning the difference in pressure between the exterior and interior faces. The pressure measuring device, such as a manometer, should therefore be referenced in a similar manner to limit the effects of wind fluctuations or building operations during the test. The simple act of opening an interior door can have a significant effect on the actual differential pressure across the test area that a manometer will not register correctly unless the reference side of the manometer is properly located.

10.3.2.2 The effect of kinetic energy can be simulated by spray testing with a calibrated nozzle operating at a prescribed pressure at a specific distance from the test surface, and moved at a specified sweep rate as described in AAMA 501.2. This method is intended primarily for wall systems with non-operating joints, but it has also proven useful for other diagnostic purposes.

10.3.2.3 A hydrostatic head can be used to simulate differential pressure. A confined test area can be flooded, and the height of the water head correlated to a static differential pressure. Sill sections are often tested in this manner after the weeps are temporarily blocked, as described in AAMA 502, 2.1. Vertical surfaces can also be tested this way if a small trough is fabricated from wax, putty or tape and adhered to the surface. Troughs are useful for localized testing of joints, cracks, gaskets, etc.

10.3.2.4 Spray testing using a calibrated nozzle, and flood testing, may not simulate all of the effects of differential pressure or the ability of air moving through cracks or openings to transport water by percolation.

10.3.3 Testing of isolated areas usually begins at the bottom of the test area, and progresses vertically to the top as selective masking is removed or as selective testing with a calibrated nozzle advances. Starting at the bottom helps eliminate ambiguity about the origin of a leak that might result from water running vertically down the surface of the test area.

10.4 *Tracing Leaks*—Once testing reproduces an in-service leak, the entry point and the path followed by the water within and through the wall must be traced. A single entry point may lead to several concealed water paths or several entry points may merge together internally. Every contributory source to each water path must be identified if a complete diagnosis and repair is to be developed. Tools that are useful for tracing leaks include:

10.4.1 Flashlight and mirror.

10.4.2 Optical Borescope.

10.4.3 Infrared thermography.

10.4.4 Paper strips or other absorbent materials that can be used to probe concealed spaces for indications of water.

10.4.5 Smoke pencil that can be used to expose air paths leading to water percolation.

10.4.6 Moisture meters.

10.5 *Isolation*—Effective diagnostic testing should result in the identification of entry points, not just a "pass or fail" result. Selective masking of the exterior is useful for controlling the components exposed to the test water source. If a leak is induced, only those components exposed to the water source need to be considered in identifying the entry points. Selective masking can then be progressively removed and the wall retested, exposing more and more of the wall to the test water source until the entire area of interest is exposed.

10.5.1 It may also be useful to temporarily repair a water entry source during a progressive testing program to eliminate it from further consideration during the test. Thorough record keeping and clearly identifiable temporary repairs are necessary if this technique is used.

10.5.2 Materials that are useful for selective masking and temporary selective repairs include duct tape, 6 mil clear plastic sheeting, wax, and silicone sealants. Drying with a heat gun or hair dryer, or wiping with alcohol, or priming with a spray adhesive may be necessary before attempting to adhere selective masking materials to wet surfaces. Sealants must be allowed to at least skin over or they can be washed away by further testing.

11. Analysis

11.1 The objectives of an evaluation program are broader than the objectives of a standard test. A test may have a pass/fail criteria for the result of a standardized test that is completely described by reference to its name and the relevant test standard. An evaluation is conducted in response to a problem situation and a non-performing wall, and may involve several techniques and procedures specifically adapted and applied in a systematic manner to diagnose a specific problem.

11.2 The information systematically accumulated in a leakage evaluation is analyzed as it is acquired. The information may motivate a change in approach or focus for subsequent steps in the evaluation process.

11.3 The evaluator is expected to establish a cause and effect relationship between wall characteristics and observed leakage. This requires an appropriate selection of activities and a logical analysis and interpretation of the acquired information. The analysis will address issues such as:

11.3.1 Reduction of quantitative data.

11.3.2 Resolution of conflicting data and observations.

11.3.3 Patterns and commonalities in the data and observations.

11.3.4 Identification and explanation of anomalies.

11.3.5 Correlation with known wall performance.

11.3.6 Significance of an observation or measurement, and its relevance to the behavior of the entire facade.

11.3.7 Corroboration between various procedures used.

11.4 The conclusions and findings from an evaluation must be rationally based on the activities and procedures undertaken and the information acquired, if they are to be considered legitimate and substantiated.

11.5 The record should be sufficiently complete so that any interested party can duplicate the evaluation program and acquire similar information. Notes on the analysis and interpretation of the acquired information should be clear and complete enough to be understood by any other building professional skilled in leakage evaluation.

12. Report Preparation

12.1 Prepare a report describing the conditions under which the evaluation was conducted, the methodology used, the observations and measurements made, and the findings and conclusions. The report should be comprehensive so that it will serve as a permanent addition to the project record. Reports issued by the investigator should be prepared on paper with a letterhead, logo or some other feature that will make it distinguishable from copies.

12.2 Use a writing style appropriate to the intended reader of the report, and also anticipate that the report may be reviewed by other building professionals.

12.3 *Organization of Report*

12.3.1 Generally, a report of the evaluation should contain the following sections in the sequence listed:

12.3.1.1 Title page with mandatory information.

12.3.1.2 Executive summary.

12.3.1.3 Statement of objective or scope.

12.3.1.4 Description of evaluation process, with rationale for selection.

12.3.1.5 Analysis of acquired information.

12.3.1.6 Identification of cause(s) of leakage.

12.3.1.7 Distribution list.

12.3.2 Not all of the above headings may be required. Other more appropriate headings may be used, if they better describe the content and scope of work.

12.3.3 When the expected readership includes both construction professionals and laymen, a summary of background information, methodology and findings in non-technical language may be useful.

12.4 *Title Page with Mandatory Information*

12.4.1 *Title*—brief but definitive, including identification of the building.

12.4.2 *Author*—first name and surname, and any professional registration, included in a by-line for positive identification. This information may also be presented on a signature page at the end of the report.

12.4.3 *Date(s)* of evaluation and tests, and date of report.

12.4.4 *Evaluating Agency* with mailing address.

12.4.5 *Sponsoring Agency* with mailing address.

12.5 *Executive Summary*—Provide a concise statement of the investigation findings and recommendations, for use by a reader who does not have the time or construction background to utilize the detailed information in the body of the report.

12.6 *Statement of Objective or Scope*—State the reason(s) for undertaking the evaluation and the scope of the evaluation, including limitations.

12.7 *Description of the Evaluation Process*—Describe the methodology used in the evaluation process. Where appropriate, put the steps in the evaluation process in context by giving a rationale that associates the steps with the objectives.

12.7.1 *Sources of Information*—List or describe the project documents, product literature, standards, reports by others, etc., reviewed in the course of the evaluation. Information generated by others that was relied upon in the evaluation should be clearly identified.

12.7.2 *Performance Criteria*—List specific performance criteria relevant to the evaluation, including wind loading, structural loading, deflection limits, temperature ranges. Any differences between the performance criteria used in the original design of the wall and criteria used for the evaluation must be clearly identified.

12.7.3 *Description of Design Intent*—Describe the specific methods, components, systems, etc. intended to resist water leakage. Identify items critical to performance of the wall system with respect to water leakage, such as method(s) to accommodate volumetric changes and structural movements, material compatibility, pressurization, drainage, etc.

12.7.4 *Description of the Wall Components or System(s)*—Describe materials, primary components, dimensions, include sketches and/or photographs as necessary. Describe the physical condition of the wall assembly, including damage, deterioration, normal wear, prior repair attempts.

12.7.5 *Service History*—Describe the known performance record of the wall system, including the physical symptoms of water leakage, progression of leakage behavior, maintenance and repair history, extent and locations of leakage, correlation of leaks with wind direction, building operations, season, etc.

12.7.6 *Inspection*—Describe methods used in inspection of the wall system, including access, equipment, and documentation.

12.7.7 *Testing*—Describe the tests performed, including access, equipment, sequence and modification made to the test area. Include reference to industry standards for test methods and identify adaptation and modifications made to the standard test methods.

12.7.8 *Conformance with Design Intent*—Describe any observed variations in the as-built wall assembly from the design, including any apparent modifications or prior repairs to the wall. The discussion can be qualified and limited to differences that are relevant to the causes of leakage.

12.8 *Analysis of Acquired Information*—Describe the analysis of observations and measurements in a manner appropriate to the scope of the report.

12.9 *Identify Cause(s) of Leakage*—List or describe those elements or components of the system that contribute to the leakage. Describe the point(s) of water entry, and the internal path(s) of the leakage. Describe the cause-and-effect relationship between wall characteristics and observed leakage.

13. Keywords

13.1 evaluation; inspection; testing; water leakage

ANNEX

(Mandatory Information)

A1. BACKGROUND

A1.1 Consequences of Leaks

A1.1.1 Water leakage in exterior walls of buildings has a broad range of possible effects. Water that penetrates through a wall assembly can result in wetting of interior finish materials, including interior sills, wall finishes, drywall, insulation, and floor and ceiling finishes. Intermittent or prolonged contact with water can cause component damage, including corrosion of connection materials and embedded reinforcing, wetting and loss of "R" value in insulating materials, mildew and bacterial growth, peeling of paints, efflorescence in masonry and mortars, deterioration of concealed sealants, and damage to perimeter seals in insulating glass units, among other effects. Water leakage within a wall system is sometimes not observed on the interior surfaces, but remains hidden within the wall, ceiling and/or floor systems. Trapped and concealed water can contribute to significant deterioration. Water leakage can also contribute to freeze/thaw damage of a wall system.

A1.2 Performance Criteria

A1.2.1 Performance requirements of exterior wall assemblies and fenestration are established by the project contract documents and the building codes. Criteria relating to structural integrity are typically mandated by the building code, which will control thickness and/or types of glass, required strength and stiffness of framing members and connections. Geographic location is considered in establishing performance criteria for design wind pressures, hurricanes, seismic movements, thermal performance, and condensation resistance. Occupancy type will establish the relative importance of the various performance aspects of the system. Criteria for air infiltration and water penetration should be established by the specifier, with a clear understanding of these considerations. The air infiltration and water penetration criteria are typically demonstrated by testing of prototype units or project mock-ups under laboratory test conditions and may be verified as part of a quality assurance program during construction.

A1.3 Maintenance

A1.3.1 Performance criteria for new construction are specified as a means of establishing the relative quality of the assemblies, and their expected performance characteristics. The long term performance of installed systems will require a program of regular maintenance of various components of the system, consistent with their specific material characteristics. The long-term performance of exterior seals, sealants, and water-proofing membranes require particular attention.

A1.4 Sources of Water

A1.4.1 Water leakage through exterior wall assemblies can come from several possible sources. Rain on the exterior surface of a wall may lead to some degree of penetration, due to the effects of gravity, surface tension, kinetic energy or capillary action. Wind-driven rain, which wets an assembly under a pressure differential, can force water through small openings, seams, and cracks in the assemblies or over the top of barriers with insufficient height. Air moving through openings in an assembly can transport water by percolation.

A1.4.2 Penetration of wall assemblies can occur at discontinuities between materials such as at mortar joints, cracked or damaged materials, gaps in sealants, window joinery, gasketed or weatherstripped operable joints, splices, butt joints, expansion joints, or due to failed or omitted flashing, missing or damaged end dams, or blocked or improperly executed weeps.

A1.4.3 Permeation of the wall materials is the process of water passing through a component such as a porous brick or concrete block. Permeation of walls incorporating porous materials should be anticipated in the design, and the wall detailed accordingly. Excessive or unanticipated permeation of wall materials can be a symptom of material deficiencies or misapplication.

A1.4.4 The direction of water movement on the wall surface is determined by the combined effects of gravity, surface tension and wind velocity. The effects of wind velocity can be greater than the effects of gravity, resulting in regions of the wall where wind-driven rain actually flows upwards or sideways.

A1.4.5 Surface tension can cause water to cling to and migrate along horizontal surfaces, thereby wetting areas not directly exposed to rain or in the path of water flowing down the face of a building. Drip grooves at the edge of horizontal overhangs are intended to interrupt the effects of surface tension.

A1.4.6 Water can penetrate a wall by being transported along a stream of moving air. It will percolate across barriers or through cracks and holes. Control of penetrating water usually also requires considering the control of air movement.

A1.4.7 Interfaces between vertical and horizontal surfaces are often subjected to large amounts of water due to sheeting action along the vertical surfaces. Areas where water accumulates in large amounts on the horizontal surfaces are particularly vulnerable to eventual water penetration. The proper design and functioning of interface joinery, sealants and closures between vertical and horizontal elements are essential to the performance of the system.

A1.4.8 Water retained within cavities or absorbed by material components of wall systems can cause significant damage if it freezes. Snow and ice can block drainage systems designed to accommodate water, thereby preventing these systems from functioning properly. The service history and conditions under which leakage occurs are particularly important in evaluating leaks of this type because they might not be recreated during diagnostic testing.

A1.5 Methods of Resisting Leaks

A1.5.1 The intended behavior of a wall system is determined by the principles of physics applied in its design. Evaluating wall leakage requires an understanding of the design of the wall system, the materials used, and the conditions of exposure.

A1.5.2 The "first line of defense" against water penetration is the exterior exposed surfaces of the wall system. In order for leakage to occur, water must first penetrate the outer surfaces. The ability of a wall to resist leakage may or may not be totally dependent on the "first line of defense".

A1.5.3 The design of a wall system can be described in two broad categories: barrier walls and water managed walls. A wall system may have characteristics of both a barrier and a drainage wall in various combinations. Every wall must have an identifiable mechanism to resist leakage, whether it is a distinct barrier material whose only function is to resist the movement of water toward the interior, or a combination of several wall elements intended to function together to provide leakage resistance. The anticipated volume of rain penetration, the method of controlling rain that penetrates, the location of a barrier within the wall assembly, the interaction of the wall components, the materials used, and the exposure of the barrier to environmental wind pressure and rain, determine how a wall is intended to function and how it is categorized. Terms and definitions describing the mechanics of a wall system are currently evolving, and are being influenced by new wall concepts and a better understanding of existing wall concepts. The discussion below is presented for information only, and does not necessarily represent consensus definitions at this time.

A1.5.3.1 *Barrier Walls*—The mechanism intended to prevent leakage in this type of wall is blocking or interrupting the movement of water to the interior.

(a) Mass Barrier—The thickness and properties of wall materials are relied upon to provide a barrier. The wall mass itself may absorb water, but permeation to the interior is prevented by sufficient thickness and absorption capacity, or a layer with low permeability within the wall. Examples: solid multi-wythe masonry and stone walls; masonry walls with filled collar joints.

(b) Face-Sealed Barrier—The exterior surfaces are relied upon as the only barrier. All joints and interfaces must be sealed to provide a continuous exterior barrier, and the absorption properties of the materials must also be controlled. The materials within the wall assembly must be able to sustain occasional short-term wetting as might occur between maintenance cycles of the exterior seals or from unintended incidental water infiltration. The system can also incorporate a secondary water resistant system in selected areas where incidental infiltration is anticipated. Examples: precast concrete panels; some prefabricated metal or stone panels; adhered EIFS systems.

A1.5.4 *Water Managed Walls*—The mechanism intended to prevent leakage in this type of wall is the control and discharge of anticipated and accepted amounts of water that penetrates the exterior surfaces.

(a) Drainage Walls—Penetrating water is intended to reach a cavity incorporated within the wall and then to flow towards a flashing or drainage system, where it is discharged to the exterior. Water within the cavity is intended to flow freely and not be retained. Therefore, the cavity must be wide enough so that surface tension does not cause water retention, and must be relatively free of obstructions and construction debris. If water can cross to the interior side of the cavity at intended bridging