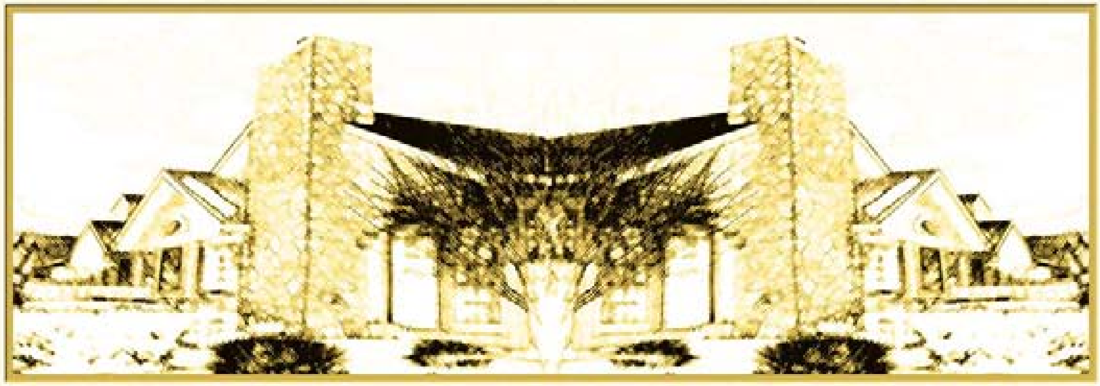
The Art of Replicating and Sourcing Leaks to the Interior of Buildings;

Engineered Doctrine or Applied Fundamentals?



By Don Kilpatrick

Mankind has been building structures for the express intent of comfort and protection from the elements for thousands of years. It could be said that the primary, most desirable aspects of our built environment – most notably those structures intended to house people – are those specific to comfortable, dry, leak-free occupancy. Generally speaking, departures from the "entitled" dry occupancy are not well received by those dealing with the realities of stained interior finishes and the all-too-real threat of mold. Invariably, the source(s) of these objectionable performance characteristics is determined to be related to an ever-present nuisance leak that has typically been occurring since the purchase agreement was signed.

These nagging water entry problems can significantly detract from what might otherwise have been a successful new development or addition to an existing structure. Initial accolades for the developer, architect, general, and subcontractors have quickly turned sour, and the blame game begins, with the end user leading the charge. At the end of the day, each of these parties will be called upon to participate in fixing the problem, fully expected to bear a portion of the costs for remedial repairs to a building where the expected leak-free environment was either never established or was determined to be of questionable integrity soon after occupancy.

Increasingly, roof consultants find themselves fulfilling the role of "building envelope scientist," referee, or expert witness, engaged by facility owners to source recurring leakage in structures. Recognizing the shortcomings of our built environment (leakage to the building interior), standards for water testing have been developed. There are currently many prescribed standard test methods for water passing through the combined wall and window construction, including, but not limited to, the following:

ASTM E-1105, Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls, and Doors by Uniform or Cyclic Static Air Pressure Difference.

Through this standard, a wall or cladding assembly is subjected to negative pressure from the inside while water of a known volume and pressure is uniformly applied to what would be considered the exterior of the test assembly or existing structure. The test requires skilled operators installing blowers and manometers, calibrated spray racks, and isolation of the test area with temporary, airtight walls (floor to ceiling) to maintain the requisite negative pressure against the test area. Based on the above, it can be expected that some interior disruption (beyond the apparent leak) will occur.

The engineering community has established fees for this test method in the range of $7,000 to $10,000 per test. Price alone may be cause enough to give serious consideration to other methods of leak sourcing; or, at a minimum, some legwork ahead of the expensive and obtrusive big guns, which may include the AAMA 501 test procedure.

The AAMA (American Architectural Manufacturers Association) 501

The AAMA (American Architectural Manufacturers Association) 501 leak-sourcing test procedure is a simpler means to water-test cladding features. It may be considered appropriate for some architectural metal cladding systems. This test is much more economical than its ASTM counterparts, with up-front investment limited to the purchase of a proprietary, Monarch-calibrated spray nozzle, and a garden hose. The procedure directs the user to point and pass the nozzle across the feature of the cladding assembly thought to be contributory to a leak. This specially calibrated nozzle comes equipped with a pressure gauge so the operator can make sure the prescribed pressure of 35 psi is achieved during the test.

Right: Photo 1 – Damage to interior finishes at basement floor line.

Below: Photo 2 – Typical wood-framed, stone-clad chimney enclosure.

Failure to comply to the letter of either procedure could impeach the results, with attorneys quickly dismissing any of the findings as irrelevant. This is the unfortunate reality of an engineering community caught up in analysis paralysis. These standards are based on rigid test criteria that seem hopelessly centered on everything but the fact that the described leakage to the building interior is usually weather related. Buildings and their respective latent defects aren't particular about spray racks, blowers, negative pressure, and manometers. The tests are simply a means to replicate ambient and mechanical system conditions that may contribute to the leak.

It is not being suggested that the above-cited standard tests have no place in the industry. ASTM standards are routinely used as "acceptance tests" for window assemblies prior to installation – either at the factory or in one of the many labs that are equipped to perform the procedures. This is a good thing, as it establishes baseline performance characteristics (usually minimum standards) for the product prior to or as installed after sale. Other standards are established for *in situ* testing of the same products. The groups that develop the language and testing protocols for the varied cladding assemblies (including windows and doors) should give consideration to developing minimum performance standards for everything around them. This would include flashings and the form, function, and continuity of drainage planes.

Most in the industry who have promoted leak sourcing as a service area quickly realize the majority of investigations invariably spotlight these system features as contributory to the cause of leakage. This should be painfully evident to the roof consultant considering adding wall investigations to his or her portfolio of services. A wall with windows, doors, and flashings is nothing more than a low-sloped roof presented on a vertical plane.

Water entry into buildings is usually the result of latent defects in one or more components of the envelope assembly. These leaks typically occur from a combination of flawed design, the use of materials of inferior quality with questionable performance histories, and poor workmanship. The ability to locate, define, and replicate the described pattern(s) of water entry is an art in itself that normally can be practiced

Photo 3 – The "U"-shaped pattern established as the wet stone cladding began to dry.

without following the nomenclature presented in the ASTM and AAMA test protocols.

Reasonable success in analyzing leaks can be achieved using means and methods that don't necessarily require any of the aforementioned special equipment or, for that matter, any recognition of the standards and their respective test protocols whatsoever. "What?" you say. "Perform a test in the absence of direction offered by a consensus standard?" That's right; sometimes it's good to run with scissors.

Example No. 1

A townhouse complex in the upper Midwest reported persistent leakage into the basement of several units (*Photo 1*). The water first showed up at the juncture of the rim joist and sub-floor, slowly migrating down the foundation wall as evidenced in one of the units with an unfinished basement. Other owners had installed clever interior drain tiles to channel water harmlessly into a pail set on the floor. A stone veneer was present over the wood-framed chimney enclosure that was, for all practical purposes, centered over the leak location (*Photo 2*). The townhouse association had recently hired a masonry contractor to perform selective removal and repairs to one of the three affected units. The leaks persisted.

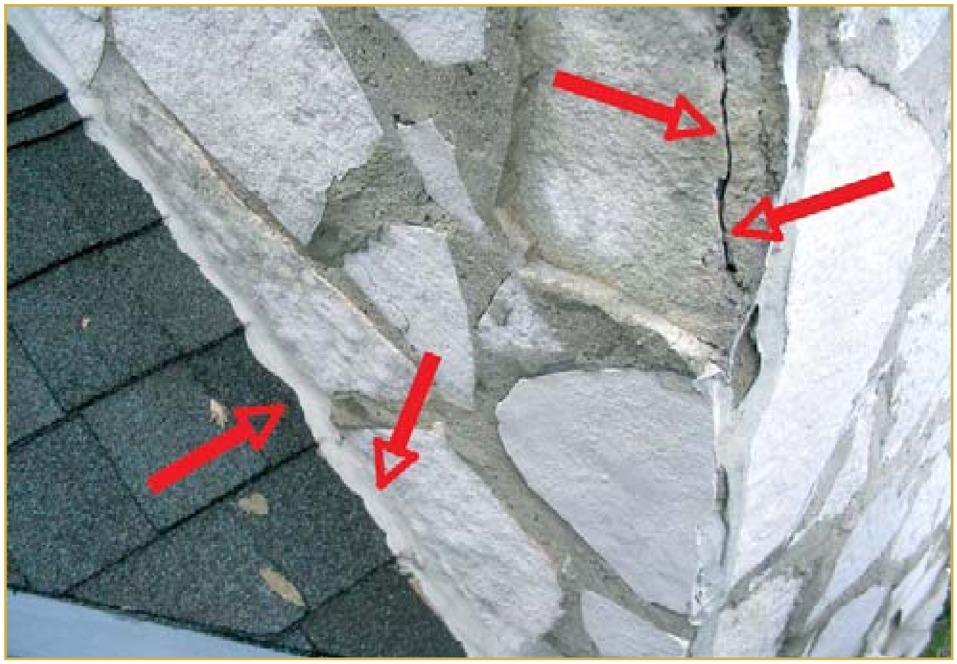


Photo 4 – Removal of loose stone cladding revealed openings in mortar bed. The shingle covering the interface with the stone cladding is sealed with caulking, restricting the harmless discharge of water from the above-roofline features.

During our initial inspection, it was noted that the stone-to-stone joints were open and vulnerable to water entry. Interviews with long-time community mem-

Left: Photo 5 – Overall of involved roof area.

Below: Photo 6 – "Head of water" test on involved roof area.

bers were conducted to understand the types of weather conditions that resulted in active leaks. We were told, "This one leaks when it rains from this direction; that one leaks when it rains from the other direction; and that one over there just leaks when it rains." Short answer: "Stay out of the basement when it's raining."

Obligated to perform a water test as described in the proposal, we opted to return another day with two men – one to perform the water test and the other to entertain the inquisitive long-term resident(s). The property manager suggested we were dragging our feet and insisted we respond quickly and take care of the problem because association members were beginning to complain about the perceived lack of response. (Nevermind that daytime high temperatures were just beginning to eclipse the freezing mark).

As luck would have it, the morning of the water test, it was raining and had been for a good portion of the prior evening. Fortunately, the skies cleared about an hour before arrival at the project site. To water test under these conditions would be difficult, with everything around the suspect areas thought to be contributory to the leakage already wet.

The sun broke through the thinning clouds, and the cladding features began to dry. Interestingly, the drying of the stone cladding on the chimney soon developed a pattern consistent with a horseshoe. The center of the "U"-shaped pattern was notably drier than the outside corners. The drying pattern suggested that the largest volume of water had entered the stone-clad chimney somewhere at or above the roof line (*Photo 3*). The above-described conditions prompted a visual examination of the roof and interfaced flashings of the stone-clad chimney.

At this location (much as described by the long-term resident handyman), it was noted that the shingle roof covering had been sealed with a liberal application of caulking directly to the stone cladding (*Photo 4*). As the open stone-to-stone joinery above the roof line was accepting water, the handyman's efforts with the strategically placed sealant bead had effectively closed the only opportunity for the moisture to harmlessly exit the wall section. In summary, on this day, our hoses never saw the bib. The water test (more importantly, the dry-

Photo 7 – Water test of the flat lock seam metal wall panel using a spray bar.

Photo 8 – Flashing termination accepting of water that moved throughout the joinery of the flat lock seam metal panel wall.

ing pattern from earlier rains) provided sufficient direction to correctly identify and source the leak.

Example No. 2

The subject is a 24-floor high rise in the upper Midwest. At the ninth floor, a low-sloped, built-up roof is present between two cooling towers that are housed in lower mechanical wells, representative of the eighth floor. These floors are over the parking garage, extending beyond the footprint of the adjoining high rise. Persistent leakage was reported in the mechanical room below the ninth floor roof.

In a work scope developed by another consultant prior to our involvement, a repair plan was implemented using an elaborate and expensive deck-level supplemental drainage system. The repair means and methods were accepting of the fact that the free moisture in the roof system was there to stay, assuming the curtain wall-to-roof interface was the source of the moisture.

This repair was put in place without first identifying the source of the leakage, a practice that in most circles would be considered irresponsible. The repair did, however, result in short-term gains. The recurring leakage over the wall-mounted electrical circuits had been controlled, but not stopped. In the interim, the balance of the roof area had been loading with moisture to the point that it had moved through the cold joint in the concrete pours at the area perimeter.

Metal cladding was present, with concealed fasteners to hat channels at two of the three perimeter walls. The third wall was shorter, with a surface-mounted, sheet-metal counterflashing extending over the membrane base flashing (*Photo 5*). The investigation began with a "head of water" test on the roof membrane, followed by a four-hour water test at the base of the curtain wall (*Photo 6*). At no time during the test did the rate of discharge increase from the supplemental drains or deck opening at the primary drains.

The spray bar (borrowed from ASTM standards, less the calibration) was then moved and directed at the flat-seam, metal wall panels for a duration of approximately two hours, or until there was a measurable increase in the rate of discharge – not from the supplemental drains, but the rough opening through the concrete roof deck for the drain bowl (*Photo 7*). Free moisture that made its way past the flat seam panels was

Photo 9 – Evidence of roof system movement in exposed membrane plies.

running down the concealed face of the CMU wall and entering the roof at the top of the base flashing. The top of these flashings was not secured to the block wall, due in part to the absence of a nailable substrate (*Photo 8*).

It was determined that the insulation section of the roof system was essentially loose-laid EPS over concrete, allowing system movement that manifested itself at the perimeter flashings in the form of a gap that would easily accept the moisture that moved past metal panels (*Photo 9*).

On this project, a water test was required. However, the means and methods of the test were not consistent with any written directive or test protocol established by ASTM or other industry members. As a point in fact, had the water testing been performed according to any of today's applicable standards, sourcing and replicating the described leakage would likely have not been achieved. With the source of the water entry identified, the owner requested design services that included a drainage plane behind the reused, flat-seam, metal wall panels; a fully tapered and attached insulation system; and new modified roof, added slope, and improved drainage off the cantilevered extension of the roof deck beyond the wall.

The Running with Scissors Part

The leak profiles noted above are just two examples of many water entry problems that have been successfully diagnosed and resolved without following a published standard. The art of leak sourcing is not found in busy standards structured around one basic type of wall construction (e.g., curtain walls, aluminum cladding) or requiring specialized equipment (special nozzles, blowers, manometers, racks, etc.) See *Photo 10*.

It can be summarized as the simple process of strategically directing large or small quantities of water toward critical areas of the vertical or otherwise oriented plane of a building's cladding features, teamed with a basic understanding of the components of the wall assembly and accessory flashings. However one chooses to frame it – "critical path thought processes," "knocking over silos," "thinking outside of the box," – doing things people may tell you not to do can produce favorable results for those willing to push the building envelope.

Photo 10 – Tools of the trade: shop-made spray bar and pneumatic drain plugs.

Don Kilpatrick

Donald Kilpatrick has been with Inspec, Inc., since 1985. Through his years of experience in the field, he has performed hundreds of water entry investigations on existing structures. Information derived from the investigations has been used successfully in the development of design, repair strategies, and litigation support. Don is a past recipient of the Horowitz Award for outstanding technical contribution to *Interface* journal.

CORRECTION:

In the July 2006 issue of *Interface*, the definition for tapersawn shakes was switched with that for shingles. We regret the error. The correct descriptions are below.

Tapersawn shakes

- Sawn on both sides, for a semi-textured look with a stronger shadowline than a shingle for a tailored appearance.
- Most common are 18" and 24" lengths.
- Butt thickness ranges from 5/8" to 1-1/2".

Shingles

- Sawn on both sides, giving a tailored appearance with a heavier shadowline than a shingle.
- Available in 16" Fivex, 18" Perfection, or 24" Royal lengths.
- Butt thickness is gauged using a stack of shingles to meet the proper measurement.

— Cedar Shake & Shingle Bureau