

EXPENSIVE MOISTURE/INSULATION SYSTEM
PROBLEMS @ SEVERAL CENTRAL FLORIDA
AND SO. TEXAS NURSING HOMES

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ABSTRACT

These nursing homes were designed and built in the 80's and 90's. They experienced similar design and construction deficiencies and expensive repairs.

Some of the issues to be discussed in this paper are the interactions of architectural and HVAC shortcomings that result in a synergistic increase in mold, mildew, corrosion and rot.

ASHRAE 62 requires 24 hour per day toilet exhaust and fresh air. What do you do to control humidity when the A/C duty cycles when the thermostat is satisfied? There needs to be humidity control designed into the HVAC system.

Architects and contractors frequently take a "head in the sand" approach to wall and attic vapor barriers. This needs to be looked at realistically.

We have seen several nursing homes whose moisture/sheet rock damage was severe due to design defects that allowed free interchange of hot humid air between the attic and the space inside interior partitions.

Allowing air interchange between the attic and outdoors:

- can cause overheating of water in pipes in attics where temps. Reach 150° F.
- increases condensation due to inadequate details in mechanical insulation on ducts and pipes

Vinyl wall covering is well known to be a disaster in this climate but interior decorators continue to specify it on various walls.

HVAC balance needs to be considered. Frequently the kitchen exhaust design is not coordinated with the HVAC engineer. There needs to be a reasonable balance between air in and air out of the building.

When air is allowed to flow through the insulation system R value is reduced to near 0.

In order to prevent mold and mildew and expensive failures, along with even more expensive lawsuits, the HVAC system design and the insulation system design must be integrated.

INTRODUCTION

Over the past 40+ years as a consultant on insulation and moisture problems, I have seen thousands of buildings in distress. Many of these building owners had filed lawsuits against the architect, engineer, general contractor, sub contractors and material/equipment suppliers/manufacturers. I have served as an expert for both plaintiffs and defendants. During the early stages of the lawsuit the various defendants frequently state "we are not to blame and we will not pay." Unfortunately, before the case is settled, most defendants do pay, both to their lawyers and to the plaintiff. Settlements can range into the millions of dollars. It is not uncommon for a lawsuit to drag on for 5 to 10 years after the building is completed.

It would be so much better to do it right the first time and not have to pay the lawyers.

This paper is an attempt to assist owners, designers and contractors involved in buildings in hot – humid climates to stay out of court.

My use of the term "nursing home" may not be technically correct. Each of the 13 facilities studied for this report serviced elderly and/or disabled persons in a group residential setting.

CASE HISTORIES

1. Florida – 1980's – 5 nursing homes. These were completed within the year before my inspection and construction moisture (from drying concrete, mortar, etc.) was still an issue. The buildings were all single story and designed by a northern team of architects and engineers. At indoor temperatures ranging from 70 – 78°F

(21 – 26°C) the relative humidity ranged from 72 – 87% during my inspection. There was mold and mildew everywhere including on lamp shades, on beds and behind the vinyl wall covering.

There were low cost thru – the –wall air conditioners that removed minimal humidity. There were also 70 temporary portable dehumidifiers in one building! The walls were stucco over polystyrene foam (commonly called E.I.F.S.). The caulk in construction joints left much to be desired (it was terrible – holes everywhere). There was no vapor barrier in the ceilings. There was vinyl wall covering on many walls. The vinyl was stained due to the mold and mildew and many joints in the wall covering were gaping open due to the very wet gypsum wallboard. There was a slight positive pressure in the buildings.

The gypsum wallboard was near collapse due to saturation resulting from the lack of a warm sidewall vapor barrier combined with moisture/water leakage at the holes in the EIFS caulking. The vinyl wall covering became “the vapor barrier” in the wall and, for this climate, it was on the wrong (cold) side of the wall.

The lack of a ceiling vapor barrier increased the humidity in the buildings and stains were evident on the ceilings resulting from condensation.

These 5 projects were scattered all over the state from northwest to southeast and they were built from essentially the same set of plans.

2. So. Texas – 1980’s 2 nursing homes – both within 30+ miles of the Gulf. At indoor temperatures of 70 – 77°F (21 – 25°C) I measured relative humidities of 71 – 84%. (Similar excessive humidity to the Florida projects above). The patient rooms had individual thru-wall air conditioners. The common spaces had simple split system DX air conditioning with ducts above the acoustical ceiling. There was no effective humidity control (as was indicated by the R.H. data).

There was no vapor barrier in the ceiling/attic and no vapor barrier in the walls (except for the vinyl wall covering – on the wrong (cold) side of the wall).

There was condensation dripping from all of the ceiling penetrations – at smoke detectors, lights, and ducts. The door frames on interior partitions had mold growth (another case of moist attic air moving down interior partitions.) The glass fiber duct insulation workmanship was poor, resulting in more condensation drips in the corridors. Similar sloppy fiberglass pipe insulation application added to the attic condensation drips and stains. As in the Florida projects that I had seen a few days before, there was mold and mildew everywhere you looked. The building was porous to moisture infiltration and the air conditioning system was not designed to control humidity. The lack of a wall vapor barrier on the exterior was exacerbated by the vinyl wall covering. The inappropriate (for this climate) mechanical insulation specification, combined with sloppy workmanship in a hot humid attic resulted in stained, sagging acoustical boards. Not a pretty sight.

The exterior walls were stucco on metal lath over gypsum sheathing on one building and brick in the second facility. The building maintenance people were finding mold behind pictures on the walls (common in this climate). They found that after cleaning off the mold it would reappear within a few days (to be expected at 71 – 84% R.H.).

3. Central Florida - 1990’s – 5 locations – all multi-story nursing homes.

All were designed by a Boston area architect and engineers with limited hot-humid climate experience. The indoor relative humidity was measured from 66 to 78%. The architect specified a taped vapor barrier in the top floor ceiling but (unfortunately) the vapor barrier was deleted at the 11th hour of construction. The exterior walls were E.I.F.S. (Exterior Insulation Finish System).

The buildings were designed with a serious negative pressure (16,500 CFM of exhaust and 2900 CFM of fresh air make-up).

Vapor flows by diffusion (through most building materials at a quantity defined by the perm rate) and also flows with the direction of airflow. In these 5 buildings the diffusion vapor flow and the (negative pressure) air flow were both from outdoors into the building. In some buildings the diffusion flow and airflow can be in opposite directions. It is important to note that

when air flows through an insulation envelope (whether the insulation is fiberglass batts or urethane boards) the R value is reduced to near 0.

The thermal concept of fibrous insulation is that there is “dead” air trapped between the fibers. In this building, we had 90°F outdoor air being sucked (the building negative pressure) down through the fiberglass batts in the attic and through either the acoustical ceiling (most acoustical boards are quite porous to air flow) or through holes in the gypsum ceiling at mechanical and electrical penetrations (sprinkler pipes, recessed lights, etc.) into the conditioned (72°F) space. When air flows from outdoors (or in the opposite direction) to indoors through the insulation the temperature at the 2 surfaces of the insulation is the same and hence the R value goes from 19 down to 0. (assuming 5 ½” batts).

Outdoor humid air was sucked into the buildings via every hole – including the interior partition spaces (which on the fourth floor were open to the attic). Condensation and mold problems started on the top floor and worked its way down to the ground floors. Huge sums of money were spent removing the vinyl wall covering and the saturated gypsum wall board. Condensation and mold were severe at fire alarms, lights, vanities and other wall and ceiling penetrations.

The exterior walls were E.I.F.S. and there was no vapor barrier in the walls or ceiling.

At great cost the owners added 15 tons of air conditioning to each building in an attempt to reduce the humidity with “brute force.” The problems persisted. There were continuing condensation problems at the failed fiberglass A/C duct and chilled water pipe insulation.

The cost of the lawsuit will be remembered by all of the parties for the rest of their lives.

Part of the reason for the negative pressure in the buildings was the split responsibility (and lack of communication) between the HVAC engineer and the kitchen (exhaust hood) equipment consultant/contractor.

4. South Texas – 1990’s – single story – 1 nursing home within 20 miles of the Gulf.

At 68°F indoors (outdoors 82°F (28°C), 100% R.H.) the relative humidity was 68%. The building has brick walls and a sloped roof attic space containing piping and HVAC units. There were 2 dozen 5 ton DX (direct expansion) split system units in the original design.

The bare copper cold water pipes in the attic were delivering “cold water” to bathroom faucets at 114°F (46°C) due to the “solar” heating of the hot attic. This caused a bit of a panic as the state mandated maximum hot water temperature is 110°F (43°C). The plumbing pipes in the attic have since been insulated with elastomeric foam pipe insulation.

The attic during cloudy days and nighttime was the same hot – humid condition as outdoors. This warm moist attic air was free to travel into the interior wall partitions and cause mold problems behind the vinyl wall covering.

Condensation stains and mold were evident on the ceiling and walls.

The brick walls provided a degree of “vapor barrier” performance and I saw no need to tear out the brick to retrofit a vapor barrier to the walls.

The big moisture sources were the fresh air (required by code) and the more or less free interchange of humid air between the attic and the conditioned spaces.

The attic space had large areas where insulation was “forgotten.” The mechanical insulation on the pipes and ducts in the attic was inadequately specified and poorly installed resulting in more condensation.

The split system air conditioning had little effect on humidity control – especially when the fresh air fans ran 24 hours per day (per code) and the compressors cycled on and off to satisfy the space thermostats.

During the design phase there was confusion (at best) and a lack of coordination between the HVAC engineer and the food/kitchen consultant regarding the kitchen hood and make-up air. Texas Law (Title 40 Part I, Chapter 19 Subchapter D, 19.340) requires a balance of airflow in and out of the kitchen (NFPA 96) and also requires humidity controls to keep the living space below 60%. This was not done. The

HVAC engineer stated, during a legal deposition, that the owner didn't ask for humidity control. The response was that the owner also didn't ask for mold and mildew estimated to cost over \$1,000,000 to repair and correct.

Many tons of air conditioning split systems were added in an attempt by subsequent (local consultants) to control the humidity. It didn't work. However they now have enough tons of A/C capacity to get the space down to 60°F (15°C) if the occupants requested it! The excessive humidity continues.

Room by room, the owners are removing the vinyl wall covering and replacing the damp, moldy gypsum sheet rock.

PROBLEMS AND SOLUTIONS

A. Architect - Engineer

An owner hires a designer from the North to design a building in the South – or the other way around – this frequently leads to disaster unless the designer has adequate experience in the climate where the building is being built.

The engineer and architect need more communication and cooperation. The engineer needs to know about vapor barriers and the architect needs to be aware of humidity control and the consequences of the lack of R.H. control.

Kitchen hood – and the necessary make up air system design - need to be the responsibility of the HVAC engineer not a kitchen equipment “consultant.” Too many commercial kitchens have the air system “happen” instead of being designed to meet codes and be a part of the total building HVAC system. Inadequately designed (ie. Little or no make-up air) kitchen hoods cause or contribute to many of the expensive moisture problems that I see – especially in nursing homes.

A major aspect of the moisture problems in most of the above mentioned case studies was the imbalance of air in these buildings. Frequently the imbalance is due to a lack of make-up air for the kitchen exhaust hood.

NFPA 96 is the nationwide code for commercial kitchen hoods. This code requires “Replacement air quantity shall be adequate to prevent negative pressures in the commercial

cooking areas . . .” This means that if the hood exhausts 15,000 CFM then the HVAC design should have 15,000 CFM of treated make-up air.

When there is a negative pressure in the nursing home due to an improperly designed (ie. No make-up air) kitchen hood then the 15,000 CFM of hot-humid outdoor air is being sucked into the building via every crack and hole in the building. This results in condensation, mold, mildew, staining, rot and corrosion.

I shudder every time I see an architect's specification that reads “Install the building vapor barrier in accordance with the manufacturer's instructions.” I have been closely working with vapor barriers (or vapor retarders if you prefer – all the same) for over 40 years and I am not aware of any U.S. vapor barrier manufacturer that publishes any instructions on how to install their product.

If you don't know how to install a vapor barrier, ask some one who does know. Don't write an impossible specification.

B. Insulation and Vapor Barrier in Hot-Humid Climates

We all know that insulation is quite cost effective in this age of high-energy costs.

Some architects and contractors still do not realize that vapor barriers are even more cost effective. With a good, continuous vapor barrier system the air conditioning system can be smaller and cost less to operate. The main benefit is the reduction of mold and mildew problems. Vapor barriers in any climate must be as hole-free as is practical. Perfection is not necessary. Sealed joints are necessary. Wall vapor barriers that are sealed to ceiling vapor barriers are necessary.

Appendix A is a brief calculation for typical hot-humid climate nursing homes without a vapor barrier. Multiply these daily numbers by the actual square footage of your nursing home and you will see the water vapor diffusion (without a vapor barrier) costs money to remove either by more air conditioning or separate dehumidifying equipment. If there is a negative pressure in the building you can multiply the Appendix A numbers by 10 or even 100.

Factory facers on fiberglass batts are seldom adequate as a vapor barrier as there is no practical method to seal the joints.

Also most residential batt facers are very combustible and a code violation to have them exposed in any area of the building – including the attic.

The vapor barrier must be on the warm side of the insulation, which in hot-humid climates is on the exterior of the insulation. Vinyl wall coverings should NEVER be used in this climate.

Interior partitions must be sealed airtight from the attic space – probably also a requirement to prevent the spread of fire from a wall into the attic (check your local code).

Interior room partitions should always be sealed at the attic ceiling interface. By not sealing these partition spaces the hot, humid attic air (and fire) can travel freely into the partitions resulting in condensation and a “hole” in the hoped for thermal barrier (the attic insulation). The buildings I have seen you could look from the attic down into the partition space as there was no top plate on the partition.

Some designers in this climate like to “prevent moisture problems” by having a good positive pressure inside the building. I strongly disagree. Remember that air flow through an insulation envelope negates the insulation R value.

I prefer to insulate the roof of a building or in a retrofit, to insulate at the top chord of the roof trusses. This requires a rigid insulation rather than fiberglass batts. The probability of attaining a continuous, well installed, insulation system is much better with rigid boards such as foil-faced iso than with batts. It does cost more however.

Vapor barriers are not necessary in every building in every climate but a well designed, properly installed vapor barrier will make the building last longer and cost less to operate.

C. AIR CONDITIONING AND HUMIDITY CONTROL

Air conditioning, by its very nature, (except desert evaporative systems) reduces the humidity level in a conditioned space. *Generally* the less

expensive the system the less moisture it will remove from the air.

From cheap to expensive:

<u>\$</u>	<u>System</u>	<u>RH Control</u>
Cheap	Through Wall Or P.T.A.C.	least moisture control
Moderate	Split-System DX	some moisture removal
Expensive	Chilled water With reheat	controls humidity

There are also dedicated, single purpose dehumidifying systems such as treated rotary wheels and dehumidifying heat pumps.

Now there is a new split system package desuperheat control that proportions the refrigerant so that the compressor runs all of the time. The primary problem with split systems is when the compressor cycles off there is no moisture removal. This control can be retro-fitted to the average split system for \$1000 - \$2000 installed. It is a cost-effective way to have a split system remove moisture all the time not just when the thermostat is calling for cooling.

Appendix B shows the calculation for the amount of water brought into a building that must be removed to control to a 50% relative humidity inside the building. This water is air borne in the required make-up or fresh air. ASHRAE #62 is the law in most states. This code requires 25 CFM of fresh air per person. For a nursing home with 100 occupants (residents and staff) the required fresh air would be 2500 CFM. Using the calculations from Appendix B shows a need to remove a ton (2000+ pounds) of water per day in an Orlando nursing home or 2320 pounds of water in a Corpus Christi nursing home with 100 occupants. Add to that any extra make-up air for the toilet exhaust system and 10-15,000 CFM for the kitchen hood. This requires an air conditioning system that is specifically designed for this level of dehumidification. Thru the wall A/C (PTAC units) will not come anywhere near

this level of required dehumidification. Most DX A/C systems will not remove this much moisture from the air but are somewhat better than PTAC units.

D. MECHANICAL INSULATION IN HOT-HUMID CLIMATE

Fiberglass is an excellent, cost effective ubiquitous insulation. That said, it is not the best insulation where there is a high moisture stress – such as cold surfaces in a hot humid climate. The fiberglass is completely dependent upon a thin vapor barrier, which is sensitive to sloppy installation and subsequent perforation. I always specify, for A/C ducts an elastomeric foam insulation.

Generally, domestic cold water pipes don't need insulation to prevent condensation (as is required in the North where cold water is cold), but if the pipes are in a hot space (see hot attic story above) then the cold water pipe should be insulated.

All insulation joints must be carefully sealed - on any cold insulation especially. Care must be taken to have the correct pipe hangers and saddles and adequate structural support for the pipe.

Valves must be carefully insulated to prevent condensation. A lot of the very poor quality pipe insulation work that I see was done by every trade except pipe insulators.

Chilled water pipes require extra care to prevent condensation problems. I usually specify either cellular glass or double layer elastomeric foam.

Any elastomeric foams used outdoors must be protected with mastic or paint.

Urethane (Iso) or polystyrene foams on cold piping require a high performance vapor barrier (and outdoors a weatherproof jacket in addition to the vapor barrier).

SUMMARY

Attention to detail is the key to preventing moisture problems.

Hot-humid climates in the U.S. do not have much experience with building vapor barriers

and unfortunately the result is frequently “acceptance” of, mold and mildew problems. It doesn't have to be this way.

The physics/thermodynamics of moisture problem solution is quite simple:

1. Install vapor barriers on the exterior (warm side) of the insulation. Seal the joints/penetrations in the vapor barrier (in both walls and ceilings).
2. Dehumidify the make-up (fresh air) coming into the building to keep the relative humidity below 55%.
3. Maintain a relatively neutral pressure in the building so that the R value of the thermal envelope is not compromised by air flowing through the insulation.
4. Insulate cold pipes and ducts with good quality foam insulation, carefully installed.

APPENDIX AVapor Diffusion Calculations (assume no holes)

Typical wall – stucco, gypsum sheathing, fiber-Glass, sheet rock, paint.

$$10,000 \text{ sq. ft. of wall} \times 1 \text{ perm} \times 24 \text{ hrs} \times \frac{1}{2} \Delta P \\ = \frac{120,000 \text{ grains}}{7,000 \text{ grains/\#}} = 17\# \text{ water vapor per day per } 10,000 \text{ sq. ft.}$$

Typical ceiling – painted sheet rock

$$10,000 \text{ sq. ft. of ceiling} \times 3 \text{ perms} \times 24 \times \frac{1}{2} \Delta P \\ = \frac{360,000}{7,000} = 51\# \text{ water vapor per day per } 10,000 \text{ sq.ft.}$$

The basic assumption of no holes will never happen as there are always electrical, plumbing, and HVAC holes in any building wall or ceiling – unless you are in a submarine.

APPENDIX BFresh Air Moisture Calculations

For every 1000 CFM of fresh air in this climate and assuming 78°F (21°C) (54 grains) and 50% R.H. there is 800 – 900 pounds of water (vapor) that must be removed daily. That is called latent load.

Most of the buildings in this report have had a total fresh air flow of 10,000 – 16,000 CFM.

$$1000 \text{ CFM} \times 60 \text{ min./hr.} \times 24 \text{ hrs.} = 1.44 \times 10^6 \text{ ft}^3 \text{ per day}$$

$$\frac{1.44 \times 10^6}{14.2 \text{ ft.}^3 \text{ per \#}} = 101,408 \text{ pounds of air per day}$$

Orlando design

$$93^\circ\text{F}, 76^\circ\text{WB}, 46\% \text{ RH} = 110 \text{ grains/\#}$$

$$\frac{101,408 \times (110-54)}{7,000 \text{ gr./\#}} = 812\# \text{ water vapor per day per } 1000 \text{ CFM}$$

Corpus Christi design

$$94^\circ\text{F}, 78^\circ\text{WB}, 49\% \text{ RH} = 118 \text{ grains/\#}$$

$$\frac{101,408 \times (118-54)}{7,000} = 928\# \text{ water vapor per day per } 1000 \text{ CFM}$$