Johns Manville

717 17th St.
Denver, CO 80202
(800) 654-3103
(303) 978-2318 FAX
www.jm.com

TECHNICAL BULLETIN — Insulation Systems

Bulletin No: IST09-005
Date: April 15, 2009
Distribution: External

Convection in Fibrous Attic Insulation

BACKGROUND

The performance of any insulation material depends on how it is installed and the environment to which it is exposed. The overall insulating efficiency can vary due to installation quality, type and percentage of framing present, aging, settling, and moisture content. Air movement within and around a building, coupled with extreme temperature conditions, can also impact insulation performance.

In particular, attic insulation in a cold climate can be especially susceptible to performance variation when the insulation is directly impacted by different sources of air movement. In vented attics, wind driven air flows from improperly vented soffits and other air leakage sites can degrade insulation performance by stripping heat away from the exposed insulation surfaces (wind washing). Air leakage through unsealed ceiling light fixtures and vents can allow heated air to directly escape from the building interior to the cold attic, within and around the insulation. For some very permeable types of loose-fill insulation, heat loss can also occur due to buoyancy induced air movement within the material. This type of heat loss is known as natural convection.

To minimize undesirable heat loss effects in attic insulation, the principles of convection are important to understand. Convection is the transfer of heat via the movement of air. It can result from forced air movement, natural air movement, or a combination of the two effects. Forced convection in an attic/ceiling system typically results from wind pressure and HVAC equipment. Wind washing and air infiltration are primarily the result of forced air movement. Natural convection results from thermal buoyancy effects. In attics, natural convection is a cold weather phenomenon only. If a large enough temperature difference exists, warm air near the ceiling will rise and be replaced by colder dense air from the attic. The cycle of rising warm air being replaced by sinking cold air is called a convective loop and, left unchecked, can be a very efficient means of heat removal. Fortunately, insulation breaks the convective loop by providing resistance to air movement and preventing heat losses from the ceiling.

Fibrous insulation, such as fiber glass, cellulose, and rockwool, are commonly installed in attics to minimize heat losses to the attic space. Fibrous insulation is composed of fibers and air. The role of the fibers is to reduce heat losses through the insulated region by: 1) eliminating convection (air movement) and 2) absorbing and scattering thermal radiation. If properly designed, all fibrous attic insulation products can effectively minimize heat loss.

PARTIAL INFORMATION CAN BE MISLEADING

In 1992, Oak Ridge National Laboratory (ORNL) published thermal performance results[1] from a series of tests conducted on several types of attic insulation under severe winter temperature conditions. The results of this study included very permeable loose-fill fiber glass insulation that suffered significant thermal performance loss due to natural convection when attic air temperatures dropped below about 20˚F. Unfortunately the study generated perceptions that all fiber glass insulations (batt or loose-fill) begin to lose effectiveness at temperatures below 20˚F.

For many years competing industries have disseminated this misleading information. They continually reinforce the perception that all fiber glass insulation products, regardless of density, permeability or material type, are subject to significant natural convection related thermal performance loss.

THE FACTS

The ORNL study showed that natural convection could occur within very permeable loose-fill insulation, even under ideal installation conditions. It also showed that convection related heat loss decreased as the loose-fill insulation became less permeable. Additionally, fiber glass batts tested during this study showed no evidence of natural convection heat loss.

Since the release of the original ORNL study, JM has conducted hundreds of cold temperature tests on various types of attic insulation according to the ASTM C 1373 test procedure "Determination of Thermal Resistance of Attic Insulation Systems Under Simulated Winter Conditions". Consistent with the results published by ORNL, JM test data showed that insulation permeability[2] has a significant influence on the presence of natural convection. The JM tests demonstrated that with proper glass fiber diameter and nodule size design, the air permeability of the installed product could be greatly minimized.

The findings from both the ORNL and JM studies were used in subsequent years to establish design specifications for all of Johns Manville's loose-fill fiber glass attic insulations to improve winter thermal performance. The design specifications primarily focused on maintaining an appropriate nodule or tuft size, which decreased the permeability of the installed insulation. Figure 1 shows the performance[3] of JM Climate Pro® loose-fill insulation after new design specifications were implemented. Note that as the attic air gets colder, the thermal resistance initially improves because the contribution of thermal radiation decreases. However, below -15˚F the effect of natural convection is larger than the gain in radiative resistance, so the overall thermal resistance (R-value) begins to decrease as the air temperature gets colder, but not to the point where the R-value is less than advertised label performance. Figure 2 shows the performance of JM Climate Pro® MH which has very small nodules, thus no convection heat loss. Figure 3 shows the performance of JM fiber glass batt attic insulation, also unaffected by convection due to low permeability.

[1] A. Delmas and K. Wilkes, "Numerical Analysis of Heat Transfer by Conduction and Natural Convection in Loose-Fill Insulation – Effects of Convection on Thermal Performance", ORNL/CON-338, 1992.

[2] Loose-fill materials susceptible to natural convection typically have high permeability resulting from large interconnected voids (air pockets) that exist between the individual nodules of material.

[3] The R-values shown represent full thickness installation in a simulated attic/ceiling system. The interior air temperature was maintained at 70°F while the attic air above the insulation ranged from about -40°F to 50°F.

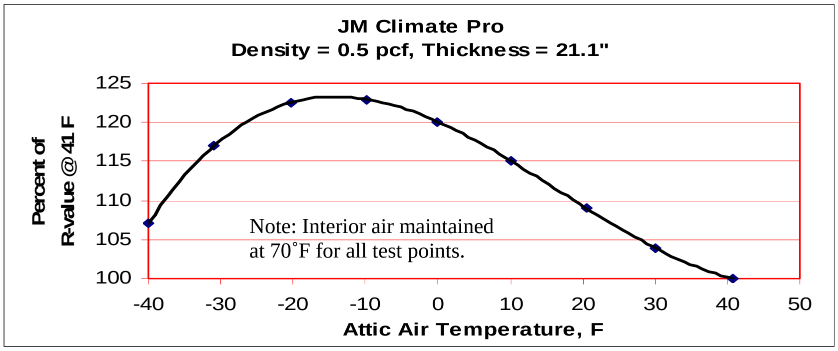

Figure 1 - Winter Performance of JM Climate Pro® Fiber Glass Loose-Fill Attic Insulation

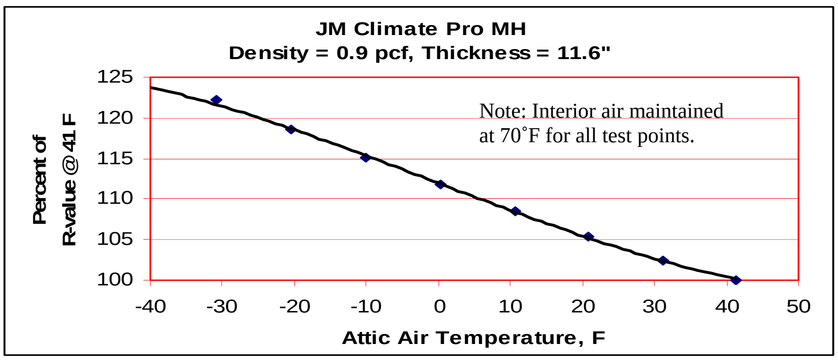

Figure 2 - Winter Performance of JM Climate Pro® MH Fiber Glass Loose-Fill Attic Insulation

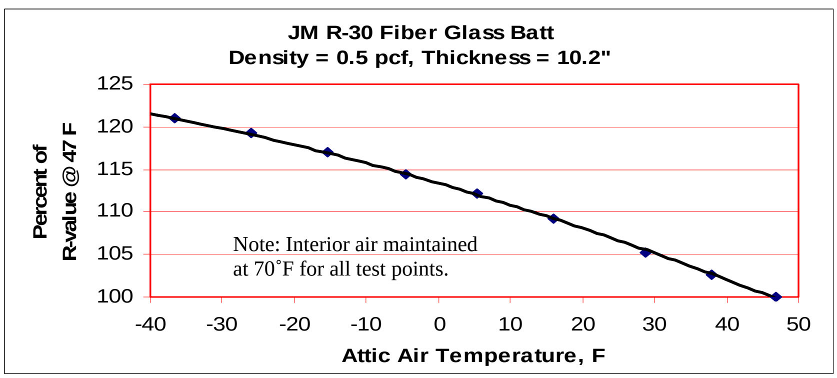

Figure 3 – Winter Performance of JM Fiber Glass Batt Insulation

CONCLUSIONS

- Natural convection in loose-fill fiber glass insulation can be controlled or eliminated by reducing permeability with nodule size change. JM loose-fill attic insulation products (Climate Pro® and Climate Pro® MH) perform well, even at temperatures as low as -40°F.
- JM fiber glass batts have high air flow resistance (low permeability) and are unaffected by natural convection.
- Based on energy analyses conducted by ORNL and JM, any additional energy usage that results from the presence of convection is insignificant. This is because extremely cold temperatures only occur a few days per year for most climates and typically only for a few hours per day.