



Condensation Fact Sheet

The Condensation Process

Condensation occurs when warmer moist air comes in contact with cold surfaces such as framing members, windows and other accessories, or the colder region within the insulation envelope (if moisture has penetrated the vapor retarder). Warm air, having the ability to contain more moisture than cold air, loses that ability when it comes in contact with cool or cold surfaces or regions. When that happens, excessive moisture in the air is released in the form of condensation. In metal buildings, there are two possible consequences of trapped moisture in wall and roof systems: (1) corrosion of metal components and (2) degradation of the thermal performance of insulation.

Dew Point and Relative Humidity

Dew point is the temperature at which water vapor in any static or moving air column will condense into water. In other words, the air is saturated and can no longer hold the moisture at this temperature. When the air temperature drops below its dew point, excess moisture will be released in the form of condensation. Condensation problems are most likely to occur in climates where temperatures frequently dip to 35°F or colder over an extended period of time.

Relative humidity is a percentage measurement of the amount of water vapor present in the air in relation to the amount it is capable of holding at that temperature. For example, 50% relative humidity indicates the air is carrying one-half of the maximum amount of moisture that it is capable of containing at the given temperature. There is a relationship between the dew point and relative humidity. A high relative humidity means that the dew point is near the current air temperature. Therefore, a relative humidity of 100% indicates that the dew point is equal to the current temperature. This relationship between dew point and relative humidity is given in [Table C-1](#).

Visible and Concealed Condensation

Two things must be present for condensation to occur: warm moist air, and cool surface temperatures below the dew point. The proper control of these two factors can minimize condensation.

In metal building systems, we are concerned with two different areas or locations: visible condensation which occurs on surfaces below dew point temperatures; and concealed condensation which occurs when moisture has passed into interior regions and then condenses on a surface that is below the dew point temperature.

Signs of visible surface condensation are water, frost or ice on windows, doors, frames, ceilings, walls, floor, insulation vapor retarders, skylights, cold water pipes and/or cooling ducts. To effectively control visible condensation, it is necessary to reduce the cold surface areas where condensation may occur. It is also important to minimize the air moisture content within a building by the use of properly designed ventilating systems.

Signs of concealed condensation include damp spots, stains, mold and/or mildew on walls or ceilings, delamination of laminated surfaces, bubbles or blisters in asphaltic surfaces, peeling paint, and damp insulation. Concealed condensation is the most difficult to deal with and can be the most damaging. This type of condensation may be controlled in metal buildings by the proper use of vapor retarders and by minimizing moisture content within the building by proper ventilation. Additional condensation control can be accomplished by venting the cavities of the walls and roof.

Vapor Retarders

A vapor retarder is used to inhibit the passage of warmer moist air into the inner regions of the roof or wall system. The proper selection and installation of the vapor retarder can help control condensation problems in a building. Vapor retarders are rated by the amount of moisture that can pass through them. The lower this rating, called a perm rating, the less vapor transmission will occur and the more effective the vapor retarder will be. Water vapor transmission rates (perms) are determined using ASTM E 96, *Standard Test Methods for Water Vapor Transmission of Materials* (ASTM, 2005).

Types of Vapor Retarders

There are various types of vapor retarders available, such as:

1. Structural membranes, including rigid steel sheets or other

Dew Point Temperature (°F) ¹															
Relative Humidity	Design Dry Bulb (Interior) Temperature														
	32°F	35°F	40°F	45°F	50°F	55°F	60°F	65°F	70°F	75°F	80°F	85°F	90°F	95°F	100°F
100%	32	35	40	45	50	55	60	65	70	75	80	85	90	95	100
90%	30	33	37	42	47	52	57	62	67	72	77	82	87	92	97
80%	27	30	34	39	44	49	54	58	64	68	73	78	83	88	93
70%	24	27	31	36	40	45	50	55	60	64	69	74	79	84	88
60%	20	24	28	32	36	41	46	51	55	60	65	69	74	79	83
50%	16	20	24	28	33	36	41	46	50	55	60	64	69	73	78
40%	12	15	18	23	27	31	35	40	45	49	53	58	62	67	71
30%	8	10	14	16	21	25	29	33	37	42	46	50	54	59	62
20%	6	7	8	9	13	16	20	24	28	31	35	40	43	48	52
10%	4	4	5	5	6	8	9	10	13	17	20	24	27	30	34

¹ Chart adapted from ASHRAE Psychrometric Chart, 2005 *ASHRAE Handbook of Fundamentals*

Table C-1: Dew Point Temperature (°F)¹ versus Relative Humidity

impermeable materials. The list below is not exhaustive, nor is it an effort to limit the designer, but these membranes may include the following in roof and/or wall construction:

- a. Steel formed panels, properly sealed on edges and ends.
- b. Steel, zinc alloy, copper or aluminum sheets with caulked and formed standing seam edges and ends.
- c. Vinyl siding applied to suitable structural substrate or sheathing.
- d. Tilt-up concrete panels, suitably sealed at end and side laps, with a painted exterior.
- e. Vinyl, metalized plastic and similar overlays on rigid board insulation.
- f. Foam insulated metal panels, caulked and sealed at ends and side laps.
- g. Bituminous spray or trowel-on coating on concrete or masonry.

2. Flexible membranes, such as foils, coated papers, or plastic films. Usually, these membranes are rated by “perm” of 1.0 or less, per ASTM E 96, Standard Test Methods for Water Vapor Transmission of Materials (ASTM, 2005). The most common applications for metal buildings are membrane retarders laminated to fiber glass blanket insulation. Plain white vinyl with a perm rating of 1.0 is not an effective vapor retarder, especially in buildings with a high relative humidity.

3. Coating membranes, which includes paints, trowel-on bituminous coatings, epoxy and urethane foams.

Laminated facings for fiber glass batts serve several purposes other than appearance. They prevent the blanket from sagging. They prevent most water vapor from penetrating the fiber glass batt. They provide resistance to impact and provide reflectivity and emissivity benefits. Most facings have three parts:

1. A base made up of natural or white kraft paper or aluminum foil.
2. A fiber glass scrim netting is provided for reinforcing and sag prevention.
3. An exterior film made up of polypropylene, vinyl, metalized polyester, or aluminum foil is applied on top.

Table C-2 lists some of the most popular types of facings and shows their water vapor transmission rates (perm ratings). The North American Insulation Manufacturers Association (NAIMA) recommends that metal building insulation be faced with a vapor retarder having a permeance of not greater than 0.10 perms.

Facing Description	Perm	Details
White Vinyl	1.0-1.3	.003" vinyl economical, but not an effective vapor retarder
Polypropylene scrim kraft	.09-.02	White or metalized polypropylene, fiber glass reinforcing, 11-30 lbs white kraft
Polypropylene scrim polyester	.02	Metalized polyester, 14 lb kraft
Foil scrim kraft	.02	Aluminum foil, fiber glass reinforcing, 30 lb kraft
Vinyl reinforced polyester	.02	

Table C-2: Water Vapor Transmission Rates

Besides the most popular facings, the industry provides special facings that have high impact resistance for gymnasiums, facings for high UV applications and black colored facings for structures where ceilings are not used.

Sealing Vapor Retarders

Careful attention must be paid to the insulation seams at side and end-laps to maintain the integrity of the vapor retarder. Some common methods used to seal the seams include rolling and stapling the side-laps, peel and stick tabs at side-laps, and sometimes insulation tape. The use of insulation tape alone to seal the seams may not be advisable. Job site conditions such as humidity, dirt, and access to the underside of the insulation can make this difficult. Where used, tape should be at least the same quality as the vapor retarder, and the tape should be approved by the insulation supplier for the particular product. In the case of a membrane type retarder, any punctures or tears in the material should be repaired using the self-adhesive repair tape supplied with the insulation. More information and downloadable literature can be found on the NAIMA website via <http://www.naima.org>, or visit National Insulation Association (NIA) at <http://www.insulation.org>.

Because there is a growing trend to add insulation to existing metal buildings, a proper vapor retarder is of critical concern. One of the most common methods is to add an additional layer of insulation to the bottom flange of the purlin system. This can create an air space where moisture laden air can accumulate if the integrity of the new vapor retarder closest to the warm insulating surface of the building has not been maintained. It is important that an intact vapor retarder is not left within the insulation mass.

Ventilation

All metal buildings require some level of ventilation, and more often this ventilation is becoming the responsibility of the metal building contractor. A lack of ventilation can create an uncomfortable working condition through elevated heat levels, excessive humidity, and stale air. It can also contribute to condensation problems. Ventilation can best be represented by the number of times per hour the building air is replaced with outside air. This is referred to as air changes per hour. The number of air changes required per hour widely varies per application.

The following example illustrates a calculation for ventilation requirements:

Assume a 100 feet wide x 250 feet long x 30 feet high building being used for light manufacturing, assembly and storage.

1. Determine the total volume of the building.
 Volume = 100 feet wide x 250 feet long x 30 feet high
 = 750,000 ft³.

2. Next, determine the required air flow in cubic feet per minute (CFM) to provide 5 air changes per hour.
 Air Flow = 750,000 ft³ x 5 air changes/60 minutes = 62,500 CFM

Therefore, 62,500 cubic feet per minute of air must be moved through this building to provide five air changes every hour.

Allowances must be made for a place for air to enter the building and for air to exit the building, and the airflow must be evenly distributed throughout the building. Typical methods of moving air include exhaust and supply air fans, ridge ventilators and louvers.

Controlling Condensation

Table C-3 provides guidance on controlling condensation problems as listed in this section. Note that all listed control measures do not address the possibility of a leak defect through the roof membrane. This is a general checklist to control condensation through possible remedial measures. It is not designed to address specific difficulties in specific buildings.

1. At the Source - Limit the amount of water vapor within the heated interior.
 - a. Provide a well drained base course such as crushed rock or washed gravel under grade level slabs to prevent moisture from permeating into the building through the slab.
 - b. Provide for adequate ground water drainage.
 - c. Divert rain and melt water accumulations away from the foundation.
 - d. Vent all mechanical heating apparatus with hydrogen-oxygen by-product exhausts to the outside.
 - e. Reduce supplemental interior humidification.

- f. Be aware that the pouring of concrete within a newly erected structure presents special considerations. While the practice should be held to a minimum, an individual project assessment must be made to prevent both visible and concealed condensation.

2. By Insulating - A properly designed insulation system effectively raises surface temperatures within the building envelope above the dew point temperature. This is accomplished by controlling the heat loss at the exposed (exterior) sides of those surfaces. However, insulation added above an existing roof should be placed at the existing roof level and not against the retrofit roof if possible. Adequately ventilated space is required because any trapped warm air may condense at the cold metal roof.

- a. Provide additional insulation in ceiling and/or wall cavities or replace existing damp or water soaked insulating material within these cavities.
- b. Install double or triple glazed windows or insulated storm panels with thermal break frames.
- c. Install insulated doors.
- d. Install insulation wrap (with exterior vapor retarder) around cold pipes and/or cold air duct work.
- e. Insulate floor slab edges exposed to exterior temperatures with a rigid insulation-pressure treated plywood combination.
- f. Paint condensation prone surfaces with moisture absorbing paints.

3. With Vapor Retarders - A vapor retarder is a membrane of polyethylene film, aluminum foil, paint, asphaltic laminate and/or glazed, asphalt saturated building paper that exhibits a permeance of less than one perm. All joints and seams must be lapped, sealed, and secured, in order to reduce the amount of water vapor that combines with the given cavity air mass.

- a. Employ (or repair) a vapor retarder at the warm side surface of all insulating material. In the case of the fiber glass blanket insulations, the retarder may be laminated to the insulating fiber. All joints at crawl spaces, under slab

Condensation Problem	Methods of Control (See Section 4.4.5)
Moisture, frost or mold on underside of uninsulated metal roof.	1d, 1e, 2a, 2f, 3a, 3b, 4b1, 4b2, 4b3
Moisture or frost on skylights.	1d, 1e, 3b, 3d, 4b1, 4b2, 4b3
Moisture or frost formations on interior vapor retarder.	1d, 1e, 2a, 3b, 4b1, 4b2, 4b3
Moisture dripping from ceiling fixtures.	2a, 4a1, 4a4
Moisture, dampness and/or mildew on floor areas.	1d, 1e, 2g, 3c, 4a3
Moisture and/or frost on exterior windows, doors and metal frames.	1d, 1e, 2a, 2b, 2c, 2d, 4b1, 4b2, 4b3
Dampness, stains, mildew or blistering and peeling paint on ceilings.	1d, 1e, 2a, 2f, 3a, 3b, 4a1, 4a4, 4b1, 4b2, 4b3
Dampness, stain, mildew or blistering and peeling paint on walls.	1d, 1e, 2a, 2f, 3a, 3b, 4a2, 4a4, 4b1, 4b2, 4b3
Moisture dripping from cold water pipes or cold air ducts.	1d, 1e, 2d, 2f, 3b, 4b1, 4b2, 4b3
Soggy or damp insulation in ceiling or walls.	1d, 3a, 4a1, 4a2, 4a4

Table C-3: Controlling Condensation

- ductwork, attic openings, ceiling fixtures and/or other wall, ceiling and floor penetrations must be properly sealed.
- b. Install a vapor retarder ground cover over interior, exposed ground surfaces.
 - c. Install a vapor retarder between sub-flooring and ground slab.
 - d. Install a clear vapor retarder over skylight openings and seal off to warm side insulation retarder.
 - e. Install a vapor retarder on both sides of the insulation in buildings with a cooler, controlled atmosphere and in cold storage buildings to prevent condensation inside the insulation.

4. Through Ventilation - The dilution of a moist interior air mass with drier outside air for the express purpose of lowering the relative humidity of the air mass can be accomplished through ventilation. For retrofit applications, venting above existing roof may not be necessary if the source below is eliminated by adequate means of vapor retarders. The natural amounts of water vapor from outside air exchange will dissipate gradually without any effect.

a. Cold Side Venting - The venting of "exterior" cavities (cavities at the cold side of the insulation envelope but contained within the general building envelope) of the building's structural elements. One square foot of "free" vent area must be provided for each 300 square feet of convective cavity area. Vents should be uniformly distributed to provide the best overall air flow and also should be screened and louvered to prevent insects and rain from entering the cavity.

- 1) Provide ridge and eave vents in building "attic" areas.
- 2) Provide for base and eave line ventilation to wall cavities.
- 3) Install foundation vents to any crawl space areas.
- 4) Install exhaust fans.

b. Warm Side Venting - The venting of the interior building envelope.

- 1) Install convective type venting apparatus.
- 2) Install remote exterior air changers with heating and distributing systems as required.
- 3) Install exhaust fans. (Note: Borderline effectiveness - depends heavily upon infiltration for air change.)

High Humidity Conditions

Applications where the relative humidity in a building is expected to be above 30% warrant careful consideration of condensation issues, and those with relative humidity above 50% are especially prone to problems if proper design and installation of the insulation retarder system is not carried out. Some examples of these high humidity situations are buildings that house swimming pools, ice rinks, wineries, livestock, highway maintenance garages, and waste processing facilities.

The importance of the proper selection, installation and sealing of the vapor retarder is magnified in a situation where the relative humidity is high. The perm rating of the vapor retarder should be less than 0.05 for high humidity conditions. All seams, laps and joints in the vapor retarder must be properly sealed. Folding and stapling seams is not recommended for laminated fiber glass insulation.

In the case of a flexible membrane type retarder, any punctures or tears in the material should be repaired using the self-adhesive

repair tape supplied with the insulation. Careful inspection after all trades have completed their work is recommended to verify the integrity of the vapor retarder. In some high humidity applications where a flexible membrane retarder could be at risk for damage and penetration, a structural membrane might be the most prudent option. Another option would be the use of dual layer rigid board insulations systems. rigid foam insulation should have a foil facer and staggered joints (min 6 inches) to prevent moisture migration. Insulation joints should be well sealed and care should be taken to ensure that detailing is well sealed at rake edge of roof/wall juncture and at all penetrations.



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