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Air Infiltration in Coastal Regions – The "Paston Effect"

Ronald B. Bailey, P.E., CIAQP, CIE
Hollace J. Swanson, P.E., CIAQP, CIE
Bailey Engineering Corporation

ABSTRACT

This paper describes actual field conditions encountered during investigations of high humidity in residential and commercial structures and their direct effect on indoor relative humidities. Uncontrolled air leakage and moisture migration into structures causes severe deterioration of building components as well as resulting in poor indoor comfort.

Unfortunately, when moisture levels become excessive, a variety of problems including destructive mold and mildew occur. This study is not a theoretical approach, but a hands-on cause and effect cure designed to aid readers in investigating and recognizing actual field problems. The "Paston Effect" comes from an investigation of a large residence, where numerous conditions existed that affected the indoor relative humidity.

INTRODUCTION

In humid climates, the outdoor specific humidity is often twice that of a humidified building in the North. Rain soaked walls can cause vapor pressure differentials outside to inside of up to ten times that of the northern humidified building. Experience has shown that when graphing the specific humidity of the outdoor air vs. indoor air in South Florida, the driving force is to the inside of the conditioned structure more than 95% of the time.

Construction as well as building codes in humid regions rarely address proper placement of vapor retarders and vapor barriers. Construction practices exacerbate the problem.

Since 1979, Florida has addressed the energy use in structures through the Energy *Efficiency Code for Building Construction.* This code has largely addressed the thermal heat transfer through the structure by adding thermal insulations and limiting glass areas as well as encouraging many effective energy conservation devices and products. Through tightening of the thermal standards of the codes, the sensible heat gained by structures has been lowered significantly, however the moisture gains through materials remains essentially constant.

A serious effect recognized over the past two years is the increase in exterior wall surface relative humidities in the winter months causing the increased occurrence of microbial growth on interior surfaces of exterior walls.

Primarily, this paper will deal with construction deficiencies commonly found in investigations of failed residences and some methods of correcting these deficiencies. While some solutions may be somewhat controversial, the results are quite effective and the rationale well founded.

TYPICAL SYMPTOMS OF THE "PASTON EFFECT"

The call to investigate a failed residence is often prompted by the residents experiencing high humidity, moisture problems, and odors of mold and mildew. Sometimes, questioning will indicate that there are problems maintaining proper space temperature during the few winter heating nights also. Usually, the initial focus is on the HVAC system, since it is supposed to control the temperature and humidity of the interior spaces.

Checking the equipment operation commonly results in further confusion, since the equipment usually is performing at or close to the specified conditions expected.

A checking of the temperatures in the spaces may indicate normal temperatures, since it is common to check equipment performance in the warmest weather possible, and that is when there will be the least indication of the conditions, which combine to create the "Paston Effect."

A continued pursuit to discover the reason for the resident's complaints may lead you into the attic if you haven't been there already to check the equipment. While in the attic, you may note the attic temperature is warm, but not nearly as unbearable as you might have expected. There may be some condensation present on the ductwork and the air-handling unit itself. Further observation may indicate that structural tie down straps and plates show rust spots and indications of corrosion. Even fairly new support chains for AHU's may show signs of rusting. Light may be visible from openings to the exterior and to the conditioned space, as well as through vents in lighting fixtures recessed into the ceiling. Ductwork may seem to be supported and sealed as is commonly acceptable in the industry. If you start touching things, you may note a dampness to the batt insulation is some areas, usually close to ductwork, or under refrigerant piping. There may also be a damp feel to the structural members. A slight discoloration of the radiant barrier and foil duct surfaces may be noted.

Having not found any specific reasons for the high humidity levels causing the complaints, you probably will return to the conditioned space. There you may check the thermostats, which may seem to be operating sporadically and attempts to correct the operation may result in the idea that they cannot be calibrated correctly. The normal settings on the thermostats may also seem to be lower than normal.

Usually, this is the point where the initial investigation of the problem ends, as no real reason is found for the complaints, except the problems with the thermostats. It is determined that they need to be fixed or replaced, and then the people will be happy.

If the "Paston Effect" is present and the homeowners are persistent, the investigation will continue several months later, when the high humidity and odors of mold and mildew continue to get worse. Usually preceded by a weather change of some sort, the owners will get to a point of not being able to live with the problem anymore.

A return to the site will be accompanied by many observations and complaints by the owners, of specific locations where the mold and mildew odors are most prevalent, of complaints regarding the ruining of some clothing, bedding or other cloth items, of allergy type symptoms occurring more frequently, and the general complaint of never being comfortable even though they constantly have to adjust the thermostat.

During this visit, you may be able to detect some odors within certain areas. You will probably be shown mold and mildew on surfaces and clothing, and you may note mirrors with discoloration of the silver surfaces, as well as the general appearance of "premature aging" of the residence. Other than this, you may still not be able to determine a reason for the complaints.

It is time to call in an "expert."

THE "EXPERT'S" INVESTIGATION OF HIGH HUMIDITIES IN RESIDENCES

The "expert" will begin his investigation by absorbing as much information as possible through observation and note taking. He will take note of things that are seemingly unrelated and will ask many questions that may seem "of the track." That is part of his looking at the big picture – for that missing piece of the puzzle.

The "Paston Effect" has affects on the structure, which are exaggerated and proceed rather rapidly. Since the basic deterioration of the structure is so obvious and definitely attributable to the high humidity levels, the effects of high humidity on a residence and their progression was made totally clear to us by the observation and inspection of the original residence where the "Paston Effect" was found. This case made the role of the multiple components involved clear, and has allowed us to identify the components in other structures before the effects are detected, thereby eliminating the repeating of another major residential building failure.

FOUND COMPONENTS CONTRIBUTING TO THE "PASTON EFFECT"

The location of the residence must be considered. Residences located on islands, on waterways and oceans front properties are subjected to wind effects three times that of a residence located in a suburban neighborhood. Pressures exerted on the structure by winds cause the infiltration of moisture-laden air contaminated with corrosive salts. This combination of unusual wind pressures and patterns can combine with other considerations and cause a substantial portion of the contribution to the "Paston Effect."

ROLL DOWN SHUTTERS

The roll down type of shutters is often housed in the eve's overhangs. The bottom of the shutter often forms a scoop with a 2" wide linear slot leading up into the attic when it is rolled up, and when rolled down, the shutter forms a wind barrier with a relief opening into the shutter box at the eve. These scoops allow air to be introduced into the attic at a prominent point of wind impingement on the structure. The result is excess pressure buildup in the attic, well beyond the anticipated .016 inches of water that is appropriate for effective air leakage control through building components, as per the *ASHRAE Handbook of Fundamentals* – Chapter 23 table 3.

Homes on waterways almost always have twice the area of eve opening on the waterside as the landside.

Corrective measure-

Always provide a tightly sealed shutter box around all shutters.

CONTINUOUS LINEAR SOFFIT VENTS

Continuous linear soffit vents re like roll down shutters – they are often located close to the wall and they become a pathway for trapped wind to enter the attic and over pressurize it. In addition, they cause a high rate of moisture laden air exchange through attic areas. Generally HVAC components sweat sometimes profusely, under these circumstances. This is discussed later in a section on duct sweating.

Corrective measure –

Seal up unneeded soffit ventilation. Provide the absolute minimum attic ventilation that you can provide. If you must ventilate the attic, locate the vents on the exposures away from the local prevailing breeze.

RECESSED LIGHT FIXTURES

Many recessed light fixtures installed in Florida homes have several vent holes to release heat from the light bulb. These vent holes allow the rapid infiltration of moist attic air into the home.

Corrective measure –

Use only sealed cans and limit the use of recessed lighting fixtures.

DYNAMIC WALLS

Today's custom homes come with a variety of ceiling elevation changes. It is common that these

walls are not draft stopped. Thus they become a path for air pressure air movement and moisture migration into the home by exposing hundreds of square feet of building materials and additional construction joints to attic conditions. Although these wall cavities are often not visible from the attic after installation of insulation, air movement through insulation materials occurs easily with any pressure differential. This air movement penetrates down into the wall cavities and the walls become dynamic, rather than a concealed space with a stagnant air cushion.

Corrective measure –

Draft stop at all ceiling elevation changes and at the tops of walls.

CHASES

It is not uncommon to find chases in two story structures and even some "dead corners" in single story homes that are not sealed off from the attic. This practice allows the communication of moisture and moisture-laden air into spaces and up against materials that are often at the dew point temperatures of the air.

In some cases, the interstitial space between the conditioned floors, is found to be vented intentionally and unintentionally, to the exterior – an absolutely disastrous combination. Outdoor air with wet bulb temperatures of 80ºF contacting materials at 72ºF to 76ºF, causes condensation and surface relative humidities that cause mold and mildew.

Corrective measure –

Seal and caulk all areas from the exterior and the attic.

UNSEALED OPENINGS

Conduit, wiring, plumbing pipes, and leaks of joints of wall materials into the attics permit walls to behave as additional pathways of moisture migration, heat gain and pathways for air infiltration. The pressure differential *through* conduits can cause the sporadic operation of the thermostats.

Corrective measure –

Seal up all openings and caulk all seams.

ATTIC INSULATION

Poorly distributed attic insulation or improperly installed insulation leaves gaps for the direct contact of hot moist laden air directly to transfer surfaces. A very small percentage of area with poor coverage of attic insulation, significantly reduces the overall effectiveness of the product.

Constantly, we find foil-faced insulations with the foil facing turned to the conditioned space. In hot humid climates, this practice is absolutely improper. Many of these materials are often installed improperly, but they are "in accordance with the manufacture's printed instructions."

Corrective measure –

Install all materials with care, and in accordance with recognized standards. Manufactures instructions may be wrong, look at where the material is manufactured and tested before applying. Use common sense.

VAPOR RETARDERS

Never ever install a vapor retarder on the inside of an outside wall. Vinyl wall coverings have become biological playgrounds and the source of many disappointed homeowners. Large expanses of mirrors on outside walls can become a large problem when applied directly against a wall surface.

Corrective measure –

Remove all vinyl wall coverings from exterior walls. Stand mirrors off walls with small spacers with a space at the top and a space at the bottom.

CHIMNEY

Chimneys for fireplaces become an excellent source for moisture migration around loose fitting dampers. Many dampers are found not to close properly.

Corrective measure –

Assure all fire place dampers close tightly.

ATTIC FANS

Attic fans reduce the temperature of the attic. They also place a negative pressure across the entire diaphragm of the ceiling into the home. This causes an air exchange from the conditioned space of the home to the attic, which must be made up by the infiltration of moist conditioned outside air into the home. In most cases, shutting off attic fans, when air conditioning is running, reduces the home's energy bills.

Corrective measure –

Do not ventilate the attic by forced ventilation while air conditioning the space.

DUCT AIR LEAKAGE AND DUCT SWEATING

Duct air leakage into an attic places the inside of the home under a negative pressure forcing moisture and moisture-laden air to be pulled into the home. Duct leakage must be kept to a minimum. Where possible, ductwork should be run within the conditioned envelope.

In humid climates, where ducts conveying cold air (air at temperatures lower than the dew point) touch each other, touch insulation or other elements of the attic, condensation occurs. A very delicate balance is found in attics in humid climates. Surface temperatures of cold air conveying ducts often border on being at the dew point of the surrounding attic air. Duct insulation R-values are specified based on a temperature difference between the cold air conveyed through the duct and the expected attic air temperature. When the attic temperature is reduced, the temperature of the outside surface of the duct is reduced. If the R-value is appropriate for a large temperature difference, then less heat will be transferred into the duct material as that temperature difference is reduced by reducing the attic temperature. This means the temperature of the duct material will continue to drop and will go below the dew point. Experience has shown us that raising the attic temperature is far more effective in stopping duct condensation than adding insulation to the ductwork.

Over-ventilated attics, with radiant barriers and attics whose roof surfaces are heavy clay or white ceramic tile are subject to condensation of ducts, equipment, and piping. This is particularly true in attics with high-pitched roofs where the heat can't pocket around the materials.

Corrective measure –

Keep all ductwork separated from other ductwork, attic insulation and building construction materials. Keep conditions in the attic such that the dew point of the attic air is higher than the skin temperature of the ductwork at *all* times.

SALT PENETRATION OF THE ATTIC SPACES

In homes near or on salt and brackish water, it is common to find deterioration of the metal structural and non-structural components, ductwork skin and equipment. Over ventilated attics offer only accelerated deterioration.

Salt deposits on attic materials cause the materials to be moist whenever the outside relative humidities exceed 80%, due to the salt acting as an absorbent. Salt deposits on the thermal batt insulation cause the insulation to feel moist.

Addison Mizner, a noted architect of many Palm Beach estates and city buildings, designed and built many homes with no attic ventilation. Seventy-five years later, inspection of these attics reveal pristine conditions of all the materials in the attic.

A study of attic ventilation in the *ASHRAE Handbook of Fundamentals* reveals that the purpose of attic ventilation is to stop condensation from occurring when the moisture flows from the inside of the structure to the outside during winter conditions. In hot humid climates, quite the opposite occurs. A 20°F rise in attic temperature caused by closing off the attic vents in a properly insulated R-30 attic is quickly offset by the cooling load removed by lowering the vapor pressure in the attic and as a result closing off the moisture's pathway (the attic vents).

Corrective measure –

Close off the attic vents in humid climates where cooling is the primary condition, particularly on or near salt water. Check the insulation and ceiling surface for moisture. The insulation may need to be replaced if it is too laden with salt.

FAN CYCLING

Constant operation of fans in residences can result in a 10% increase in the relative humidities in homes with properly sized air conditioners. In oversized systems, corrections of 20% have been seen by using fan cycling in lieu of constant operation. This is due to the re-evaporation of moisture off the coil when the coil is inactive.

WATER BARRIERS VS VAPOR BARRIERS (VAPOR RETARDERS)

The selection and placement of vapor barriers in humid climates is critical to a successful job. A true vapor *barrier* is non-existent. Materials which have a high by not complete resistance to water vapor passage are available and referred to as both vapor retarders and vapor barriers. To be effective, a vapor retarder must be placed where condensing temperatures will not be achieved.

Many times, products which can effectively retain water in droplet (liquid) form are used as vapor retarders. Although it seems a natural conclusion that a material that is "water proof" of "moisture resistant" should be a good water vapor retarder, this type of assumption has been the downfall of many building structures. Careful research of the materials must be done to determine both the imperviousness to water in a liquid form and to water vapor, prior to using a material for a specific purpose.

Do not assume that mold and mildew growth on the interior of exterior walls is from moisture migration from the outside. Today's thermally insulated walls with effective vapor barriers are experiencing these problems. Adding insulation in walls does not always allow enough heat through the wall in humid climates to keep the surface humidities below conditions conducive to mold and mildew growth, especially during mild weather when air conditioners seldom cycle into the cooling and dehumidifying mode.

Corrective measure –

Careful study of the materials to be used and a complete understanding of the purpose for which the material is to be included in the construction, is the best way to eliminate problems caused by water barriers and vapor retarders.

ROOF DESIGN

Observation of field conditions indicates that there is a relationship between some roof types and a higher incidence of duct sweating problems in the attic. Some of the noted factors that appear when increased incidence of attic ductwork sweating occur are:

1. Roof slopes are 5 in 12 and greater

- heat pockets are kept high up in the attic away from the equipment and ductwork
- wind effects on high sloped roofs create higher levels of air exchange through the attic lower attic temperatures

2. Concrete tile or clay tile roofs. Attics under heavy roof decks operate at cooler temperatures. Light colored tile roof decks and "S" style barrel tile run cooler than other types of roof finishes. When attic ventilation is blocked off in these attics, attic temperatures do not reach the same levels as the same design with asphalt type roof finishes.

3. Radiant barriers in attics do a great job of reducing the sensible heat load into the attic space. However, their benefits to the overall cooling of the residence is in question.

To be properly installed, there must be ventilation to the attic provided at the lower edge of the surface from which the radiant barrier is supported, and there must be heat relief openings at the peak. These openings are the same ones that allow the moisture to come into the attic. This combination of moisture flow and temperature reduction, results in an increase in the dew point temperature of the attic. In a humid climate, this often raises the dew point temperature of the attic above the temperatures commonly present at the skin of ductwork and air handling units located in the attic spaces.

Roof structures with these same features, also located in the hot humid areas, but without the constant flow of air through the attics, often have little or no sign of duct sweating.

In all instances observed by us, in humid regions, the reduction of the air flow through the attic from the exterior has resulted in the reduction of duct sweating.

CONCLUSIONS

One of the most interesting features of the "Paston Effect" is that the initial investigation into the complaints commonly leaves the contractors, architects and equipment suppliers in confusion due to the appearance that "they did everything right." The home is normally designed with energy efficient components, i.e. good insulation R values, radiant barriers, overhangs for shading, high efficiency A/C equipment, etc. Construction on first inspection all seems to be normal for the standards of the area, etc.

One note – *usually* the residence is over 2500 square feet and a "custom" design rather than a "typical spec house" for the area.

Usually the problems are not located until an experienced "expert" is called in, or someone is very persistent in determining the reasons for the problems.

Most problems are a direct result of poor construction and poor construction practices, usually accompanied by poorly detailed plans. Some are caused by improper selection and installation of materials.

Most of the problems stem from lack of knowledge and use of the basics of building construction. A review of almost any book located in a contractor's, architect's or engineer's references will find information on these same concerns, and basic principles which must not be ignored.

Moisture intrusion was not covered here, neither was the design and selection of HVAC systems. Both can be major contributors to high humidity conditions. However, the "Paston Effect" occurs even when these two elements are correct and appropriate in both design and installation.

Even though all codes used commonly in the United States call for attic ventilation, it is imperative that we use common sense and look at the primary purpose for that ventilation before we contribute to an owner's problems. If the residence is on salt water in a humid climate, consider the reason for the attic ventilation requirement, and explore other methods of curing that particular concern, while reducing the

intrusion of salt laden air into the structure.

Moisture migration and infiltration must be reduced by paying more attention to the envelope of a home and the actual construction techniques of it. Remember that the "envelope" of the residence should be continuous for the best control of the space. Sometimes the thermal "envelope" and the vapor "envelope" will occur at different places, unless both the designer and the contractor understand the overall effect of the envelope and endeavor to maintain it's integrity at all times.

Energy conservation measures have decreased the sensible heat gain of homes, yet the moisture gains of the structures have not been equally reduced. The selection of HVAC equipment to maximize moisture removal is paramount in today's homes in humid climates.

If application of the basics of construction techniques and common sense is not used in the construction of the home, even the most careful of designers will end up looking at owner complaints.

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Ronald B. Bailey, P.E. CIAQP, CIE and Hollace J. Swanson, P.E. CIAQP, CIE are principals of Bailey Engineering Corporation, 8633 Damascus Drive, Palm Beach Gardens, Florida, 33418