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To Whom it may Concern:

Re: **Cold Climate Recommendations for the use of Spray-Applied Polyurethane Foam**

Summary

The use of any insulation in building assemblies in cold climates potentially risks water vapor condensation, moisture accumulation and mold growth. The more permeable the insulation, the greater the risk. Fibrous insulations (such as fiber glass) are highly permeable and, consequently, highly susceptible to condensation problems. Open-cell Spray Polyurethane Foam (SPF) is less susceptible, but still carries risk in colder climates. Closed-cell SPF, with its relatively low permeability, is a highly forgiving insulation material for use in cold and extreme climates.

This paper discusses the cause of condensation, the factors affecting condensation, the types of SPF, and U.S. climate zones as defined by the building code. Finally, specific recommendations are provided in Table 2 for using open-cell and closed-cell SPF in various climate zones.

Introduction

When designing walls, roofs and other insulated building assemblies in cold climates, always take into account the potential for condensation. Just as heat flows from warm regions to cold regions, water vapor transfers from regions of high absolute humidity to regions of low absolute humidity. In a layer of insulation, if the rate of heat transfer and the rate of water vapor transfer are not balanced, the water vapor will reach its dew point temperature and condense into liquid water. This phenomenon depends on a number of factors including the R-value and permeance of all of the materials used in the wall or roof assembly and the temperature and humidity differential across the assembly.

The following factors tend to **increase** the potential for condensation:

- Insulation having high water vapor permeability
- Low water vapor permeable materials or vapor retarders on the cold side of the assembly
- Cold exterior temperatures
- High humidity interiors
- High temperature differential

Vapor retarders can be used with highly permeable insulations to mitigate the risk for condensation. However, vapor retarders are rarely installed perfectly. Furthermore, their effectiveness can be significantly reduced by (1) failure to air seal electrical boxes and other openings in the wall or ceiling; and (2) punctures due to occupant installation of wall or ceiling mounted light fixtures, pictures and other treatments.

Types of Spray Polyurethane Foam

One of the choices that SPF insulation contractors can control is the type of SPF used in cold-climate building assemblies. SPF comes in two types: Closed-cell and Open-cell. See Table 1 for a quick comparison of the two materials.

Table 1: Comparison of SPF Types

Type	Closed-cell SPF	Open-cell SPF
Synonyms	Hard foam, medium density	Soft foam, low density
Density	1.8 - 2.2 lb/ft^3	0.4 - 1.0 lb/ft^3
Compressive Strength	20 - 30 psi	2 - 4 psi
Closed-cell content	90 + %	15 - 40%
Permeability	~ 1.8 perm-in	~ 15 - 55 perm-in
R-value per inch	5.5 - 6.5	3.5 - 4.1
"Feel"	Firm to the touch	Soft to the touch
Application (stud wall, typical)	Underfill	Overfill and trim

Because of its high permeability, open-cell SPF is more susceptible to condensation problems in cold climates than is closed-cell SPF. In fact, there have been several documented incidents of this occurring (see *Energy Design Update*, April 2005 and July 2005 issues).

The condensation potential with open-cell SPF in cold climates can be reduced through the use of well designed and properly installed vapor retarders. Alternatively, closed-cell SPF can be used instead. Closed-cell SPF rarely requires the use of vapor retarders due to its low water vapor permeability (exceptions include unusual building conditions such as freezers, coolers or high-humidity environments).

Climate Zones

Building assemblies typically have low permeable sheathing (such as plywood or OSB) on the exterior side (in essence, the sheathing is a vapor retarder on the exterior side of the assembly). In cold climates, this vapor retardant sheathing is on the "wrong" side of the assembly, encouraging condensation. This effect can be compensated for by (1) installing a low permeable insulation or (2) installing a high permeable insulation with a vapor retarder on the warm side.

As mentioned above, due to its low water vapor permeability, closed-cell SPF rarely requires the use of a vapor retarder. Open-cell SPF is trickier.

Generally speaking, in Climate Zones 1 - 3 (warm climates where air conditioning predominates), no vapor retarder is required on the interior side of open-cell SPF: the predominant vapor drive is from the outside to the inside, the exterior sheathing acts as a vapor retarder and it is on the warm ("correct") side of the insulation.

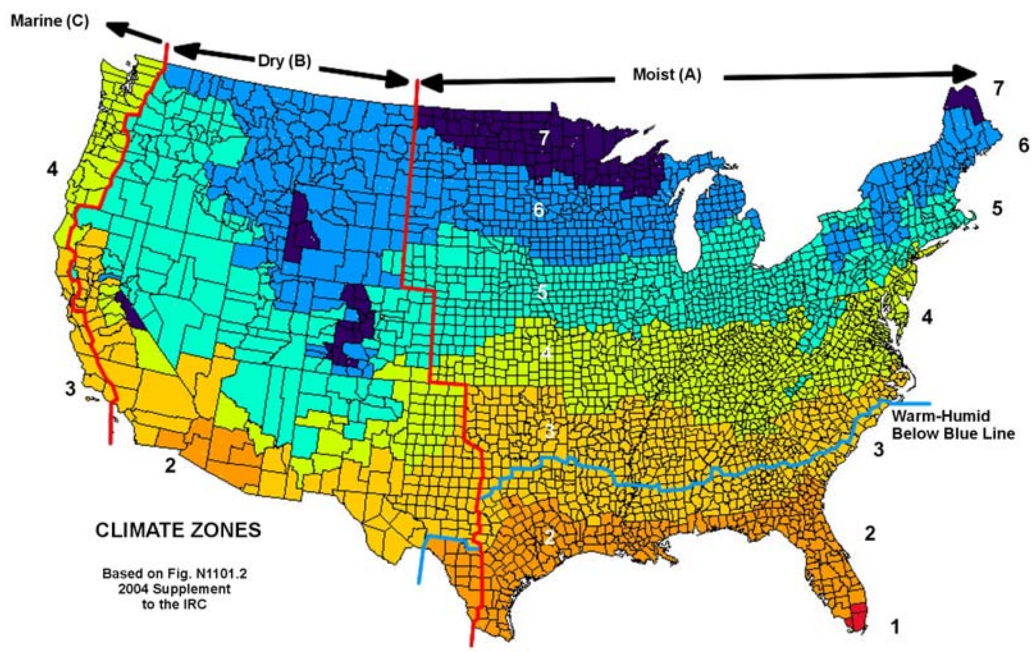

Figure 2: U. S. Climate Zones

In Climate Zones 4 - 7 (cold climates where heating predominates), since the vapor retardant sheathing is on the cold ("wrong") side of the open-cell SPF, there's a high potential for condensation to occur: a vapor retarder may be required on the interior (warm) side of the insulation. The further north and higher in altitude (the higher the climate zone), the greater is the potential for condensation and the greater is the need for a lower permeance and tighter vapor retarder.

However, keep in mind that vapor retarders are never perfect. The choice of an insulation that is more resistant to high moisture and thermal gradients is always a better choice than dependence on a vapor retarder.

Recommendations

Table 2 below summarizes the likelihood of needing a vapor retarder with the two types of SPF. When concerns for condensation potential arises, Deer Ridge Consulting, Inc. performs WUFI simulations (a computer-based model for simulating the one-dimensional hygrothermal [heat and moisture] behavior of building assemblies) to make specific recommendations. WUFI is a powerful tool for estimating the likelihood for condensation to occur within walls, ceilings, and other assemblies. This model was jointly developed by Oak Ridge National Laboratory (Oak Ridge, TN) and the Fraunhofer Institute for Building Physics (Holzkirchen, Germany).

Because the need for a vapor retarder is based on the physical properties of the materials within the building assembly, the type of insulation, the geographic location and the characteristics of the building interior, WUFI simulations and Deer Ridge Consulting's subsequent recommendations are building specific.

Table 2: Need for Vapor Retarders (see Note below)

	Need for Vapor Retarder on the Interior Side of SPF Insulation	
Climate Zones	Closed-cell SPF	Open-cell SPF
1-3	None	None
4	None	Run a WUFI simulation to determine need for and type of vapor retarder on the interior side of the insulation.
5	None	
6	None	Vapor retarder is strongly recommended. Run a WUFI simulation to determine need for and type of vapor retarder on the interior side of the insulation.
7	Run a WUFI simulation to determine need for and type of vapor retarder on the interior side of the insulation.	Open-cell SPF is not recommended in this Climate Zone

Note: Vapor retarders are never perfect . The choice of an insulation that is more resistant to high moisture and thermal gradients is always a better choice than dependence on a vapor retarder.

Open-cell and closed-cell SPF are both excellent insulations that consistently outperform their fibrous competitors. In cold climates, care must be given to the type of SPF specified and the need for a vapor retarder. In Climate Zones 6 and 7, Deer Ridge Consulting recommends the use of closed-cell SPF. In any case, Deer Ridge Consulting can provide specific recommendations for closed-cell or open-cell use in all climate zones.

If you have any questions on the above, we will be glad to discuss them with you.

Sincerely,
Deer Ridge Consulting, Inc.

Roger V. Morrison, P.E., R.R.C.
President