CONDENSATION IN REFRIDGERATED BUILDINGS

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Introduction

The following discussion reviews the basic causes of condensation in refrigerated buildings and the related construction requirements.

Relative Humidity and Dew Point Temperature

An air mass at higher temperatures has greater molecular activity than at lower temperatures. The greater molecular activity allows a warmer air mass to contain more water vapor molecules than a cooler mass. However, there is a limit to the maximum capacity of water vapor that an air mass can contain.

The percentage ratio of actual water vapor in the air mass, relative to its maximum water vapor capacity, is referenced as "relative humidity" or "RH". For example: when the air mass contains its maximum capacity of water vapor, its relative humidity is 100%. When the air mass contains half its maximum capacity, its relative humidity is 50%, etc.

If the amount of water vapor in an air mass remains constant while the temperature of the air mass is lowered, the maximum water vapor capacity is lowered and approaches the actual water vapor content in the air mass. In other words, as the air mass cools the relative humidity of the air mass approaches 100%.

When the temperature is lowered to the point where the maximum water vapor capacity becomes lower than the actual amount of water vapor in the air mass, the excess water is expelled from the air mass by its condensation into a liquid water condensate..

Broad area condensation such as rain and fog typically occurs when a high humidity air mass is cooled by mixing with a cooler air mass. Localized condensation, such as dew on the grass and condensation on the exterior surface of a cold glass typically occurs when the air mass is cooled by contact with cooler surfaces.

The temperature at which condensation of the excess water vapor will occur is referenced as the "dew point temperature". At 100% relative humidity, the dew point temperature is equal to the air temperature. If the relative humidity of an air mass decreases, the dew point temperature becomes progressively lower than the air temperature.

Water Vapor Migration and Vapor Pressure Differential

Water vapor will migrate within an air mass as necessary to equalize the distribution of the water vapor throughout the air mass.

In the typical refrigerated building, water vapor in the interior air mass is cyclically removed by its condensation on the cooling coils of the building's refrigeration system.

As the water vapor migrates to the coils and is removed from the air mass, this will cause a continuing lowering of the interior air's water vapor content (relative humidity).

Note: the actual interior humidity may be influenced by excessive migration of exterior water vapor through door openings and vapor barrier leaks.

When the interior air's water vapor content is different than that of the exterior air, a vapor pressure differential is developed between the interior and exterior of the building. This would typically occur between the low humidity interior air of a refrigerated building and warmer, more humid exterior air.

In the attempt to equalize the vapor pressure between the exterior and interior, water vapor will migrate through any available opening which may function as an interconnection of the exterior/interior air spaces, such as through intentional opening of doors or through unintentional voids in the building's vapor barrier system.

Note: an important aspect of vapor migration is that it operates independently of air flow, although the vapor drive effects may be influenced by significant movement of the respective air masses.

Vapor Drive
The direction of the water vapor migration (vapor drive) will be from the high humidity (high vapor pressure) side to the low humidity (low vapor pressure) side. The vapor drive intensity will be relative to the magnitude of the vapor pressure differential. For the typical, non-humidified, refrigerated building, vapor drive will be primarily be from the exterior to the interior.

Exceptions: one might assume that the vapor drive would be reversed for buildings subject to exterior temperatures colder than the interior temperature. However, the potential exterior/interior vapor pressure differential is reduced because of the exterior cold air's typical low humidity level.

In buildings that are intentionally maintained at high interior humidity levels, the vapor drive may be reversed when the exterior air is less humid than the interior air.

Interior Condensation
Warm, humid exterior air often has a dew point temperature greater than a refrigerated building's interior temperatures. When such humid exterior air is allowed to migrate into the building's interior, its water vapor is subject to condensation into liquid water on the interior surfaces that are cooler than the infiltrating air's dew point temperature.

Interior surface condensation is typically observed as water droplets and rivulets, or as residual staining on interior wall surfaces. Condensation may also be observed as droplets and drippage from overhead roof and framing surfaces, drip spots on the floor and water puddles at the base of the wall. In freezer buildings, the condensate typically freezes and is observed as frost or ice on the interior surfaces.

Because of the convection effects upon the warmer exterior air migrating through door openings, interior condensation of the incoming water vapor will typically occur as a broad distribution of water droplets or frost on the upper interior wall surfaces, underside surfaces of the roof or ceiling, and overhead framing surfaces in the general area of the door opening.

In the case of very large volumes of inward migrating water vapor (such as through a door opening), condensation of the water vapor may occur directly within the cooler interior air mass in the form of a fog. In freezer buildings, the water vapor may freeze and be observed as light snow within the fog.

If the temperature gradient between the interior and exterior causes surface temperatures within wall or roof construction to be equal or less than the dew point temperature of air that is allowed to migrate through the wall or roof, condensation may occur within the wall or roof construction itself.

Vapor Barrier Function

The function of a vapor barrier is to prevent (or retard) the migration of water vapor between the building's exterior and interior. Because of the reduced humidity level in the typical refrigerated (cooler/freezer) building, the vapor pressure differential (and resulting vapor drive) can be substantially greater than that of a non-refrigerated building. This requires a more critical understanding and precision in the design and installation of the vapor barrier related construction.

The common practice for refrigerated buildings is to treat only the exterior of the floor, walls and roof or ceiling as a continuous vapor barrier envelope. The intent of the exterior vapor barrier is to prevent exterior water vapor from infiltrating into the wall, ceiling or roof construction and from continuing the migration through the construction into the building's interior.

The intent of not having a vapor barrier on the interior side of the construction is to allow residual or infiltrating water vapor within the wall or roof construction to be freely absorbed into the low humidity interior air mass. If actual condensation has occurred within the wall and roof construction, the condensate water is expected to eventually be evaporated and absorbed into the interior air mass during less humid conditions.

Vapor Barrier Design

On the typical refrigerated building with insulated metal wall, ceiling or roof panels, the exterior metal panel facing and sealed panel joints function as the vapor barrier.

Insulated metal panels are ideally suited to function as vapor barriers. The metal facing material is impervious to water vapor penetration and is extremely durable and stable. The joint sealing material is also impervious to water vapor penetration and is fully protected within the tongue & groove assembly of the metal facing edges.

Depending upon the building's specific conditions, the concrete foundation/floor slab may function as the vapor barrier, or the floor slab may be protected from water vapor infiltration by an exterior membrane material that functions as the vapor barrier.

At the wall-to-foundation and wall-to-roof junctions, the respective flashing assemblies are designed to provide continuity of the adjacent vapor barriers across these junctions. For buildings with insulated metal panels, these assemblies typically consist of exterior and interior metal flashing, thermal insulation and sealing materials.

For more critical vapor barrier requirements an elastomeric membrane may be used as the actual vapor barrier material to interface with the vapor barrier surfaces of the adjacent constructions (such as at the junction between the wall and roof). The membrane is then protected by covering with an exterior metal flashing.

Thermal Transmission and Exterior Surface Temperature Variations
Although the modern cooler/freezer building with insulated metal panels is exceptionally well insulated, a very limited amount of thermal transfer still occurs between the interior and exterior of the building.

Because of the limited thermal transfer, a refrigerated building's exterior surface temperatures will always be slightly cooler than the temperature of the exterior air. An exception occurs when the exterior air temperature is equal or cooler than the building's interior temperature, or when the exterior surface is being warmed by solar radiation (or other heat source).

The exterior surface temperature of a wall or roof construction is determined by the actual exterior/interior air temperatures, the wall or roof's coefficient of thermal transmission and the resulting magnitude of exterior/interior temperature differential, plus the influence of wind chill and solar radiation effects.

Panel Joint Areas**:**
At the panel joints, there are several factors that increase thermal transmission through the panel in the immediate area of the joint. The depth of the tongue & groove configuration at the edges of the metal panel facings reduces the effective thickness of the panel's insulating core. And, within the relatively small area of the joint cavity, the thermal resistance is provided by a dead air space rather than the foam core. These factors cause the exterior surface temperatures in the immediate joint area to be an additional few degrees cooler than the surface temperature at the field areas of the panels.

Panel Attachment Areas**:**
At the panel attachment locations, metal screws penetrate a partial thickness of the foam core and transmit conductance to the metal panel clip concealed within the joint. At the very small area of the clip locations, the exterior surface temperature may be an additional few degrees cooler than the rest of the joint area.

Note: because the area of the panel joint's are very small relative to the overall area of the respective wall, ceiling or roof, the actual effect of the joint's additional thermal conductance upon the wall or roof's overall thermal insulating performance is extremely limited or insignificant.

Flashing Conductance**:**
If the metal flashing assemblies fully or partially penetrate the panel thickness at the wall, roof and foundation junctions, greater thermal conductance will occur. The greater thermal conductance of the metal flashings causes the exterior surface temperature of the flashing to be cooler than the nominal wall panel surfaces. Thermal conductance between the flashing and the wall panel can also cause a localized cooling of the immediately adjacent wall panel surfaces.

Vapor Barrier Leaks**:**
Voids in the wall joints and flashing assembly seals, can allow cooler interior air to wash over the exterior panel and flashing surfaces, further cooling those surfaces. The pattern of the exterior surface cooling by the exiting cooler interior air may be dependent upon wind effects, convection forces and the baffling effects of the panel and flashing profiles.

Foundation Conductance:
At the exposed edges of foundations, the greater thermal conductance of the concrete causes its exterior surface temperature to be cooler than the nominal panel surfaces. Thermal conductance between the concrete and the wall panel/ flashing assembly can also cause a cooling of the adjacent wall panel surfaces. Insulating the foundation reduces the thermal transmission and cooling effects, but even an insulated foundation is typically more conductive than the wall panels.

Exterior Condensation
When the exterior air's humidity level causes its dew point temperature to be greater than the temperature of the exterior building surfaces, condensation of the exterior air's excess water vapor will occur on those surfaces.

On refrigerated buildings with insulated metal wall panels, the exposed exterior surfaces at the foundation, wall panel joint areas and flashing are typically cooler than the field areas of the wall panels. On such buildings, it is common to observe condensation and its residual effects on those surfaces more often than on the field areas of the panels.

Such condensation may be seen as water droplets and rivulets on the exterior surfaces of the wall and flashing, and wetting or water accumulation on the exposed surfaces of the foundation.

This is a common but temporary condition occurring most often during humid weather and cool overnight temperatures. This is the same effect that causes condensation on your car's windshield and on the grass in the early morning. As the morning sun warms the air, the air's capacity for water vapor increases and the water condensate on the affected surfaces is reabsorbed into the air mass by evaporation.

Mold Considerations

Sustained microbial growth (mold) requires mold spores, liquid water, a nutrition (organic food) source and a temperature conducive to growth. The mold spores and food source can be readily available as air born dust (especially common in agricultural areas). The steel facings and urethane foam core of insulated metal wall panels are inorganic and inert, and do not provide a source of food for mold growth. However, mold can be found on almost all building materials when the proper conditions of a surface food source, surface water and adequate temperature conditions exist.

In the building interior, mold growth on interior surfaces can be prevented by correcting and eliminating exposure to long term water accumulation such as caused by continuing surface condensation, water leakage through the wall or roof and water or vapor spray from equipment or leaking pipes, etc.

On the building exterior, it may not be possible to totally eliminate condensation on the exterior surfaces as a means of preventing mold growth. However, the magnitude of mold growth can be significantly reduced by correction of conditions where leakage of cooler interior air or excessive through-conductance has further cooled the exterior surfaces and increased the potential for condensation.