Index

Healthy Indoor Air-Quality & Ventilation

Construction History

For years, changes in North American housing construction requirements have been introduced with the intent to reduce energy consumption. Many older buildings with hollow exterior walls did not receive dedicated air-barrier, vapor barrier or insulation materials and thus experienced serious air-leakage. Blower Door depressurization tests on older homes have recorded 10 complete air-changes per hour (ACH) or more at -50 Pascals (- 0.2" w.c. the standard pressure difference to estimate simulated peak building air-leakage conditions).

During the heating season, large temperature differences between indoor-air and ambient-air cause leaky buildings to act like chimneys and this "stack" effect alone causes significant air-leakage to occur. Wind also creates pressure differences on the exterior of the building that cause air leakage. Finally, mechanical systems and other fans inside the building lead to air pressure differences that also cause air leakage. All three pressures cause conditioned air to leak out (exfiltration) or unconditioned air to leak into (infiltration) the building, depending on the climate and season. This leakage occurs through holes in the building envelope where the air barrier is incomplete, improperly installed, or damaged. In northern winters, humidification is needed as excessive air exfiltration causes uncomfortably low indoor relative humidity levels. In humid summer conditions, excess infiltrated moisture must be removed from the interior of the building with air conditioning and/or dehumidifiers.

Other air-quality problems are present as ambient air contains mold and mildew spores, bacteria, pollen, dust, etc. In addition, air leakage through structures carries moisture vapor with it, which condenses on colder surfaces. This condensation causes wood decay and contributes to the set-up of microenvironments that are suitable for the development of mold and mildew.

In older buildings, uncontrolled air leakage can be responsible for 50 to 60 % of the heating and cooling energy consumption, and large capacity heating and air-conditioning equipment is required. During times when even small temperature differences exist between inside and outside and/or no wind is blowing, leaky buildings still experience under-ventilated conditions.

Where We Are Today

With the adoption of air barriers and insulation requirements, typical new housing air leakage rates are now 5 to 7 ACH @50 Pa during peak leakage tests. Builders who provide extra attention, labor, and many sealing materials provide structures that test for peak air leakage at 3 to 4 ACH @50 Pa.

Building Code changes and extra tightening efforts by custom builders have been implemented with the intent of improving energy efficiency and comfort. Savings from reduced heating and air-conditioning equipment requirements are realized, but as energy efficiency is improved more under-ventilated periods will occur.

Ventilation by Accident or by Code

Virtually any building is likely to experience under-ventilated periods often unless continuous ventilation is employed. Until recently, little concern has been devoted to varying weather conditions in relation to indoor air-quality. Although most residential building codes require point-source exhaust fans for spot use, few specify make-up air for combustion appliances. With a few exceptions, building codes do not address under-ventilated conditions in residential buildings.

Add an indoor environment that is a chemical / biological soup

Many building materials such as carpets, furniture, plywood, particle boards, flooring, and so on off-gas VOC's (volatile organic compounds). Cleaning solvents and solutions vaporize. Smoking and cooking odors are often present. Oxygen is consumed. Human activities and related processes produce moisture vapor that helps to produce microenvironments suitable for biological development. Mold and mildew feed on organic materials like the cellulose in paper and pet or human skin dander. Dust mite life cycles produce dried carcasses and feces that often become airborne (these allergens are known to trigger asthmatic attacks). Their digestion processes also produce gasses such as aldehydes, alcohols and keytones (moldy odors).

During under ventilated conditions a myriad of pollutants are introduced to the indoor air, building up to unhealthy levels. The U.S. Environmental Protection Agency has performed studies indicating that average indoor air is 10 to 70 times more polluted than outdoor air. The U.S. EPA also estimates that people typically breathe in two tablespoons of particulate-type contaminants and chemicals each day.

Build tight – Ventilate Right

The solution is to build buildings as tight as possible and take full control of fresh air requirements with continuous mechanical ventilation. This minimizes unwanted air and moisture movement through the structure and allows the intake and cleansing of the correct amount of air for the specific building. Buildings are complicated and, when using conventional insulation and air/vapor barrier materials, extremely tight construction is difficult and expensive to achieve.

The Icynene Insulation System® Healthy Home

An Icynene® insulated thermal envelope coupled with minimal caulking typically tests for peak air-leakage at 1.5 ACH @50 Pa or less. Natural air-change rates are typically 0.05 to 0.1 ACH. Due to Icynene®'s low air and vapor permeance, additional vapor barrier materials are not required in most instances.

Into this tightly controlled indoor environment, a properly designed continuous mechanical ventilation system is installed. The choice of system (exhaust, supply, or balanced) depends on the type of building, climatic conditions, and cost. Extra ventilation may need to be provided to compensate for large point source exhaust fans (ie. kitchen cook top fans, clothes dryer fans). Ventilation systems that are installed with Icynene® operate much more efficiently than before because of greatly reduced random air leakage through the exterior walls, roof, and floors. The result is a healthy indoor environment, superior energy efficiency and ultimate comfort.

Humidity and Mildew: Causes and Cures

Mold and mildew is a major problem in warm, humid climates such as the U.S. southeast where as many as 70% of all homes are reputed to eventually suffer from mildew problems. Mildew increases the risk of making the building occupants sick and gives rise to expensive and frequent repairs and redecorating. Mildew is a mold that grows under warm, humid conditions. Optimal growth conditions are from 77° to 86° F (25° to 30° C), and between 62% and 93% relative humidity.

Sources of humidity in homes

Relative humidity (RH) inside buildings can be greatly increased by adding moisture to the air in many different ways. In houses, human activities such as preparing meals, washing dishes and clothes, steam baths, whirlpool tubs, showers, aquariums, plants, and even breathing add a lot of moisture to the air. A 15-minute shower can add 1.7 pounds (0.75 kg) of moisture to the air; a cord of uncured wood drying out can add 600 pounds (272 kg) of water; the infiltration of humid air can add 360 pounds (163 kg) of water a day to a typical home.

Moisture also enters from outside – through open doors and windows and by infiltrating the building envelope. Natural ventilation through cracks, crevices and chimneys will cause some air infiltration, but this is accelerated by makeup air entering the building to replace air that has been "exhaled" by exhaust fans. Infiltration can change the air 24 to 48 times a day, and when moisture laden outside air is brought in it throws a tremendous load on air-conditioning equipment. This moisture can amount to hundreds of pounds a day. With 100% relative humidity, clothing, paper products, wood and some textiles can absorb up to 20% of their weight in water.

Another source: Oversized air conditioners

Improperly sized air conditioning units can also greatly increase the humidity inside buildings as well. The role of air conditioning in humid conditions is twofold; remove moisture from the air, and reduce the temperature. Removing moisture from air requires a far greater amount of energy than simply lowering the temperature. Thus, it is vital that A/C units run constantly in humid conditions to keep the RH below 60% (the level at which mildew mentioned previously begins to grow)

Unfortunately, A/C units are often oversized in humid climates for the load requirement of the building. In these cases, the units only run long enough to reduce the air temperature, and do not actually remove much moisture. The result is a lower indoor temperature, but actually a higher RH (colder air cannot hold as much moisture as warmer air). To the occupants, this environment feels clammy or "cave-like" and less comfortable. This causes the occupants to turn down the thermostat further, which can make the problem worse, and wastes energy keeping the building cooler than it needs to be.

Oversized A/C units are commonplace in humid climates because of building practices of the past. Older buildings had high rates of random air leakage. Ductwork for systems were typically placed in unconditioned spaces (i.e. attics and crawl spaces), and there was a loss of conditioned air into these spaces due to leaks in the ducts (see design note titled: Insulating and sealing Ductwork). These practices led to a great uncertainty for the A/C contractor, who had to design a system to make up for the shortcomings. The result was over-designed, oversized units.

Solving the problem: Control air-leakage and correct A/C sizing

The only way to avoid mildew is to control the interior RH through reduced air leakage and proper sizing of A/C equipment. Building an air-tight structure accomplishes two things; it limits the amount of moisture-laden air that gets inside, and it makes life easier for the A/C contractor, who can size a system that does not need to account for all that random infiltration. A properly sized A/C unit runs for longer periods, removing more moisture from the air and lowering the RH as a result. Further reduction in A/C sizing can be achieved by sealing ductwork and/or installing ductwork within the conditioned space of the building (see design note titled: Unvented Attic and Cathedral Ceiling Construction). Unfortunately, constructing buildings in humid climates that are free from high RH and mildew has been difficult to achieve in the past.

Vapor barriers are NOT the solution

Most air leaks into buildings occur through sill plates, electrical outlets, duct systems, and penetration through attics, floors, and around windows and doors. One attempt to combat the moisture problem has been to apply a vapor barrier placed against the inside of the interior wall. This is the wrong place for a vapor barrier in a humid climate. The vapor barrier, at this relatively cool location, provides a surface for condensation to occur as outdoor air moves inside. Placing the vapor barrier on the inside of the exterior wall creates another problem in the winter, when interior vapor is trying to move outside.

The solution is a monolithic air barrier with The Icynene Insulation System®

The recommended solution was first proposed by the School of Building Construction at the University of Florida: Eliminate the use of a vapor barrier and instead use an air-retarder in the wall to inhibit the passage of airborne moisture into the building. While an air barrier inhibits the entry of air it must be slightly vapor permeable to allow building materials to dry.

The Icynene Insulation System® is a site-installed cellular foam material that provides an excellent air barrier throughout the entire building envelope. By expanding into cracks and crevices and adhering to other building materials, this soft flexible foam ties all other building assembly materials together into a monolithic continuous envelope.

No other sheet-type air barrier material or method can match Icynene's® performance when applied to an entire building situation. With the air-sealing ability of Icynene® in place, preventing outdoor moisture from entering the building the A/C contractor can select a system that is sized appropriately for the cooling load. Experience has shown that typical A/C size can be reduced by 30 to 50% in humid climates. The smaller unit(s) run for longer periods of time keeping the indoor RH lower while consuming less energy.

Additional tips for occupants

- Set air-conditioner temperature higher when using a ceiling fan.
- Set heating thermostat lower when the building is not occupied.
- Keep the interior temperature below 75° F (24° C) and RH below 60%.
- Wipe-dry any thing that gets wet after use – things like shower doors, wet floors and tiles, counter-tops, sinks, and spills in general. And hang wet towels, mops and clothing outside to dry. By doing this, the amount of moisture evaporating inside the home will be drastically reduced.
- Close the fireplace damper when not in use.
- Keep doors and windows closed in the morning or after a rainfall, when the humidity is high.

Tips for builders

- Build a tight building easily using Icynene® insulation.
- Install mechanical ventilation that also dehumidifies incoming air.
- Ensure that shower stalls and baths drain properly and do not puddle.
- Waterproof and seal exterior block walls.
- Do not install a vapor barrier on exterior walls.

Construction Without A Vapor Barrier

Moisture problems in walls and ceilings are caused by air leakage, which delivers a large quantity of vapor through gaps in air barriers and through insulation to condense on a cold surface. Abundant literature has documented that condensation due to vapor diffusion is the source of only 1% of moisture transfer, while airborne transfer usually accounts for 99% of moisture migration – and moisture problems.

Airborne moisture movement

Icynene® has low air permeance, low enough to be classed as an air barrier. Therefore, there is no moisture movement through polyicynene foam by air transfer.

Moisture movement by diffusion

Moisture conveyed by diffusion is usually not a problem as it is so small that it is measured in nanograms (billionths of a gram), and is typically overcome by normal storage/drying cycles of building materials.

Five inches of Icynene® foam has a vapor permeance of 10 perms. This property allows extremely low rates of moisture diffusion to occur, just enough to allow breathing of adjacent building materials, preventing moisture entrapment. Its permeance was conservatively extrapolated from tests made with 2-inch (50 mm) foam core, without either of the two skins. More foam and the inclusion of skins would lower its permeance further.

Such diffusion as does occur through Icynene® will pass through the insulation without condensing, provided that the substrate to which it is attached is equally, or more vapor permeable.

What happens to the moisture?

Eyre and Jennings (Saskatchewan Research Council) explain what happens to moisture. "Water vapor will usually pass beyond the dewpoint location without causing condensation or frosting, and will continue to move outward through the cavity until it encounters the right condition (a cold surface) to condense and build up."

Practical performance

Practical experience has been gained using Icynene® without a vapor barrier, where it has been injected into renovated cavity walls. In this situation no opportunity exists for the inclusion of a vapor barrier. Experience has also been gained where Icynene® is applied to the underside of steel-deck roofing without a vapor barrier.

This experience demonstrates that no moisture buildup occurs where Icynene® is used without a vapor barrier. In fact, only in the following conditions require vapor barriers:-

1. Extreme conditions of humidity (i.e. indoor swimming pools, ice hockey arenas, greenhouses, coolers etc.)
2. In extreme northern climates. The National Association of Homebuilders recommends those climates with greater than 7,500 degree days F (4,200 degree days C) of winter heating.

Taking the Guesswork out of HVAC System Sizing

Standard Practices

A good Heating, Ventilation and Air-Conditioning (HVAC) contractor will use one of the standard methods for determining heating and cooling loads on buildings, such as Air Conditioning Contractors of America's (ACCA) Manual J and Manual N. These methods take into account specific building characteristics including orientation, dimensions and thermal performance of exterior components (i.e. walls, ceilings, basements, windows and doors). Local averaged weather data as well as summer and winter peak design temperatures are also considered. Then, a building is placed into an air-leakage category based on construction tightness estimates and a generalized wind shielding description to guess at how the building will perform (or not perform) in breezy or windy conditions. This, in short, is the accepted standard method for heating and cooling load calculations in North America.

In the interest of customer satisfaction, to insure that desired interior design conditions can be met at all times, an HVAC contractor will often add considerable extra heating and cooling capacity when selecting equipment. This fairly common desire to oversize is largely due to the un-predictability of performance that is expected from typically constructed "leaky" buildings. Extra heating and cooling capacity add significant extra cost and additional HVAC system space requirements.

This is particularly true on the cooling side. Humid summer conditions coupled to oversized A/C units lead to conditions of short cycling that super-cool without de-humidifying adequately. This produces a cold clammy environment with high relative humidity (RH) which is a breeding ground for mold and mildew (see design note titled: Humidity and Mildew: Causes and Cures). Building occupants are faced with poorer Indoor Air Quality coupled with higher energy costs due to ineffective oversized systems.

Removing the Unpredictability

Once again, "Building Tight and Ventilating Right" is the answer to minimizing guesswork involved in HVAC equipment selection. Tight construction drastically reduces the significance of air-leakage and its effect on HVAC system sizing. And, tight construction coupled with mechanical ventilation ensures proper air quality to occupants during all weather conditions. Unfortunately, constructing tight buildings that are increasing in complexity with conventional materials and methods has proven to be a difficult and costly challenge.

Icynene®: A Multi-Function Product That Works

The Icynene Insulation System® handles the "tightness" challenge easily. Using a Blower Door diagnostic air leakage test, Icynene® insulated residential buildings regularly test at less than 1.5 ACH @50 Pa (1.5 Air Changes per Hour at -50 Pascals of internal pressure). This compares very favorably to conventionally constructed homes that often test at 5 to 7 ACH @50 Pa. In addition to air sealing, flexible Icynene® provides thermal insulation to R-3.6 per inch (RSI-0.62 per 25 mm) of thickness throughout any size cavity. Without convective airflow within the cellular material, Icynene®'s R-value remains virtually the same in all conditions of temperature and air pressures.

The Bottom Line Benefits

Now, sizing HVAC systems for buildings is far less of a challenge than ever before with The Icynene Insulation System®. Icynene® ties together all other building assembly materials creating a monolithic envelope that is extremely airtight and thermally efficient in all weather conditions. The HVAC contractor no longer needs to guess at air leakage levels or compensate for shortcomings in air barrier and insulation materials. The net result for the consumer is an average of 30 to 50% reduction in heating and cooling system size and a similar reduction in energy costs.

Sealing and Insulating Ductwork

Construction Differences

In many areas of North America, it is not common to have conditioned basements or crawl spaces in residential and commercial construction. In southern climates or areas with high water tables, slab-on-grade construction is the norm. In many areas, the standard practice is to insulate floors over unconditioned crawl spaces, and vent those spaces to the outside with wall vents. Air conditioning ductwork systems for these buildings are often too large to be located within the walls and ceilings of the building itself, and are thus put in unconditioned crawl spaces and/or attics. Depending on materials used and the age of a system, this ductwork is poorly insulated and sealed. As such, it leaks air into unconditioned spaces, which increases energy consumption and system size.

Standard Practices and Materials

Supply air duct systems incorporate main trunks or plenums, typically running the length of a building, with many branch-runs usually extended to the perimeter. Return air systems are often far reaching to central locations of individual zones of the building. Regardless of materials used, all ductwork systems in unconditioned spaces involve many connections that require proper sealing. Duct tape is the most common method used to seal duct connections but leaks develop over time, as the tape falls off the joints due to temperature and humidity extremes. Some plastic flexible duct materials break down and leak over time due to the frequent temperature swings as well.

Conditioned Air Under Pressure

While HVAC equipment is operating, significant negative and positive pressures exist within the ducts. These pressures make even small leaks exchange large amounts of air. In the heating season, supply air leaking out of the ducts can be as hot as 150° F (65° C) while return ductwork draws ambient outdoor air into the conditioned space. During the cooling season, supply air at 55° F (13° C) is lost to the unconditioned space through leaks while hot, humid air from these spaces enters the return air duct. This often results in deteriorated ductwork and desirable conditions for mold and mildew growth.

Disproportionate Insulation Levels

Duct systems also lose or gain energy from unconditioned spaces through insulation. Consider that duct systems are typically insulated with R-5 to R-8 (RSI-0.86 to 1.38) fiber type material for protection in unconditioned spaces. However, the temperature difference between cold air inside the ducts and unconditioned spaces is often two to four times the temperature differences that exterior walls must deal with, and walls are typically insulated with two to four times more insulation! Consider an attic space in summer that is vented to the outside. The air temperature in the attic can be 150° F (65° C), compared to air inside the ducts at 55° F (13° C), for a difference of almost 100° F (52° C). At temperature extremes such as this, R-5 (RSI-0.82) insulation is virtually ineffective. Poorly insulated supply air ductwork in humid unconditioned spaces provides a cold surface for ambient air to condense on, leading to the same conditions mentioned above.

Air sealing and insulating with Icynene®

Icynene® is a low-density foam material that provides air sealing and highly effective insulation in a one step application (for metal ductwork, a vapor diffusion retarder is recommended on the warm side of the ductwork). Icynene® completely encapsulates and isolates ducts from unconditioned spaces, eliminating all of the traditional problems.

Icynene® provides an effective R-12 to 20 (RSI-2.07 to 3.45) with a 3 to 5 inch (75 to 125 mm) thick application. Along with air sealing, this level of insulation is sufficient to minimize heat transfer through the ducts themselves.

The result: Smaller, more efficient space conditioning requirement

By minimizing heat transfer and eliminating air leaks in ductwork, Icynene® allows the HVAC contractor to select smaller sized heating/cooling equipment for the building. In the case of two-story residential buildings, there is now the possibility of reducing cooling requirements substantially in humid climates and the number of zones needed. This can greatly reduce the initial cost to the building owner, and save on energy bills year after year for the life of the building (see also design note titled: Unvented Attic and Cathedral Ceiling Construction)

Unvented Attic

The unique performance characteristics of Icynene® facilitate design flexibility by allowing it to be used in either vented or unvented attic applications. In vented attic applications, Icynene® is sprayed onto the floor of the attic and attic ventilation is provided in the traditional manner. In unvented attic applications, Icynene® is sprayed directly onto the underside of the roof sheathing as well as the soffits. No attic ventilation is provided in this application and the attic space becomes semi-conditioned space.

The traditional practice of attic ventilation was introduced in the 1940's due to experience in cold climates, specifically using air permeable fibrous insulation materials. It was observed that insulating the floor of the attic space with fibrous insulation decreased the roof sheathing temperature. At the same time, warm interior air was free to leak through the fibrous insulation into the attic. The reduced sheathing temperature, in combination with the leakage of interior air through the permeable insulation on the attic floor created conditions that were favorable for condensation to occur. This is due to the fact that warm air has a capacity to hold more water vapor, however, when it is cooled this capacity is reduced and excess moisture is deposited as condensation. In order to reduce the potential for condensation, attic ventilation was introduced to replace the attic air with relatively dry exterior air.

Why unvented attics do work with Icynene®

The traditional reasons cited for attic ventilation are:

1. Reduction of shingle temperature to prevent premature shingle deterioration
2. Removal of moisture from the attic to prevent condensation on the cold roof deck (applicable to cold climates)
3. Prevention of ice damming (applicable to cold climates with high snow fall)

The above concerns have been addressed as follows:

1. Studies have found that shingle temperatures are not significantly reduced by attic ventilation. The results indicated that shingle temperatures were reduced approximately 3% by attic ventilation. It stands to reason that a 3% difference in shingle temperature should not impact shingle life significantly.
2. It has been documented in studies that by far the dominant water vapor movement mechanism is air leakage. Since Icynene® controls air leakage very effectively, the majority of water vapor is prevented from reaching the cold roof deck and condensing there.
3. Icynene® provides effective thermal resistance. Therefore, when sufficient R-value is provided to the underside of the roof deck, ice damming will not occur.

A unique material property of Icynene® is its ability to form an air seal while at the same time not trap moisture. This feature has allowed it to excel in unvented attic applications. In the event of a future roof leak, Icynene® will allow the water to pass through it. When the leak is repaired Icynene® will dry and retain its original properties.

Unvented attics can provide advantages in some cases. However, the decision of whether to do an unvented attic application should be based upon the climate and the building's details.

Hot-Humid Climates

A hot-humid climate is defined as a region that receives more than 20 inches of annual precipitation and where the monthly average outdoor temperature remains above 45°F throughout the year.

Unvented attics in hot-humid climates usually provide more advantages than vented attics. This is due to the fact that the general practice in these regions is to have air conditioning equipment and ducts in the attic. Therefore, in these climates, it is generally recommended to spray 3-5" of Icynene® directly to the underside of the roof sheathing and over the soffits[2]. This prevents the hot and humid exterior air from entering the attic space and coming into contact with the air conditioning ducts.

Hot-Dry/Mixed-Dry Climates

A hot-dry climate is defined as a region that receives less than 20 inches of annual precipitation and where the monthly average outdoor temperature remains above 45°F throughout the year.

A mixed-dry climate is defined as a region that receives less than 20 inches of annual precipitation, has approximately 4,500 heating degree days[3] or less and where the monthly average outdoor temperature drops below 45°F during the winter months.

Icynene Inc. recommends that in these climates the floor of the attic be insulated with 3-5" of Icynene®[2] and that the attic be ventilated.

Mixed-Humid Climates

A mixed-humid climate is defined as a region that receives more than 20 inches of annual precipitation, has approximately 4,500 heating degree days or less and where the monthly average outdoor temperature drops below 45°F during the winter months.

Icynene Inc. recommends that 3-5" of Icynene® be applied directly to the underside of the roof sheathing[2] and over the soffits.

Cold Climates

A cold climate is defined as a region with approximately 4,500 heating degree days or greater.

Generally in cold climates both vented and unvented attics will provide similar performance. However, cathedralizing attics will use more material than spraying the floor of the attic due to the increased area. Therefore, in cold climates unless there is a reason to cathedralize an attic, vented attics would be preferable.

In vented attic applications in cold climates, Icynene Inc. recommends that 3-6" of Icynene® be sprayed to the floor of the attic[2].

Some situations where unvented attic applications are beneficial include:

- cathedral ceilings
- attic having scissor trusses which make it difficult to insulate the floor
- attic will be converted into living space in the future
- HVAC equipment located in attic

When the unvented attic method is used in a cold climate Icynene Inc. recommends the following:

- 4,500-7,500 heating degree days – spraying the surface of Icynene® with a low permeance paint
- less than 7,500 heating degree days – spraying the surface of Icynene® with a vapor barrier retarder paint (less than 1 perm, or equivalent)

In high snowfall areas where ice damming is a concern, sufficient thickness of insulation should be applied in order to provide the thermal resistance necessary to prevent ice damming.

Notes

1. A significant amount of research has been conducted on the subject of unvented attics. This research has demonstrated that unvented attics can be a viable design option if done correctly. However, the traditional approach has been to provide attic ventilation. Although the building science community is recognizing the results of these studies, building codes and public perception is slower to change. There are regions where unvented attics are readily approved, nevertheless, there are still building codes that require attic ventilation and building officials that are not familiar with this approach. **In these cases we recommend approaching the building inspector and explaining the unvented approach with Icynene® prior to installation.**

2. The recommended thickness in this design note is based upon the performance characteristics of Icynene®. This thickness may differ from the prescriptive requirements (ie. specified R-value) of the energy code. However, most energy codes have an alternative compliance method called the Performance Approach. Due to Icynene®'s air sealing advantage, it can often satisfy the energy code requirements at a lower R-value by using the Performance Approach option of the code. This approach involves conducting an energy analysis on the building to demonstrate that the overall energy consumption of the building satisfies the energy code. If this approach will be used, we recommend discussing it with the building official prior to installation.
3. Heating degree-days is a measure of yearly heating requirements. It is the sum of the departures of the daily mean temperature from 65°F for each day on which the temperature falls below that value.

Cold Floors: Causes and Cures

One of the building industry's oldest problems is the cold floor. Cold floors occur when they are built over unconditioned spaces, such as above a garage, over a porch, over a crawl space and cantilevered beyond the exterior wall of the building. This problem is most noticeable when the floor has been tiled.

The building codes in many areas dictate that these floors should be insulated to R-25 (RSI-4.3). But experience tells us that R-25 (RSI-4.3) of fiber material does not ensure a warm floor. In theory, the floor in a properly insulated room should be at room temperature. In practice things are quite different; it is common to find floors that are 10°F (5.5°C) cooler than the room. Why? Because it is virtually impossible to install a fiber batt so that it is in contact with, and stays in contact with, the floor above. It is also impossible to install it accurately around bracing and bridging between joists. Unfortunately, due to voids and air spaces that allow air movement, fibrous materials do not perform to their rated R-value. (R-values are determined under ideal, still-air laboratory conditions.) Because air gaps usually exist between the floor and insulation there is room for cold air to infiltrate from the exterior. The cold air essentially "short-circuits" the insulation material and renders it ineffective. When this happens it means that the floor is essentially not insulated.

Heated plenums

Some designers and builders have tried to overcome the problem with heated plenum using a dropped ceiling isolated with a fiber batt. Heated house air is then ducted in to the space created under the floor. While this helps the problem, experience proves it does not solve it. This is especially obvious when water pipes are run within the plenum; frozen pipes are still commonplace.

Why? One possible reason is that the builder may not have insulated and air-sealed the exterior wall of the heated plenum. Most builders do not place a vapor barrier over the insulation to protect it from the humid, heated air. The result is that moisture condenses in the fiber batt and on the cold exterior plenum wall, creating a potential long-term structural problem. Again, this negatively impacts R-value. Also, if a return air duct is installed to remove the heated air, it runs the risk of conveying glass-fiber particles to the house. This crude and faulty design will cost the building owner in higher energy bills for the life of the building.

Air sealing with Icynene® is the solution

The Icynene Insulation System® is a site-installed cellular foam material that expands to fill the tiniest and most awkward spaces and adheres to the floor above. Icynene® eliminates voids and the resulting air movement that have plagued generations of builders and homeowners. Thousands of floors over porches, garages, crawl spaces and cantilevers have been insulated and air sealed with The Icynene Insulation System®. Many more buildings with cold floors have been cured by an Icynene® refit. Cold floors are simply not an issue any more when insulated with Icynene®.

Insulating Cavity Walls During Renovations

Many older buildings may be beautiful examples of architecture, but they all tend to suffer from the same problem; they are energy wasters. Old buildings cost much more to heat and cool than newer ones, are drafty and uncomfortable, and allow outside noise and pollutants inside. One of the single biggest improvements that can be made to older buildings is the addition of a thermal insulation and air barrier into wall cavities.

The challenge

However, one of the challenges faced by renovators is how to insulate cavity walls in older buildings without dismantling the wall. Materials like cellulose, rockwool or vermiculite have been tried. These were blown into the cavity through holes made through the outside cladding or the inside plaster/drywall.

This method could result in material getting "hung-up" on some inside obstruction, preventing it from completely filling the cavity. The solution typically involves hammering the wall in the hope that this would shake the material down. Because no additional air or vapor protection could be installed, it left serious concerns about moisture becoming a problem later on. Similarly there was the possibility that these materials would settle in time, leaving a void at the top of the cavity. In extreme cases there was the possibility of the insulation being vulnerable to rain penetrating the outer wall. The flaws in these methods left serious doubts about their long-term performance and overall effectiveness.

The solution: The Icynene Insulation System® pour fill formula

The Icynene Insulation System® pour fill formulation is a very different alternative. It is installed by injecting a liquid into wall cavities, through small ½-inch (13 mm) holes. As a two-component liquid material, Icynene® runs to the bottom of the cavity, filling every void. Over 2 to 3 minutes, the material expands into a low-density cellular foam that is 60 times the volume of the original liquid. While it expands it remains in a resilient state, filling every contour of the cavity. When the expansion is completed, Icynene® sets into an inert, soft, fine-celled foam.

Site assessment and installation

An assessment of the wall is the first step in deciding if The Icynene Insulation System® is suitable.

1. The wall cavity must be empty. If it already contains insulation material, the existing material must be removed before upgrading to The Icynene Insulation System®.
2. The interior plaster/drywall must be in sound condition. While very little pressure is exerted by the foam as it expands (it expands along a path of least resistance), there is a risk of damage to the interior plaster/drywall; this risk is low but it does exist.
3. The width and depth of the cavities are measured (using a probe) so that the amount of insulation to be injected may be determined. Diagonal cross bracing is detected this way, and additional holes are made below so that the foam may be injected into the space below the bracing.

Injection of material can be made from inside or outside of the building. The method employed often depends on whether interior or exterior surfaces and finishes are to be renovated. Application of Icynene® proceeds by injecting liquid material into ½ inch (13 mm) application holes. The injections are timed so that there is minimal risk of bowing or blowing off interior finishes. Any excess material that oozes through the application holes is easily broken off by hand.

When the application is complete, infrared thermography can be used to determine whether any inaccessible places have been missed. With Icynene® there is little risk of the material getting "hung-up" on plaster keys or nails, because the foam expands upward from the bottom of the cavity, totally filling the space through which it moves. Additional repairs are limited to the small application holes. The finishing contractor or homeowner typically takes responsibility for repairs to application holes.

The net result: Better performance from old buildings

Icynene®, installed in 1½ inch (38 mm) wide cavity, will provide about R-6 (RSI-1.03) insulation which results in a 90% reduction in heat flow through the cavity. The material will not sag with time, because it adheres to everything with which it comes in contact, creating a monolithic wall structure.

Icynene® will not shrink, break down or settle over time. In combination with the other building components, Icynene® is an excellent air barrier and as a result will provide a much more thermally efficient building. The Icynene Insulation System® does not suffer from moisture problems over the long term, or any of the other drawbacks associated with the other insulation materials and methods mentioned previously.

Moisture will not degrade the performance of Icynene® because only very small quantities of moisture can propagate through the cavity by diffusion. This moisture remains in a vapor state and passes through the foam without condensing on exterior or interior surfaces. Icynene® is hydrophobic and does not wick or absorb moisture.

In summary, adding The Icynene Insulation System® cavity fill material may be the single most effective way to improve on the performance of old buildings. The interior space will be Healthier, Quieter, More Energy Efficient® than ever before.

Controlling Sound With Icynene®

Controlling sound in single and multi-unit dwellings is an important design consideration today. Selecting the right materials, including insulation, will determine how effective sound control measures will be. Icynene® is a spray in place two-component liquid material that expands into low-density foam. Icynene® provides excellent sound deadening properties in buildings.

Airborne Sound

Sound can travel through a variety of mediums, but the most common is through air. Loud stereos, highway and city noise, and human speech are common sources of airborne sound. Sounds propagate through the air at many different frequencies, but it is the mid-range frequency noises that are most noticeable. The most effective way to eliminate the transmission of these sounds is to effectively control air movement. Icynene® is an air barrier thus it effectively reduces these types of sounds.

Flanking sound

Often, reducing airborne sound by providing an air barrier material is not enough. Every possible pathway that sound can travel through the assembly to another room must be eliminated. This is flanking sound, and to have a reasonable chance of eliminating it, a site applied material that fills every gap and crevice must be used. It is a known fact that flanking sound can reduce STC (Sound Transmission Class) ratings by up to 5 or more. This is why STC requirements for sound barrier construction are high, because designers know these values will not be achieved in the field.

Icynene® fills every gap and crevice in the building cavity while adhering to all adjoining components for a tight seal. This greatly reduces flanking sound, and can produce STC ratings similar to theoretical design values in a smaller cavity, thus using less material and saving money.

Reducing plumbing noise

Running water can cause the piping behind walls and above ceilings to vibrate, and transfer that sound into the structure of the house. Once the vibrations get into the structure, the sound can be transmitted to other parts of the building. This is a big issue in apartment dwellings when everyone turns the shower on at 8 o'clock in the morning. Icynene® is a flexible, open cell material that can be applied around these pipes. The vibrations will then be greatly dampened, and structure borne noise reduced. Properly securing the piping inside the wall or ceiling and good design will minimize the vibration and water hammer sound even more.

Impact noises and structure borne vibrations

Icynene® is a great insulator to airborne sounds, and can also be combined with other materials to reduce impact and structure borne vibrations. Impact noise is not being transmitted through the air; rather it is causing vibrations within the building assembly itself. Adding insulation will not dampen those sounds effectively; the floor must be isolated from the rest of the structure.

Combined with drywall mounted on resilient channels, Icynene® provides a structural break between two parts of a structure, isolating the vibration or impact noise from the people on the other side. Insulating equipment rooms with Icynene® and mounting the equipment on isolating pads reduces both low frequency vibration sounds, and the airborne noise transmitted by such machinery.

STC and NRC ratings

ASTM testing (standard E-90) in a 2x4 wood frame assembly gives Icynene® an STC rating of 37. The NRC rating in the same test is 70. It is important to realize that these values, like similar values for all insulating materials, are obtained in ideal laboratory conditions. It is commonly accepted practice to reduce these numbers by 5 or more to more accurately simulate field conditions. The quality of installation is the main determinant to producing an effective sound barrier.

Icynene® is a site applied material that adheres to most building substrates. In practice, Icynene® performs better than most pre-manufactured batt-type materials, since the material is custom installed for each project. By completely sealing every cavity in a wall or ceiling, Icynene's® STC and NRC ratings obtained in laboratory conditions are close to what is achieved in the field, since flanking paths are eliminated. Further reduction in sound transmission can be achieved by adding mass to the wall or ceiling. Every doubling of mass will reduce the STC by 6 dB. Since Icynene® is a low density, lightweight material, adding gypsum board or drywall to a sound barrier is an easy and effective way to significantly increase STC values.

Radon Reduction with Tight Construction

The U.S. Surgeon General has warned that radon is the second leading cause of lung cancer in the United States. It is estimated that 1 in 15 homes in the U.S. experience elevated radon problems. The U.S. Environmental Protection Agency and the Surgeon General recommend that all homes be tested for radon. They also recommend reducing elevated levels through isolation and sub-slab depressurization if necessary.

Where Radon comes from

Radon is a radioactive isotope that occurs naturally in soil and rock. It is created through the natural decay of uranium in soil, rock and ground water. As a gas, radon moves up through the ground to the atmosphere via fractures and fissures in rock and porous soils. Radon gets into buildings through seams, cracks and penetrations in foundation floors and walls. Not all areas are equally prone to radon; the U.S. EPA publishes maps on those regions that have the highest concentrations.

With conventional construction methods, stack and wind effects cause significant air leakage producing negative pressures at lower levels in buildings (see design note titled: Healthy Indoor Air Quality & Ventilation). Negative pressures in basements and crawl spaces allow soil gasses including radon into buildings below grade. Once inside, radon moves freely up through the building into the living spaces, affecting the occupants within.

The EPA recommends solving this health hazard by installing a gravel layer below a sealed basement floor or slab that is directly vented through the roof of the building. Radon accumulating in the gravel layer is passively vented directly to the atmosphere with a stack that runs up through the roof. In those regions where radon concentrations are very high, an attic-mounted fan may be required.

This approach is sound in theory, but it requires an airtight structure. When considering the air-sealing capabilities of The Icynene Insulation System®, a cost-effective approach to radon control can now be taken with the shell of the building itself.

The solution: Build Tight and Ventilate Right

Since radon infiltrates buildings due to negative pressure differences caused by air-leakage, it follows that a tightly constructed, positively pressurized building is far less likely to draw radon gas from the soil around it. Ventilation requires a tight structure in which to operate properly. This is where The Icynene Insulation System® comes in. In areas of particularly high radon concentrations, passive sub-slab depressurization consisting of vent pipe as previously described may be all the further control that is needed. It should only be in extreme cases that fan forced sub-slab depressurization system is required.

Radon Reduction with Tight Construction… the Easy Way!

Many builders go to considerable extra costs for material and labor to reduce air leakage in new structures. This is most commonly done to reduce heating and cooling costs and to improve comfort levels. It has been known for some time that tight construction reduces energy consumption but buildings are complicated, and air tightness is difficult to achieve with conventional materials.

Unlike other types of insulation, The Icynene Insulation System® is multi-functional, providing excellent insulating value and superior air sealing. The Icynene Insulation System® eliminates the need for an air/wind barrier (housewrap and associated taping). And where a vapor barrier is deemed necessary, a coating of vapor diffusion retarder primer on the inside surface is sufficient. This approach has been used on homes that, for energy efficiency program requirements, must test below 1.5 ACH @50 Pa (air-changes/hour at -50 Pascals pressure) with a blower door air-leakage test. Some of these homes have actually tested below 1.0 ACH @50 Pa. With tight construction and positive pressure ventilation, buildings are not affected to the same degree by wind or stack effects as those without these systems. Thus extreme lower level negative pressures (which draw radon in) will not be experienced.

Existing Buildings with Elevated Radon Levels

Where living space exists over an unconditioned crawlspace or basement, an isolation technique can be employed using The Icynene Insulation System®. When applied to the floor and joists from below, Icynene® effectively isolates the living area from the radon source. The unconditioned area can then be ventilated to the atmosphere using wall vents or a passive vent pipe up through the building. In cold climates, care must be taken to prevent plumbing from freezing below insulated floors.

Hotels and Nursing Homes

Critical considerations in the design of hotels and nursing homes are:

- Maximize occupancy rates, referrals, lengths of stay and repeat visits.
- Keep guests comfortable, draft free, cool in summer, warm in winter.
- Reduce sound transmission between rooms and bathrooms and limit exterior noise transmission from planes, highways, trucks and street noises.
- Control moisture and mold inside wall cavities and inside room interiors.
- Provide high quality indoor air to accommodate guests with allergies, etc.
- Minimize energy cost.
- Minimize maintenance cost.
- Minimize construction time.
- Minimize mechanical and electrical equipment costs.

The Icynene Insulation System® offers the opportunity to accomplish all these goals with its one step Thermal Envelope/Acoustical System. This foam material allows a general contractor to create a virtually airtight building envelope in one step.

Combining air sealing with Icynene® low-density foam insulation and properly designed mechanical ventilation and heating/cooling system provides a building that is healthier, quieter, more comfortable and energy efficient. The benefits of Icynene® applied to the entire building envelope are:

Improved guest comfort by:

- Elimination of drafts.
- Elimination of convection inside walls cavities and reduction in air exchange between outdoors/attic, and the interior. This results in interior wall temperatures close to ambient room temperature and reduced radiant cold/heat experienced by guest.
- Better dehumidification in summers due to more frequent operation of smaller a/c units.
- Less fluctuation in interior temperatures in any season.

Natural air leakage through walls and the attic is reduced to 0.15 ACH or less resulting in:

- Elimination of moisture and mold formation in interior walls.
- Reducing the heating/cooling load on the building by 40%.
- Reducing outdoor sound transmission by having a virtually air tight wall assembly.
- Lowering all room circuits to 110-120 volts.
- Reducing room distribution panels.
- Dropping interior power distribution circuit sizing.
- Downsizing power supply lines from the utility grid.
- Reducing the service entrance transformer sizing.
- Reducing electrical energy consumption.
- Reducing peak electricity demand.

Direct from room mechanical exhaust and conditioned makeup air supplied to corridors result in:

- Elimination of individual room exhaust fans and electrical circuitry.
- Better air quality and reduced temperature differentials between rooms and corridors, resulting in a reduction in mold formation inside rooms.

Improved acoustics by incorporating Icynene® into interior partition walls:

- Potentially reduced thickness of walls (from 2x6 to 2x4 construction) with equal or superior performance
- Eliminates need for extra thick acoustical materials and sealants to interior finish.
- Reduced sound from interior fans and smaller A/C units.
- Reduced sound transmission from bathtubs and plumbing due to Icynene's® custom fit, adhesion, and sound absorbing properties.

Reduced construction time and cost:

- By elimination, or reduction of many steps and materials, including interior vapor barriers, exterior building wrap, soundboard, preformed mechanical pipe insulation, glass fiber batts, individual room fans and electrical work.
- By reduction of site traffic, by an estimated 30 truckloads of materials in a 100 unit motel and the storage and handling of these goods through the corridors the productivity of other trades can be enhanced. Due to the high speed of The Icynene Insulation System® installation because it does not involve handling bulky materials and fasteners.
- Incorporating the benefits of The Icynene Insulation System® into a building results in a superior structure with a net capital cost saving to the owner.

Reduced maintenance cost:

- Elimination of moisture and mold spores inside wall cavities eliminates the growth of mold behind wall finishes and prolongs the life of vinyl interior wall finishes
- Reduction of mold growth in room interiors reduces routine cleaning and prolongs the life of carpeting & bedding and soft furnishings.
- Elimination of moisture related structural problems, increasing building life expectancy.
- Decreased utility costs for the life of the building.

Mold Abatement and Rehabilitation

There has been an alarming increase in the number of "sick building syndrome" cases we hear or read about that result in the closure of homes and large buildings due to poor indoor air quality. The occupants cannot concentrate, lose their productivity, and in certain instances, become extremely ill. Very often poor air quality is the result of mold growth. Mold can grow almost anywhere if the conditions are right, and it is only recently that we have become aware of mold within the wall cavity or building envelope. There are specific environmental conditions required for mold to propagate. A specific temperature range and source of food are basic factors that must be in place, but the most important element is the presence of moisture.

Moisture can enter the building envelope by several means. The primary transportation mechanism is water infiltration due to imperfect construction or detailing. Water infiltrating the building via this transportation mechanism can be substantial in quantity. The moisture infiltration is due to gravity or capillary action, and because these two transport mechanisms are efficient, there is immediate and noticeable damage usually associated with weather conditions. The secondary transportation mechanism for moisture to enter the building envelope is air leakage or diffusion. This mode of transport is less visible and the damage takes longer to develop.

Moisture entering the building envelope due to imperfect construction or detailing is usually easy to identify and correct. Experience has shown that when moisture travels by gravity or capillary action, the cause is usually quite evident so the contributing problem can be corrected. Unfortunately this is not the case where the transport mechanism is the more complex diffusion or air leakage. In such cases the approach has often been a short term action to repair the damage by replacing the affected components instead of identifying and correcting the root causes. This approach is used primarily for the following reasons:

- a lack of understanding of the cause or inability to determine the cause of the damage
- and/or lack of suitable materials to solve the preexisting condition
- and/or the high costs involved in retrofit.

Another factor contributing to the presence of moisture within the building envelope is the increased use of HVAC equipment and the way it is used. This equipment maintains a substantial temperature and vapor pressure differential, which enhances both the air and moisture drives, resulting in the potential for condensation within the building envelope. The desire for higher comfort levels, combined with an increased need to conserve energy results in tighter buildings that maintain higher differentials in environmental conditions between the exterior and interior, further aiding the condensation process.

In order to minimize the potential for mold growth, a building envelope system has to meet all of the following criteria:

- The building envelope must prevent water from penetrating. Therefore the structure must be properly sealed and contain an effective drainage plane. A drainage plane in itself will not solve the problem, if drainage away from the building is not provided by proper site positioning and grading. As basic as these principles are, it is surprising how often they are overlooked and lead to severe problems.
- The building envelope must control the air leakage. Uncontrolled air leakage can lead to condensation and mold growth within the envelope system.

In addition to mandatory requirements there are additional performance criteria that an effective healthy building envelope should deliver.

All building envelopes have the potential at some time to get wet. It is desirable that the building envelope system have the potential to dry quickly. Therefore, the components of the building should resist moisture and once wetted should have the potential to dry quickly (they should be hydrophobic).

Overall cost and ease of application are the two factors that can not be overlooked. All components should be installed with relative ease and should not be installation-dependent for their ultimate performance.

Icynene® spray applied foam insulation comes closest to satisfying the criteria as specified above.

The concept of spray applied Icynene® foam insulation to control air leakage and condensation in one application is the most appropriate approach and the most promising technology to assist in controlling the spread of mold. Developments in soft foam insulation, specifically The Icynene Insulation System®, have taken an excellent concept and eliminated all restrictions. Not only is Icynene® a good investment, it has no application restrictions, and is environmentally safe because there are no emissions to affect chemically-sensitive occupants. The material is polyicynene (a water-blown polymeric material in the family of polyurethane).

The Icynene Insulation System® is a proven technology that offers the utilization of water only, as the blowing agent. This is important because the use of water as the blowing agent creates a unique set of performance characteristics that are particularly suited for mold control. The most important distinguishing characteristic is that water blown polyicynene is hydrophobic (not only does it resist getting wet, but once wetted it dries quickly under favourable drying conditions, with no deterioration in its insulation or air sealing performance). The use of water as the blowing agent results in a flexible and open celled foam. Flexibility allows movement with the rest of the building components, thus preventing a potential compromise of the all important air seal. The open celled structure allows for optimum drying and shedding of water. Although open celled, this material controls air movement and increases thermal performance.

Icynene® has a high rate of expansion (100 times its initial volume in seconds) which ensures effective air leakage control by filling all crevices, cracks, seams, and holes, while maintaining continuous and lasting performance. All of the performance characteristics of Icynene® combined drastically reduce the potential for moisture accumulation in the building envelope and within the building itself.

Controlling air leakage also significantly lowers the latent heat load on air conditioners, thereby reducing the required capacity significantly (30-50% is not uncommon in high humidity regions). The equipment and energy savings are a supplementary benefit in that the right sizing (reduction both in capacity and shortcycling) reduces the relative humidity which is a main contributor for mold proliferation.

The superior performance characteristics of polyicynene have made it the material of choice where there is a need for insulation and mold prevention. These same performance characteristics have also made The Icynene Insulation System® the material of choice in mold remediation/rehabilitation projects.

The Economic Thickness of Thermal Insulation

The conventional method of evaluating the performance of insulation is to measure the R-value, the conductive heat flow resistance of the material.

The measurement of conductive heat flow resistance is made using the guarded hotbox apparatus. This test procedure (ASTM C-518-02) measures the thermal conductivity of insulation material. In this test, one side of the specimen is heated to a specific temperature and after steady state heat flow has been reached, the temperature on the opposite side is measured. Through this temperature measurement the R-value is calculated. The outside surface of the test apparatus and the specimen is sealed and insulated to minimize the heat loss through the edges and eliminate the effects of any convection or radiant heat flow. This measurement solely defines the conductive heat flow resistance of the insulation material, the R-value.

Once the R-value of an insulation material is determined, the heat flow through it can be calculated using Fourier's steady-state heat flow equation.

$$Q = \frac{A \times \Delta T}{R}$$

Where:

Q = Rate of heat flow, BTU/hr

A = Area, ft^2

ΔT = Temperature differential, °F

R = Resistance to heat flow, hr.ft^2 °F/BTU

This equation is used to calculate the benefit of increasing the thickness of any type of insulation as long as there is no air movement (convective heat transfer) through the insulation.

As an example, consider 1000 ft^2 of insulated area with a temperature differential of 40°F. Let us include the outside air film at R-0.2 and R-0.7 for the inside air film. The total R-value is 0.09 before the application of any insulation. Increasing the insulation thickness by 1" increments at R-3.6/inch provides the following heat flow rates as shown in Figure 1.1 & 1.2.

Figure 1.1
Percentage of total heat flow

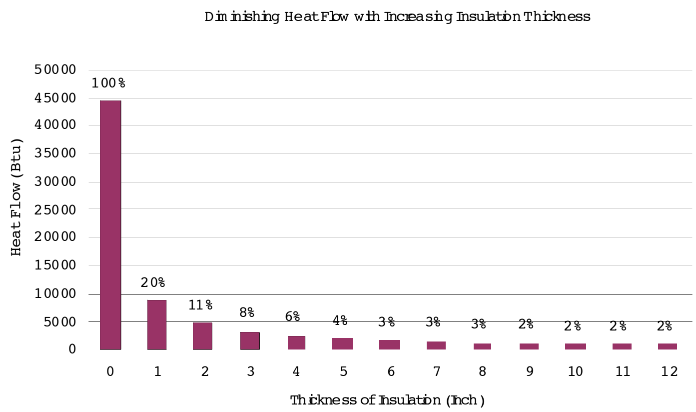

Figure 1.2
Percentage of total heat flow reduction

In Figure 1.1 we can see that the first 1" of insulation reduces the heat flow to 20% of the total and at 5" of thickness, the heat flow is reduced further, down to 5% of the total. In looking at Figure 1.2 we see that increasing the insulation thickness from 6" to 12" only provides an additional heat flow reduction of 2%. Doubling the insulation thickness (R-value); doubling the cost; only provides a modest 2% increase in heat flow reduction. Based on this observation, it is very difficult to justify the additional cost of adding insulation thickness beyond 5".

The Icynene Insulation System® fills any shaped cavity and adheres to almost all materials, thereby, forming an insulation layer with very low air permeance. Air flow is eliminated and for this reason, conductive heat loss can be used as a sole criterion for establishing insulation thickness with Icynene®.

As shown in Figure 1.2, insulation material with R-value of 3.6 per inch blocks out 95% of conductive heat flow within the first 5 inches of the material. Thickness beyond this point would bring more reduction in heat flow but it would not be economically justified since the returns on additional R-value have greatly diminished.

Reduce Air Filtration - Reduce Energy Use Reduce Equipement Size

In the case of insulation material with significant air permeance, conductive heat loss should not be the only criterion used for establishing insulation thickness. Convective heat loss must be considered as well, particularly when a substantial latent load is involved.

Oak Ridge National Laboratory (ORNL) conducted an experiment[1] to determine the efficiency of a roof assembly insulated with low density, loose-fill fiberglass insulation and discovered that up to 50% of the heat loss occurred as a result of convection; air circulation through the insulation. This result showed that the air-permeable insulation had lost its anticipated thermal performance level by half and that convective heat transfer had a significant negative impact on insulation performance.

[1]ORNL's Building Envelope Center: Fighting the Other Cold War
URL: www.ornl.gov/ORNLReview/rev26-2/text/usemain.html

The importance of reducing air infiltration can be easily demonstrated by analyzing the energy consumption for heating and cooling houses that have different air infiltration rates. The following evaluation was generated using the REM/Design energy analysis software. This evaluation deals with three identical houses, located in different North American cities with three different levels of insulation and air-infiltration. The house design is fully detached, has approximately 2000 sq.ft of floor area with two stories and a double car garage.

The first is a **Typical** house designed according to the general building code requirements; with fiberglass insulation, R-30 in the attic, R-19 in the walls and an air infiltration rate of 0.7 ACH at natural pressure.

The second is a **Better** version of this house with fiberglass insulation, R-43 in the attic and R-19 in the walls and 0.6 ACH at natural pressure.

The third is an **Icynene**® house with an insulation level of R-20 in the walls, R-20 in the ceiling and an air infiltration rate of 0.1 ACH at natural pressure.

Heating and cooling costs and the required heating and cooling equipment capacities for each house are plotted on the following graphs. The utility rates are set at $0.15 per kWh for electricity and $0.90 per Therm for natural gas.

Figure 2.1 Savings on Heating Costs with Icynene®

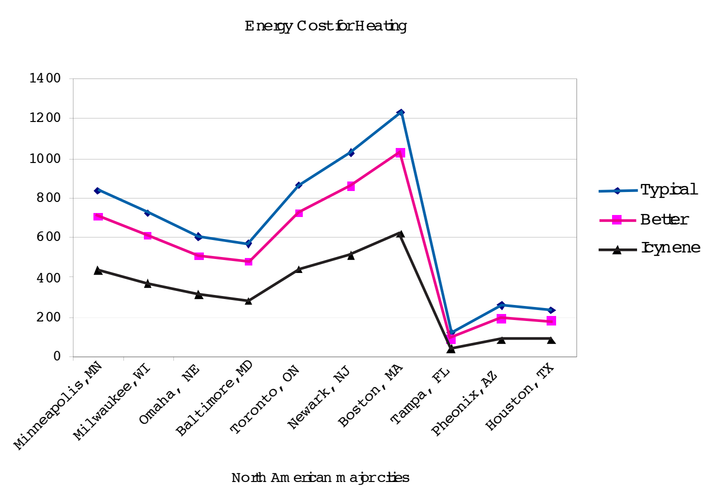

Figure 2.1 shows the energy costs for heating in several different cities throughout North America. The heating costs are compared for the three different insulation systems. It can be seen that savings on heating cost reached up to 40% – 50% with Icynene® when compared to the Typical insulation system. Also, the graph indicates that the colder the climate, the greater the heating cost savings are with Icynene®.

Figure 2.2 shows savings on cooling costs with Icynene®. They provide savings of 25% – 40% over the typical insulation system. The cities in a hot & humid climate show greater savings due to the higher cooling demand.

As far as sizing heating and cooling equipment is concerned, Icynene® provides a significant reduction in both heating & cooling load due to its air sealing property. Figures 2.3 & 2.4 show the equipment size required in these houses for heating and cooling. The graphs show that there is a significant reduction in required capacity for both heating and cooling relative to Typical & Better systems. Often with Icynene, size reduction for heating equipment can reach up to 50% and for cooling, it can be up to 40%.

Icynene®'s air seal capability eliminates convective heat transfer within the insulation and reduces unwanted air leakage through the building envelope. This feature improves the efficiency of the building envelope thereby reducing the heating and cooling costs and reducing the size of HVAC equipment as outlined in figures 2.1 through 2.4. As a result lower operating costs are realized and the cost of the operating equipment is reduced.

Often, air permeable insulation at twice the R-value gets used and still comes short of the desired energy savings as shown in Figures 2.1 and 2.2.

The on-site spray applied application of Icynene® provides an excellent air seal that ensures a low air infiltration rate for the building envelope. This quality improves energy efficiency of the building as demonstrated through the graphs above and in addition, the overall performance of the building results in better sound attenuation, healthier indoor environment and enhanced thermal comfort.

Figure 2.2 Savings on Cooling Costs with Icynene®

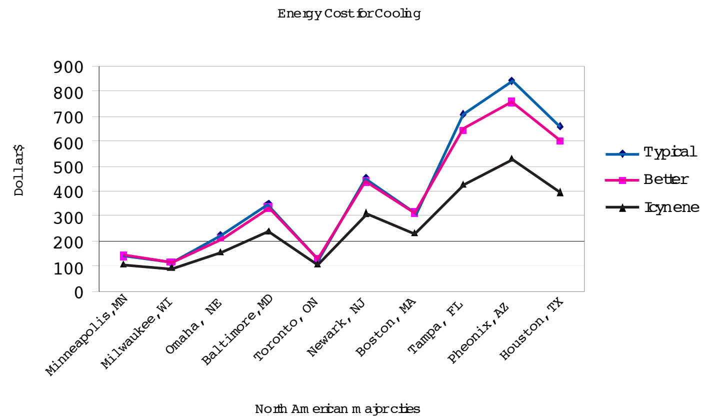

Figure 2.3 Heating Equipment Size

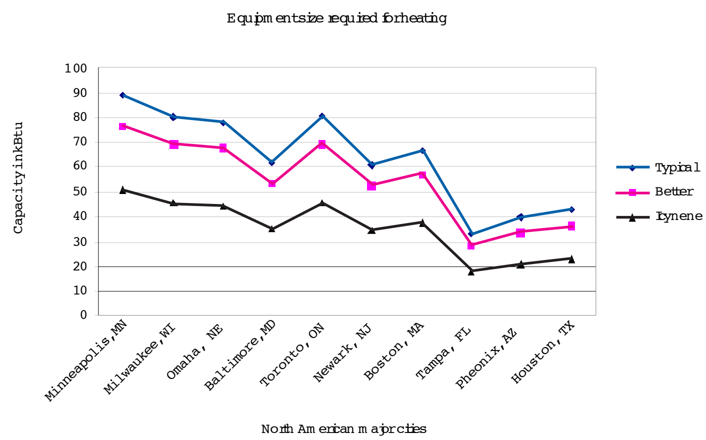

Figure 2.4 Cooling Equipment Size