Is Your Green Building the Best it Can Be?

By J. David Odom, Richard Scott and George H. DuBose

It seems that some of the "best practices" and "lessons learned" in other fields are not being applied in a precise enough manner when it involves green construction, at least as that applies to moisture control.

> "Most new products are experiments and most experiments fail."
>
> -Quote from "How Buildings Learn: What Happens After They're Built" by Stewart Brand (1994)

Stewart Brand's caution in 1994 about using new products is engaging and even quite controversial, since progress can only be made through the use of new products and innovative approaches. Yet Brand's caution echoes what forensic building consultants and building scientists have seen for decades; anything that departs from the "tried and true method" often fails. This finding is not surprising, since even traditional building materials experience some percentage of catastrophic failures from moisture and mold problems.

Brand's caution seems particularly appropriate today with the proliferation of new products, many intended for LEED (Leadership in Energy and Environmental Design) certification. Although many of these products have been developed within the last five years they are intended for use in buildings that should last for 50-plus years. Even a casual review of the literature indicates that some of these products appear to have minimal in-situ testing or performance verification. Additionally, many of these products have not been marketed in a manner suggesting caution about regional or climatic restrictions in their use. Finally, we suspect that there has been even less testing of the complex, interrelated assemblies in which these products will be asked to co-exist for the next half century or more.

Yesterday's seal of approval for new products was "It was developed by NASA." Today the seal of approval is: it's "organically produced," LEED certified, "earth friendly," or some variation of the above. Just as "NASA-developed" was no guarantee of success, neither is LEED-certified any assurance of no problems, especially those problems related to moisture accumulation.

Although some indicators of a building's performance (such as occupant comfort, energy usage, and odors) can be ignored, you can't easily ignore water pouring through a wall assembly. We don't believe that anyone would deem a structure "sustainable" if it cannot survive the first five years without a major renovation because of moisture problems.

It's our belief that the moisture integrity of a building is one of the best report cards on the performance of its design and construction process and the correct use of materials.

After reviewing the designs of hundreds of new buildings over the past 20 years and observing the failures in an equal number of structures the authors have found the following consistent truths:

- **Building commissioning.** The current industry approach to building commissioning (even the LEED Enhanced Commissioning version EA Credit 3) is unlikely to prevent moisture and similar building failures in almost any climate, except for the most forgiving climate.

- **New materials.** The use of many new building products often have the unintended consequence of performing in unexpected ways, sometimes encouraging significant moisture accumulation and mold growth. Since wall and roof assemblies have historically been high-risk areas, it should be no surprise that the increased use of new products in these areas can dramatically increase the overall potential of moisture problems within the envelope.

- **Increased building ventilation.** The positive benefits of increased outside air ventilation for the occupant's health and comfort can often be outweighed by the increased potential for moisture problems, some of which have caused catastrophic failures in the past. Forensic engineers have strong evidence that buildings can perform in unexpected and damaging ways when additional air is moved through them. Through our evaluation of various LEED credit opportunities for designers, we hope to establish the fact that a sustainable building must be equally designed to prevent likely moisture and mold problems. We believe that a building attaining LEED certification is not necessarily a building with a low potential for failure due to moisture intrusion. However, it is our belief that it is possible to combine LEED certification with the best practices for moisture and mold problem avoidance – but it will require extra effort from both architects and mechanical engineers.

An important aspect to avoiding moisture problems in green buildings is the inclusion of the best practices from the waterproofing/HVAC (heating, ventilating, and air-conditioning) disciplines in combination with the LEED certification principles. It is unwise to assume that LEED certification has automatically incorporated those best practices. Green building practices must always be subservient to best design practices in areas such as exterior waterproofing, good humidity control, and proper due diligence in selecting new construction materials.

In order to facilitate the dual vision of an environmentally sensitive building with a highly durable, well-performing, moisture-resistant building, we have compressed a significant amount of data into the following discussion. This discussion moves from an overview of LEED certification points with potential moisture issues (shown in a table) to a more detailed analysis of several specific LEED credits that we view as examples of high risk. These are credits that align with the consistent truths we listed above concerning building commissioning, new materials, and ventilation issues.

The concerns raised in the following pages are not climatically or regionally specific, but are universal concerns for all but the most forgiving climates. Forgiving climates would include those areas with very low rainfall, year-round moderate temperatures, and minimal humidity levels. Even in those climates specific building types could be expected to exhibit problems if best practices are not followed.

FUNDAMENTAL COMMISSIONING (EA PREREQUISITE 1) AND ENHANCED COMMISSIONING (EA CREDIT 3)

Intent of EA 1: *Verify that the building's energy-related systems are installed and calibrated, and perform according to the owner's project requirements, basis of design, and construction documents.*

Intent of EA 3: *Begin the commissioning process early during the design*

OVERVIEW OF LEED CREDITS THAT HAVE INCREASED POTENTIAL FOR MOISTURE & MOLD PROBLEMS

The following is a summary of LEED credits that, if not carefully considered, designed, and constructed, have the potential for creating moisture and mold problems. This summary also includes LEED credits that can be enhanced to minimize the potential for moisture and mold problems:

LEED Credit Number	Description	Issue	Comments
Sustainable Sites (SS) Credit 7.2	Heat Island Effect: Roof	Option of installing a vegetated roof for at least 50% of roof area.	Vegetated roofs have more moisture due to irrigation and constant hydrostatic head of water than typical roofs, making it difficult to prevent water intrusion and condensation problems. Moisture migration & concentration between impermeable membranes is a possibility.
Energy & Atmosphere (EA) Prerequisite 1 and EA Credit 3	Fundamental Commissioning of the Building Energy Systems and Enhanced Commissioning	Enhanced commissioning addresses only the most forgiving climates.	1. The typical commissioning design review is not likely to predict the potential for future moisture and mold problems. 2. The reviews normally do not incorporate an analysis of the building envelope performance.
EA Prerequisite 2 and EA Credit 1	Minimum Energy Performance Required and Optimize Energy Performance	Increases in energy performance can reduce moisture control in buildings.	1. Increased thermal insulation changes wall system performance (dew point location) with possible condensation in wrong location. 2. Modifying heating, ventilating, and air-conditioning (HVAC) control schemes alters equipment run times and impacts moisture control.
EA Credit 5: Measurement and Verification	Ongoing energy measurement and verification	Sacrificing adequate relative humidity control to reduce energy usage.	Any good energy management plan must be subservient to adequate moisture control.
Materials and Resources (MR) Credits 1.1 and 1.2	Building Reuse: Maintain 75% to 95% of Existing Walls, Floors, & Roof	Moisture control performance of existing building envelope components re-used under this credit.	1. Quality and performance of existing components such as flashing, rainwater barriers, air barriers, need to be investigated and possibly tested. 2. Model both new and re-used component to identify how each component will act toward good moisture control — this includes interaction with the HVAC system.
MR Credits 1.3, 2.1, 2.2, 3.1 and 3.2	Building/Materials Reuse and Construction Waste Management	Inadvertent reuse of previously water damaged an increased risk. Construction workers at risk of handing mold contaminated materials.	1. Mold contamination is not often visible in the occupied side of materials and is not generally found by air testing in a construction environment. Destructive testing and evaluation may be required. 2. Construction waste management plan may need to include section on handling moldy materials.

LEED Credit Number	Description	Issue	Comments
MR Credit 6	Rapidly Renewable Materials	Use of rapidly renewable natural building materials and products without understanding their properties related to water (permeance, absorption, etc.).	The mixture of synthetic materials with natural materials in the building envelope can create increased potential for moisture condensation and entrapment.
Indoor Environmental Quality (EQ) Prerequisite 1, EQ Credit 1, and EQ Credit 2	Minimum Indoor Air Quality (IAQ) Performance, Outdoor Air Delivery Monitoring, and Increased Ventilation	Ventilation in many parts of the United States must to be carefully designed to avoid moisture problems.	Increased ventilation air should never be added without an overriding control of both pressurization and dehumidification.
EQ Credit 3.1	Construction IAQ Management Plan: During Construction	Typical construction sequencing does not always allow for meeting credit objectives for protection of materials from water damage.	Construction sequencing needs to be reviewed and material protection measures understood and enforced.
EQ Credit 3.2 (and 3.1)	Construction IAQ Management Plan: Before Occupancy	Pre-occupancy flush out.	Introducing required air for this credit in many geographic areas can result in indoor moisture problems.
EQ Credit 5	Indoor Chemical & Pollutant Source Control	Requires significant exhaust rates for source control.	Local exhaust can result in local depressurization and introduction of humid outside air into building envelope. It can also result in inadvertent pollutant movement within a building.
EQ Credit 6.2	Controllability of Systems: Thermal Comfort	Providing operable windows can allow untreated humid air or rainwater to enter building.	If operable windows are installed, consider sensors and automatic overrides.
Innovation in Design (ID) Credits 1.1-1.4	Innovation in Design	Recognizing the inherent increased risk of using new products that have less in-field experience.	1. Probably unrealistic for the design and construction team to understand the performance characteristics and limitation of new products and the additional risks that their use might carry. 2. Particular concern about the introduction of new products into the highest moisture risk areas of the building (i.e., the envelope and the HVAC system) since in these areas there is added risk.

process and execute additional activities after systems performance verification is completed.

Building commissioning (even the enhanced version of commissioning in LEED EA Credit 3) is not likely to prevent catastrophic moisture and mold problems. Traditional commissioning fails to accomplish two primary requirements in avoiding moisture problems:

- The design review is not likely to be a "standard of care" technical peer review, but is more often a review intended to determine if the constructed building, once built, can be commissioned and if the design meets the owner's intent. In our experience the typical design review will not predict the potential for moisture and mold problems. Without this prediction it cannot offer specific solutions to avoid them.

- These reviews are not required to incorporate an analysis of the building envelope's performance – the acknowledged component that fails the most frequently and usually the most dramatically.

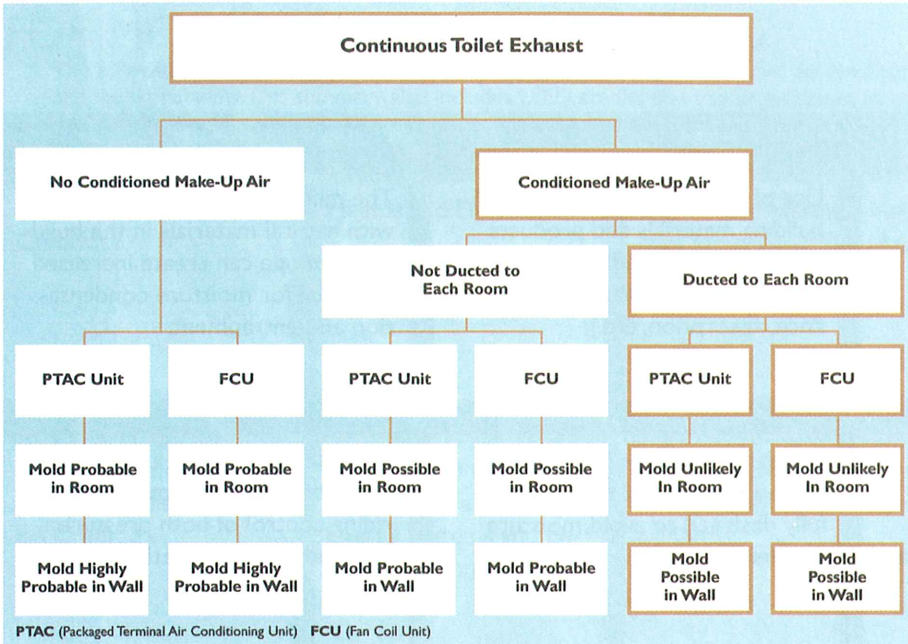


Figure 3.1: Prediction chart of the probability of moisture and mold in a hotel-type building with a series of HVAC system choices and an unforgiving wall system—i.e., a misplaced vapor retarder in conjunction with moisture sources. Other combinations of decisions can increase or decrease the risk. (Note: This example makes numerous assumptions such as there are no significant rainwater leaks. This prediction chart also assumes that the outside moisture conditions are conducive to mold growth.)

What the building science industry has known for some time is that moisture and mold problems are often very predictable, even in the early design stage. However, for this analysis to be successful the review team must be very savvy about what combination of design choices create a high risk of causing problems and what other choices are lower risks.

Figure 3.1 shows an example of the predictability of moisture and mold problems in a hotel type building.

Some concepts that should be included in building commissioning to reduce the possibility of moisture and mold problems include the following:

- During the design phase a technical peer review of the document should identify issues which will likely be a major cause of moisture and mold problems in the operating building. This review may need to be accomplished by someone other than the traditional commissioning agent since they may not have the requisite skill set to conduct this type of analysis. It's our opinion that this review needs to specifically identify which building components and systems have a high potential for moisture problems and offer alternative solutions to the design team.

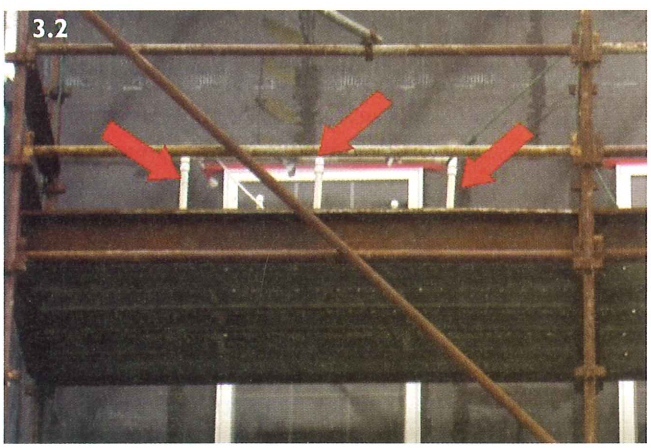
- The commissioning process needs to consider the interrelationship of the building envelope and the HVAC system. This area is often overlooked because it involves the dynamic interaction between two separate technology areas.

- The building envelope needs to be commissioned in a manner that would avoid rainwater leaks, excessive air leakage, and condensation problems. In cases where the envelope is commissioned, both individual envelope components (like windows) should be tested as well as assemblies of multiple adjacent components. Testing individual components does not address the connection points and intersections between various envelope components where most of the failures occur. Assembly testing can include a mix of qualitative (Figure 3.2) and quantitative testing, such as ASTM tests.

- Construction phase commissioning of envelope components may require adjustment of installation methods based on test results. Checklists should be developed that allow for certification that such adjustments are implemented (Figure 3.3).

Figure 3.2: Qualitative water testing of window and stud wall assembly after installation of membrane water proofing. Note spray rack (red arrows) above and to the side of window that washes the wall while the cavity side of sheathing is checked for leaks. **Figure 3.3:** Checklists for commissioning of sliding glass doors. These checklists are completed by the contractor. The checklists may be modified after installation and quantitative testing of the first several doors.

3.2



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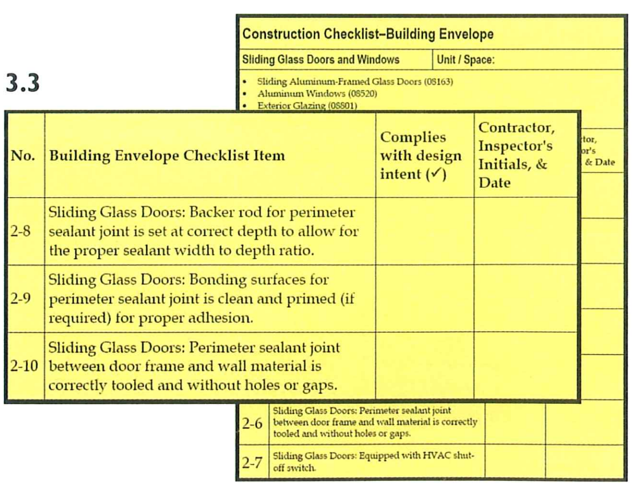


Construction Checklist–Building Envelope

Sliding Glass Doors and Windows | Unit / Space:

- Sliding Aluminum-Framed Glass Doors (08163)
- Aluminum Windows (08520)
- Exterior Glazing (08801)

No.	Building Envelope Checklist Item	Complies with design intent (✓)	Contractor, Inspector's Initials, & Date
2-8	Sliding Glass Doors: Backer rod for perimeter sealant joint is set at correct depth to allow for the proper sealant width to depth ratio.		
2-9	Sliding Glass Doors: Bonding surfaces for perimeter sealant joint is clean and primed (if required) for proper adhesion.		
2-10	Sliding Glass Doors: Perimeter sealant joint between door frame and wall material is correctly tooled and without holes or gaps.		
2-6	Sliding Glass Doors: Perimeter sealant joint between door frame and wall material is correctly tooled and without holes or gaps.		
2-7	Sliding Glass Doors: Equipped with HVAC shut-off switch.		

MATERIALS & RESOURCES AND OTHER CREDITS: USE OF NEW MATERIALS IN HIGH-RISK LOCATIONS

Intent of these 14 Materials & Resources credits: Reuse of existing building components, the management of construction waste, materials reuse, amount of recycled content, the use of regional materials, the use of rapidly renewable materials, and the use of certified wood.

New green materials can often meet requirements in several LEED credits. For example, organic-based insulation materials can satisfy LEED Material & Resource Credit 6 as a rapidly renewable material, Energy & Atmosphere Prerequisite 2 and Credit 1 for energy performance, and Indoor Environmental Quality Credit 4.1 for low emitting materials. Many new materials and concepts can also fall under the Innovation & Design Process credit requirements for developing new solutions, employing new technologies, or realizing exemplary performance.

We believe that it is reasonable to assume that if we are relatively unfamiliar with a new material's individual performance then we probably know even less about the material's interaction with other adjacent components. Our ignorance about the performance of new materials should not be disregarded because the manufacturer of these materials assures us that the product is appropriate for LEED-certified buildings. The recognition of additional risk in the use of innovative products (especially in the envelope and HVAC systems) by the development team should demand a higher degree of rigor in the evaluation of these products.

As previously mentioned, the interaction between the HVAC system and the envelope creates an unusually high risk area. The impact of this condition is that any deficiency in either system can cause dramatic building-wide moisture problems.

It may be only a slight overstatement to state that there is no wall system which a creative architect can envision that a poor HVAC system cannot destroy. Conversely, a very well-performing HVAC system can often compensate for a marginally designed (or constructed) building envelope to the point where many moisture problems may never be noticed. However, there is a point where even an exceptionally well-performing HVAC system cannot compensate for a poorly designed wall system, especially a wall that allows rainwater intrusion or is excessively leaky to air movement.

A simplification of the concept can be stated as:

- Bad Envelope Design + Bad HVAC Design = Guaranteed Moisture Problems

- Good Envelope Design + Bad HVAC Design = Likely Moisture Problems

- Bad Envelope Design + Good HVAC Design = Likely Moisture Problems

- Good Envelope Design + Good HVAC Design = Likely Success

(Note: The term "good envelope design" refers to the correct design and construction of the air barrier, vapor retarder, and thermal barrier. It does not refer to rainwater intrusion issues since even minor rainwater entry past the water resistive barrier can be problematic. "Good HVAC design" refers to the proper building pressurization for the specific climate, proper dehumidification, and proper air distribution within a building.)

Although new wall system products are often intended to provide better thermal insulation, reduce air movement through the walls, or allow enhanced drying of the wall assembly (via vapor diffusion) they can also perform in unanticipated ways. These new products can dramatically change the way moisture flows through wall and roof systems and the potential for condensation within these cavities. The use of these new products mandate that the designer implement several additional steps to avoid problems:

- Better understand the performance characteristics of these new products. This may require a more rigorous evaluation of these materials than is required with traditional products. As with any product – but more so with new products – the performance answers may not be found in the product data sheets, but may require experiments and mockups to determine their performance. This type of evaluation may be beyond the scope and expertise of the design team – but it should nevertheless be implemented. In Figure 3.4, a new insulation material (marketed for "green" buildings) was able to hold a considerable amount of water despite a data sheet that indicated it was a non-absorptive product. The use of this material in wall cavities could create massive mold problems if there is water leakage through the water resistive barrier since the normal wet-dry cycling will not likely occur.

- Analyze the vapor retarder, air barrier, and bulk water retention properties to better understand where the material should be placed, if at all, within the wall system.

- Model the wall systems for performance during the early design stages to predict the potential for water vapor transmission through the wall assemblies and potential for condensation to occur. Minimally, this modeling should predict the dew point location and the vapor transmission profile during the most extreme season for the location.

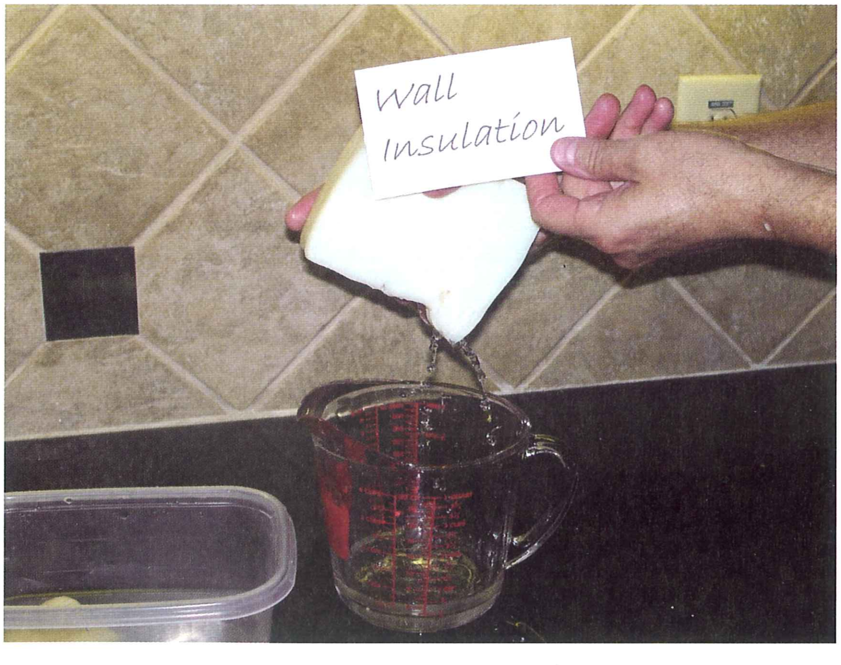
- Perform a three-dimensional analysis of rainwater barrier geometry, especially at complex joints and changes in plane.

All other standard good practices for wall system design should continue to be followed whether new or traditional products are used including:

- The use of water resistive barriers as the first line of defense,

- Designing drainage planes to channel water down and out of the envelope,

Figure 3.4: Example of the amount of water absorbed by a wall insulation product. This experiment demonstrates that many products intended for wall and roof assemblies can absorb huge amounts of water in spite of their data sheets attesting to the opposite.



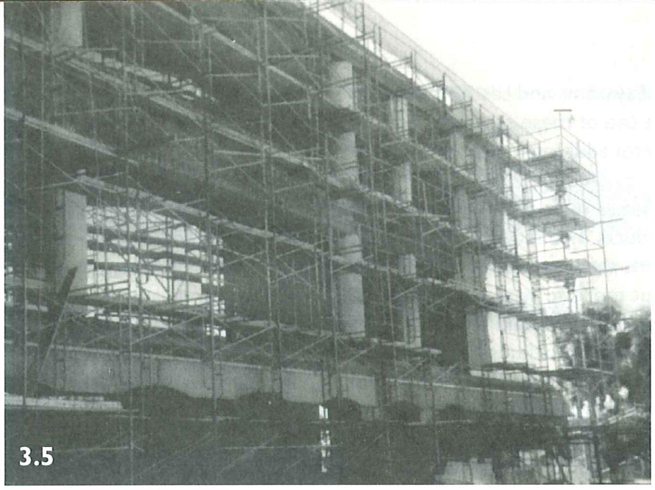


Figure 3.5: Martin County Courthouse, Stuart, Florida. The HVAC design produced high rates of outside air ventilation but poor temperature and humidity control which contributed to mold and moisture problems, resulting in over $10 million in renovation costs for a three-year-old building.

- Installing secondary barriers for redundancy, and
- Designing proper flashing and sealant joints.

INCREASED VENTILATION (EQ CREDIT 2)

Intent: Provide additional outdoor air ventilation to improve air quality for improved occupant comfort, well being and productivity.

For decades there have been competing arguments within the mechanical design community on whether to increase or decrease the amount of outside air that is introduced into commercial and institutional buildings. Although there are sound arguments on both sides of the debate, today's emphasis on increased building ventilation to achieve LEED credits has given an added incentive to increase the amount of outside air to buildings. The experience of many forensic building experts (especially in the eastern half of the country) do not necessarily support the theory that adding more outside air creates a better performing, more sustainable building – sometimes quite the opposite (Figure 3.5).

What is known about ventilation air is that in regions with ambient high dew point conditions and elevated relative humidity levels (which include much of the entire eastern half of the country during portions of the year) there is a direct correlation between the number of moisture problems and increased rates of mechanical building ventilation. This can occur for obvious reasons, such as the additional moisture load that is introduced into the building along with the outside air. However, more obscure reasons can also increase the risk of adding outside air to a building. Unbalanced (or partially depressurized) buildings can be the result of moving large amounts of air around a building. When this condition occurs moisture problems become more prevalent. These unbalanced conditions happen when air is trying to flow from the supply side of the air handler equipment to the return side but is restricted by structural or architectural barriers.

Florida Solar Energy Center (FSEC) of Cocoa, Florida called this condition the "Smart Air Syndrome" concept – that air is supposed to be smart enough to get from one place to another in spite of barriers. Additional ventilation air should always be designed in conjunction with considering the impact of the distribution of the ventilation air. This requires identifying parts of the building that could become depressurized with respect to outside conditions, thus potentially drawing humid outside air into the envelope cavity or occupied spaces. (Note: Even in less humid climates an unbalanced HVAC system can inadvertently transfer odors and airborne pollutants in unintended ways through a building.) This increased risk of moisture problems caused by greater air volumes (and thus unbalanced areas of the building) is depicted in the FSEC graphic (Figure 3.6).

FSEC's research has demonstrated the relationship between building complexity (architectural and structural complexity), the intensity of the HVAC drivers (air volumes and pressures), and the risk of building failures. The solution is not to build simpler, less ventilated buildings but it is to insure that the ventilation air is effectively delivered to the space. This means that ventilation must be distributed so that it not only reaches the desired breathing zone but does so in a manner that does not adversely affect the building.

The HVAC system that introduces ventilation air must also do so in a manner that properly dehumidifies the air. The "golden rule" of moisture control is that under no circumstances should adequate dehumidification be sacrificed for increased ventilation. In many regions of the country during summertime conditions the moisture load contributed by the outside air can exceed the amount of moisture that the air conditioning system can effectively remove.

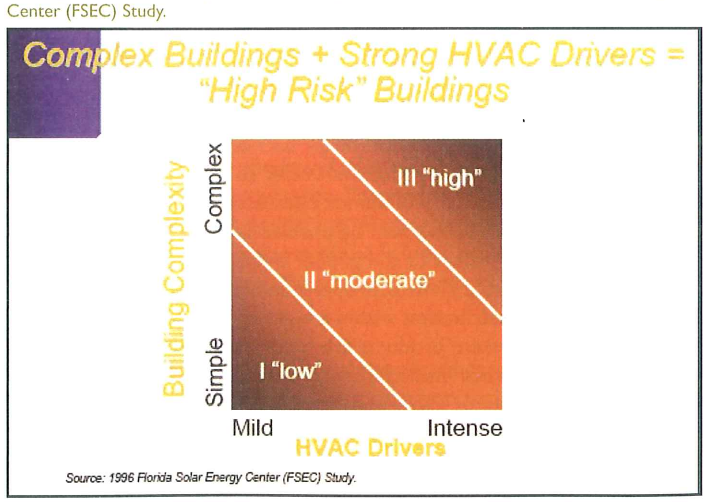
The solution is to address these risk factors in several ways:

- Ensure the correct distribution of air flows within buildings (to avoid pressure imbalances). This can usually be accurately predicted during design.

- Increase the verification of HVAC system performance by adding additional elements to the building startup and commissioning programs. This post-construction verification includes detailed pressure mapping of the building to confirm proper air distribution and using temperature and relative humidity (RH) data loggers to confirm conditions during the first year's operation. This pressure mapping and data logging needs to also include the building cavities – areas that are often ignored. Many of these elements are frequently absent in today's standard HVAC system startup and building commissioning programs.

What experience demonstrates is that increased amounts of outside air can be safely added to a building if the known causes of increased

Figure 3.6: FSEC graphic on risk of building failures related to building complexity and intensity of HVAC drivers (air volumes and pressures). Source: 1996 Florida Solar Energy Center (FSEC) Study.



risk (such as proper air distribution) are addressed during design and verified after construction.

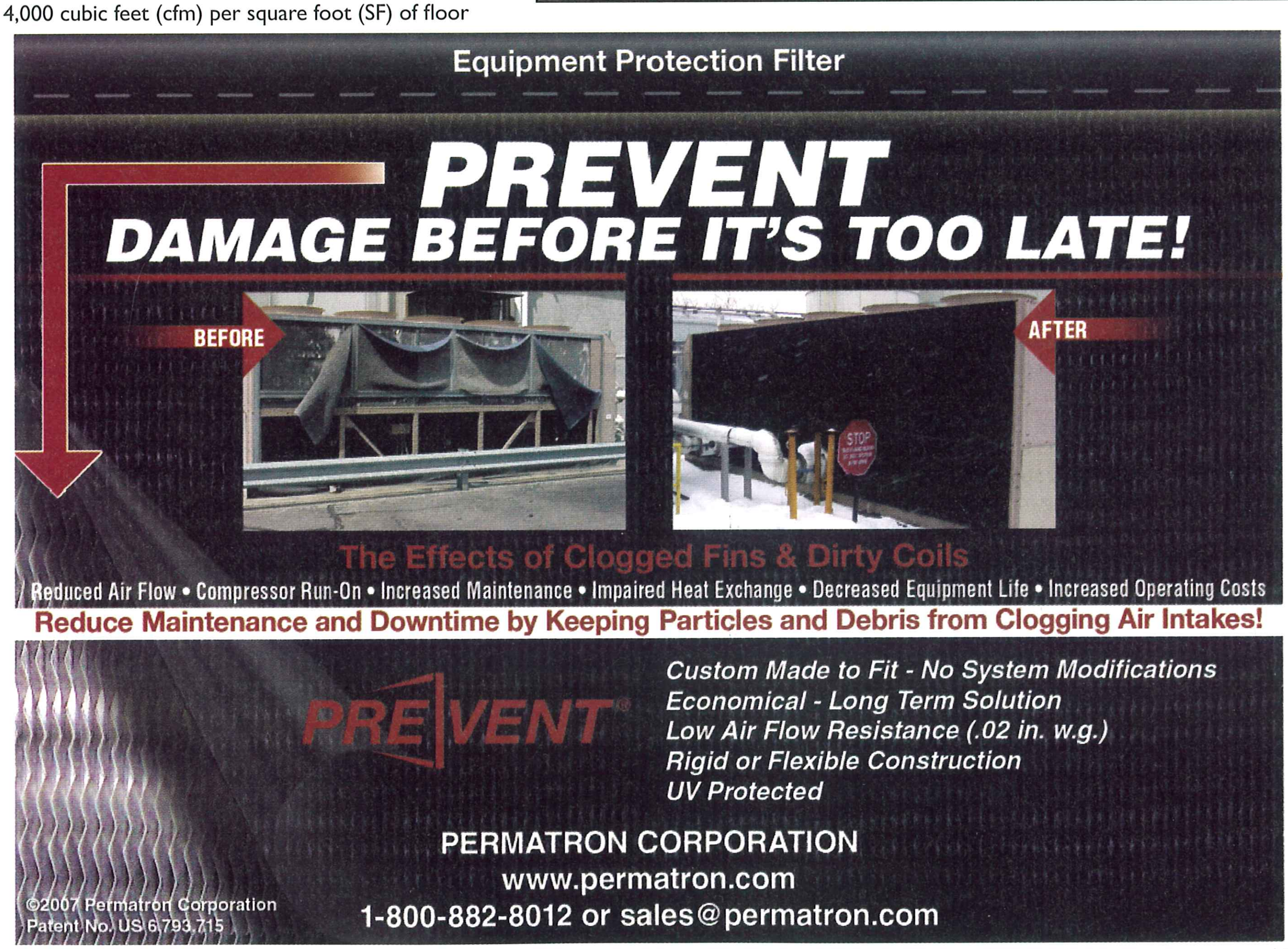
CONSTRUCTION IAQ MANAGEMENT PLAN DURING CONSTRUCTION AND BEFORE OCCUPANCY (EQ CREDITS 3.1 AND 3.2)

Intent: Reduce indoor air quality (IAQ) problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants.

During construction there can be increased pollutant load in a building because of various factors: heavy particulate load and the off gassing of formaldehyde and volatile organic compounds (VOC's) from newly installed products. There are various methods of controlling this additional pollutant load such as additional air filtration, the use of temporary air handlers for heating and cooling, and flushing out the building with additional amounts of outside air.

As proposed by LEED Credit 3.2, building flush-out can occur either late in the construction phase or after the building is occupied. While the use of outside air to flush out the building may reduce the concentration of off gassing it can also inadvertently cause moisture problems. Although the moisture problems may be short term (decreasing after the flush out is finished) the resultant mold problems could be long lasting.

The EQ Credits related to the Construction IAQ Management Plan allow for two separate approaches to building flush out, one during construction and an alternative plan after occupancy. Both approaches involve a substantial amount of outside air volume – 14,000 cubic feet (cfm) per square foot (SF) of floor



area. Whether this flush out occurs rapidly over a several week period (during the late stages of construction) or more slowly over several months (during post construction) moisture problems are likely to result in many parts of the country during the summertime.

Increased building ventilation over the design amounts can create a range of problems such as inadequate sizing of the air filters and an inability of the air conditioning equipment to handle the increased moisture (or latent) load. While the LEED credit mandates a 60% RH maximum level during this flush out period, this requirement may not be feasible with the building's equipment. Since final building finishes should be in place prior to flush out (otherwise there are no materials to off gas) it makes the entire building susceptible to mold growth problems. If building flush out occurs after occupancy then even the furnishings are susceptible to moisture problems.

In a typical 100,000 square foot building the amount of outdoor air required to meet the flush out portion of this credit is 1,400,000,000 cubic feet. This amount of air volume in the eastern portion of the country during the humid summer months can be equivalent to over 200,000 gallons of additional moisture introduced into the building. This moisture is in addition to the normal moisture load from construction activities, cleaning liquids, or construction-related moisture from curing concrete, paint drying, etc.

One of the additional risks with conducting building flush out (especially in an occupied building) is that it is usually done in the evening when the heat load (sensible) is the lowest and the moisture load (latent) is the highest. This can result in even greater relative humidity levels in the building because the unfavorable ratio of sensible to latent load can either cause overcooling of the building (resulting in flash condensation). The additional likelihood that the HVAC system might still be unbalanced at the time of the flush out increases the potential for moisture problems as the result of this process.

INDOOR CHEMICAL & POLLUTANT SOURCE CONTROL (EQ CREDIT 5)

Intent: Minimize exposure of the building occupants to potentially hazardous particulates and chemical pollutants.

Depending on the climate where the building is located it may be important to utilize different types of ventilation approaches to control indoor air quality degradation and indoor chemical and pollutant source control. In climates with outdoor air conditions that carry large summer moisture loads (which includes much of the eastern portion of the country), ventilation approaches should include a combination of exhaust and make up air to achieve the pressure differentials required by the credit.

This credit requires a pressure differential of 5 Pascals (Pa) between the area with the chemical or pollutant source and adjacent areas. The recommended approach is to exhaust the space with the chemical or pollutant source to a point that is at least 5 Pa negative when compared to adjacent areas and a minimum of .50 cfm per SF. If this recommendation is incorrectly applied its result can create depressurization of the entire building (or portions of the building).

The inherent risks associated with increased building exhaust as recommended in this LEED credit are numerous:

- It increases the importance of a very accurate test and balance process to insure that adjacent building areas are not accidentally depressurized (including wall and ceiling cavities).

- The suggested pressure differentials (5 Pa) are significantly more precise than the average test and balance firm can measure, likely leading to errors.

- Since the suggested exhaust rates and pressure differentials are minimum figures there might be a tendency for some practitioners to vastly exceed these amounts (under the concept that "more is better") which could result in an even increased potential for uncontrolled air flows and moisture problems.

It has been the experience of many practitioners in the field of forensic building science that achieving negative pressure conditions in parts of a building, while maintaining overall positive building pressures elsewhere is an extremely delicate balance to achieve.

CONCLUSIONS

The green design movement is transforming the design and construction marketplace like no other innovation in the lifetime of most designers. Green design has brought to the forefront of the design and construction community a holistic view of how to design, build, and operate higher performing buildings. As such, the noble goals espoused by sustainable development and green buildings are certainly worth aggressively pursuing –
but it must be done with significant care, especially in the areas of high risk for moisture and mold problems. It seems that some of the "best practices" and "lessons learned" in other fields are not being applied in a precise enough manner when it involves green construction, at least as that applies to moisture control.

To summarize our recommendations we believe that the following should occur in an effort to enhance green designs:

- A technical peer review of the design should be implemented that attempts to predict the building performance with the new materials and products. At a minimum this review would focus on the HVAC and building envelope systems that are most exposed to moisture-related failures. This should provide a more climatologically and regionally accurate green design.

- The design team must be confident that they have incorporated the institutional knowledge already known in the fields of humidity control, waterproofing and building envelope performance. Processes that have already lost favor in the indoor environment field, such as "building flush out," should not now be incorporated into green construction as "best practices." These processes have historically shown little benefit and have demonstrated high cost, high risk, or both.

- The acceptance of new products with specific "green" benefits should be especially scrutinized. Our experience is that gaining performance in one area often means sacrificing performance in another area. If the area where performance is sacrificed is a critical parameter (such as the water absorption qualities of wall insulation) then the risk may be too great, no matter what the benefit is. We are not sure if it's realistic for a design team to make all of these required assessments, but without it building failure seems more probable.

As Fortune magazine once stated: "If mind-boggling change is the only constant, focusing on the avoidance of major blunders yields better results than the singleminded pursuit of the big win."

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The following is an assortment of companies' informational resources submitted for readers of *Facilities Engineering Journal.*

Drywall. Prentice Hall Publishing and The National Center for Construction Education and Research released Drywall Level One. This full-color modular textbook is the first of two levels and includes topics on orientation to the trade, materials and methods, thermal and moisture protection, installation, and finishing. It offers technical hints and tips from the drywall industry, presenting real-life scenarios similar to those one might encounter on the job site. Additional features include a list of key trade terms and quizzes. For more information visit www.nccer.org.

Industrial vacuums. A 22-page brochure from Nilfisk CFM features the company's full line of industrial vacuums and accessories. The line includes products for intermittent-duty for general maintenance cleaning, continuous-duty for stationary cleaning and process integration, explosion-proof models for collecting hazardous materials, wet/dry models for picking up liquids and chemicals, and central systems with various capabilities. For a free copy visit www.pa.nilfisk-advance.com.

Portable cooling equipment. Atlas Sales & Rentals Inc. has published an eight-page "Product & Application Guide" to portable air conditioning equipment for primary, supplemental and emergency cooling in all types of non-residential buildings. It offers detailed application and selection data for a wide range of air-cooled, water-cooled and other equipment with capacities of one ton and up. Typical settings for this equipment include office and commercial spaces, data centers, hospitals, schools, public buildings, TV/film production and special event locations, and process cooling in manufacturing areas. To download the guide go to www.atlassales.com and click on "Catalog".

Ventilation standard. ASHRAE's Standard 62.1-2007 User's Manual is available. It provides an understanding of the design, installation and operation requirements in ANSI/ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality. The standard contains requirements for separation of environmental tobacco smoke (ETS) spaces from ETS-free spaces, clarification of humidity control design requirements, and the inclusion of new rates for high- rise residential occupancies. The cost of the user's manual is $69. For more information visit www.ashrae.org/bookstore.