# AVOIDING CONDENSATION IN BUILDING ENCLOSURES

Marius Radoane

**Principle of Avoiding Condensation**

2013

## Abstract

This paper offers a critical description of how the process of condensation can be avoided in enclosures that are thermally insulated. The only way condensation can be eliminated is by maintaining warm vapors. A configuration of any insulation material or conditions can be applied to enable a difference in the range of temperatures that can lead to condensation. This can only be achieved by making sure that the properties associated with the Vapor Impermeable Insulations (VII) are extended to ensure that the entire surface of the enclosure is covered. In another case, Non-permissive Insulation Assembly (NPIA) can be created. Therefore, it becomes necessary to create a principle that can be applied as a core method that the process of designing enclosures can borrow to avoid condensation.

## Introduction

Condensation can be defined as the process of vapor changing from a gaseous state to liquid state. In building walls, condensation leads to dampness. This is a result of warm vapor coming into contact with a cold surface which may in some cases lead to the growth of molds and weakening of walls. Condensation is caused by conditions whereby the content of moisture in the air is too high compared to the temperature, or in other cases the temperature is too low compared to the level of moisture in the air.

In building enclosures, condensation appears on interior surfaces because of thermal bridges (lack of insulation), but mostly interstitial, inside of envelope walls because of vapor migration from warm to cold.

We can define a building enclosure as any physical state that has the following three characteristics: an external environment, a thermal envelope, and an internal environment. To define the term ‘condensation’ in the context of a building enclosure would state that since all the structural materials of the building have the property of carrying out thermal conduction, warm vapor that is pushed by vapor pressure that originates from warm to cold zones condensate when it gets to the cold zones encountered in the process of wall assembly and insulation. In general terms, when thermal enclosures are exposed to thermal loads (thermal differences), it can be anticipated that if the vapor is transported via diffusion and the process of air transport, the process of condensation is likely to occur between the external and the internal surface. It should be noted that this happens only in conditions where the materials forming the enclosure are permeable to air transport and vapor diffusion. This is the core principle that is applied and accepted by designers and construction experts, which are using insulation materials that are permeable. This evidence coming from obvious facts leans to the method of constructing according to the concept of moisture control, by following in practice the so called Principles of Moisture Control.

The major objective of this report is to address another acceptable rule that can be applied as a method to prevent condensation entirely. This rule named Principle will help those in the field of construction eliminate the stress of condensation associated with building components that include wetting or drying, water accumulation, and even mold and fungi.

## Theory of Non-Permissive Insulations

To effectively apply the principle, or the theory of non-permissive insulation, we must first identify the major physical characteristics that lead to the process of condensation in building enclosures during the use of construction. One of these two characteristics is thermal conduction that results in the creation of a cold dew point in some zones of the material or assembly parts. The other characteristic is the ability to allow vapor permeability that leads to vapor diffusion via the cold zones.  As much as eliminating condensation is the priority, it should be clear that thermal flow cannot be prevented. Therefore, the cold flow (the energy deficit of heat) has to convert warm flow in an environmental separator.

Putting into consideration the physical characteristics that lead to condensation in building enclosures, there ought to be a way of preventing vapor permeability. From the above statement, we can reduce that to prevent condensation, we must eliminate vapor flow and diffusion, since they are the only factors that can be minimized to zero in the condensation equation; other factors such as thermal flow are difficult to even influence, let alone stop. The question remains of how to prevent condensation via applying this concept in conditions where thermal load variation is prevalent.

The current applications are comprised of the use of air or vapor flow preventions, diffusion retardants, air layers and ventilation of walls, control of internal moisture levels via dehumidification through air conditioning and ventilation, vapor diffusion preventions and air-pressure controllers. These strategies are ultimately dependent on the climatic conditions of where the building is located.

The new concept stipulates the solving of condensation related problems by entirely preventing water vapors to diffuse into an insulation material forming an insulation assembly that creates a thermal enclosure, separating two environments. According as stopping vapors also mean the stop of any air infiltration, water leaks and water absorption, the concept of avoiding condensation make use of the term non-permissive.

In order to have a crystal clear differentiation of vapor barriers from an insulation that is impermeable, we have to develop an appropriate terminology. The terminology will also help in the differentiation of this method from other methods, also defining the Principle. Insulation materials that have the property of being vapor-impermeable are referred to as Vapor-Impermeable Insulation (VII). On the other hand, there are assemblies that are created from assembling materials that are vapor-impermeable, referred to as Non-Permissive Insulation Assemblies (NPIA). The theory of Non-Permissive Insulations applies these terminologies to differentiate it from others. These two terminologies VII and NPIA applied to building enclosures can be classified as Environmental Separators in the concept of Avoiding Condensation.

Non-permissive Insulations can be confusing in some cases, reason being when a complete vapor barrier is used in wall assemblies this is the worst thing that can be done, whereas when Non-Permissive Insulation Assemblies are used, it is the best configuration that can be applied to prevent the condensation. The difference that lies between vapor barriers and Vapor-Impermeable Insulation assembled non-permissive regards functionality. The major physical property between the two is the fact that NPIA possesses the ability to be excellent in preventing vapor-permeability. VII and NPIA have zero-permeability. The NPIA has two advantages in that it acts as both a vapor barrier as well as a thermal retardant, while in a normal vapor barrier there are no ingredients to prevent thermal flow. The Non-Permissive Insulation concept applies the method of combining the characteristics of a particular material to be a thermal-insulator, and consequently becomes vapor-impermeable which prevents condensation.

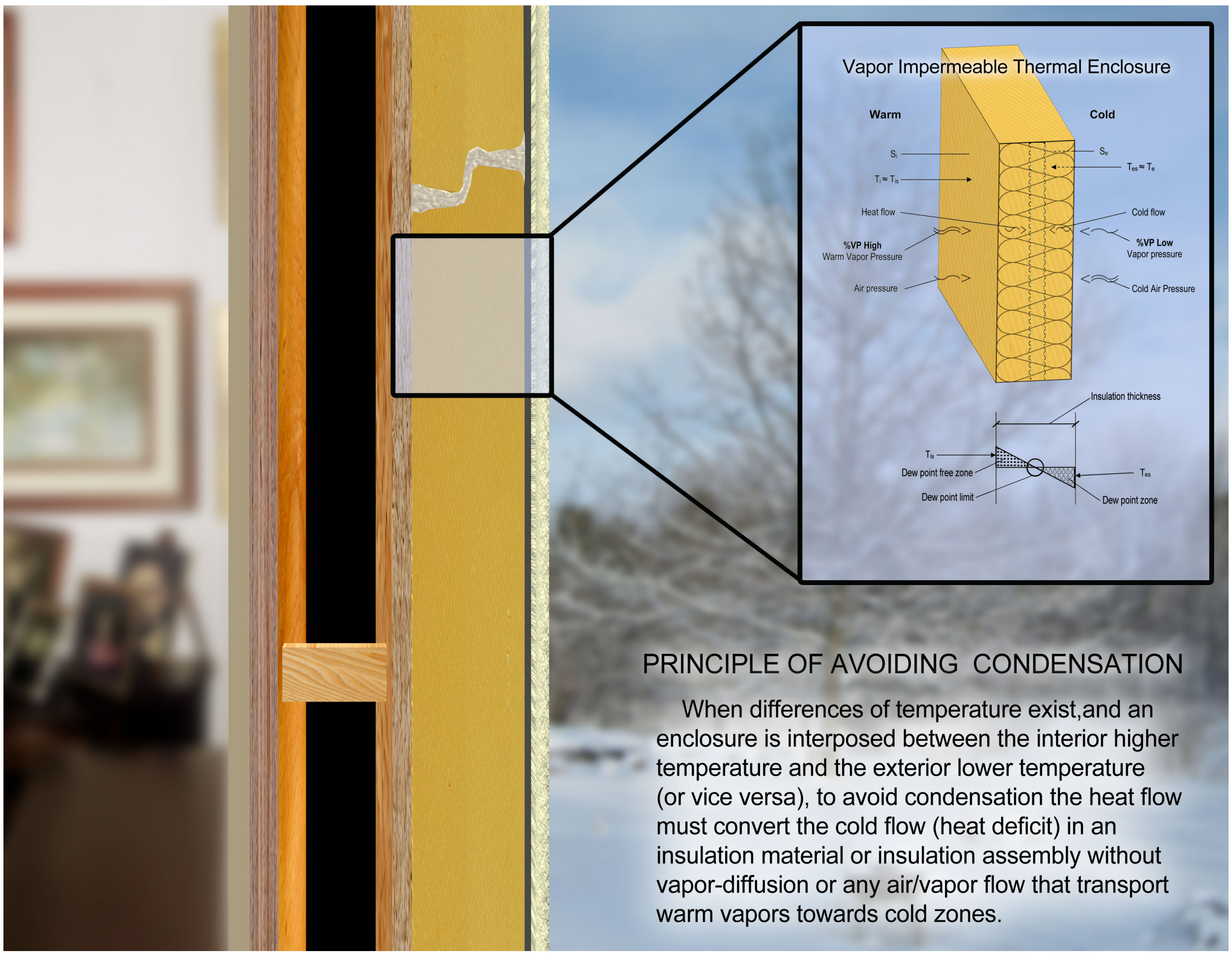
The vapor barrier is made up of two surfaces, which should have similar levels of temperatures during specific points of the process of thermal flow. The similar level of temperature on both surfaces of the vapor barrier leads to them becoming a condensation surface for warm vapors; this occurs when there is a difference regarding the level of temperature. The NPIA or VII is configured in a way that two surfaces that are vapor-impermeable are detached from the insulation field. To prevent condensation, the insulation value should be in the required state regarding thermal loads. Furthermore, in this state of thermal loads, the flow of heat will pass on the NPIA or VII surface that is warm, causing the temperatures of that particular surface to rise above the dew point which means condensation will not take place. In other words, the warm vapor will be in contact with warm surfaces, preventing any conditions that can lead to condensation. This makes the problem of condensation easier to solve and simpler. Heat flows have to keep the surfaces of the NPIA and VII warm, and vapors have to be prevented from reaching the cold zones that will result in condensation. The warm surfaces of the NPIA or VII together with air volumes and materials that are permeable to the warm vapors have to accumulate and maintain temperature levels that are higher than those required to attain dew point. One of the major requirements that help in maintaining the zero diffusion-rate of vapor is the statement that warm vapor flow should not trespass the boundary of the NPIA surface that is warm. The insulation value, in this case, is set in such a way that it is about thermal loads (cold flow versus heat flow.) This dimension leads to a conversion of the cold flow (deficit of heat) by the heat flow in the involved insulation field. In NPIA or VII, vapor diffusion and moisture that is transported by air are completely eliminated. Therefore, condensation has zero or minimal chances of occurring.

## Enunciation of the Principle

By these facts is established a general rule for avoiding condensation.

The Principle of Avoiding Condensation can be enunciated as thus:

**When differences of temperature exist, and an enclosure is interposed between the interior higher temperature and the exterior lower temperature (or vice versa,) to avoid condensation, the heat flow must convert the cold flow (heat deficit) in an insulation material or insulation assembly without vapor-diffusion or any air/vapor flow that transport warm vapors towards cold zones.**




After a deep understanding of the phenomenology and configuration of Vapor-Impermeable Insulations or Non-Permissive Insulation Assemblies, the Principle of Avoiding Condensation can have a simple enunciation:

**The condensation is avoided when the heat flow converts the cold flow in a Vapor Impermeable Insulation or a Non-Permissive Insulation Assembly.**

Unlike other devices and assemblies created before on principles, in this method exists constructive elements or assemblies as would-be window panels, sandwich panels etc. that follow the principle of avoiding condensation. The knowledge of this principle arrives as a starting point in designing insulated enclosures and in any situation where it is imperative to avoid condensation. Even if this theory is for a general method, the utility of this principle cannot be ignored.

The term “permissive” includes all ways in which air/vapor leakage affects and interacts with the enclosure, as would be: vapor diffusion, enclosure air flow (air-tightness), infiltration/exfiltration, wind washing or forced convection, looping in air-permeable insulation, looping through gaps around insulation, in-cavity convection, water absorption, and capillarity. In non-permissive insulations, all these factors are eliminated, leaving only the thermal conduction and heat flow analysis, with the presumption that the problems of condensation are eliminated. Also, the true R-value is not affected by permissive features (R-value is effective).

In practice, the theory of non-permissive insulations separates the insulation from the wall structure, which means the insulation has the role of separating the warm environment from the cold environment, including the passage of vapors (through the insulation,) while the wall simply maintains the structural role. If a Non-Permissive Insulation Assembly is applied to the exterior of a support wall, the structural wall can be made less airtight, making the unidirectional drying (the drying of the structure in one environment) easily realized. The NPIA takes on the role of environmental separator, which keeps the substrate wall dry and allows for massive energy savings due to reduced heating and cooling costs. When NPIA is applied to the exterior of a wall (the best configuration) the substrate wall is dried; and the insulation system transposes in practice the laboratory-specified insulation-material coefficients.

The concept of walls having air/vapor flow all the way from interior to exterior (from warm to cold) is a method that leads to the problems generated by wetting and drying cycles.

As is apparent from the specification, the exposed method is suitable for various constructive situations.

A material that partially follows the Principle of Avoiding Condensation as VII is wood. For example, an exterior wood door having a thickness of two inches is not affected by condensation in a cold season, when separating the environments. The wood has an R-value of approximately 1/inch, so for two inches, R=2 (Btu system). This insulation is sufficient to enable the interior (warm) surface of door to have a temperature higher than dew point. In addition, wood has a very low vapor-permeability, and the protective layers (varnish and paint) makes wood even more impermeable. Thereby, condensation is avoided and the rate of wetting from condensation is insignificant. In other words, condensation is practically avoided, but in actuality small increases of humidity in wood exist because of vapor diffusion.

When vapor-permeable materials are used in the configuration of walls and the materials are water/moisture sensitive, usually the accumulated moisture exceeds the safety level of tolerable wetting storage capacity of the materials, making deterioration occur.

It should be known that techniques used to predict condensation potential, and teachings saying that condensation can be avoided by the judicious use and placement of insulation and breathable or retardant materials are only for reducing the effects of wetting and drying---the cycle is by no means removed.

The benefits of preventing condensation and use of the full insulation coefficient (laboratory tested R-value) are likely to occur only if the Principle of Avoiding Condensation is applied. The resulting enclosure will show satisfactory weather resistance and insulation without any need to prevent the wetting effects.

In the category of NPIA, a convincing exemplification can be shown in window panels.

An average window panel is made of two glass panels separated by an inert gas that performs as insulation. The glass panels are sealed all around to create a complete air/vapor tight insulation assembly. The heat flux allowed to occur in window panels during a cold winter day has long been much larger than through walls. A window with a U-value of 0.35 allows about five times as much heat flow on a cold day than through an R20 wall enclosure. Glass is known as the most propitious surface for condensation, nevertheless even on a cold day we don’t see any moisture on the window. Knowing the Principle of Avoiding Condensation, the explanation is simple: the heat flow warms the interior glass surface and raises the condensing surface temperature above dew-point, and the inert gas insulation keeps this temperature dew-point free. Because the insulation assembly is air/vapor impermeable, all problems of condensation are avoided.

Installing continuous layers of rigid and semi-rigid vapor-impermeable insulation materials such as extruded polystyrene (XPS) or faced boards is one of the preferred methods of increasing enclosure performance. Products such XPS insulation boards and closed-cell spray foam are particularly vapor-impermeable, but only installation methods that provide continuity at joints and sealing at intersections can make those products perform as a Non-Permissive Insulation Assembly in the spirit of the Principle of Avoiding Condensation. However, the use of VII materials led to spectacular results on wetting control, evidenced by a much smaller number of potential condensation hours.

The NP-EIFS, (US 8789329) is an Exterior Insulation and Finishing System invented to solve all problems related to these systems, and is based on the Principle of Avoiding Condensation. The concept, materials used, application technology, and the details invented leads to an insulation system that completely avoids condensation and intruding water. VII materials such XPS and closed-cell expandable polyurethane foam are used in combination with polymer-based sealant materials to create an air/vapor-impermeable insulation assembly. The joints between VII boards are triple-sealed with expandable foam and polymer sealant, and the intersections with other constructive elements are triple-sealed with expandable foam, polymer sealant, and silicone sealant. All details of intersections, penetrations, and terminations of the system are designed to completely avoid air/vapor infiltration, vapor diffusion, and thermal bridging, as VII materials are assembled to create a NPIA that complies with the Principle of Avoiding Condensation.

It is good to mention that an NPIA is the only insulation system that can be installed as interior insulation, without having condensation and mold problems. The insulation value retains the heat flow while the thermal conductivity of a non-insulated exterior wall conducts the cold flow through the inner surface of the wall assembly, meaning that behind the interior-applied insulation is a permanent dew point surface for the interior warm vapors. Any flux of vapors leads to moisture, right behind the insulation. If the insulation system is a NPIA, vapors can't reach the cold dew-point zones, and condensation is avoided. Here a question arises: what's happening behind insulation if the insulation doesn't "breathe?" If NPIA is applied as interior insulation, vapors can't pass the insulation and there is no condensation, but the conductivity of the insulation still allows for a small heat flow that will create a slightly positive vapor pressure immediately behind the insulation, and the vapors will have a tendency to move out. This means that applying an NPIA as interior insulation will allow the wall to dry instead of accumulating water.

If in normal conditions NPIA is applied, on the cold side of the wall, heat is accumulated and consequently temperatures are put above the condensation point in the whole assembly of the wall, preventing condensation entirely. In the application of this principle, condensation is avoided completely, no matter the thermal perspectives. In different climates and seasons, NPIA will perform the same, indifferent if outside is cold or hot and humid; heat-flow versus cold-flow (deficit of heat) can apply vice versa, without any change for the Environmental Separator. This is the only solution that can be used to separate the outside environment and that of buildings.

With this in mind, the Principle of Avoiding Condensation forms a starting point for insulation designs that can be applied in any situation to prevent condensation.