Humidity Control in the Humid South

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Abstract:

Humidity concerns in the southern humid climates are particularly difficult to resolve. This is because one of the most effective approaches to dealing with humidity in heating climates, ventilation, can cause major humidity problems in the humid south. The issue becomes even more complex when you realize that you can replace the word humidity in the previous sentences with the words "indoor air quality " and not change the meaning or impact. Dilution is often used as the solution to indoor pollution in heating climates. Unfortunately, in humid, air conditioning climates, the greater the rate of dilution, ventilation or air change, the greater the rate of moisture entry with the exterior air. Therefore, the greater the likelihood of mold and other biological growth problems, particularly if the moisture in this incoming air is not removed.

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Joseph W. Lstiburek, P.Eng.

Humidity concerns in the southern humid climates are particularly difficult to resolve. This is because one of the most effective approaches to dealing with humidity in heating climates, ventilation, can cause major humidity problems in the humid south. The issue becomes even more complex when you realize that you can replace the word humidity in the previous sentences with the words "indoor air quality " and not change the meaning or impact. Dilution is often used as the solution to indoor pollution in heating climates. Unfortunately, in humid, air conditioning climates, the greater the rate of dilution, ventilation or air change, the greater the rate of moisture entry with the exterior air. Therefore, the greater the likelihood of mold and other biological growth problems, particularly if the moisture in this incoming air is not removed.

Air conditioning buildings (mechanical cooling) is the major source of both humidity and indoor air quality concerns in the humid south. When exterior hot, humid air is cooled its relative humidity is increased. If it is cooled sufficiently, condensation occurs. High relative humidities and condensation can lead to mold and other biological growth. Interior relative humidities at surfaces and within building cavities need to be controlled to prevent condensation and biological growth.

An ideal approach to control indoor humidity and indoor air quality in the hot, humid south is to minimize the need for outside air. The air should be obtained in a controlled manner (mechanically with a fan). The air should be conditioned where it comes into the building. It should be dehumidified by cooling it below its dew point, and used to maintain the enclosure at a slight positive air pressure relative to the exterior. By doing so, it can be used to control the infiltration of exterior hot, humid air. Furthermore, the building envelope should be built in a manner that aides in the pressurization of the building. Tight construction is recommended. The building envelope should also exclude rain, control rain water absorption and control vapor diffusion. Vapor diffusion retarders should be installed on the exterior of building envelopes in the humid south as compared to the practices in northern heating climates. Finally, the building envelope should be forgiving so that if it gets wet, it can dry to the interior. Interior vapor diffusion retarders such as impermeable wall covering should be avoided.

This approach has implications with respect to building envelope tightness and moisture permeability/resistance, air consuming devices, interior activities, interior pollutant source strengths, housekeeping practices, operating costs for air conditioning equipment, and air conditioning loads.

Not following this approach has even greater implications with respect to health, safety, comfort, durability, maintenance and affordability.

Mold and Biological Growth Problems

When problems from mold and biological growth do occur in the humid south, they can be divided into three distinct categories:

- problems on interior surfaces due to elevated levels of moisture in the interior conditioned air (high interior air relative humidity);
- problems on interior surfaces due to surfaces being too cold leading to high relative humidities at the cooled surfaces; and
- problems within building cavities due to high cavity moisture levels or moisture passing through building cavities causing high relative humidities on material surfaces as the moisture migrates into the conditioned space

Although these problems can occur independently of each other they often occur in combination. For example, elevated levels of interior moisture are usually due to moisture passing through building cavities from the exterior resulting in both cavity moisture problems as well as problems on interior surfaces once the moisture has gotten into the conditioned space. Overcooling of the space just magnifies both problems thereby creating a third.

Interior Surface Related Problems Due to Elevated Levels of Moisture When interior moisture levels are high, relative humidities at surfaces also are high. Where relative humidities at surfaces are greater than 70 percent mold and other biological growth can occur. In the humid south, the moisture source for these problems is almost always the exterior air. Moisture must be removed from the air within conditioned spaces such that relative humidities at surfaces remain below 70 percent. Where conditioned spaces are cooled to 75 degrees Fahrenheit, relative humidities in the air within the space should not exceed 60 percent.

Air which is brought in from the exterior to supply ventilation needs and make-up air needs should be conditioned to "dew point 55". In other words, this air should be cooled to at least 55 degrees Fahrenheit in order to dehumidify it. At dew point 55, the temperature of the air is 55 degrees Fahrenheit and its relative humidity is 100 percent. Once this air is warmed up to 75 degrees Fahrenheit, the temperature of typical air conditioned spaces, its relative humidity will be approximately 50 percent. This air now mixes with the air in the space diluting/reducing the conditioned space moisture levels/relative humidity. The rate of dilution or mixing is determined by meeting the 60 percent relative humidity limit within the conditioned space.

The dehumidification capabilities of air conditioning systems are typically used to remove moisture from the air within the conditioned space. Unfortunately, the latent cooling loads (the energy required to cool/remove the moisture in the air) are usually higher than sensible cooling loads in the humid south. This means that air conditioning systems should be sized for their latent loads, rather than their sensible loads. Sizing of equipment becomes critical. Undersizing of air conditioning equipment can lead to to obvious comfort and humidity problems. However, oversizing of air conditioning equipment can also lead to high interior humidity problems since oversized equipment will not operate as often, and therefore will dehumidify less than properly sized equipment.

Concerns about energy conservation has lead to the development of energy efficient mechanical cooling systems. Unfortunately, this has also reduced the ability of many of these systems to dehumidify air. In many cases, the exterior air is not cooled sufficiently to remove sufficient quantities of moisture.

Air cooled to 55 degrees Fahrenheit is usually too cold to introduce into a space. In the past this cooled air was heated after it was cooled ("reheat") prior to use. Reheat results in a significant energy penalty, and is not allowed in many jurisdictions for this reason. To avoid reheat requirements, some systems do not cool air down to "dew point 55". Unfortunately, this can result in insufficient moisture removal and subsequent high interior moisture levels.

Two approaches have been successfully used to address the issue of reheat. One is a new technology: heat pipe heat recovery. The other dates back to the 1930's and has been recently "rediscovered": run-around coils. Both of these approaches use heat removed during the mechanical cooling process to "reheat" the cooled air once it has shed its moisture thereby reducing the energy penalty of standard reheat.

Interior Surface Related Problems Due to Overcooling of Surfaces

When surfaces become too cold, surface relative humidities rise above 70 percent. When they rise to 100 percent, condensation occurs. If air conditioned air is supplied at too low a temperature, the diffusers can be extremely cold leading to condensation ("sweating"). Where diffusers are located poorly or adjusted incorrectly, cold air may be "blown" against surfaces creating cold spots and localized areas of high relative humidity and mold growth.

Supply ducts enclosed in interior walls and dropped ceilings often are not sealed and leak supply air. This supply air is typically under substantial positive air pressure and the resulting "jet" of air can "blow" against a surface leading to localized cooling. The cooling happens from the building cavity side, whereas the mold growth usually appears on the room side.

In cooling climates, condensing surfaces of exterior walls are typically the interior gypsum board. If interior spaces are "overcooled", the interior surfaces fall below the dew point temperature of the exterior air and condensation occurs. Figure 1 illustrates the case of a wall experiencing condensation as a result of overcooling. By raising the interior conditioned space temperature, the temperature of the first condensing surface is raised. Consequently, as the graph in Figure 1 shows, the potential for condensation is eliminated in this climate.

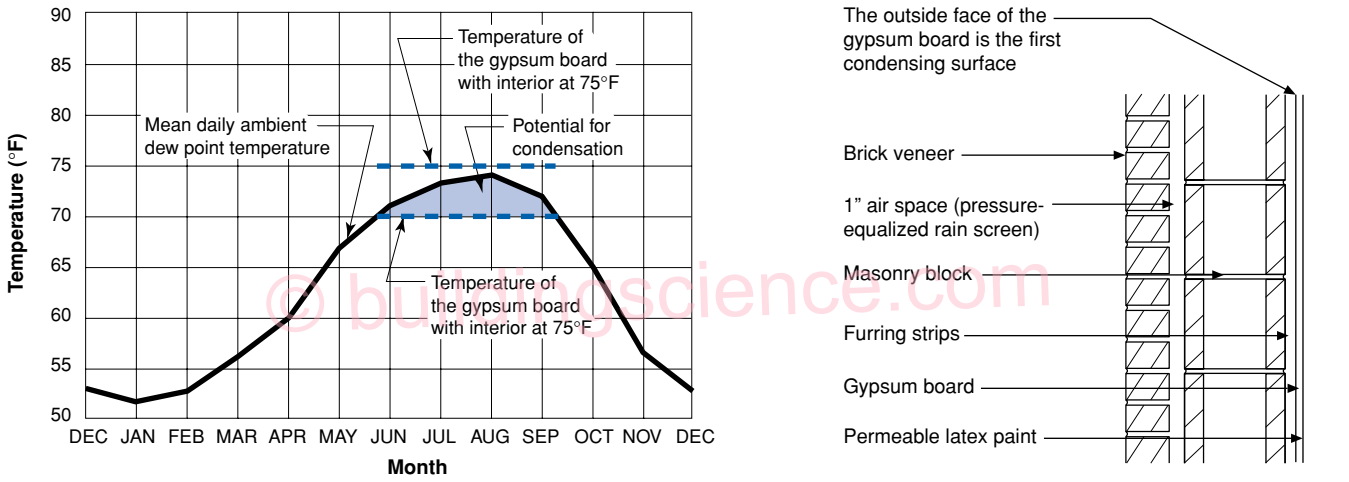

Figure 1: Potential for condensation in a masonry wall cavity in Tampa, Florida
By raising the temperature of the interior conditioned space from 70°F, the temperature of the first condensing surface (the outside surface of the gypsum board is raised above the mean daily ambient dew point temperature so that no condensation will occur.

Figure 2 illustrates the case of a wall experiencing condensation as a result of diffusion in a particularly severe cooling climate (Miami, Florida). By using impermeable rigid insulation (approximately R-7) on the interior of the masonry wall, the temperature of the first condensing surface is raised. As shown in the graph in Figure 2, condensation potential is eliminated since the temperature on the exterior face of the rigid insulation (the first condensing surface) is above the ambient range throughout the year.

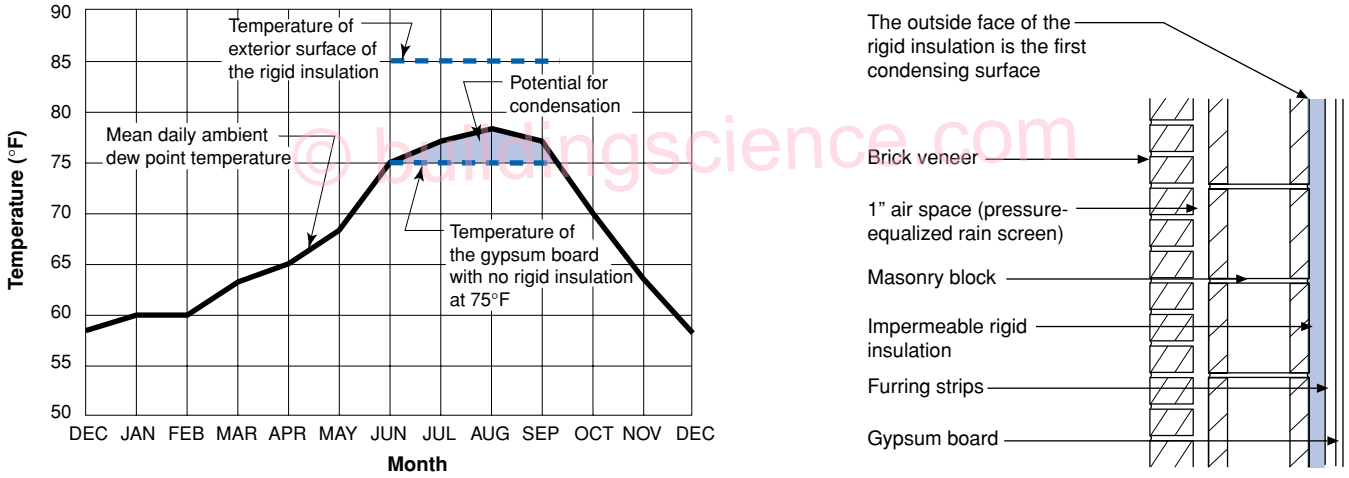

Figure 2: Potential for condensation in a masonry wall cavity in Miami, Florida
Placing rigid insulation on the interior of the masony wall raises the temperature of the first condensing surface above the mean daily ambient dew point temperature so that no condensation will occur. The outside surface of the rigid insulation becomes the first condensing surface in this assembly.

Overcooling of spaces often occurs as a result of ignorance and/or poor design. Most people in the humid south are aware of the fact that the more an air conditioner operates the greater the removal of moisture from the interior air by the air conditioner. System controls are therefore often adjusted to provide frequent operation of the system. To keep systems operating more frequently, thermostat settings are lowered below recommended levels. In addition, when systems are oversized, in order to operate for longer periods of time, thermostat settings have to be lowered resulting in overcooled spaces.

In a final, unfortunate irony, overcooling a space can actually increase latent loads rather than result in a net moisture removal. Moisture flow is generally from warm to cold. The colder the space the more moisture is drawn into the space from the exterior.

Building Cavity Moisture Problems

In the humid south, moisture flow is typically from the exterior to the interior or from the warm to the cold. If the rate of moisture entry into the building envelope from the exterior is greater than the rate of moisture removal from the building envelope into the conditioned space, accumulation occurs with building envelope cavities and serious problems result.

The general control strategy for building envelopes in the humid south is quite straightforward. Make it difficult for moisture to enter the building envelope from the exterior, and make it easy for moisture to leave the building envelope to the interior.

Moisture enters building envelopes from the exterior in the humid south three major ways:

- rain leakage
- air leakage
- vapor diffusion

Controlling these mechanisms means keeping the rain out of the building envelope, keeping exterior air out of the building envelope and keeping exterior moisture from vapor diffusion out of the building envelope. In addition it also means being realistic about the probability of success at controlling these mechanisms and therefore providing a means of drying to the interior. In practice, this usually means not preventing the normal/ typical drying to the interior conditioned space by installing an impermeable wall covering.

Rain is a particularly severe mechanism of moisture transport in the humid south. When rain wets the exterior of a building the exterior surfaces typically absorb the rain water. For instance, brick cladding is a powerful rain water "sponge". Recall that moisture flow is from warm to cold. When wet brick is warmed by the sun, a significant temperature differential is created. The sun serves to "drive" rain water into a building envelope. If the interior space is also air conditioned or cooled, the air conditioning serves to "suck" the rain water inwards as a result of a temperature differential.

The effect of incident solar radiation on a rain saturated cladding is dramatic. Consider that a brick veneer or stucco coating can be readily warmed by the sun well above 120 degrees Fahrenheit. The air contained in an airspace behind a brick veneer can be similarly warmed and can be considered to be at saturated conditions (vapor pressure of 11.74 kPa). This results in an increase of almost 500 percent in the effective exterior vapor pressure (Figure 3). Solar radiation is a powerful force that drives moisture in rain-saturated cladding inwards. This force can be ten times greater than the vapor diffusion driving moisture outwards under the most hostile conditions experienced in heating climates.

Exterior sprinklers can excacerbate problems by wetting exterior claddings on a regular basis. The normal southern climate temperature differential then serves to move this sprinkler deposited water into the conditioned space.

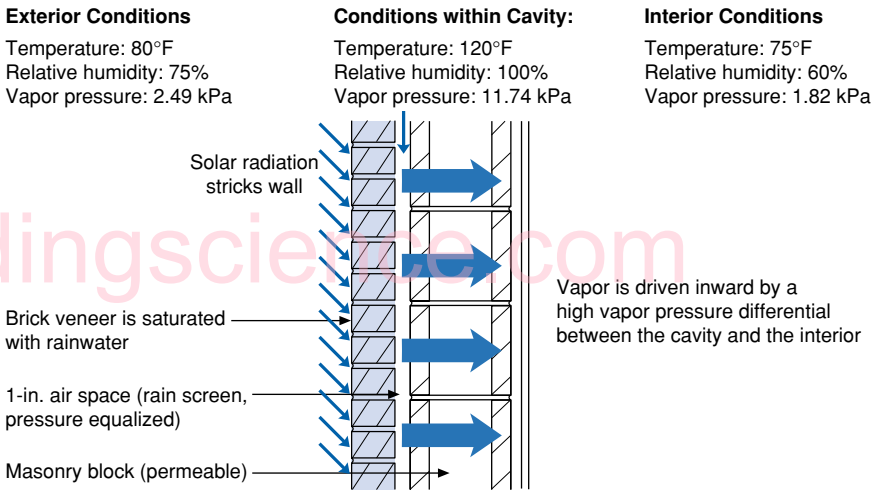

Figure 3

Rain water must be prevented from being absorbed by building envelopes. Stucco claddings should be painted/sealed to prevent rain water absorption. Brick veneers should be installed only in conjunction with air barrier/vapor barrier membranes/coatings installed between them and the rest of the building envelope.

Air leakage of exterior humid air into air conditioned building envelopes is being recognized as the major source of most of the IAQ moisture related problems in the humid south. For exterior air to be a problem in a building envelope in the humid south, three conditions must be present:

- moisture must be in the air;
- a hole, opening or pathway must exist; and
- a pressure difference must exist which draws the moisture laden air into the hole, opening or pathway.

Examining these three conditions it becomes clear that moisture will almost always be present in the exterior air. Furthermore, holes, openings and pathways will also always be present because it is not possible to ensure perfect workmanship and perfect materials are not available. The only method of controlling air leakage in the humid south is controlling air pressure differences across building envelopes and within building cavities.

Where problems have occurred, it is because interior conditioned spaces have been at a negative air pressure relative to the exterior and/or building cavities have been at a negative air pressure relative to the exterior.

Infiltrating humid air will carry moisture into wall and building assemblies. Whether moisture is deposited within the assemblies depends on the moisture content of the air and the surface temperature of each material in the wall assembly.

In the humid south, vapor pressure differences between conditioned spaces and the exterior are often greater than those typically found in heating climates. For example, the vapor pressure difference between the exterior design dew point temperature in Miami (79 degrees Fahrenheit, 2.49 kPa) and an interior air conditioned space (55 degree Fahrenheit dew point temperature, 1.50 kPa) is 0.97 kPa. In Minneapolis, with a heating design temperature of minus 16 degrees Fahrenheit (0.06 kPa) and an interior space conditioned to 70 degrees Fahrenheit at 35 percent relative humidity (0.93 kPa), the vapor pressure difference is 0.87 kPa. The cooling climate vapor pressure difference is 15 percent larger than the vapor pressure difference in the heating climate. While the cooling climate vapor pressures are more significant, measures to control vapor diffusion are more commonly accepted by the building community in heating climates.

In the humid south, vapor diffusion retarders (vapor barriers) should be installed on the exterior of building envelopes. Vapor diffusion retarders or materials which act as vapor diffusion retarders should not be installed on the interior of building envelopes. Most wall coverings and virtually all vinyl wall coverings are vapor diffusion retarders and should not be installed in buildings in the humid south (Figure 4).

Moisture will accumulate at the interface of the wall covering and the gypsum board. Mold and other biological growth can occur under these conditions. Excretions from some forms of growth can react with vinyl wall coverings, resulting in pink "blotches" that show through the finished surfaces.

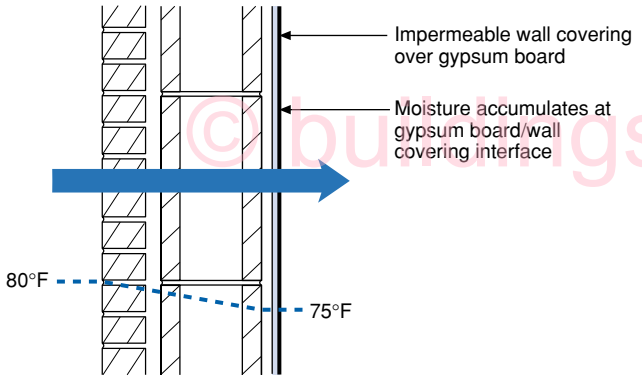

Figure 4

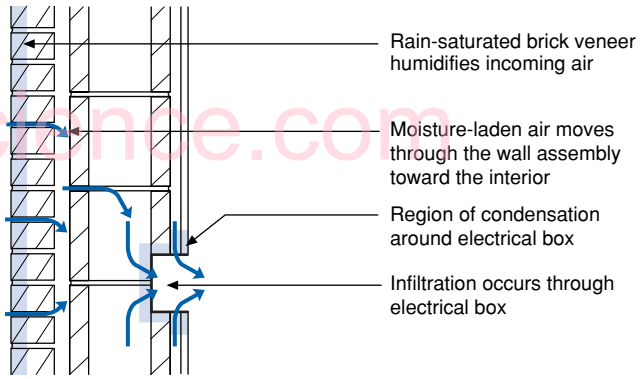

Figure 5

Where air movement and vapor diffusion both occur, air movement tends to dominate vapor diffusion and has a significantly greater effect on moisture transfer into building assemblies than vapor diffusion alone.

Figure 5 illustrates the effect of infiltrating air through an electrical outlet box in a concrete masonry block wall assembly. The effect of air leakage on the wetting of the wall assembly is significantly magnified as a result of rain wetting the exterior cladding. The rain-saturated building elements "humidify" the infiltrating air as it passes through, over, or around them.

Ventilation and Make-up Air

The minimum requirements for outside air should be set by applying ASHRAE Standard 62-1989. Unfortunately, for many buildings in the humid south, this requirement will likely be far in excess of what has been typical practice. Most existing facilities do not have the cooling capability to handle the sensible and latent loads imposed by meeting ASHRAE Standard 62-1989. In new facilities, the cooling capacity will be present as they will probably have been designed to meet ASHRAE Standard 62-1989. However, the operating cost implications of following ASHRAE Standard 62-1989 applies pressures on facilities managers to operate the systems at less than the recommended minimum outside air.

Since air change or dilution is likely to be limited, source control becomes paramount. Housekeeping practices, occupant activities, interior furnishings and building materials/components are key areas to review with respect to source strength.

The tighter a building envelope or enclosure, the less air required in order to pressurize the conditioned space. Leaky buildings require a great deal of air from the exterior in order to pressurize. The air which is brought in from the exterior in order to achieve pressurization must be dehumidified and cooled. The more air which is brought in, the greater the cooling load and the greater the operating cost. It is therefore desirable to build tight building envelopes in order to minimize the amount of air required to provide pressurization.

Many building enclosures have exhaust systems and air consuming devices such as dryers and cook tops which extract air from a building. This air must be replaced with "make-up" air. If it is not, depressurization of the conditioned space occurs, resulting in the infiltration of exterior, hot humid air (Figure 6). More air must be mechanically supplied to a building, then is extracted under all operating conditions.

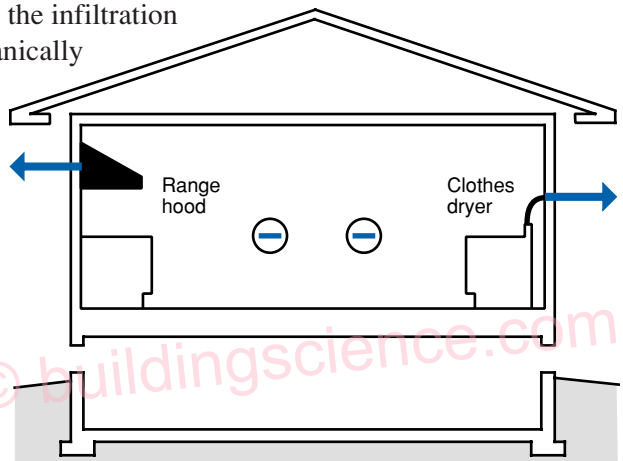

Figure 6

In some facilities, "make-up" air is attempted to be supplied "passively" through packaged terminal air conditioners (PTAC's) or heat pumps (PTHP's). These are the typical under window through-the-wall units. The approach is common in hotels and motels and involves air extracted from a washroom via a central exhaust system. For air to be drawn into the room through the PTAC or PTHP a negative pressure must exist in the room. The central exhaust system creates this negative pressure. Unfortunately, air is also drawn into the room through random leakage openings in the building envelope as well as through the PTAC or PTHP.

Some PTAC and PTHP units supply make-up air with a fan in order to deal with the negative pressure problem of passive make-up air openings. Usually this air is supplied only when the unit is operating. The duty cycle (on time) of these units is typically 20 to 30 percent. However, the central exhaust from the bathroom is usually on continuously. In other words 70 to 80 percent of the time make-up air is not being supplied and the conditioned space is under a negative pressure relative to the exterior. It is necessary to coordinate the exhaust fan operation with the duty cycle of the PTAC and PTHP units in order for this strategy to work. This is almost impossible to coordinate, and negative air pressures result.

The other major concern with supplying make-up air is that the make-up air should be conditioned. In other words, the moisture removed from it prior to being used in the facility (conditioned to "dew point 55"). Supplying make-up air through passive inlets or through window units typically provides unconditioned air with substantial moisture.

The recent experiences of serious mold and biological related indoor air problems in the humid south have underscored the need to supply make-up air mechanically and condition it prior to use. In addition, more air should be supplied than is extracted. Passive supply of unconditioned air is just asking for trouble. Recent experiences have shown that if you don't supply the make-up air deliberately, the building will supply it for you. When the building supplies it, it does so accidentally through random leakage areas likely in probably the worst possible location from an IAQ perspective.

Air Handlers, Duct Leakage and Unbalanced Flows

Air handlers create air pressure differences in buildings in two ways:

- duct leakage; and
- unbalanced flows

Most forced air duct systems leak substantial quantities of air. Field investigations have shown that 10 to 15 percent leakage of duct flow is typical. The effect of duct leakage on building enclosure pressures and air quality can be significant.

For example, if leaky supply ductwork is installed in the atttic or crawl space of a home, air is extracted out of the building, depressurizing the conditioned space. This leads to the infiltration of hot, humid air and likely mold and other biological growth related problems (Figures 7 and 8).

If leaky return ductwork is installed in an attic, air is supplied to the building from the attic, pressurizing the conditioned space. Infiltration of hot, humid air does not occur, but the pressurization is accomplished with hot, humid air significantly increasing interior moisture levels. If the

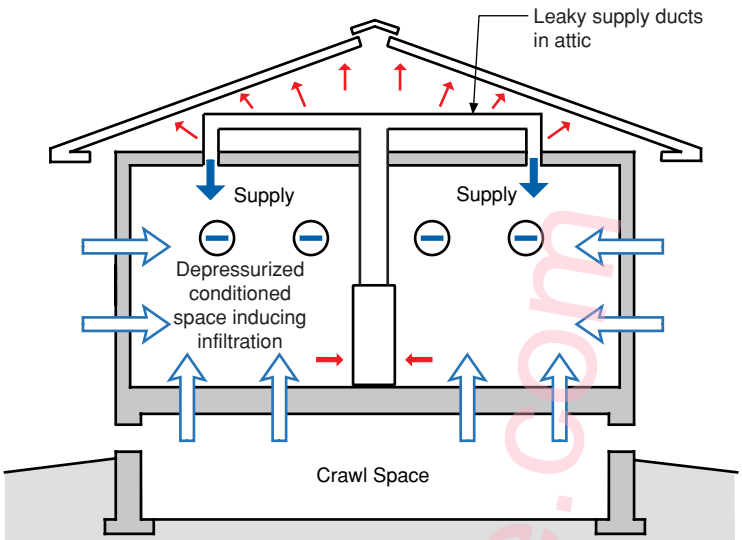

Figure 7

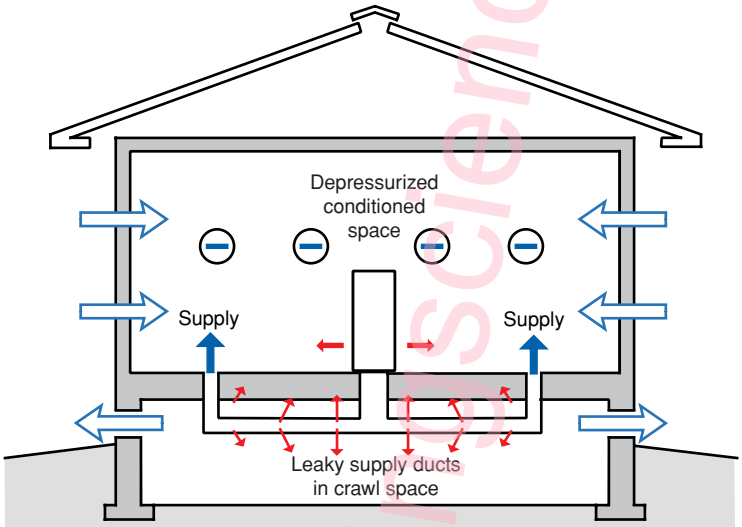

Figure 8

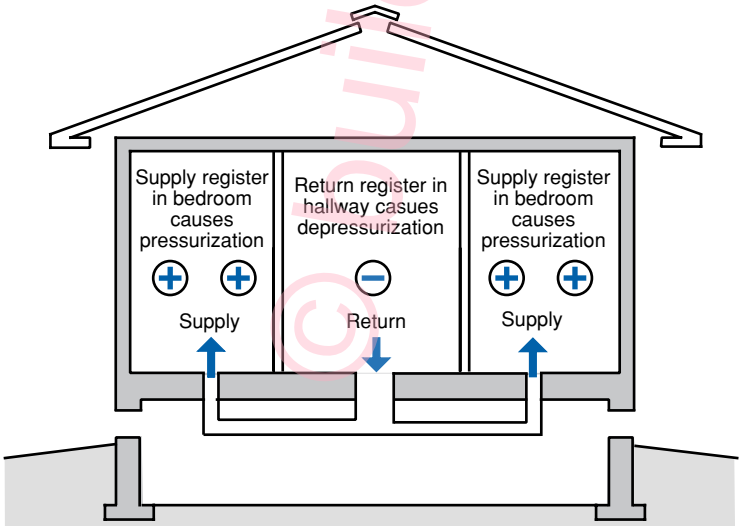

Figure 9

moisture removal capability of the cooling system is unable to remove this moisture, mold and other biological growth also occurs.

Unabalanced flows often occur when supply and return flows to individual rooms are not equal. This typically occurs when supply air registers are located in bedrooms and a return is located in a hallway. When the bedroom doors are closed, air is not able to access the return and bedrooms become pressurized and the hallway becomes depressurized (Figure 9).

A common example of an air pressure related moisture problem in a hot, humid climate occurs where the air handler for a forced air cooling system is located in a closet/utility room. A large unsealed opening often exists between the supply ductwork, which is located in the attic space, and the ceiling of the closet/utility room where the supply duct penetrates (Figure 10). Return air for the system is drawn from the hot, humid attic space into the utility room through the opening around the ductwork and into the return grill of the air handler. There are cases where the temperature of the air conditioned space has actually gone up when the air conditioner was turned on in similar installations. The cooling load increase that occurs from drawing the hot, humid air into the system is actually greater than the capacity of the cooling system. Ductwork should never be installed unless it is sealed airtight with mastic and then tested for leakage.

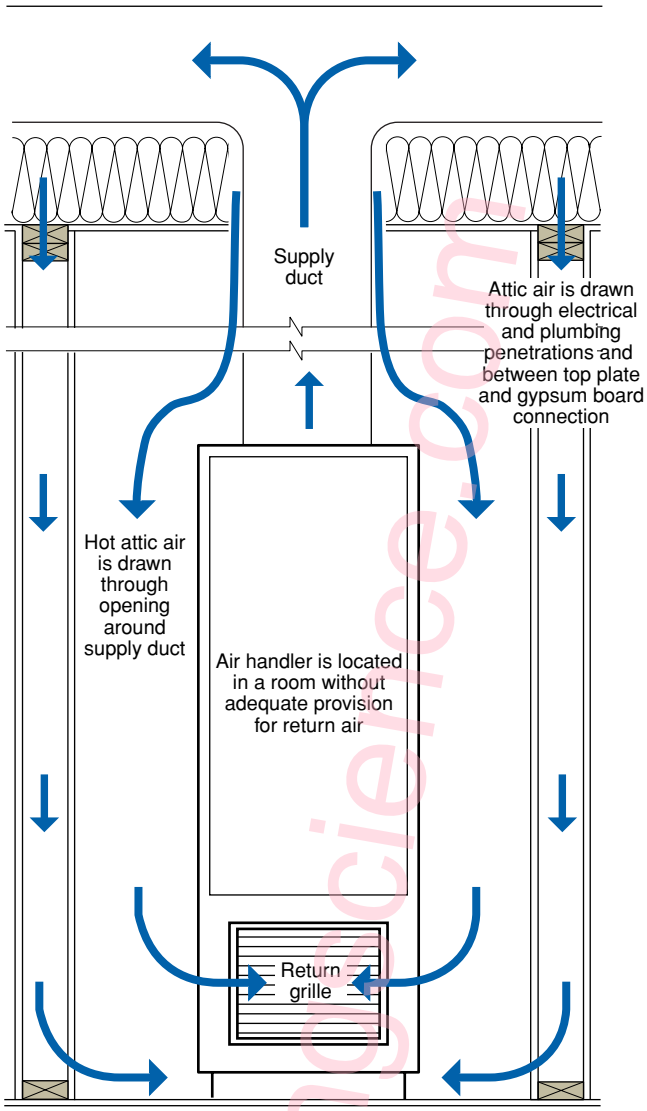

Figure 10

These principles can be extrapolated to large commercial or institutional facilities with numerous air handlers and duct systems. Now the pressure relationships can become very complicated. One zone of a building can become pressurized, while another zone of a building becomes depressurized. Furthermore, leakage of ductwork enclosed within building cavities can lead to the depressurization or pressurization of the cavities themselves. This is very common in hotel and motel facilities where individual room air handlers with leaky housings are built into exterior corners or built into dropped ceiling locations where demising wall cavities are connected directly to exterior walls. It is not unusual to have a room at positive air pressure relative to the exterior, while the wall cavities are at a negative air pressure relative to the exterior.

Negative air pressure fields in interstitial spaces can extend great distances away from air handling equipment due to the perforated nature of most framing systems coupled with electrical, plumbing, and mechanical servicing.

When the amounts of supply and return air are the same in a room or a facility, no air pressure differential occurs. Many facilities are "commissioned" by balancing contractors who measure air flows in and out of spaces. Since traditional air balancing is limited to the measurement of air flows into and out of supply and return registers, it is ineffectual at identifying duct leakage and air pressure relationships in building conditioned spaces and cavities. Zonal air pressure differentials are rarely measured. Furthermore, subtracting the sum of the return flows from the sum of the supply flows will not determine quantities of outside air or pressure relationships since duct leakage of the conditioning unit (return/supply) and exhaust ducts is not considered.

Air pressure relationships should be determined with smoke pencils and digital micromanometers. Relationships between rooms and the exterior as well as between building cavities and the exterior should be determined. These pressure relationships should be determined with air handling equipment on and off as well as with exhaust systems on and off.

Building mechanical systems can succeed in pressurizing building enclosures relative to the exterior with conditioned air. However, duct leakage from return systems and air handlers enclosed in building cavities and service chases can succeed indepressurizing demising walls and other interstitial cavities. If these cavities are connected to the exterior they become pathways for infiltrating hot, humid air. As this air is cooled on its inward journey, moisture can be deposited on the surfaces within these cavities. Once moisture is deposited on these surfaces, vapor diffusion attempts to pull the moisture into the conditioned spaces. If interior surface finishes retard this inward migration, serious problems can occur.

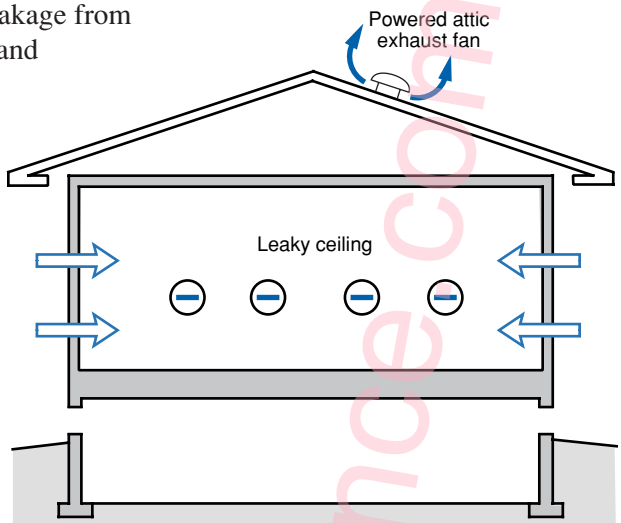

Figure 11

Depressurization of entire building enclosures can occur unintentionally through the installation of powered attic exhaust fans (Figure 11). Although these exhaust fans are located exterior to the conditioned space, leaky ceilings can effectively couple attic spaces to interior conditioned spaces.

Recommended Approach to Residential HVAC Systems in the Humid South

The choice of heating and cooling approaches limits the choice of mechanical ventilation options and should be made first. Forced air heating or radiant heating can lead to different mechanical ventilation system requirements. Mechanical cooling is usually provided through a forced air approach and similarly limits possibilities for mechanical ventilation systems. The most common approachs involve forced air heating combined with forced air mechanical cooling or distributed mechanical cooling (split system multiple coils, individual room units such as packaged terminal air conditioners, PTAC units).

Air change through mechanical ventilation can be utilized during heating periods to control interior moisture levels. Dehumidification through the use of mechanical cooling (air conditioning) can be utilized during cooling periods to control interior moisture levels.

Fuel source selection does not impact the approach to space conditioning (forced air or radiant), but does impact the type of equipment selected. If combustion appliances are selected, they should not be subject to backdrafting or spillage of combustion products.

Only sealed combustion or power vented combustion appliances should be used for space conditioning and/or domestic hot water. Ideally, combustion appliances should be installed exterior to the conditioned space (in a garage or utility room accessed from the exterior and isolated from the building). Some combustion systems provide for the installation of the combustion source exterior to the building envelope, and the associated air handler within the conditioned space (a fan coil unit located inside the conditioned space and the heat source, a gas water heaterl, located in a garage). Gas cook tops and/or ovens should be only installed in conjunction with a direct vented (to the exterior) exhaust range hood. Gas cook tops and/or ovens which can be directly vented are recommended.

Recirculating range hoods should be avoided due to health concerns. If these devices are not frequently serviced, through cleaning and filter replacement, they become a host for biological growth and a major source of odors.

Avoid unvented combustion appliances. Provide fireplaces with their own air supply (correctly sized) from the exterior as well as tight-fitting glass doors.

Air handlers should be located within the conditioned space with provision for easy access to faciltitate servicing, filter replacement, drain pan cleaning, future upgrading and/or replacement as technology improves. Hostile locations (extreme temperatures and moisture levels) such as attics and unconditioned (vented) crawl spaces should be avoided. Equipment located in attics is difficult to access, service and replace. Condensate drain pans located in attics are rarely cleaned providing a major source of microbiolgical growth related health concerns and when clogged create a major repair expense if overflowing condensate damages interior surface finishes.

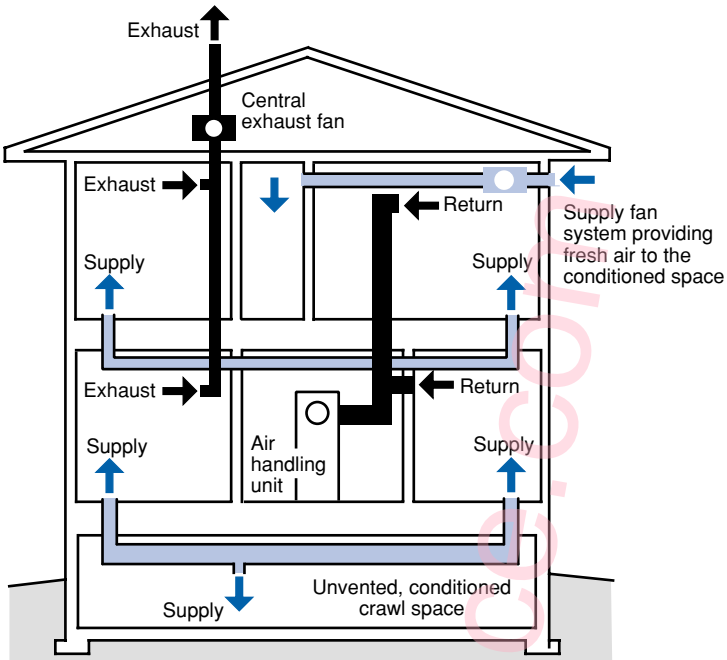

Figure 12

Floor space within conditioned spaces (inside homes) should be provided for air handling equipement such as fan coil units and furnaces. Interior utility rooms are preferred to garage locations. Garage locations are preferred to attics and vented crawl spaces. With respect to combustion appliances, air handlers are ideally located within conditioned spaces with the combustion appliance located in a garage (fan coil unit inside, gas water heater in garage). Duct work connections should be designed with sufficient space to allow upgrading/replacement for electronic or HEPA filtration and/or future replacement of air handlers.

Mechanical ventilation should be balanced (stale air exhaust and fresh air suppy), continuous, distributed and tranparent (quiet, inexpensive to operate and service).

The following system satisfies these requirements: a forced air heating/cooling system with a supply fan system providing fresh air to the conditioned space used in conjunction with a central exhaust system extracting air from bathrooms and the kitchen (Figure 12).

- stale air exhaust is through the central exhaust system
- fresh air supply is through a supply fan system
- continuous operation during occupancy is met by operational control
- distribution is through the forced air system

In this approach a control strategy (time on/off) for the supply fan system, central exhaust system and air handler is necessary during occupancy. The supply fan system typically only operates during the cooling periods and does so on a continuous basis. The central exhaust system typically operates on an intermittent basis during cooling periods to control odors in bathrooms on an occupant demand basis (timed switches in bathrooms). During heating periods, the central exhaust system typically runs continuously, or on a humidity demand basis (humidistat control, when the interior humidity goes up, the exhaust system turns on). This system is compatible with a heat recovery ventilator such as an air-to-air heat exchanger.

The fresh air supplied during air conditioning periods by the supply fan system also serves to pressurize the building enclosure. This supply fan system typically operates continuously under a "summer/cooling" setting, and does not operate at all during the heating season under a "winter/heating" setting.

The fresh air supply is typically ducted to the return side (warm side) of the forced air system via an insulated duct (to limit condensation). The fresh air is also "preconditioned" to limit condensation by mixing with interior air (60:40 interior to exterior air ratio or greater) prior to introduction into the return side of the air handling

system. Stale air is removed through a central exhaust system. Exhaust vents are located in the kitchen and bathrooms.

The central exhaust system operates intermittently under a "summer/cooling" setting, being activated by timed switches in the bathrooms. Under a "winter/heating" setting the central exhaust system operates either continously (at a low speed setting) or some fraction of time (intermittent operation ventilation approach during heating) every hour whenever occupants are present. During heating periods it may be desirable to control the central exhaust fan high speed setting by a humidity sensor.

The forced air system provides effective distribution of fresh air throughout the house. The overall system should be designed, balanced and commissioned so that positive air pressure relationships are maintained during cooling periods.

Ventilation Requirements

Enclosures should be ventilated in a controlled maner. During cooling periods controlled ventilation should be limited to minimum levels (unless the exterior ventilation air is preconditioned) to reduce latent cooling loads (exterior humidity brought in with the ventilation air) without compromising indoor air quality. ASHRAE 62-89 recommends - 15 cfm per person. When applying this rate to a residence, the design occupancy can be based on the number of bedrooms. This determines the minimum standard for continuous base rate ventilation for the house. It can be assumed that two people sleep in the master bedroom, and one other person sleeps in each additional bedroom. The following ventilation requirements result:

- one bedroom house 30 cfm
- two bedroom house 45 cfm
- three bedroom house 60 cfm
- four bedroom house 75 cfm

This minimum base rate ventilation should be continuously distributed throughout the house when the building is occupied.

Forced Air Ducted Systems

A forced air ducted system, including all duct work, the air handling unit, supply plenum and return plenum should be considered a closed system. In other words, when all registers and grills are taped shut, no air leakage occurs. The only place for air to leave the supply duct system and the air handling unit is at the supply registers. The only place for air to enter the return duct system is at the return grills.

The air handling system requires an air barrier/air retarder system similar to that required by the building envelope. The materials used to create or seal an air handling system air barrier/air retarder system should have the following characteristics:

- The materials should be healthy and safe with respect to the occupants (flame spread, smoke development, toxicity, off-gasing, aerosolization)
- The materials must be impermeable to the passage of air.
- The material or system of materials used must be continuous.
- The materials must be sufficiently rigid to resist the air pressures and gravity forces which act on them.
- The materials should be durable, maintainable, cleanable and able to last the life of the system.

Duct work can take numerous forms:

[a] sheet metal

- fiberglass duct board covered on one side with foil

- insulated plastic flex duct
- intersitial building cavities created by wood framing and gypsum board

In order to create an air barrier/air retarder system out of these duct work materials all openings, penetrations, cracks, holes need to be sealed. The preferred method of sealing these openings is fiberglass mesh and mastic. Tape is not recommended for use on metal, ductboard, flex duct and interstitial building cavity ducts due to its poor performance and unforgiving nature.

The longitudinal seams and transverse joints in sheet metal ducts and the foil side of fiberglass duct board should be sealed. The inner liner of insulated plastic flex duct should be sealed where flex ducts are connected to other ducts, plenums, junction boxes and boots/registers.

Flex ducts in inaccessible areas should be avoided as they are not cleanable with conventional duct cleaning methods. When flex ducts are used, care must be taken to prevent restricting air flow by "pinching" ducts.

Connections between grills, registers and ducts at ceilings, floors or knee walls typically leak where the boot does not seal tightly to the grill or sheet rock. Air from the attic, basement, or crawl space can be drawn into the return. Leaks can also exist within the boot and where the ducts connect to the boot. These leakage sites need to be sealed with mastic.

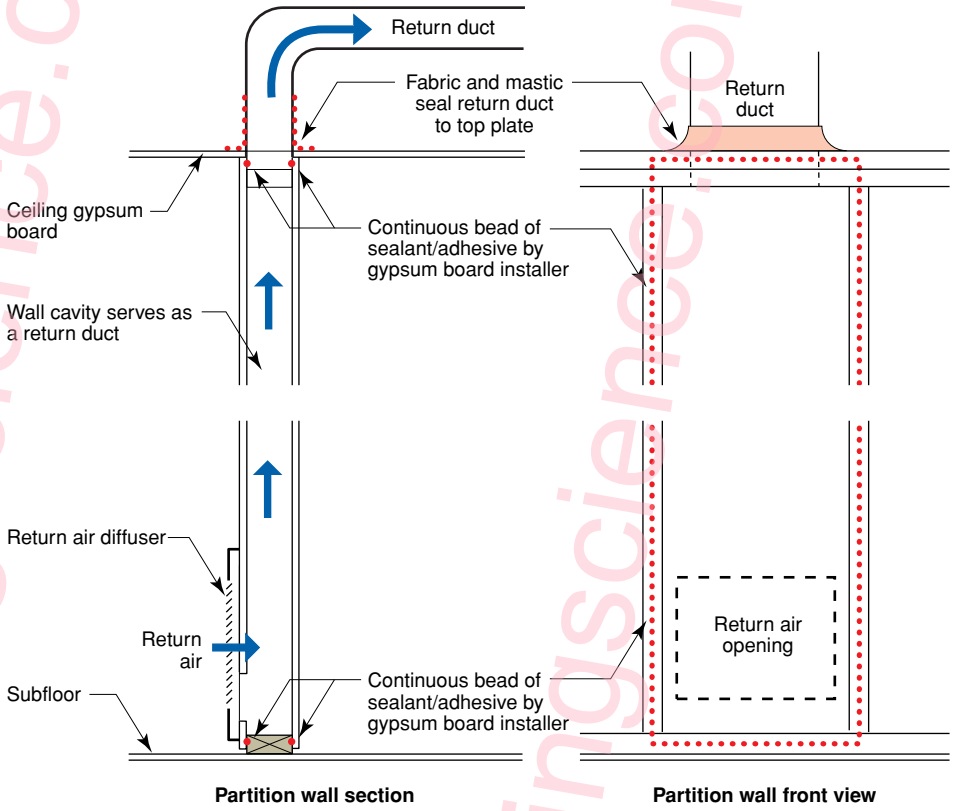

Figure 13

Interstitial building cavities are often used as ducts. A common example is a wall cavity used as a return duct and the associated leakage. These cavities often leak at the top and bottom plates to gypsum board, horizontally to other stud bays and at the duct to top or bottom plate connections. Figure 13 describes a method of avoiding such duct leakage which involves coordination between the HVAC installer and the drywaller.

In many instances, it is more difficult to seal building cavities used as ducts, than to fabricate and seal ducts sized to the cavities. This is particularly the case where floor joist cavities are "panned". In crawlspaces, basements and between floors the area between the floor joist is often used as a duct. This is done by panning of the area with sheet metal nailed to the bottom of the joists. The sheet metal is rarely sealed and is very leaky. The connection between the joist and the sub floor is also a large source of leakage. The end of the floor joist duct is also typically capped off with more sheet metal and is also a large source of leakage (Figure 14).

Due to the difficulties in sealing building cavities used as ducts, fabricated sheet metal, duct board or plastic flex ducts should be used wherever possible.

When a return plenum draws directly through a wall, the wall cavity may inadvertantly become an intersitial duct. If the penetration through the wall is not blocked and sealed, return leaks can occur when air is drawn from the wall cavity (Figure 15). The wall cavity should be isolated from the return.

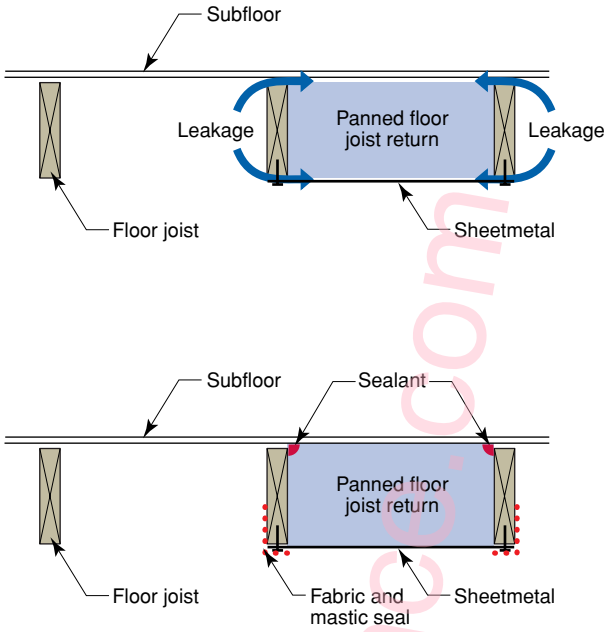

Figure 14

Sometimes return plenums leak through the floor. In floors with crawlspaces or basements, the plenum floor may not be air tight, allowing air from those zones to be drawn into the return.

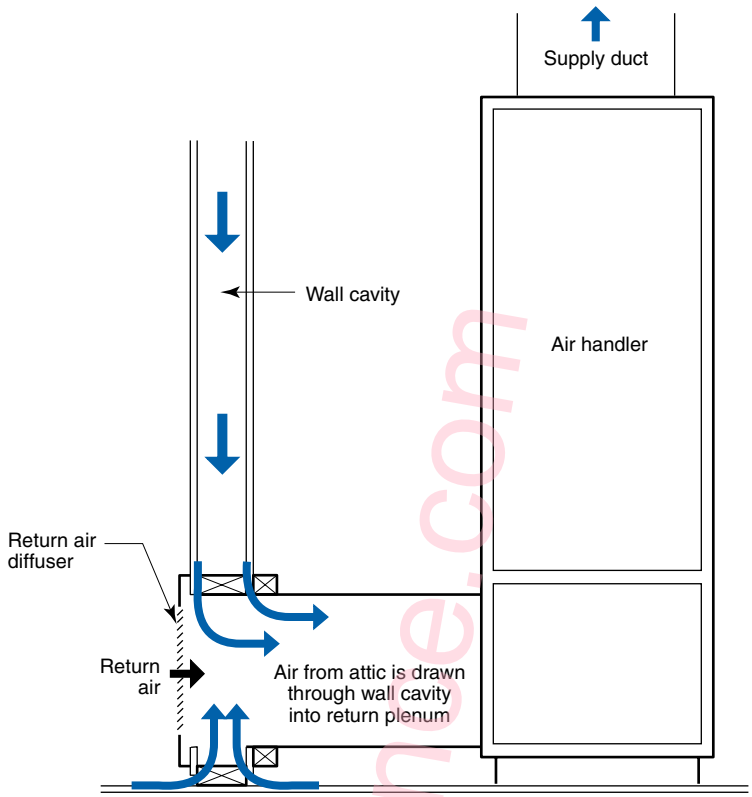

Figure 15

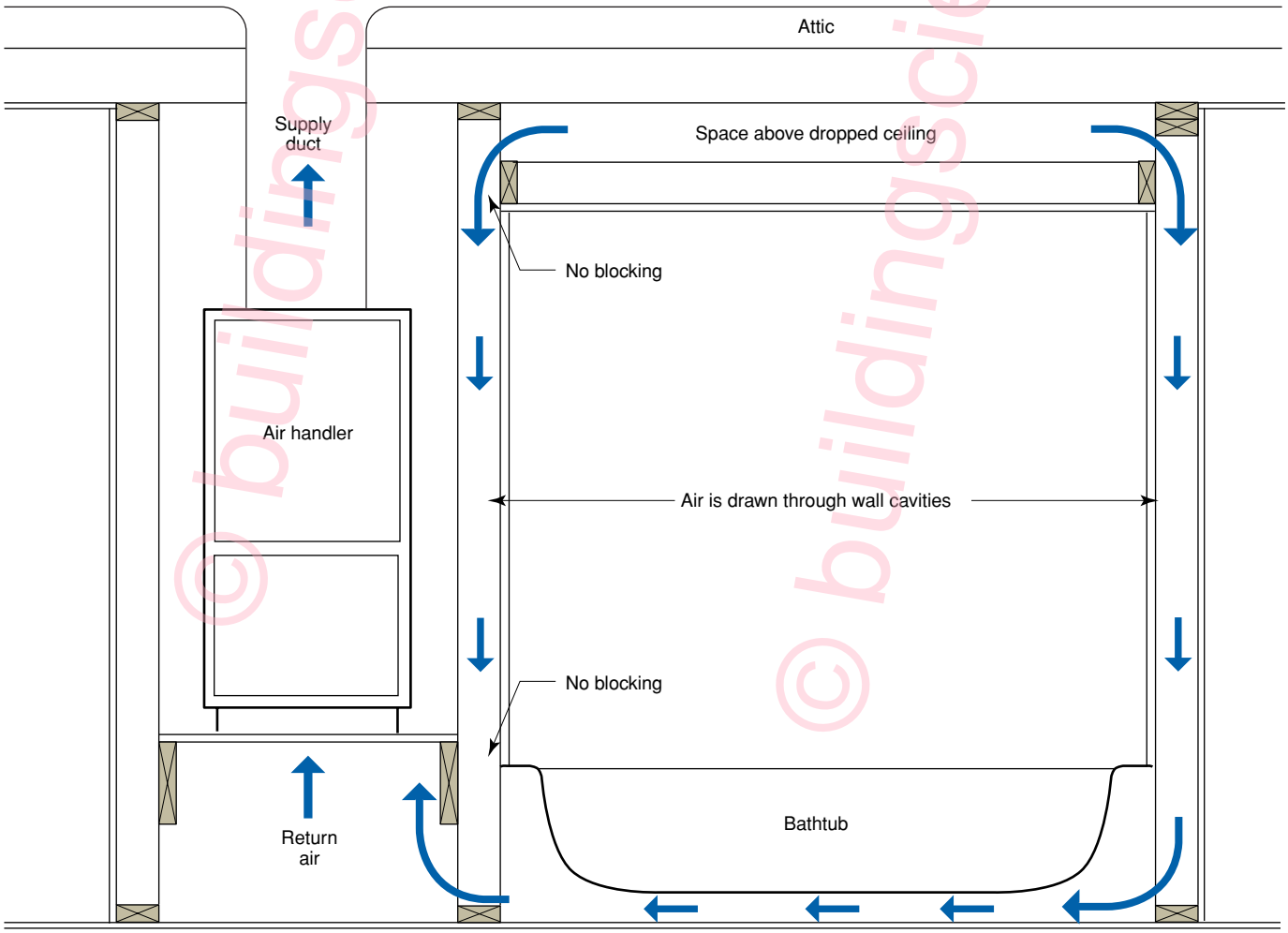

Figure 16

In some slab homes, a 4 inch diameter chase pipe enters the plenum. The chase pipe carries the refigerant lines, condensate piping, and control wiring which connect the indoor and outdoor units. This chase pipe is frequently unsealed, allowing unconditioned air or soil gases (radon, pesticides, herbicides, moisture) to be drawn into the return. Chases should never terminate inside the return air stream.

Return plenums are sometimes formed by the enclosed space below the air handler support platform. This plenum may leak to adjacent walls and directly to the space in which it is located. A return plenum in an air handler closet may have no gypsum board separating it from an adjacent tub enclosure. As a result air may be drawn from the attic (Figure 16). The adjacent walls often have plumbing and wiring in them that either comes from the attic, crawlspace, garage, basement, outside, or some other interior space. Many of these platforms are lined with insulation or fibrous ductboard because of fire codes and soundproofing. This lining is not an air barrier and leakage will occur if the joints and penetrations are not sealed.

Leakage can also occur at the connection between the air handler and the support platform. All sides of the air handler must be sealed to the support platform. Supply plenums also leak at seams, particularly sleeved plenums.

The air handler housings also have supply and return leaks which need to be sealed. Air handlers have removable panels to permit access to internal components. Gaps exist between panels and these leak sites may be enlarged when the panels are bent. The filter access panel is often a leak problem because it does not fit tightly on the cabinet. Mastic and fabric provides a permanent seal for many of the knockouts and panel joints. Access panels can be sealed with high quality tape to permit future access. A roll of this tape should be left with the unit so that owners can retape access panels after filter replacement or other servicing.

The Following Comments Are From The Overheads Presented During The Presentation

Mold, mildew, bioaerosols, dust mites, etc. are a moisture control problem.

Control moisture at surfaces and you control the problem.

How much moisture should be allowed at a surface?

air change during heating periods

dehumidification through mechanical cooling (air conditioning) during cooling periods

control vapor diffusion by using vapor diffusion retarders

on the inside in heating climates

on the outside in cooling climates

in the middle (thermally) in mixed climates

How to keep rain out of building assemblies? Easy - rain screen and/or drain screen.

How to keep ground water out of building assemblies? Easy - drain screen.

How tight should building envelopes be in order to facilitate air pressure control?

ASHRAE 62-1989 requires a minimum air change based on occupancy to provide acceptable indoor air quality (15 to 20 cfm per person).

An ideal approach would allow ASHRAE 62-1989 flows to control air pressure differentials across building envelopes.

Field experience has shown that leakage ratios of 1 to 1.5 square inches of leakage per 100 square feet of building envelope area allow ASHRAE 62-1989 flows to control air pressure differentials.

About this Paper

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