

Design Considerations for Curtain Wall Parapets in Cold Climates

Mario D. Gonçalves, Eng. ¹
Madeleine Z. Rousseau, B. Arch., M.Sc. ²

ABSTRACT

Aluminum and glass curtain walls have gained enormous popularity across Canada and the United States as an engineered system used as the vertical envelope for a variety of low-rise and high-rise building types, particularly in the office building sector. Improved standards, research and testing have contributed in significantly improving the performance of curtain wall systems, whether it be with respect to resistance to water penetration, air leakage resistance, wind load resistance or condensation resistance. The reality however is that many buildings are still experiencing problems with the field performance of recently installed curtain wall systems. Although these problems are often the result of poor installation and fabrication due primarily to the lack of adequate quality control during construction, poor design applications are frequently a source of several common problems associated with inadequate field performance.

This paper shall focus on design considerations for curtain wall parapets in cold climates. Water infiltration problems due to condensation behind curtain wall parapet assemblies is a recurring issue which often entails costly remedial repair measures. Despite the recurring problems encountered on several buildings, there are still very few guidelines available to assist designers with proper detailing considerations.

The primary objective of this paper is to provide an increased level of knowledge to the design community for improved curtain wall parapet performance. Case study examples are used to illustrate condensation related issues commonly encountered in curtain wall parapet applications. Test results of actual in-service performance, obtained through field monitoring in occupied building environments, are presented and the contributing causes and conditions which lead to the most commonly encountered problems are highlighted. Examples of both poor and good detailing are illustrated by means of drawings and photographs. Remedial repair measures and alternative design considerations are also presented through practical examples.

¹ *Mario D. Gonçalves is a professional engineer and senior building envelope consultant. He is the President of Patenaude-Trempe Inc. - a Montreal and Quebec City based consulting engineering firm with projects across eastern Canada and the north-eastern United States. He can be reached at m.goncalves@patenaude-trempe.com.*

² *Madeleine Z. Rousseau is a senior researcher in the Building and Structure Program at NRC's Institute for Research in Construction. She can be reached at madeleine.rousseau@nrc.ca.*

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INTRODUCTION

Water infiltration problems due to condensation behind curtain wall parapet assemblies in cold climates is a recurring issue which often entails costly remedial repair measures. High parapets are particularly problematic given the difficulty in providing adequate air and heat circulation behind the curtain wall (for both stick built and unitized curtain wall systems). Condensation and frost build-up that form on the back side of the curtain wall components during cold exterior winter conditions (Figure 1) eventually thaw during warmer conditions, resulting in water dripping to the interior of the building and damaging the interior finishes. Left unattended, mold growth becomes a growing concern as well as potential long-term corrosion of the anchors at the top of the curtain wall.



Figure 1: Condensation on curtain wall components behind insulated spandrel panel assembly.

The primary objective of this paper is to provide an increased level of knowledge to the design community for improved curtain wall parapet performance. Examples of both poor and good detailing are illustrated by means of drawings and photographs. Remedial repair measures and alternative design considerations are also presented through practical examples.

CONCERNS RELATED TO CURTAIN WALL PARAPETS IN COLD CLIMATES

It is common practice on metal and glass curtain wall buildings to continuously run the curtain wall upwards past the roof line to the top of the parapet level. The curtain wall at the top of the building is typically supported by a concrete or steel parapet structure and installed at approximately 25 to 50 mm in front of the edge of the floor slabs. Given that the exterior face of the parapet structure is usually in line with the exterior floor slab edge, the cavity between the back of the curtain wall and the parapet structure will be the same as the distance in front of the slab edge (between 25 to 50 mm). This cavity usually communicates with the interior ambient space and the air within the cavity will contain the same amount of moisture as the conditioned air in the interior of the building. However, given the limited width and more importantly the height of the cavity, natural heat flow is often insufficient to warm the back of the curtain wall during cold winter conditions. Condensation and frost formation occur when the surface temperatures of the curtain wall components which are in contact with the parapet air cavity are below the dew point temperature. The figure below (Figure 2) illustrates the measured ambient air temperature distribution within the air cavity of a typical 1.7 m high curtain wall parapet for an exterior temperature of -14°C .

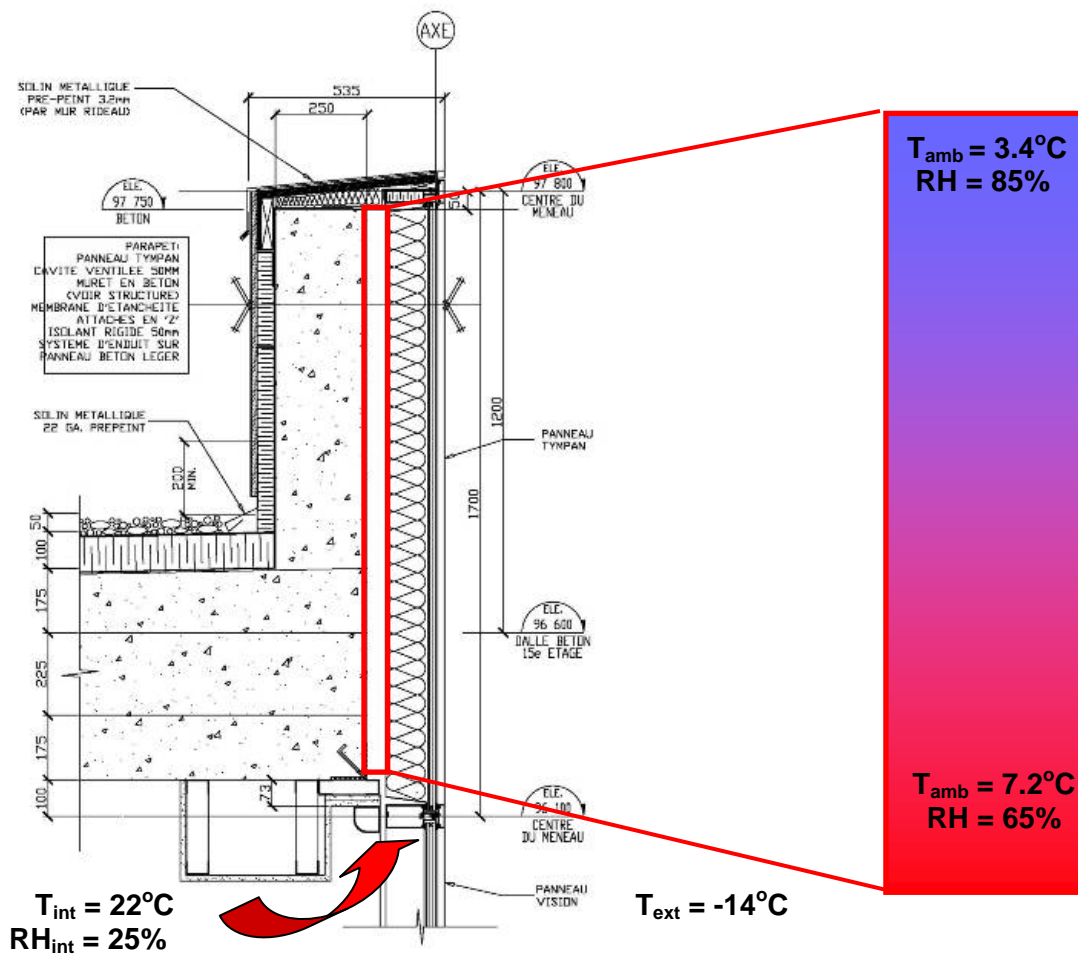


Figure 2: Air temperature and RH distribution behind a typical curtain wall parapet assembly.

The relative humidity distribution measured at the top and bottom of the air cavity behind the curtain wall is also illustrated in Figure 2. When comparing the relative humidity levels at the top and bottom of the cavity, it is important to note that the relative humidity level is a function of the ambient air temperature (ie. for the same amount of air moisture content, the relative humidity level will be higher when the ambient air temperature is lower). In practical terms, the higher the ambient air temperature, the more amount of moisture can be stored before reaching saturation. The figure below (Figure 3) provides a schematic illustration of the ambient interior and cavity air temperatures versus the corresponding relative humidity levels. In this example, the humidity ratio of the interior air and cavity air ($\text{kg}_{\text{air}} / \text{kg}_{\text{water}}$) are the same, which reflects the fact that the cavity between the back of the curtain wall and the parapet communicates with the interior ambient space and contains the same amount of moisture as the conditioned air in the interior of the building. The dew point temperature will therefore be same when calculated at either of the two conditions, as illustrated in the psychrometric chart below (figure 4).

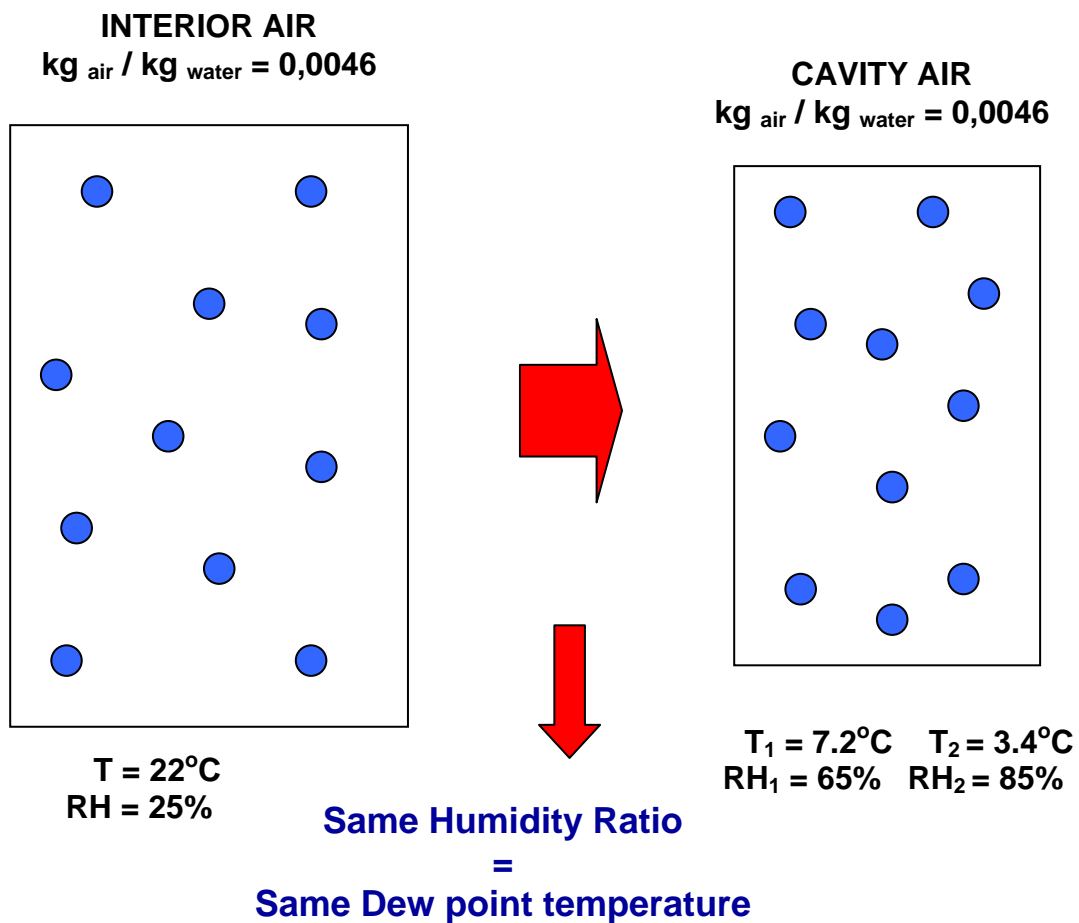


Figure 3: Illustration of ambient temperature versus relative humidity levels.

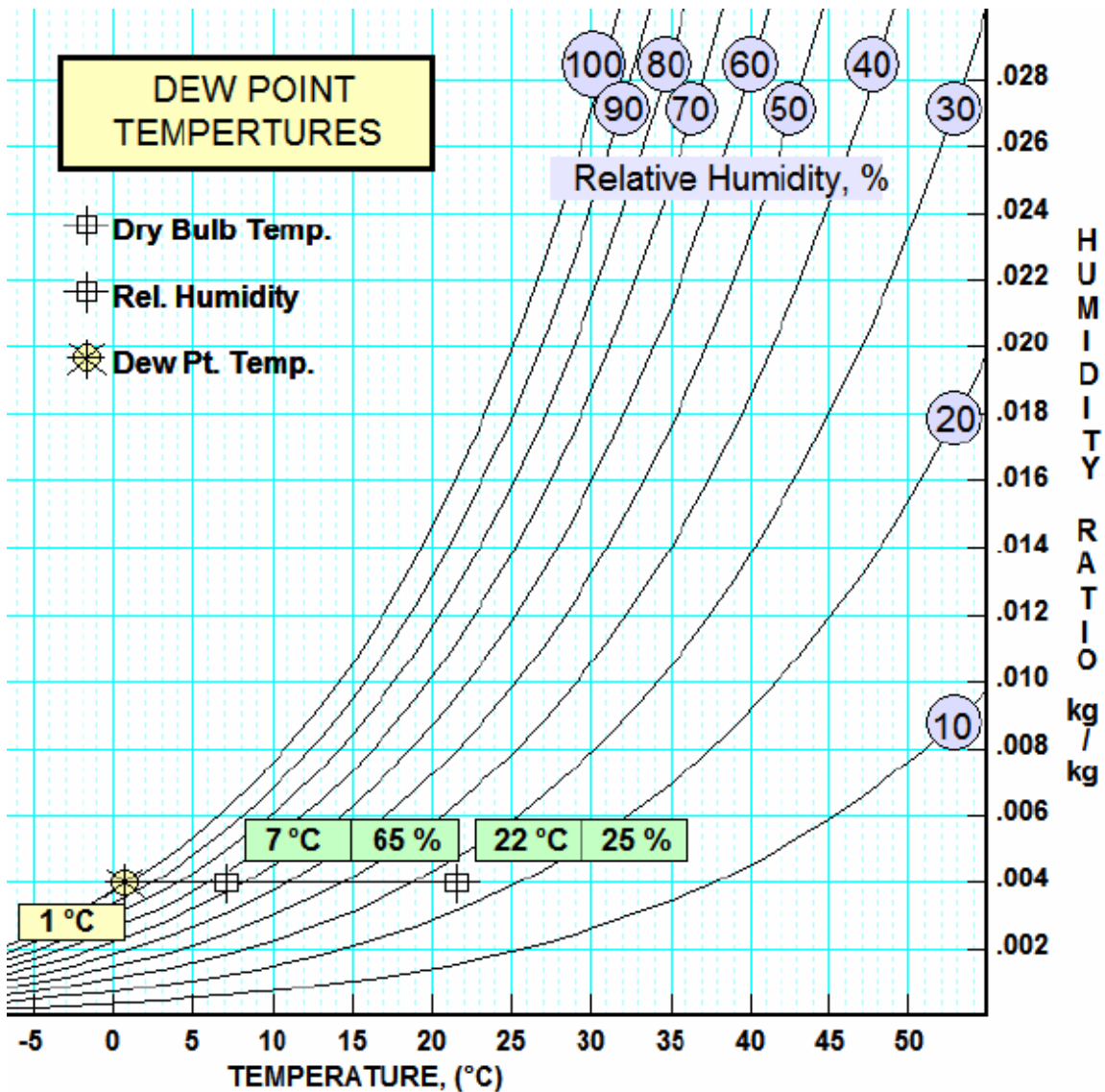


Figure 4: Psychrometric chart.

The table below (figure 5) summarizes the dew point temperatures at different relative humidity levels for an ambient air temperature of 22°C. From the table, the dew point temperature for a relative humidity level of 25% is 1.1°C. This implies for the previous example that condensation will occur on any of curtain wall components exposed to the conditioned air cavity which have a surface temperature below 1.1°C.

DEW POINT TEMPERATURES AT 22°C					
RELATIVE HUMIDITY	35%	30%	25%	20%	15%
DEW POINT TEMPERATURE	5.9°C	3.7°C	1.1°C	-2.1°C	-5.6°C

Figure 5: Dew point temperatures at 22°C.

In order to measure the surface temperature of the curtain wall components exposed to the conditioned air cavity in the example presented in figure 2, thermocouples were installed on the backside of the insulated metal pan, mullions, anchors and other miscellaneous curtain wall components. This was accomplished by removing a typical spandrel and back pan assembly at the parapet level and its subsequent reinstallation following installation of the thermocouples.

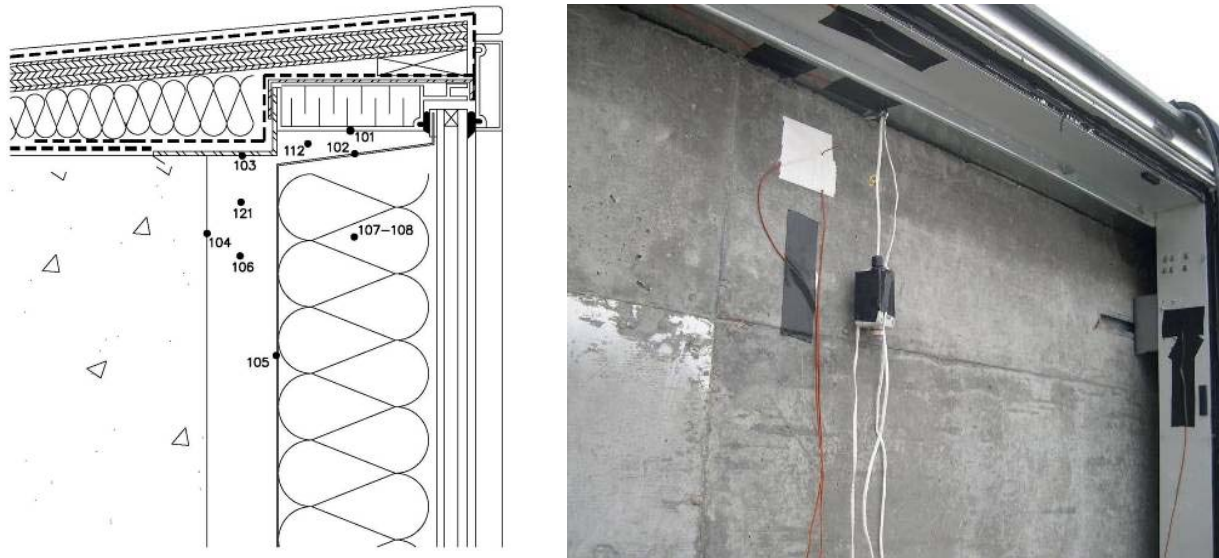


Figure 6: Thermocouples installed on back of curtain wall components.

The table below summarizes the measured surface temperatures at some key areas at the top of the parapet level, where most of the condensation was noted to occur.

CURTAIN WALL COMPONENT	MEASURED TEMPERATURES		EXTRAPOLATED TEMPERATURES	
	$T_{\text{ext}} = -14^{\circ}\text{C}$	CONDENSATION	$T_{\text{ext}} = -27^{\circ}\text{C}$	CONDENSATION
Top horizontal mullion (101)	-6°C	YES	-12°C	YES
Top of vertical mullion (107)	-2°C	YES	-5°C	YES
Top curtain wall anchor (112)	1°C	NO	-2°C	YES
Top portion of metal back pan (105)	3°C	NO	2°C	NO

Figure 7: Surface temperature of key curtain wall components.

From the table, condensation and frost formation (temperatures are below frost point) occurs at the top horizontal mullion and top of the vertical mullion at an exterior temperature of -14°C as well as at the top of the curtain wall anchor at an exterior temperature of -27°C . In this example, condensation first occurs at the top horizontal mullion at an exterior temperature much warmer than -14°C . During mild exterior conditions, the condensation and frost build-up will eventually thaw and drip down and damage the interior ceiling and wall finishes.

RECOMMENDATIONS FOR CURTAIN WALL PARAPETS IN COLD CLIMATES

As previously discussed, it is common practice on metal and glass curtain wall buildings to continuously run the curtain wall upwards past the roof line to the top of the parapet level. As illustrated above, this practice, particularly with high parapets in cold climates, is often associated with condensation related problems during the service life of the building. Drastic remedial measures are often necessary in order to address these problems. A multitude of post-construction remedial measures with varying levels of success have been implemented on several recently constructed buildings. These remedial measures are often costly, disrupting to tenants and difficult to achieve. Some common remedial measures include filling the cavity behind the parapet curtain wall with polyurethane foam in an attempt to seal the cavity from moisture ingress and the installation of heating cables or dedicated forced air heating units in order to heat the back of the parapet curtain wall components.

A practical alternative is to stop and seal the curtain wall below the parapet level as illustrated in the figure below (figure 8). In order to achieve the architectural look of a continuous curtain wall, the parapet level is “clad” with a small curtain wall section. The section of curtain wall cladding at the parapet level can be designed to match the rest of the curtain wall and the spandrel area can be comprised of glass, metal or any other material typically used in curtain walls.



Figure 8: Curtain wall interrupted and sealed below the parapet level.

In this application, it is essential to ensure the continuity of the air barrier and thermal barrier at the top of the curtain wall termination, which shall be extended behind the curtain wall parapet cladding and tie into to the roof assembly system. Once this has been completed, the curtain wall parapet cladding is installed. The parapet cladding is vented and drained to the exterior, much like in a conventional rain screen wall construction



Figure 9: Curtain wall cladding at parapet level.

This alternative approach to curtain wall parapet construction eliminates the cavity behind the back of a typical curtain wall parapet which usually communicates with the interior ambient space, resulting in condensation and frost formation during cold winter conditions. When incorporated in the design phase, this approach is efficient, cost effective and easy to undertake.

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REFERENCES AND ADDITIONAL READING

1. ASTM, “Moisture Analysis and Condensation Control in Building Envelopes (Manual 40)”, editor H.R. Trechsel, 2001, 216p.
2. CMHC, “Best Practice Guide - Glass and Metal Curtain Walls”.
3. AAMA, “Publication No. 1503-98: Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections”.
4. Quirouette, R.L, “Building Envelope Design using Metal and Glass Curtain wall Systems”, *Building Practice Note*, Division of Building Research, National Research Council Canada, September 1982.