Laboratory Investigation and Field Monitoring of Pressure Equalized Rainscreen Walls.

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NOTE: **DISPONIBLE AUSSI EN FRANÇAIS SOUS LE TITRE:**

ENQUÊTE EN LABORATOIRE ET SURVEILLANCE SUR PLACE DES MURS À ÉCRAN PARE-PLUIE À PRESSIONS ÉQUILIBRÉES

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Executive Summary

The rainscreen principle is not new. It was proposed as early as the mid sixties by researchers of the Division of Building Research of the National Research Council of Canada and the basic principles were developed. It has been applied to certain exterior wall types but it remains largely unknown because of the absence of factual data to support the claims of performance. It is only recently that interest has grown in the application of the rainscreen principle because face sealing and the drained cavity approach do not allow for the satisfactory control of moisture in cavities from rain or from condensation.

The rainscreen principle is well developed qualitatively but not quantitatively. There are no technical or engineering criteria to assist designers and few established prescriptions for the builder. The actual field performance of the rainscreen with respect to rain control is unknown and the relation to pressure equalization is also unknown. Canada Mortgage and Housing Corporation (CMHC) recognized the need to undertake further research into the engineering and technology of the rainscreen principle.

This project was commissioned by CMHC and Public Works Government Services Canada (PWGSC) to further advance the application of the rainscreen principle to exterior wall design and construction of both residential and commercial buildings.

This project included three distinct areas of interest. First, the development of a method to monitor the performance of existing rainscreen wall systems and to gain insight into the actual or field pressure equalization performance. This work was also coupled to a laboratory investigation of the wetting and drying of a rainscreen cavity in a metal and glass curtain wall. Secondly, the development of a field performance and design compliance testing procedure. The procedure is termed the Cavity Excitation Method or CEM. It is a field test that does not require elaborate preparations and substantial mockup facilities. Third, the development of performance criteria for the design of rainscreen systems and the development of commissioning guidelines for rainscreen wall system.

This report is the first of three reports on rainscreen performance research. It examines the first area of interest, field performance monitoring and wetting and drying of rainscreen cavities. The field monitoring of existing rainscreen walls was undertaken in 2 buildings. These included a metal and glass curtain wall at the University of Quebec in Hull, Quebec and a Limestone cladding and architectural precast rainscreen wall on the new Canada Life Building in Toronto, Ontario. A laboratory investigation at Queens University examined the wetting and drying of a metal and glass curtain wall rainscreen system.

This project revealed considerable information. While there were only 2 rainscreen systems monitored in the field, those two and similar experiences elsewhere by the author confirmed that pressure equalization in current rainscreen wall and window systems is virtually non existent. Several reasons were found but for the cases reviewed, the weep and vent openings were too small for the volumes served and the compartment seals were deficient or non existent. The rain penetration monitoring method using humidity and temperature of the cavity is quite promising but complex to interpret and will require further investigation. While pressure equalization was found to be poor in the cases studied, there were no observed water penetration problems.

Further work in this area should include a more detailed examination of the wetting and drying of rainscreen wall types to distinguish between the effects of water storage in masonry claddings and the cavity moisture balance and the effects of other non water absorbing rainscreen wall systems.

1.0 Introduction

There are three design approaches to rain penetration control for exterior walls and windows. These are the traditional face seal method, the drained cavity wall approach and the rainscreen principle. The rainscreen principle is the most current approach to long term performance and durability for rain penetration control.

The rainscreen principle comprises several features to include the control of direct rain entry, the provision of capillary breaks and drips to interrupt surface water drainage, the provision of weep holes and internal flashings for drainage , and a vented and pressure equalized cavity. In addition, the wall cavity must be rendered airtight and be compartmentalized from other cavities.

There have been advances in research and development of the rainscreen principle. Most of the current advances were commissioned by the Canada Mortgage and Housing Corporation (CMHC). For example there is a CMHC research project on rainscreen performance currently in progress at the National Research Council of Canada. This project is examining the effects of dynamic wind loading (sinusoidal loads at various frequencies) and water penetration control. There is also another CMHC project recently completed at Western University in London, Ontario, to study wetting patterns and the strategic locations of compartmentalization for facades. In addition, there are various private contributions of knowledge by manufacturers and a practical interest by architects and engineers for better information on the application and performance of the pressure equalized rainscreen wall or window system.

While the rainscreen principle is sound conceptually and the qualitative attributes have been applied to various wall and window designs, there is little information on the quantitative aspects of its performance. For example, what level of pressure equalization is required to control rain penetration? Is there a difference in rain penetration between a steady wind driven rain and a gusting wind during a rain storm? How much water should be allowed to pass into the cavity or be stored in the cladding materials following a rain storm? How can the design of a rainscreen system be verified for performance and the construction for compliance? It is these and other questions that are explored in this project.

This project was commissioned by CMHC and Public Works Government Services Canada (PWGSC). The project includes three areas of interest. These are;

1) the measuring and monitoring of rainscreen field performance,
2) on site testing, the CEM approach, of the rainscreen system for performance verification,
3) and commissioning the design and construction of rainscreen wall and window systems.

This report examines the first area of interest, the measurement and monitoring of rainscreen field performance. It includes the development of a field monitoring method for rainscreen systems, the monitoring of 2 rainscreen systems in the field and a laboratory exploration of the wetting and drying of rainscreen cavities. The buildings included a metal and glass curtain wall system on a low rise building in Hull, Quebec and the second involved a precast and limestone cladding rainscreen system on a medium rise office tower in Toronto. To better understand field observations the development of the monitoring method involved a laboratory exploration of wetting and drying of rainscreen cavities.

The research and development of the field testing method, the CEM approach 2) above , and the proposed commissioning protocol, 3) above are available from CMHC as separate reports. These are titled "Rainscreen Testing: the Cavity Excitation Method (CEM)" and "Rainscreen System: a Commissioning Protocol".

2.0 A Laboratory Investigation

2.1 Moisture in Cavities

It is known that wetness in a closed volume or from materials that absorb moisture will attain an equilibrium with the surrounding air. In other words water in a closed volume will raise the humidity of the air in the volume to a higher level than in the ambient surrounding air. If moisture is stored in wood or masonry but also faces a closed volume, the air adjacent will increase in humidity to some equilibrium condition. Because water does not always pool or wet in cavities at expected locations, wetness gauges within rainscreen cavities may not detect that water. However, any wetness within a cavity or stored in materials facing a cavity will cause the cavity air humidity to increase to some level above the outside conditions. It is for this reason that relative humidity is a better indicator of moisture penetration than attempting to observe rain penetration directly.

However, relative humidity is not simple to analyze because it varies with temperature. A more useful attribute is dew point temperature easily obtained from relative humidity and temperature. Dew point temperature is the temperature at which the moisture in the cavity air would condense. The purpose of converting relative humidity and temperature to dewpoint is twofold.

1) The first is because cavity relative humidity varies with temperature while the dewpoint temperature of the air in a closed volume is constant. This simplifies the installation of humidity and temperature sensors as their location is not of critical importance.

2) The second reason is that the relative humidity of a cavity that is wetted may not rise to 100% because one of the surrounding surfaces may be at a temperature that is below the dewpoint temperature of the air in the cavity. Therefore, this causes condensation to occur at a relative humidity that is lower than 100%. For this reason, comparing the cavity dewpoint temperature to outside air temperature can provide a useful indicator of the presence or absence of liquid water. If the dewpoint temperature of the cavity rises above

the outdoor temperature, it would confirm the presence of water from condensation or rain penetration.

2.2 A Metal and Glass Curtain Wall

To better understand the process of wetting and drying of rainscreen cavities, a sensitivity experiment was undertaken involving the rabbet cavity of a curtain wall system. The sample curtain wall system was composed of an aluminum frame separated into a vision part and a spandrel part (figure 1). The rabbet cavity is the volume of space
surrounding the edge of the glass. It was intentionally wetted and allowed to dry (vent) naturally to a laboratory space.

The cavity volume of the window rabbet was instrumented with temperature and humidity sensors at various locations. There were two sensors near the base of the wetted cavity, one to each side, two sensors near the top on each side cavity and one in the middle of the rabbet cavity over the window. 90 ml of water was then injected into the rabbet cavity with a seringe (figure 2). It was estimated from the overflow that about 50 ml remained inside the cavity. The temperature and relative humidity conditions of the cavity were then observed and recorded over a two week period. The data obtained from the various sensors was plotted on graphs (Appendix A).

In figure 3 below, it can be seen that the relative humidity of the cavity rises sharply in the first few hours and is sustained for a few days. Then, the relative humidity tends to fall sharply at first and then gradually over about two weeks. The data for figure 3 was obtained by averaging the relative humidity results from 2 sensors, both near the bottom of the rabbet cavity just above the injected water. From the results obtained, it is clear that water in the cavity raises the relative humidity of the cavity air. But, it also shows that water in a closed cavity does not necessarily increase the humidity to 100%. Elsewhere, in the rabbet cavity, specifically the upper end and middle top parts, the humidity sensors recorded an increase in relative humidity but not as high as the lower sensors (see graph RH4 and RH5 of Appendix A).

The difference in relative humidity readings between all the sensors is however, another matter. It was reasoned that the variation in relative humidity from bottom to top is the result of obstructions in the cavity such as setting blocks. Another source of unintentional vents was observed along the pressure plate caps; it was noted that air could leak at these locations because the screws holding the pressure plates caused the plate to wave from fastener to fastener.

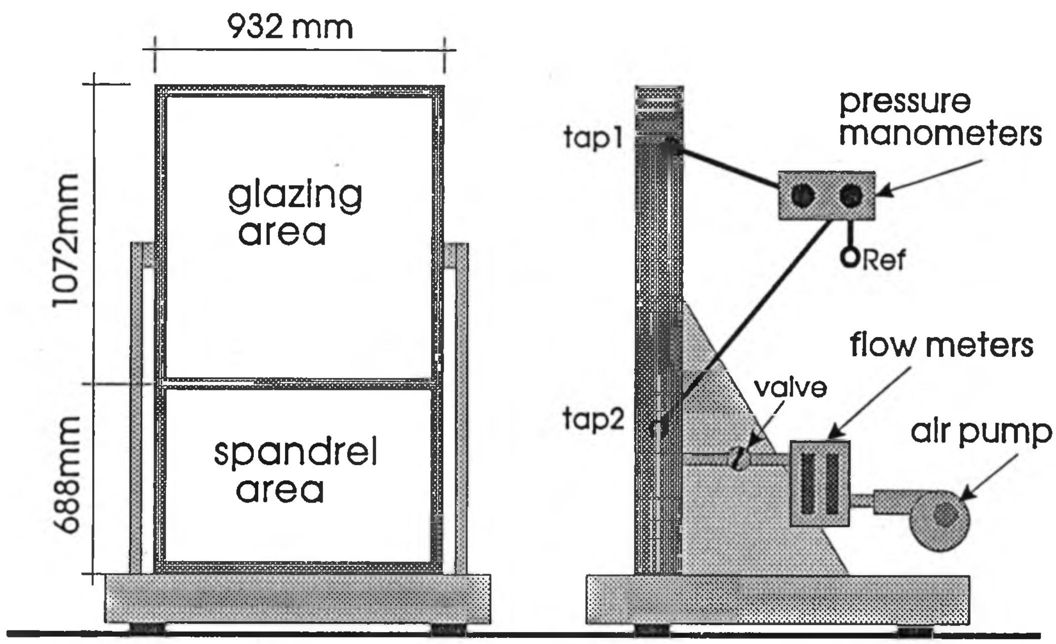


Figure 1
Metal and Glass Curtain Wall Testing Facility

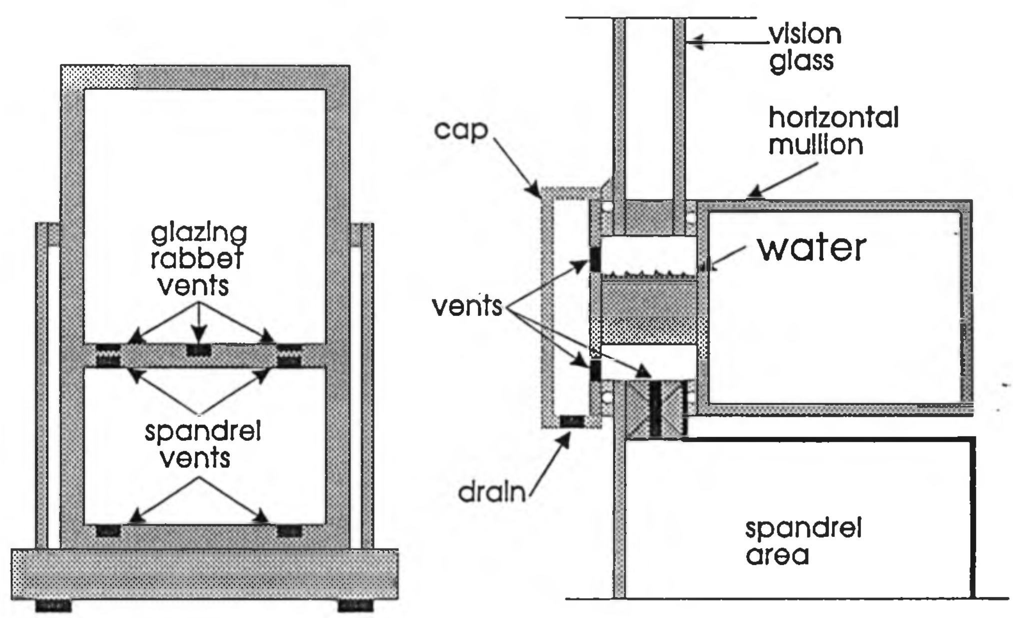


Figure 2
Venting and Details

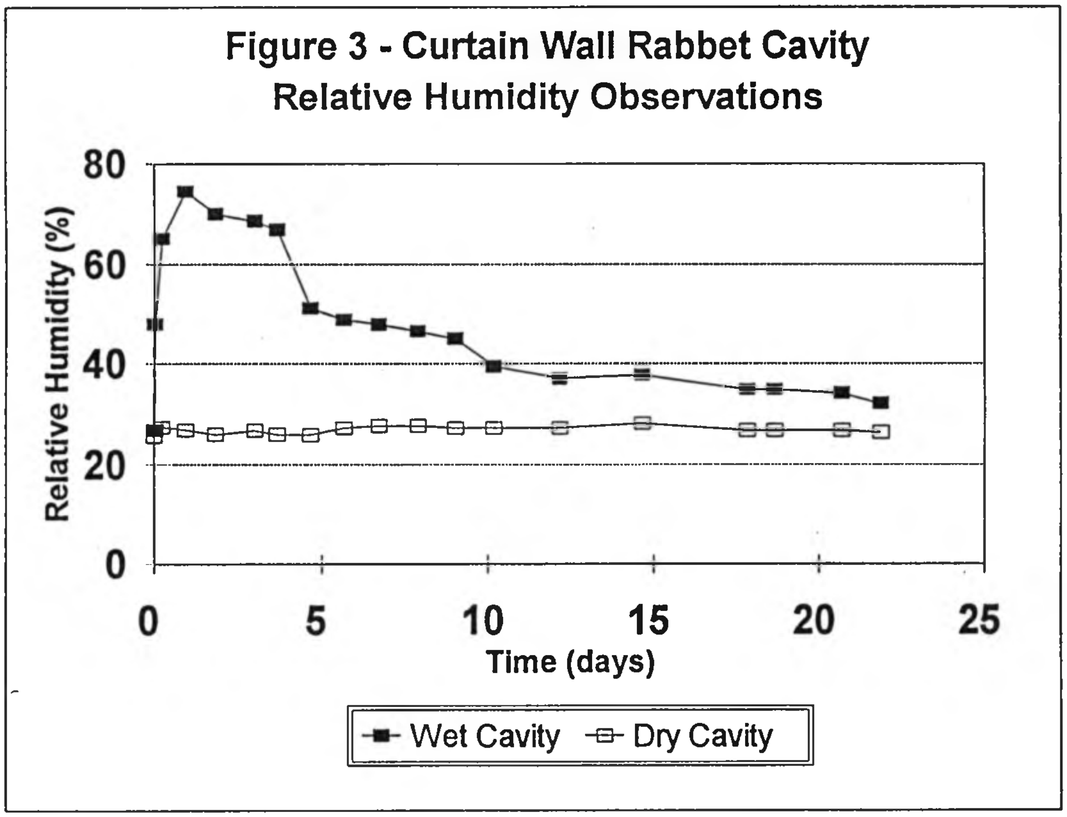


Figure 3 - Curtain Wall Rabbet Cavity
Relative Humidity Observations
Relative Humidity (%)
80
60
40
20
0
0
5
10
15
20
25
Time (days)
Wet Cavity
Dry Cavity

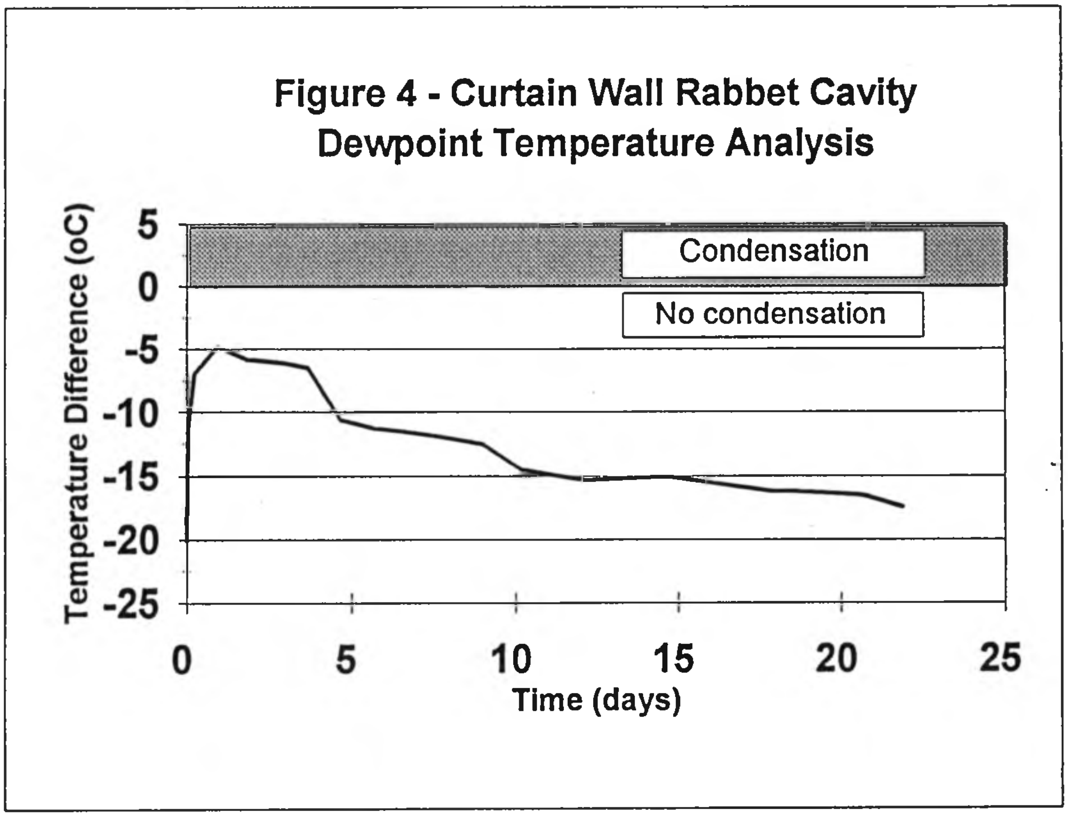


Figure 4 - Curtain Wall Rabbet Cavity
Dewpoint Temperature Analysis
Temperature Difference (oC)
5
0
-5
-10
-15
-20
-25
Condensation
No condensation
0
5
10
15
20
25
Time (days)

This unintentional venting would tend to dilute the humidity in the upper parts of the cavity with the ambient conditions of the laboratory. It would also draw moisture from the lower parts of the cavity thereby preventing the cavity moisture from reaching saturation in the lower cavity even though the temperatures of surrounding surfaces were all about the same.

2.3 Analysis and Discussion

To better visualize the effect of water in the rabbet space, the temperature and relative humidity were converted to dewpoint temperature and compared to ambient conditions of the laboratory. In figure 4, the dewpoint temperature of the air in the rabbet cavity was subtracted from the ambient laboratory air temperature and plotted as a relative temperature difference. The dotted line at -20 ^{o}C indicates the temperature difference between the ambient temperature in the laboratory and the ambient dewpoint temperature. It is clear from the graph that 50 ml of water causes a distinct rise in the dewpoint temperature of the cavity air and that its decay can be related to moisture evaporation from venting.

This experiment revealed several interesting facts. First, the wetting of the rainscreen cavity did not produce 100% relative humidity even though the cavity and laboratory temperature were essentially the same. It was interesting to note that 50 ml of water required over 22 days to evaporate completely. This was attributed to the very small vent areas and the absence of air movement in the cavity. It is confirmed however that monitoring relative humidity and temperature in cavities can provide a definite indication of the presence of liquid moisture but it also illustrates the complexity of the moisture balance in the rainscreen cavity of the curtain wall system.

3.0 Field Performance Monitoring

Rain penetration through walls and windows maybe immediate, apparent and destructive. When this occurs, owners are quick to initiate repairs usually by re-sealing the outside surfaces or caulking openings near the suspected water entry. But rain penetration is not always apparent. It can penetrate the wall or window but never show up inside the building. Instead, it may wet insulation, cause accelerated corrosion of metal parts, promote the growth of fungus and bacteria in cavities and cause premature deterioration of cladding elements.

To monitor a rainscreen system is to determine its ability to limit rain penetration in relation to wetting by wind driven rain, pressure equalization and venting. To determine the degree of rain penetration control, the local rainfall and the amount of water that has penetrated the system is observed and analyzed. From the information obtained from the laboratory experiment, field monitoring was undertaken by comparing the weather conditions at a site with the temperature and humidity conditions of a rainscreen cavity that occurred before and after a rainfall. In addition the air pressure differences across the cladding and air barrier system were observed and recorded so that water accumulation in cavities could be related to the pressure equalization performance of the rainscreen system under consideration.

In this part of the project, the measurement of temperature, humidity and air pressure differences, were undertaken in the field for two types of rainscreen systems. The first is a conventional metal and glass curtain wall on a low rise university building and the second is a stone veneer and precast wall rainscreen system on an office tower in Toronto.

3.1 University Building, Hull, Quebec

A newly renovated building at the University of Quebec in Hull, Quebec, was made available for the purpose of monitoring the wetting, drying and pressure equalization characteristics of a new rainscreen curtain wall system. The new curtain wall system was composed of aluminum mullions, metal back pans and

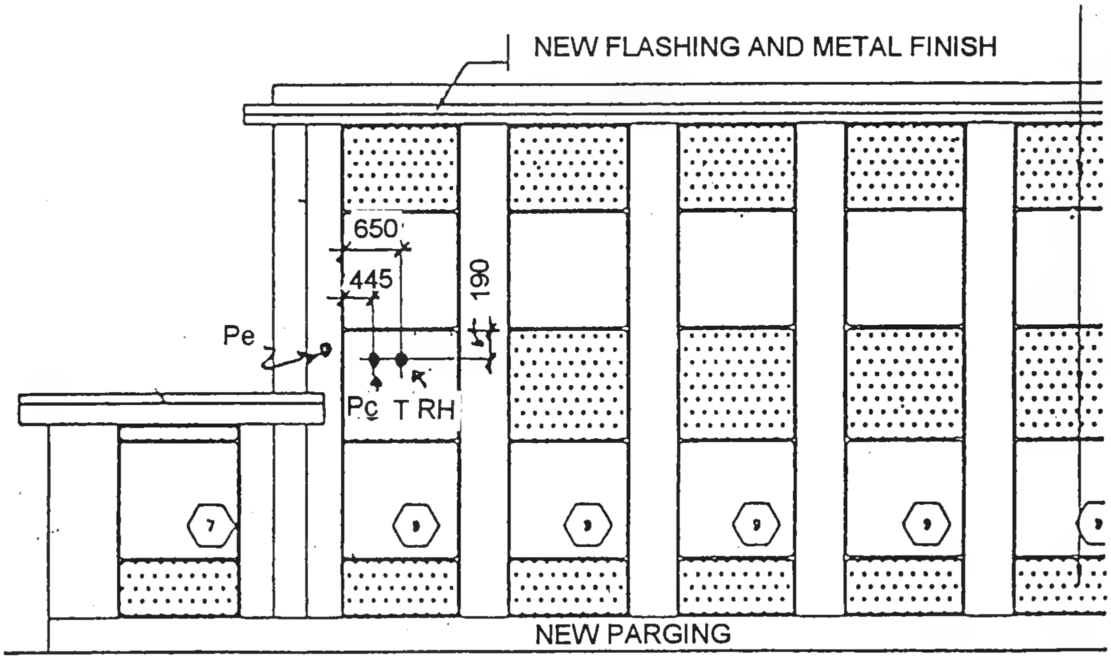


Figure 5 - Location of pressure taps (Pe, Pc), temperature (T) and humidity (Rh) sensors.

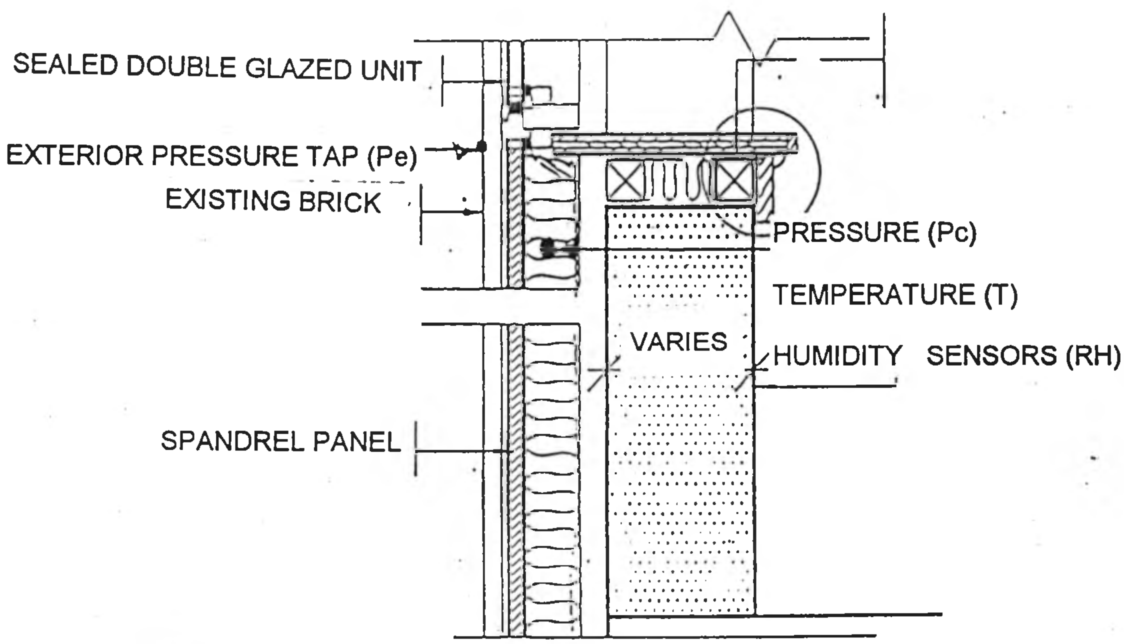


Figure 6 - Location of pressure taps (Pe, Pc), temperature (T) and humidity (Rh) sensors.

sealed glazing units. Figures 5 and 6 below illustrate the facade of the curtain wall and the location of the sensors within. Note that the curtain wall is joined to a brick wall along the jamb. The elevation shown is oriented to the North East.

The spandrel panel at the second floor was equipped with pressure taps, one on the outside surface through the seal between the metal cap and bricks and one in the spandrel cavity. The sensors also included a thermocouple (temperature) sensor in the spandrel cavity and a humidity sensor. The inside pressure of the room was assigned as the reference.

The system used to monitor the field performance consisted of a 486 Notebook laptop computer equipped with a data acquisition board and Labtek data software program to which the various sensors were connected. The monitoring system was kept in operation for a period of 4 to 6 weeks.

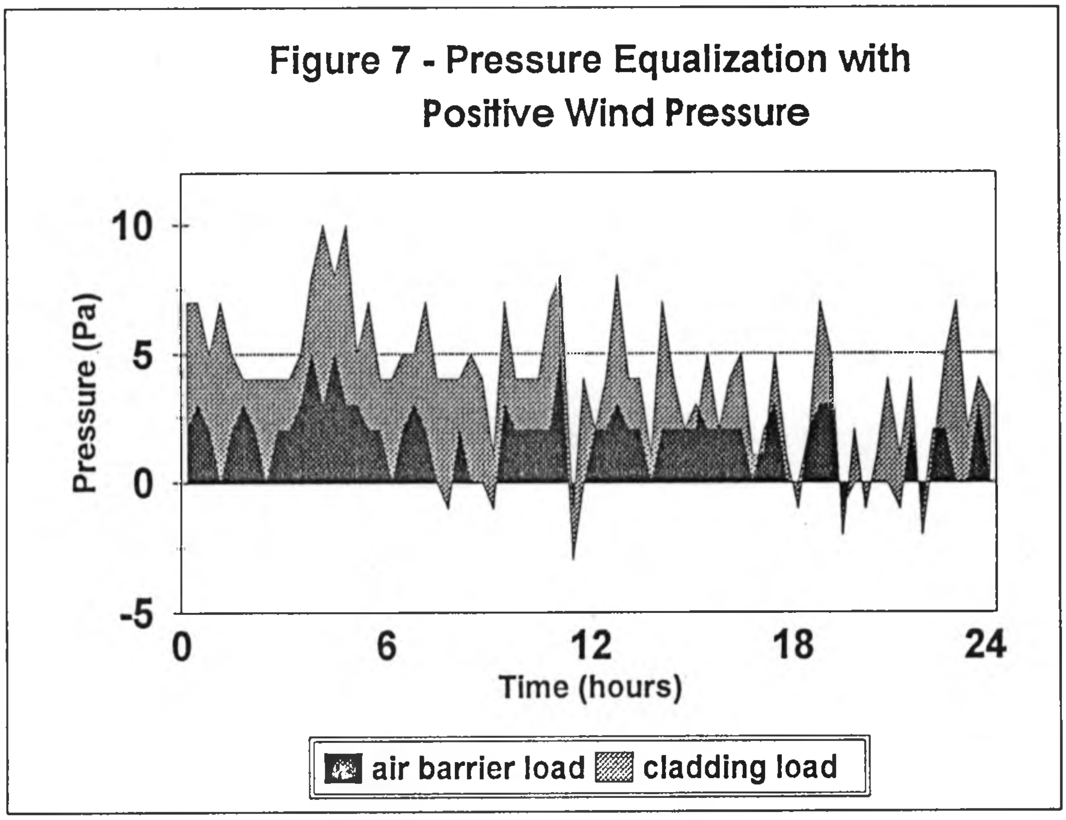
Pressure Equalization Monitoring

Monitoring consisted of recording the data of the various sensors at 20 minute intervals (long term monitoring) except when 2 consecutive pressure readings exceeded a base value of 50 pa. Then the monitoring frequency was increased to 10 Hz to obtain high frequency pressure equalization data.

Monitoring was undertaken between September and November of 1994, but because of the lack of rain in September and October, the records were limited to a period between October 25, and November 8, 1994. The results were divided into two parts; the first is the pressure equalization performance at long intervals (20 minutes) and the second part consists of the short intervals (0.1 minutes). The results were plotted and graphed (see Figures A3-A14, Appendix B).

Observations and Results

The long interval data (20 min.) was divided into day records. From these records three periods of one day each were selected and plotted. The first graph (figure 7) depicts mostly positive wind pressure. To illustrate the various pressure loads, the loads on the air barrier (the back pan) and the load on the cladding (spandrel glass) were added together and shown cumulatively in the area graph. The cumulative height in the graph represents the wind load across the window system while the individual areas represent the load on each element.



It was determined by analysis that the cladding supported 72% of the wind load during this one day interval. The pressure load on the spandrel glass should have been smaller than was found for a PER wall. The cladding load is expected to be near zero. Upon examination, many factors were found to explain this poor performance. Specifically, the vent holes leading to the spandrel cavity were too small for the cavity served. It is also believed that there were air leakage openings in the backpan that were larger than the small vents and that air leakage could occur along the pressure plates into the brick cavity.

It was also determined that the pressure equalization performance of the spandrel cavity was similar on days when the wind pressure was negative (suction). Over the period from October 25, 1994 to November 8, 1994, the wind pressures on the curtain wall averaged ±5 Pa. with light gust increasing the pressure to ± 20 Pa. The complete results of the pressure equalization monitoring of the curtain wall at the University of Quebec will be found in Appendix B.

Rain Penetration Control

Further to pressure equalization, the temperature and humidity of the spandrel cavity were recorded and analyzed. Because the outdoor temperature was below the cavity air temperature for most of the monitoring period, a comparison of the dewpoint temperature of the cavity air and the outdoor temperature provided a reasonable indication of the cavity moisture conditions before and following a rain event.

Observations and Results

The relative humidity of the spandrel cavity air, the spandrel cavity air temperature and the outdoor temperatures were plotted on a graph for comparison and illustrative purposes (figure 8). It is noted that the spandrel temperature is above the outdoor temperature and that the relative humidity is moderately high but not at saturation (100%). It is also known from the weather records that there was considerable rain during this period and particularly on November 1 and 2. It is not particularly obvious from these observations if rain entered the cavity.

If the temperature and humidity data of the cavity are then converted to dewpoint temperatures and compared to the outdoor temperature we obtained a new plot (figure 9). This plot indicates that for the most part the outdoor and cavity dewpoint temperatures appear to follow each other without touching except in a few locations, see arrows on figure. When the dewpoint temperature of the cavity and the outdoor temperature are equal we expect that the inside surface of the spandrel glass is wetted by condensation.

If a third plot is produced which examines the difference between the outdoor temperature and the cavity dewpoint we obtain a new plot (figure 10). In this figure, the difference in temperatures is wide with the exception of 6 small spikes where the dewpoint temperature exists temporarily above the outdoor temperature. This indicated that condensation was occurring. However, because the cavity dewpoint temperature dropped so rapidly, it is also believed that the cavity moisture conditions increased from the saturated outdoor air and not rain penetration. This is because, if wetting had occurred in the cavity, the condensation potential would have lasted considerably longer as was illustrated in the laboratory experiment.

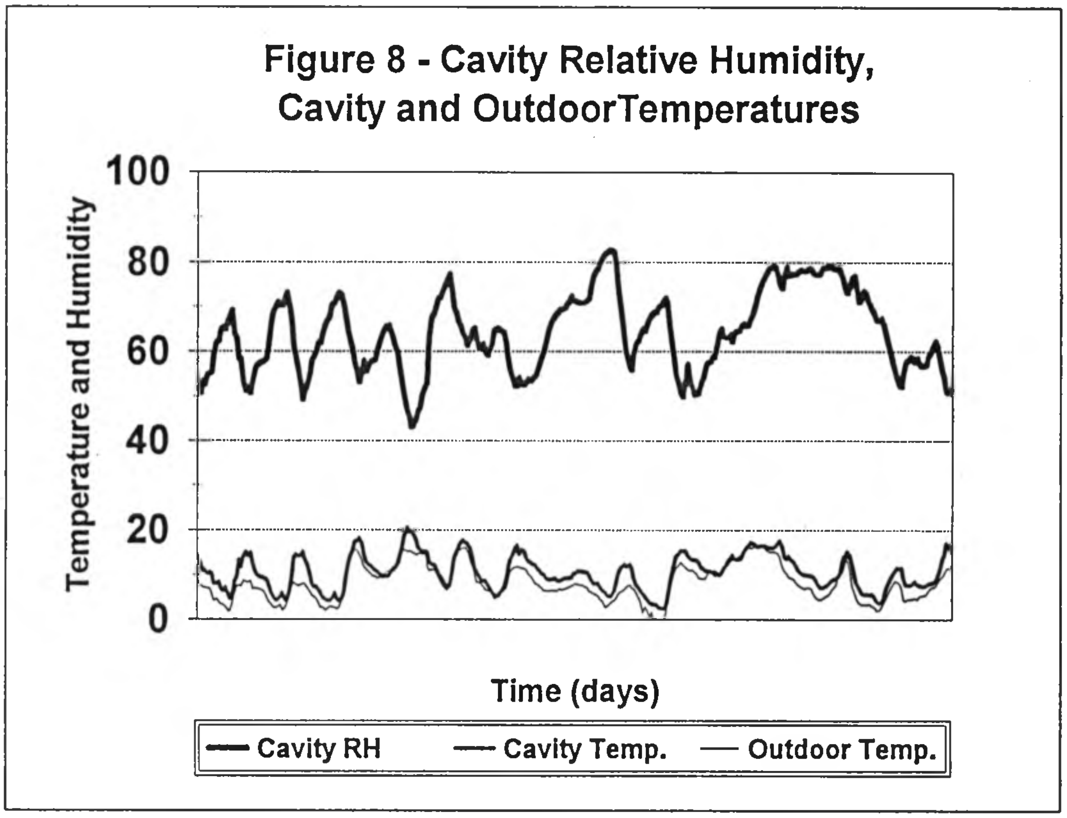


Figure 8 - Cavity Relative Humidity, Cavity and OutdoorTemperatures
100
80
60
40
20
0
Temperature and Humidity
Time (days)
Cavity RH
Cavity Temp.
Outdoor Temp.

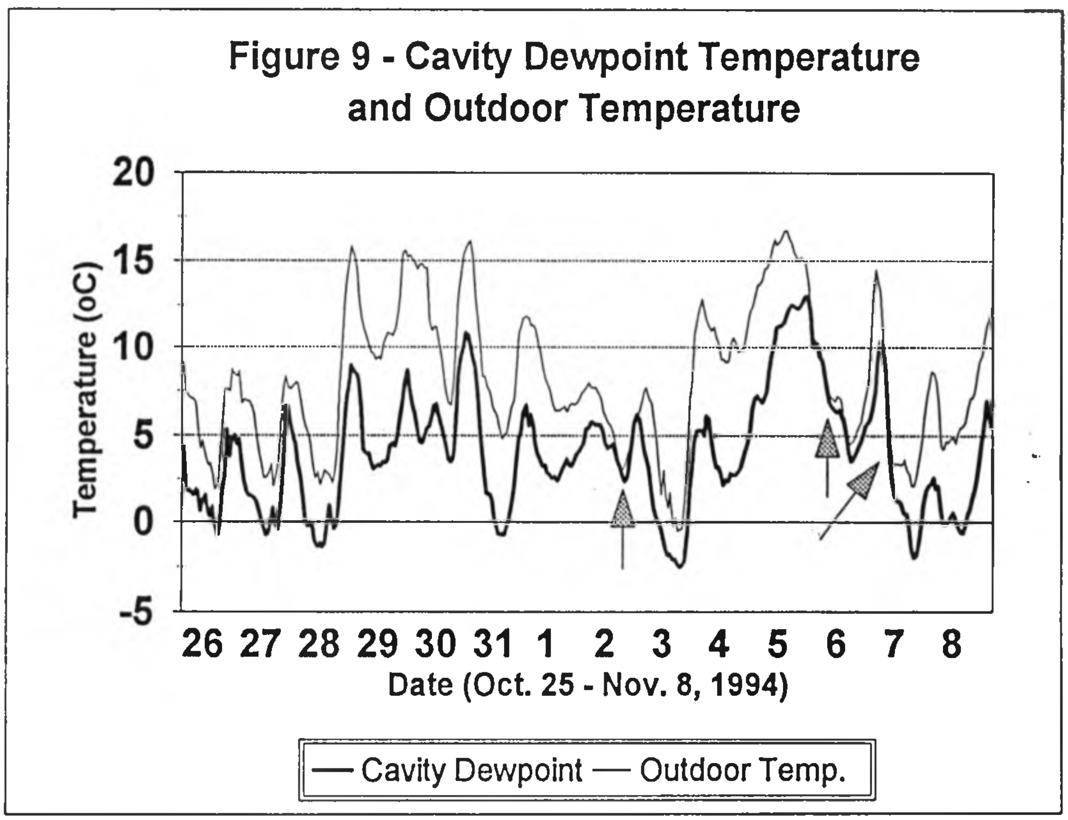
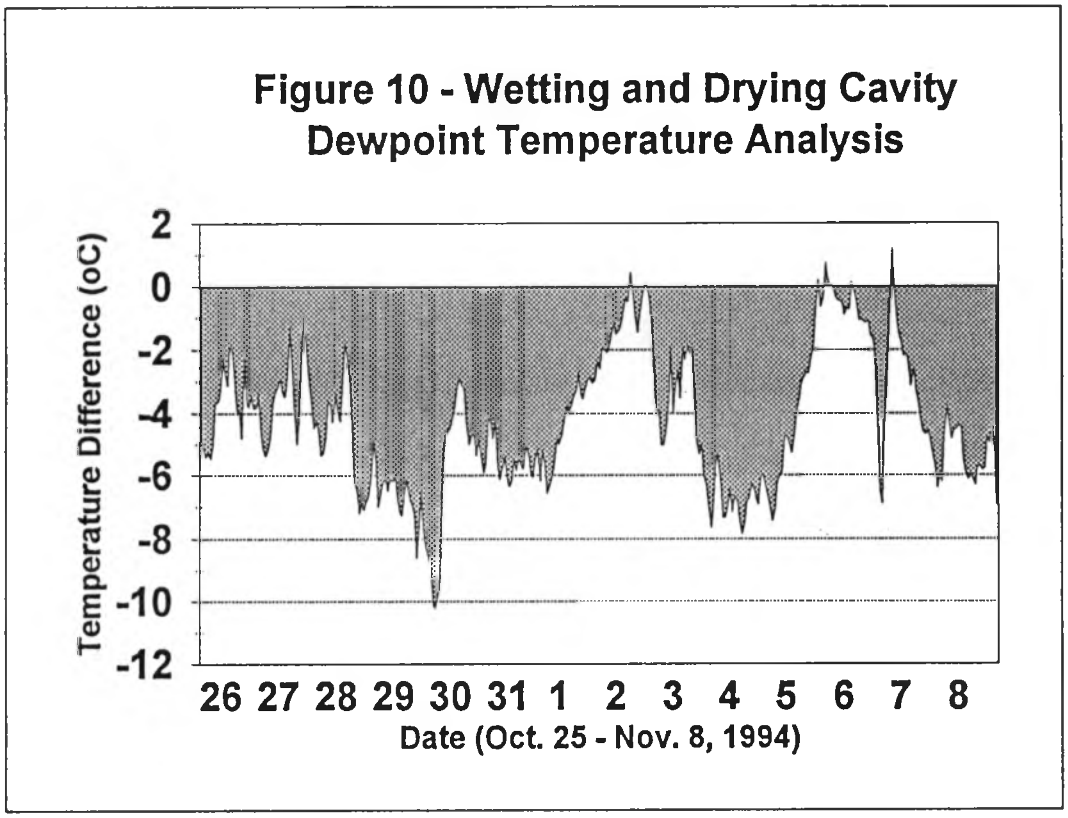


Figure 9 - Cavity Dewpoint Temperature and Outdoor Temperature
20
15
10
5
0
-5
Temperature (oC)
26 27 28 29 30 31 1 2 3 4 5 6 7 8
Date (Oct. 25 - Nov. 8, 1994)
Cavity Dewpoint
Outdoor Temp.



Discussion

The observations and analysis of the cavity moisture conditions of the spandrel panel in the curtain wall of the University of Quebec revealed that it controls the penetration of rain. Clearly the comparison of the laboratory wetting and drying and the field conditions of moisture in the cavity are not the same.

Since the cavity dewpoint temperature appeared to be bellow the outdoor temperature most of the time, it is reasoned that air leaks from inside the building were minimal, otherwise the humidity load of the cavity would have increased significantly on days without rain and particularly when the wind caused suction on the spandrel face.

The pressure equalization of the spandrel section was not as high as expected. This is believed to be the result of very small vent openings in the pressure caps and equally important the possibility that many of the spandrel cavities were interlinked through the imperfections in the spandrel pressure plate covers and possibly with the brick cavity at the jamb. This would be the effect of a leaky compartment seal.

3.2 Canada Life Building, Toronto, Ontario

The Canada Life building in Toronto, was made available by Addison Properties Ltd. for a field monitoring exercise involving the pressure equalization and rain control qualities of the stone veneer and architectural precast rainscreen wall.

Canadian Building Envelope Science and Technology (CAN-BEST) was retained by Canada Mortgage and Housing Corporation (CMHC) to carry out field monitoring of humidity levels inside the rainscreen wall cavity at the Canada Life's new headquarters building in Toronto during and following a rainstorm [(1)]. The objective of this assignment was to assess the wall's rainscreen performance when subjected to rain.

Description of Rainscreen Precast Wall Panels

The typical rainscreen panel of the Canada Life building is composed of an architectural precast interior liner (air barrier) mineral fiber insulation in the cavity, a drainage screen (Terra Drain) and (Indiana limestone) stone veneer cladding finish. The panels are sealed at the perimeter using torch-on elastomeric membranes, and vented through the jamb and head of the window. Drainage occurred through small holes in the horizontal compartment seal leading to a drainage opening between two stones to exit above the window.

Monitoring Station and Methodology

Monitoring of the cavity's relative humidity and temperature was carried out on two west-facing panels, both located on the 12th floor (top floor). The first panel is located near the center of the building. The second panel (#99) is located at approximately quarter building width from the north corner. Additional details are provided in Appendix C.

The ambient relative humidity, temperature and barometric pressure were monitored outside the building at one location on the 11th floor. The 11th

(1) CMHC Report No.......... 1995.

floor was chosen instead of the 12th floor for practical accessibility to the building's exterior side. The narrow perimeter balcony of the 11th floor was used to install the water collection troughs, and to mount the exterior instruments. An access door to the balcony was created by temporarily removing the sealed glazing unit of panel #91 which is centrally located between the two monitored locations.

Monitoring of the interior ambient relative humidity and temperature was also carried out at one location on the 11th floor. The instruments were mounted at a central location above the dropped ceiling panels.

Measuring rainfall intensity, relative humidity, temperature and barometric pressure was accomplished by using two rain gauges, four relative humidity/temperature sensors and one barometric pressure transducer. The instruments were connected to a computer-based data acquisition system programmed for unattended data collection and storage. Data was sampled at the rate of one sample per second, continuously averaged, and logged every 15 minutes.

The surface water run-off was collected and measured using two independent tipping-bucket rain gauges. A 1500 mm wide horizontal water collection trough was installed at the window sill of panels 90 and 91 located directly below the panels under investigation. The collected water was directed to the corresponding rain gauge through a down-spout located at the end of the trough.

One relative humidity/temperature sensor was placed at the bottom of each wall cavity. The cavity was accessed through one of the anchor pockets in the precast concrete panel. The pockets were opened by cutting through the interior drywall and the air seal membrane. Once the transducers were positioned at the bottom of the panel cavity, the membrane was properly sealed for the monitoring duration.

Observations and Results

During a monitoring period of four weeks, one significant rainstorm occurred. The amount of rainfall intercepted by the two test panels varied significantly. The center panel received less rain than the one closer to the building corner. In a 15 minute rain period, the center panel rain gauge registered 124 mm of rainfall compared to 205 mm registered by the other gauge.

Based on the collected data of relative humidity, temperature and barometric pressure, the Humidity Ratio (HR) curves for each wall cavity and for both the exterior and interior ambient environments were plotted prior to, during and following rainfall (see Appendix C).

The results show clearly that the cavity moisture did not reach saturation. There was however, a rise in humidity before the rainfall and a gradual drop in humidity after the rain. This pattern of change is believed to be related to the absorption and evaporation of moisture from the limestone face and its effect on the cavity conditions. To be certain however, this effect should be examined in the laboratory.

3.3 Analysis and Discussion

The monitoring of two rainscreen walls in the field has revealed several important observations and raised numerous questions. The monitoring and analysis of the wetting and drying of a rainscreen cavity is considerably more complex than previously thought. This is because cavity moisture is not only subject to evaporation within the cavity but also the limiting conditions imposed by the temperature of the cladding. In other words, moisture conditions in cavities are also governed by the outdoor air temperature.

While it is believed that the relative humidity and temperature monitoring of rainscreen cavities is a viable approach, further testing should be undertaken in the laboratory using simpler physical models. Also, further investigations in the field could be supplemented by an intentional cavity wetting calibration test to determine the boundary conditions of cavity saturation from water ingress.

Wetting and drying of cavities must be rationalized more clearly by an exploration of the water penetration ratio for a given rainstorm load and duration and the acceptable degree of wetting that will not damage interior components.

The pressure equalization characteristics of the metal and glass curtain wall in the building in Hull, Quebec, indicate a low percentage of equalization. It is not known exactly why this occurred, however, from a visual inspection and a subsequent analysis using a CMHC computer program called "RAIN", it is believed that the vents in the snap caps were too small for the volume of the spandrel cavity. It is also believed that the back pan cavity may have been connected to other spandrels areas through unintentional venting at the pressure plates. Unfortunately, the scope of this part of the project did not allow the opportunity to dismantle the system for further investigation.

The wetting and drying of the rainscreen cavity of the Canada Life building is more complex. While the cavity humidity rises with the outdoor conditions, it does not rise to or above the outdoor humidity conditions. This would indicate that the rainscreen is performing its function that of preventing rain from entering the cavity. The rise in humidity is believed to be the wetting of the stone from the exterior and the evaporation of moisture to the inboard side of the wall. This hypothesis leads to an important question and that is, how much wetting of the stone veneer has been avoided by the pressure equalization performance of the wall and even more fundamental how much water should it be allowed to absorb by design?

4.0 Conclusions and Recommendations

The design and construction of the rainscreen system is currently more art than science. There are numerous examples of its application but field evidence seems to indicate that the pressure equalization performance of those systems examined is considerably less than expected.

The most advanced rainscreen system design is the metal and glass curtain wall and one type of steel building exterior wall cladding system. However, measurements of a conventional curtain wall panel would appear to indicate less than 25% pressure equalization in a spandrel during low pressure winds to less than 15% during stronger and more steady winds. However and even though the pressure equalization performance appeared weak, there does not appear to be any rain penetration, even during a moderately severe storm.

The rainscreen system of the Canada Life building is a stone veneer and architectural precast façade compartmentalized along the perimeter of each panel and vented along the jamb and head of a window. The field observations and performance measurements would indicate that the cavity pressure equalizes better than 50% under static conditions, but it is also believed that the measurement methods may not fully represent the actual panel exposure conditions. This is because the wind gradient washes over a long vent opening.

The experiments and observations of wetting and drying in cavities have indicated that the process is considerably more complex than originally considered. This is true of systems that do not absorb water such as the metal and glass curtain walls and of systems that can store moisture in the cladding materials without necessarily any wetness appearing in the cavity.

In the case of the metal and glass curtain wall, the rabbet space wetting and drying was complicated because of the volume dividers created by the setting blocks and the extraneous venting of the pressure plate. The observations indicated that the cavity appeared to dry out quickly at first but then did not reach equilibrium before several weeks.

In the case of the architectural precast wall of the Canada Life building, the cavity moisture does not rise to saturation, but it does appear to increase with outdoor humidity changes and fall quickly thereafter. This is indicative of moisture absorption and evaporation by the stone rather than wetting of the cavity. This pattern would indicate satisfactory performance, although performance of the cavity when wetted directly is unknown.

With masonry claddings, it is believed that most rain penetration is absorbed on the face. For this reason it may be important to consider the effect of pressure equalization on storage and release of moisture rather than wetting, draining and drying of the cavity.

If this work is extended in the future, we recommend that the following project be considered. It would be useful to determine the wetting and drying characteristics of 5 or more rainscreen wall types. This work should be undertaken in the laboratory and include both non-absorptive and absorptive type construction materials, controlled wetting and drying and surface wetting tests under various pressure equalization limits.

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Appendix "A"

Laboratory Studies,
Queens University

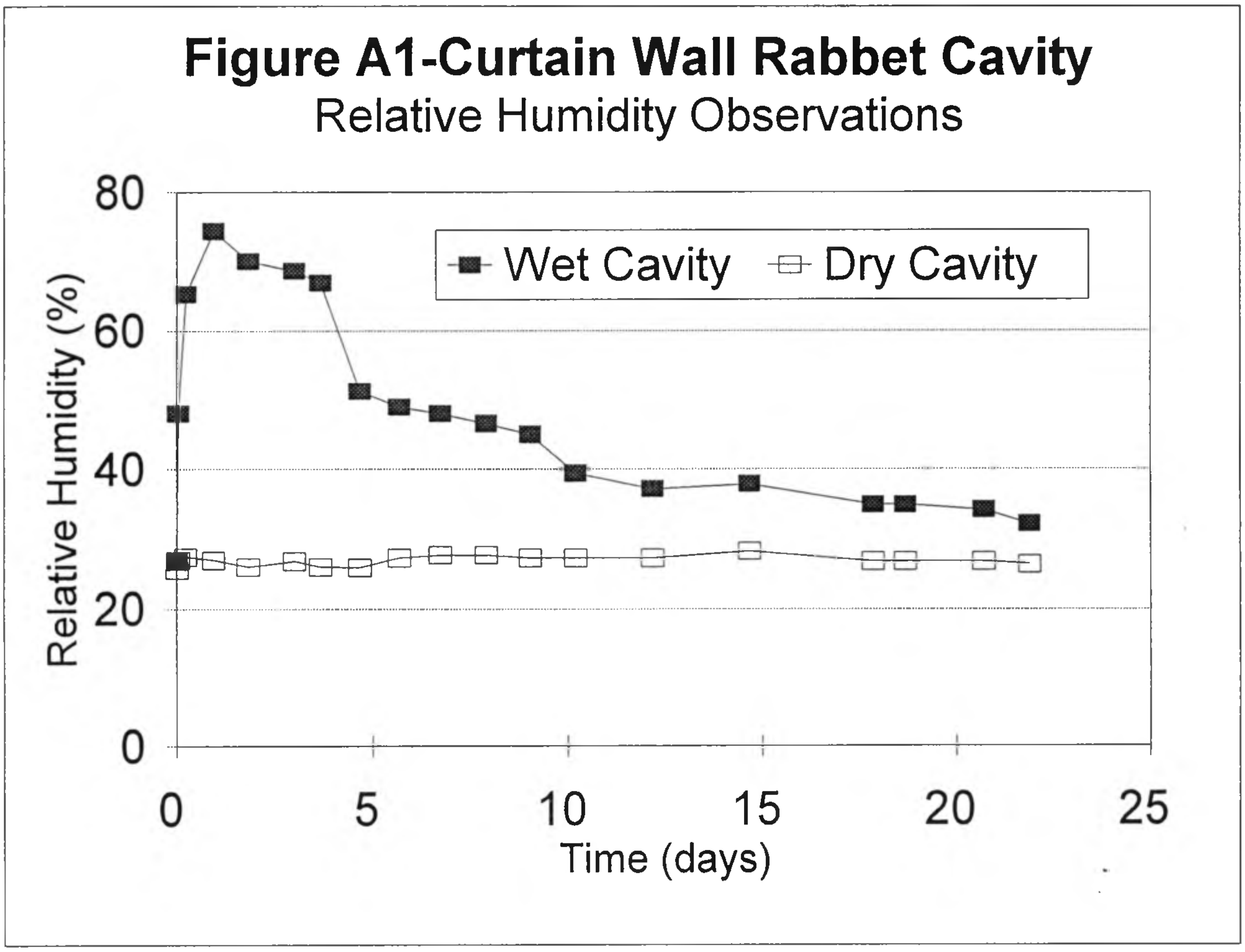


Figure A1-Curtain Wall Rabbet Cavity
Relative Humidity Observations
Wet Cavity
Dry Cavity
Relative Humidity (%)
0
20
40
60
80
Time (days)
0
5
10
15
20
25

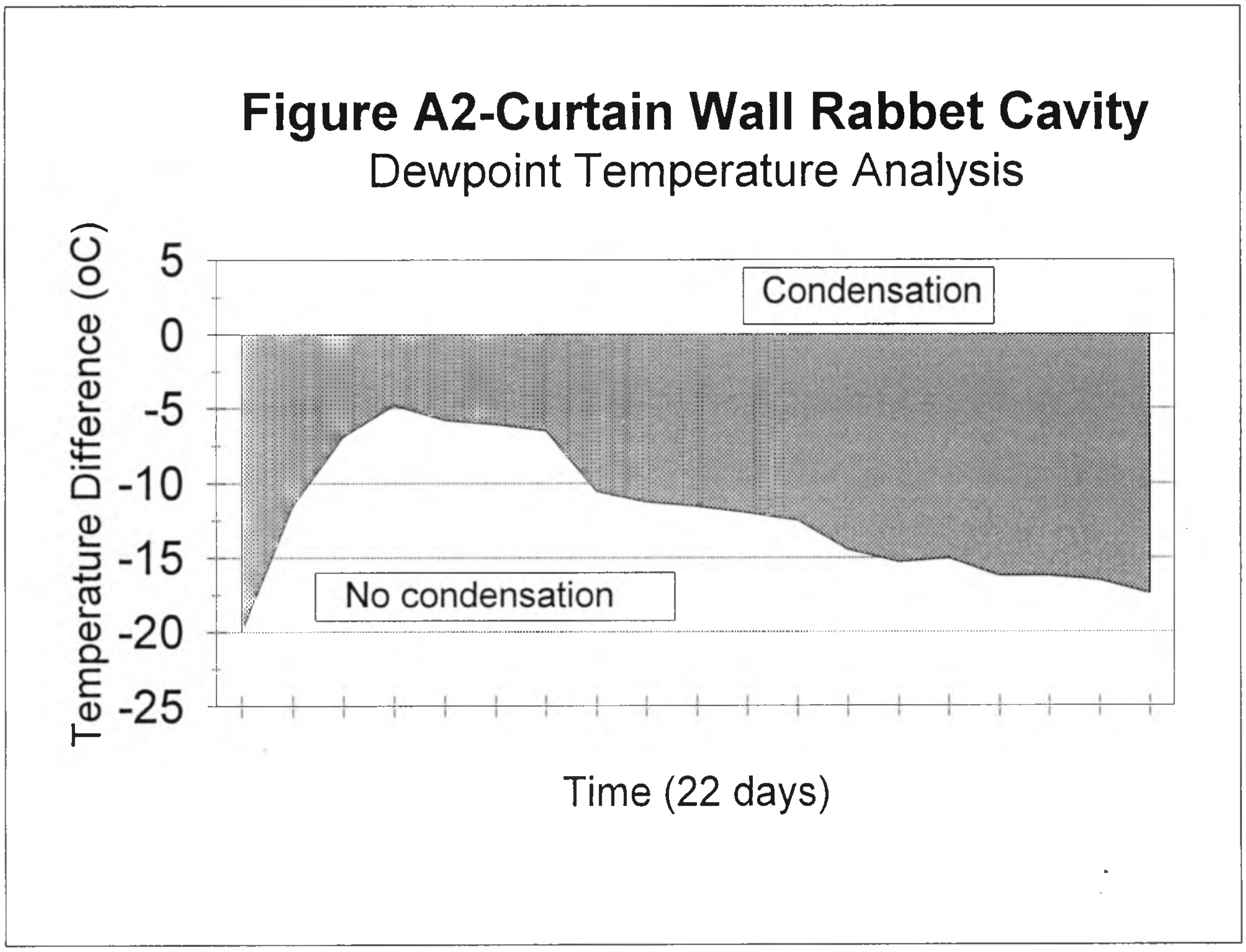


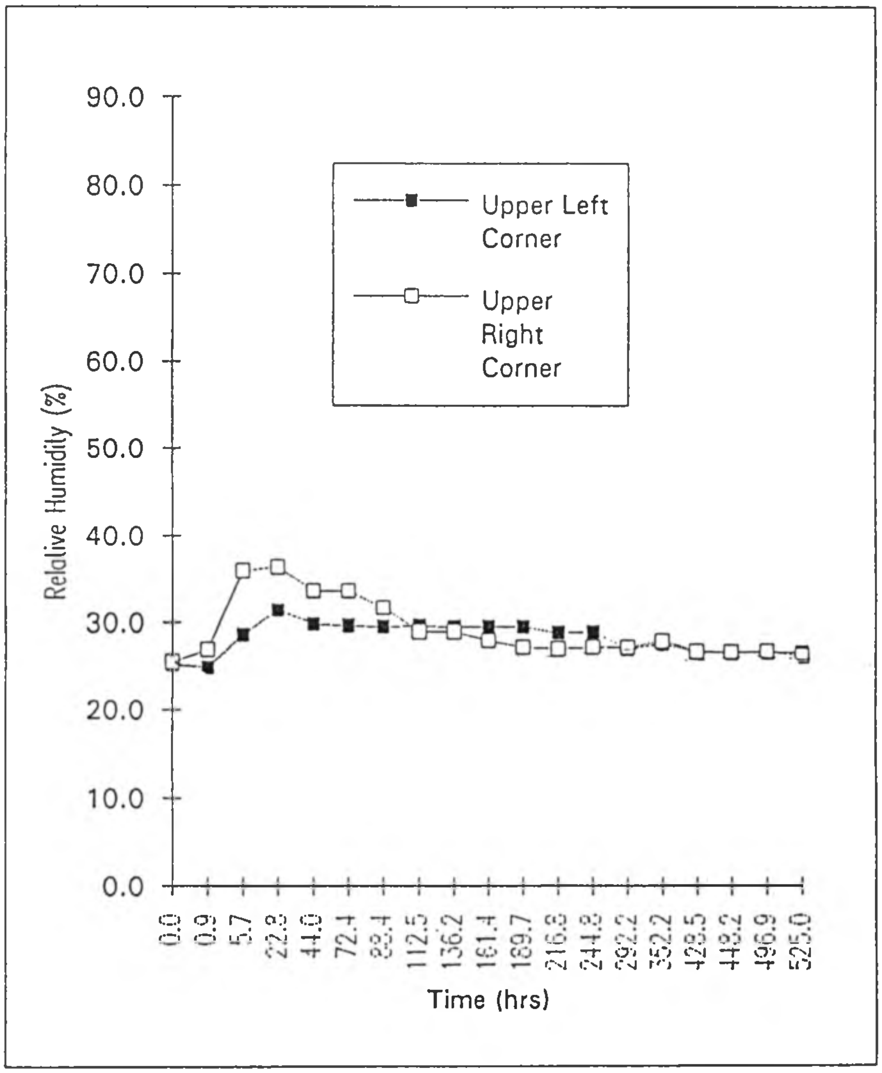
Figure A2-Curtain Wall Rabbet Cavity
Dewpoint Temperature Analysis
Temperature Difference (oC)
5
0
-5
-10
-15
-20
-25
Condensation
No condensation
Time (22 days)

GRAPH RH-4
GLAZING CAVITY RELATIVE HUMIDITY DECAY

Summary of Test Conditions	
Direction of Air Flow through Connected Source	N/A
Vision Unit Perimeter Seal	1
External Snap Caps	Off
Pressure Plate Openings	
Area	.000452 m^2
Status	Open

Notes to Vision Unit Perimeter Seal:

1. Pressure plates installed over bead of silicone sealant
2. Outer face of pressure plates sealed to outer side wall of mullion

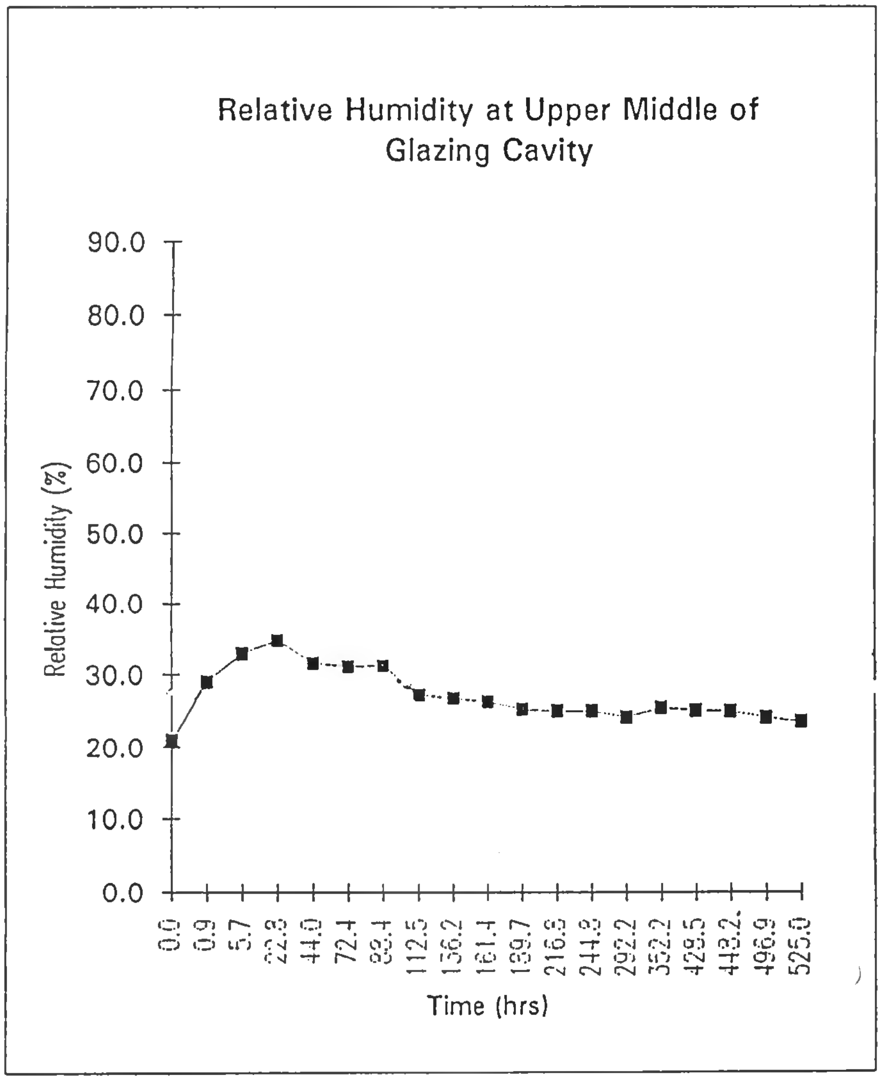


GRAPH RH-5
GLAZING CAVITY RELATIVE HUMIDITY DECAY

Summary of Test Conditions	
Direction of Air Flow through Connected Source	N/A
Vision Unit Perimeter Seal	1
External Snap Caps	Off
Pressure Plate Openings	
Area	.000452 m^2
Status	Open

Notes to Vision Unit Perimeter Seal:

1. Pressure plates installed over bead of silicone sealant
2. Outer face of pressure plates sealed to outer side wall of mullion



Appendix
"B"

Field Monitoring,
University of Quebec.

Figure A3-Curtain Wall Spandrel Panel

Long Term Monitoring Oct 25-Nov 8,1994

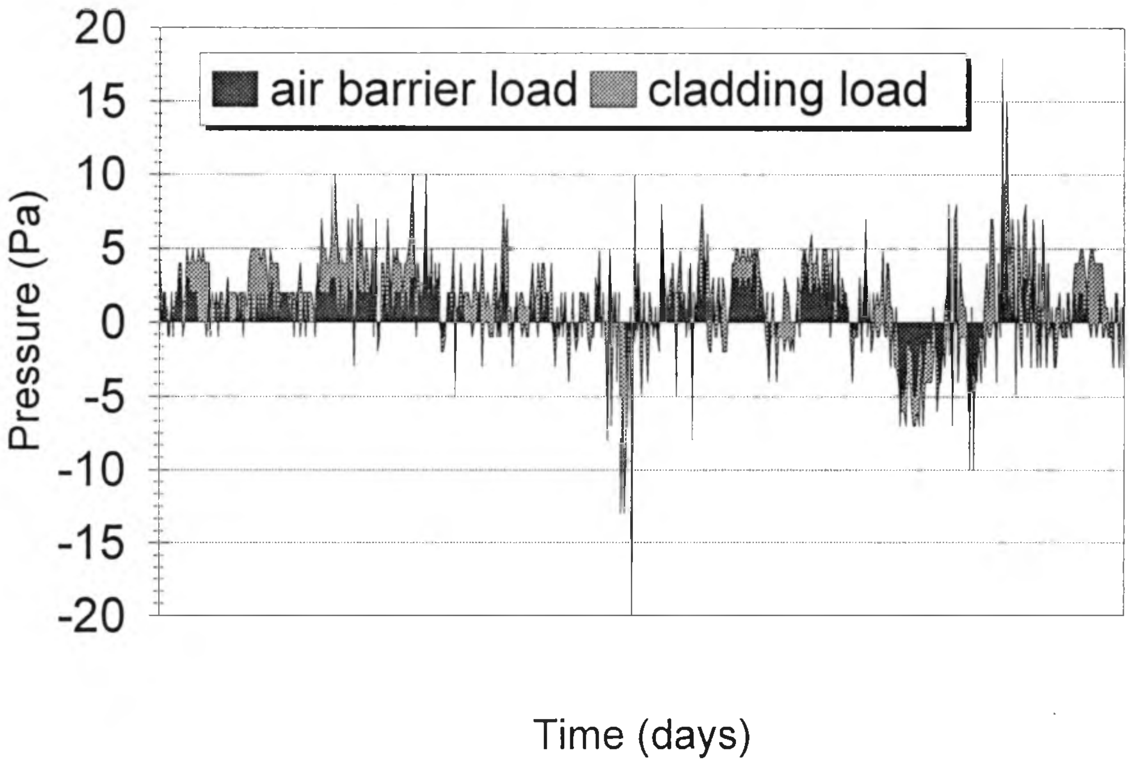


Figure A4-Curtain Wall Spandrel Panel

Long Term Monitoring Oct. 28, 1994

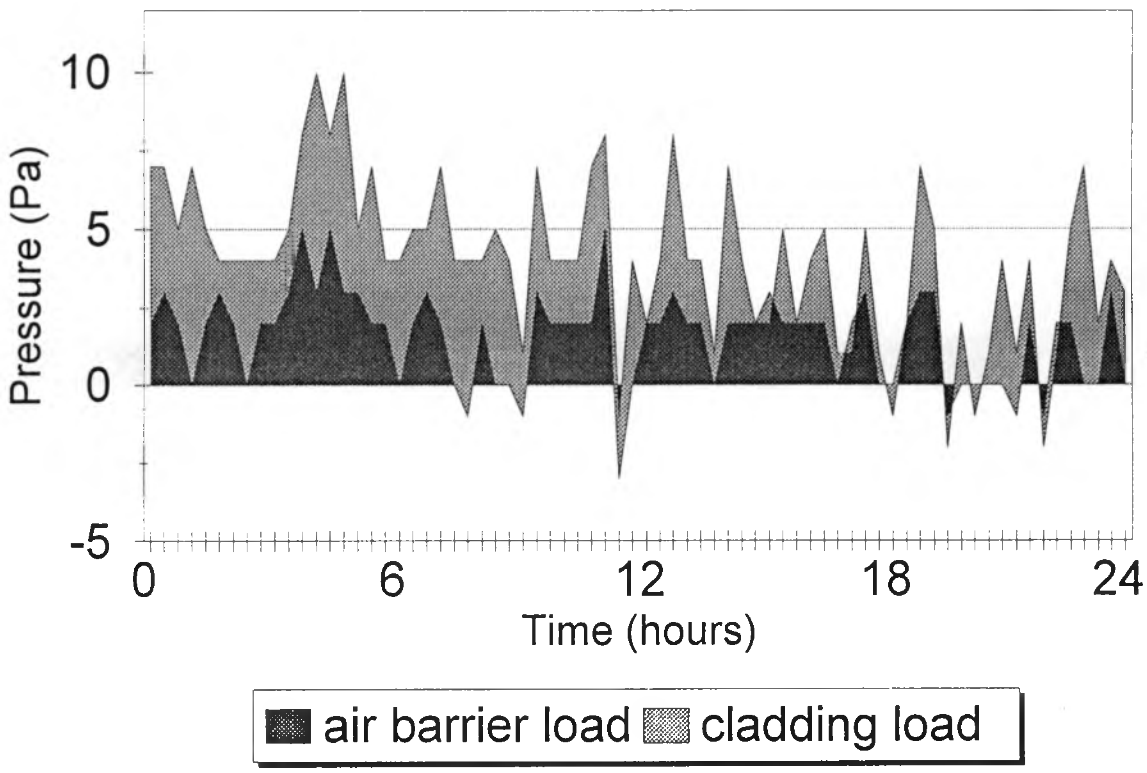
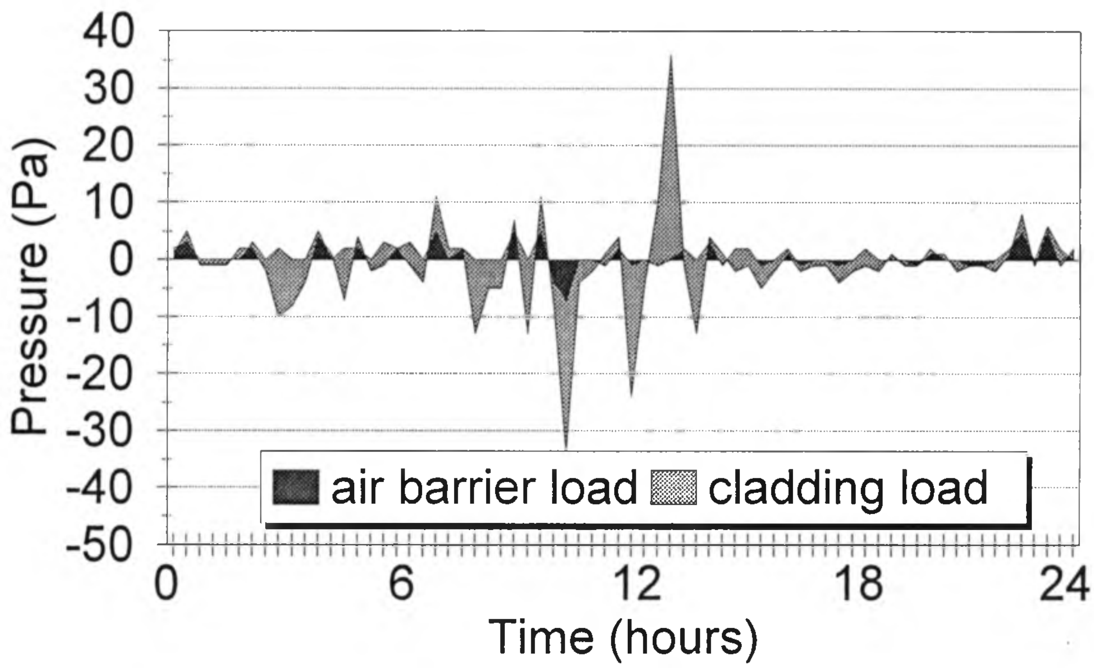


Figure A5-Curtain Wall Spandrel Panel

Long Term Monitoring Nov. 1, 1994



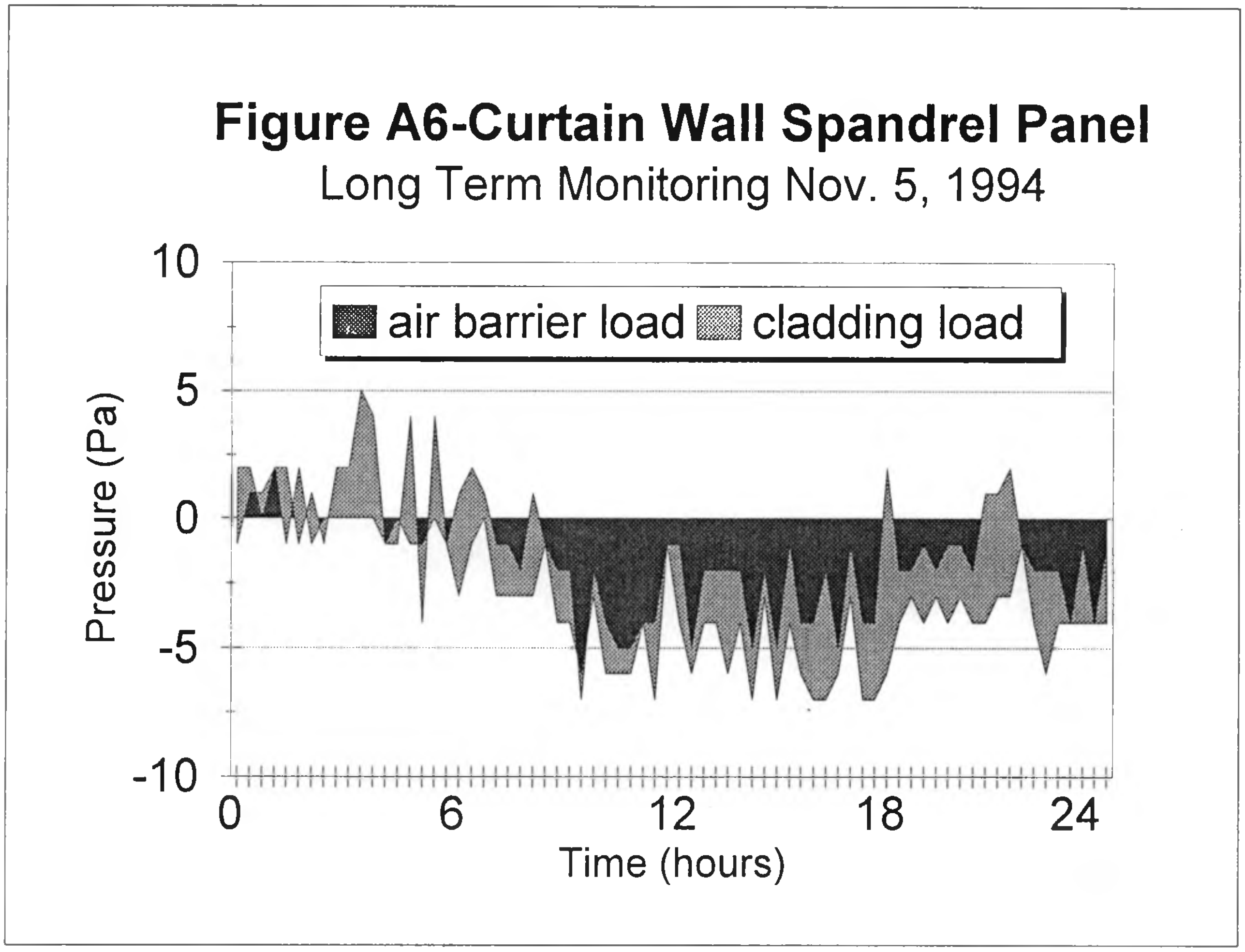


Figure A6-Curtain Wall Spandrel Panel
Long Term Monitoring Nov. 5, 1994
air barrier load
cladding load
Pressure (Pa)
10
5
0
-5
-10
0
6
12
18
24
Time (hours)

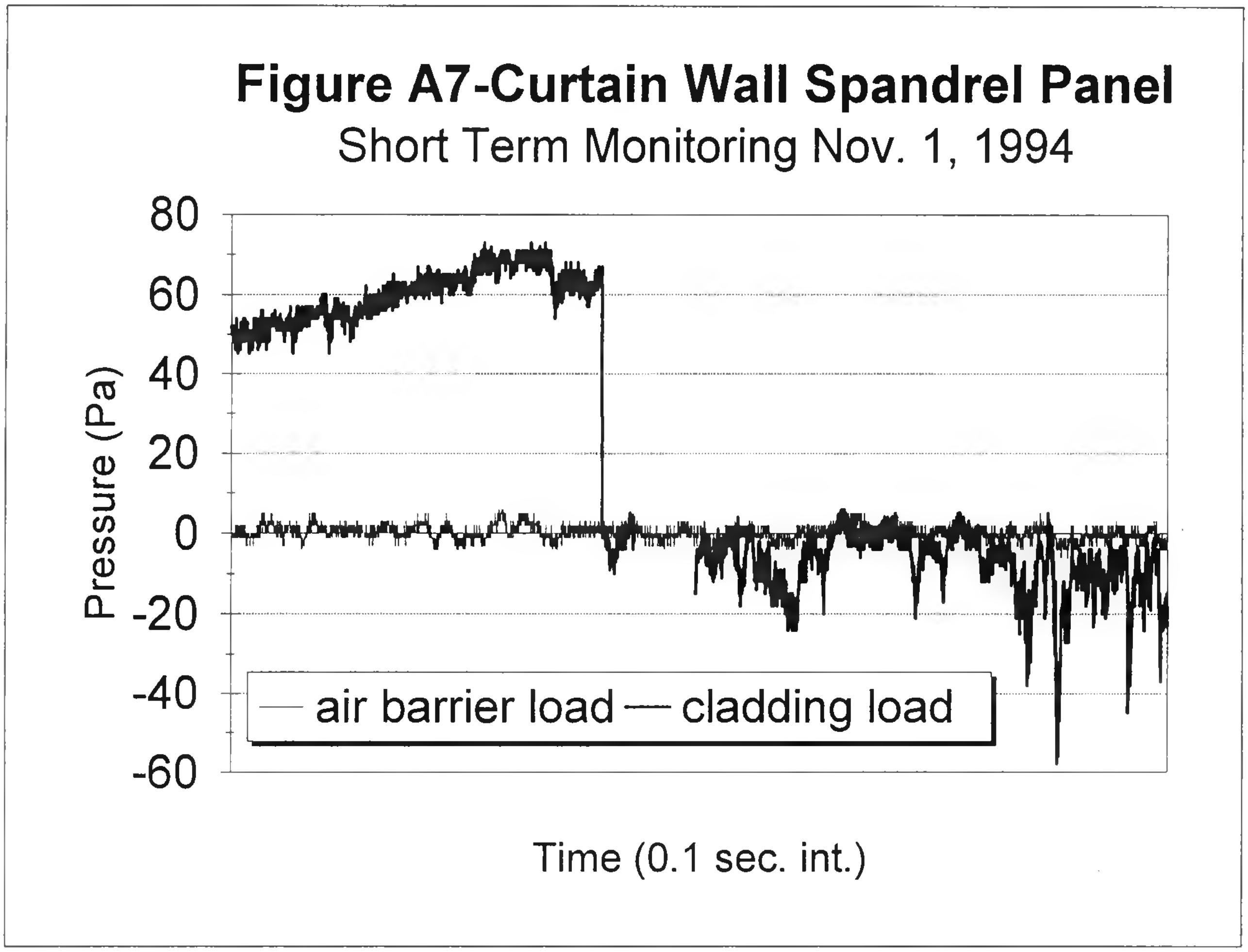


Figure A7-Curtain Wall Spandrel Panel
Short Term Monitoring Nov. 1, 1994
80
60
40
20
0
-20
-40
-60
Pressure (Pa)
air barrier load
cladding load
Time (0.1 sec. int.)

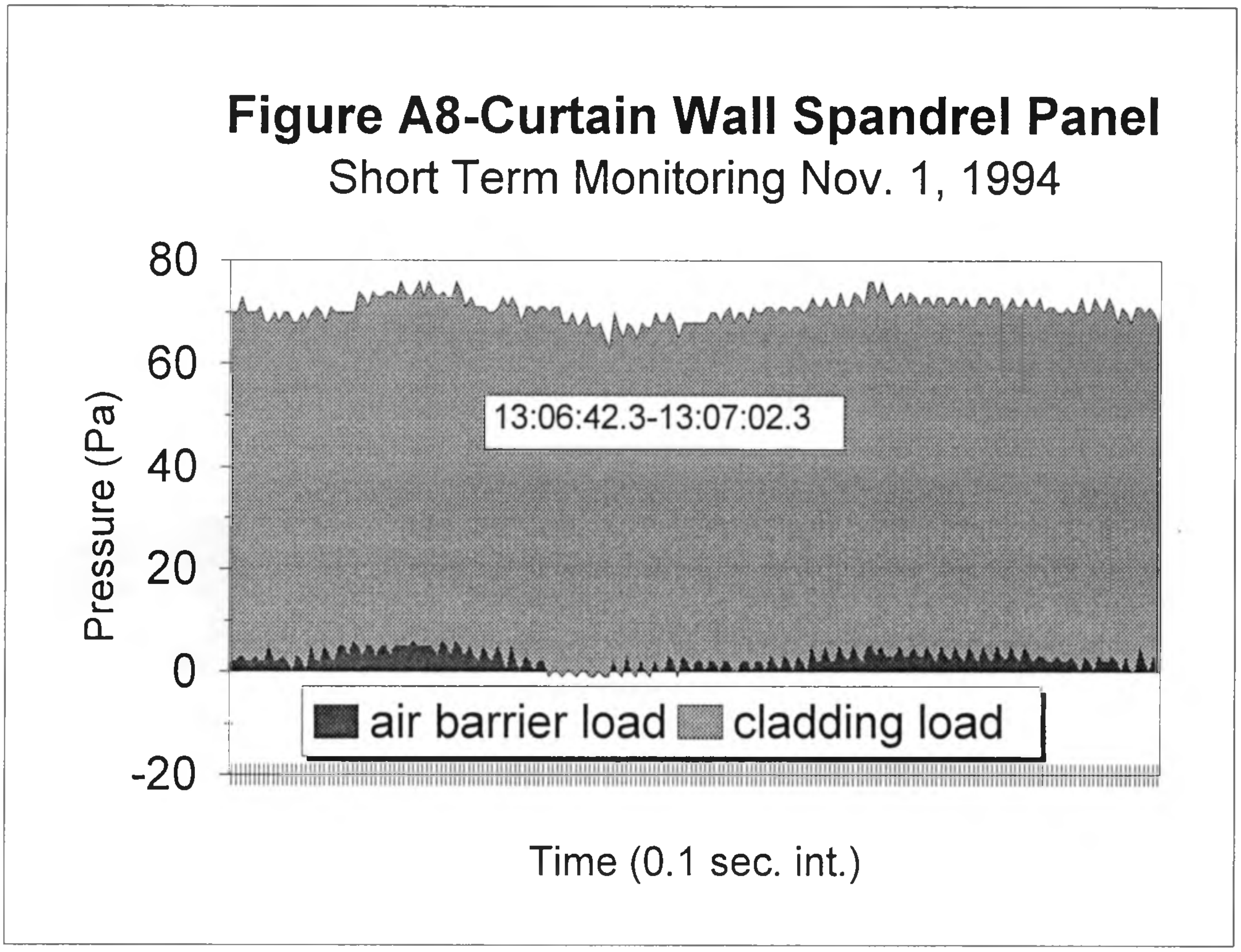


Figure A8-Curtain Wall Spandrel Panel
Short Term Monitoring Nov. 1, 1994
80
60
40
20
0
-20
Pressure (Pa)
13:06:42.3-13:07:02.3
air barrier load
cladding load
Time (0.1 sec. int.)

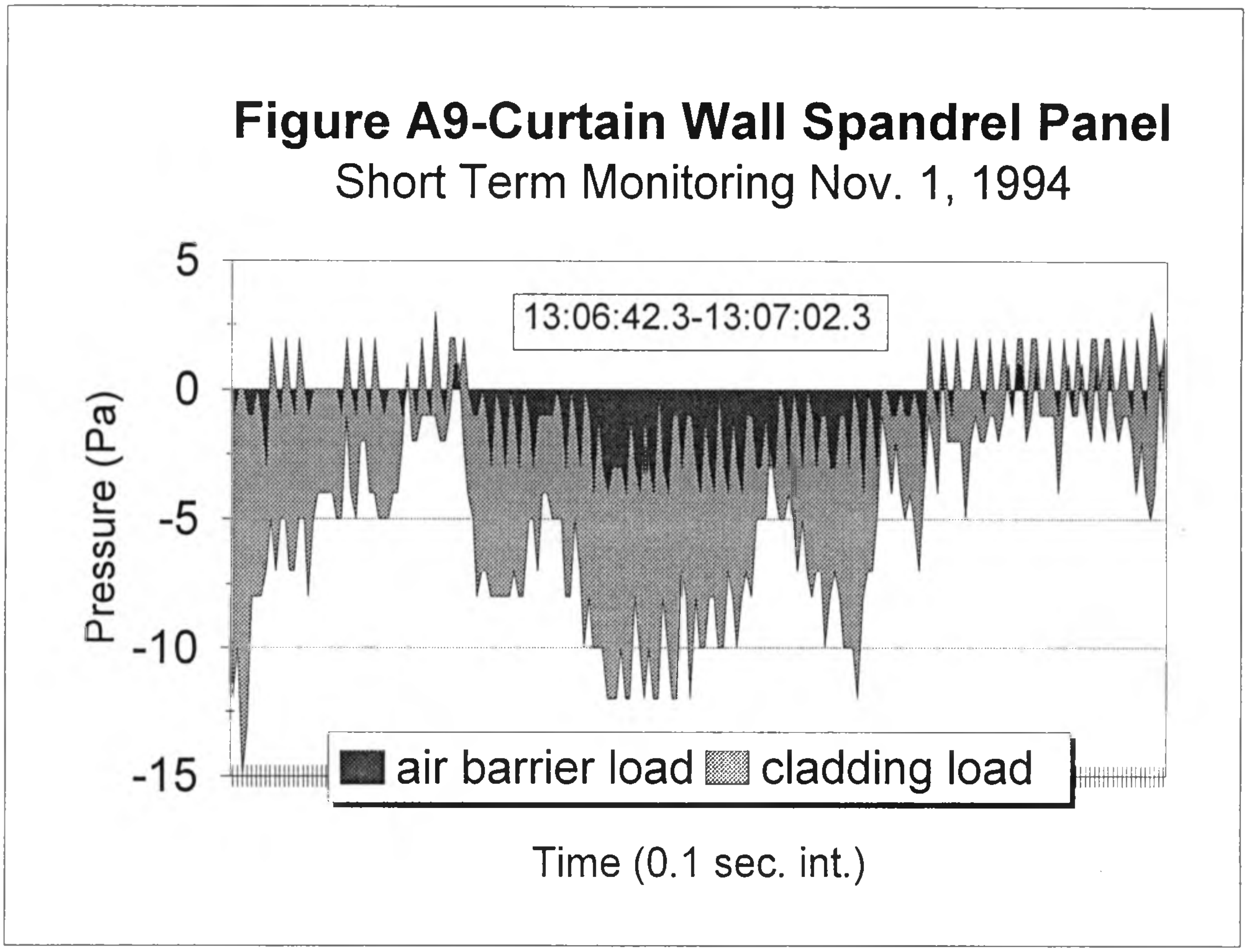


Figure A9-Curtain Wall Spandrel Panel
Short Term Monitoring Nov. 1, 1994
13:06:42.3-13:07:02.3
5
0
-5
-10
-15
Pressure (Pa)
air barrier load
cladding load
Time (0.1 sec. int.)

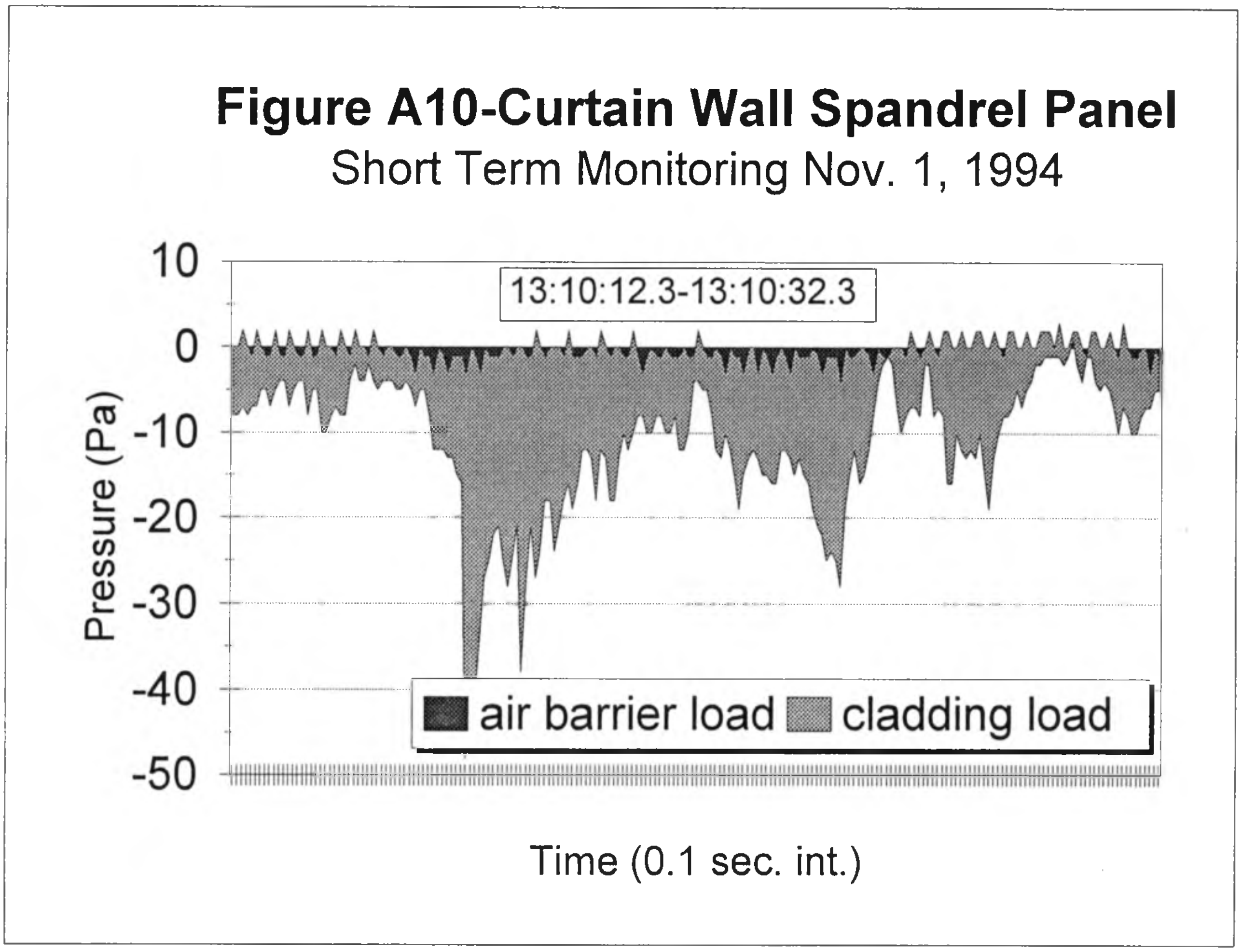


Figure A10-Curtain Wall Spandrel Panel
Short Term Monitoring Nov. 1, 1994
13:10:12.3-13:10:32.3
10
0
-10
-20
-30
-40
-50
Pressure (Pa)
air barrier load
cladding load
Time (0.1 sec. int.)

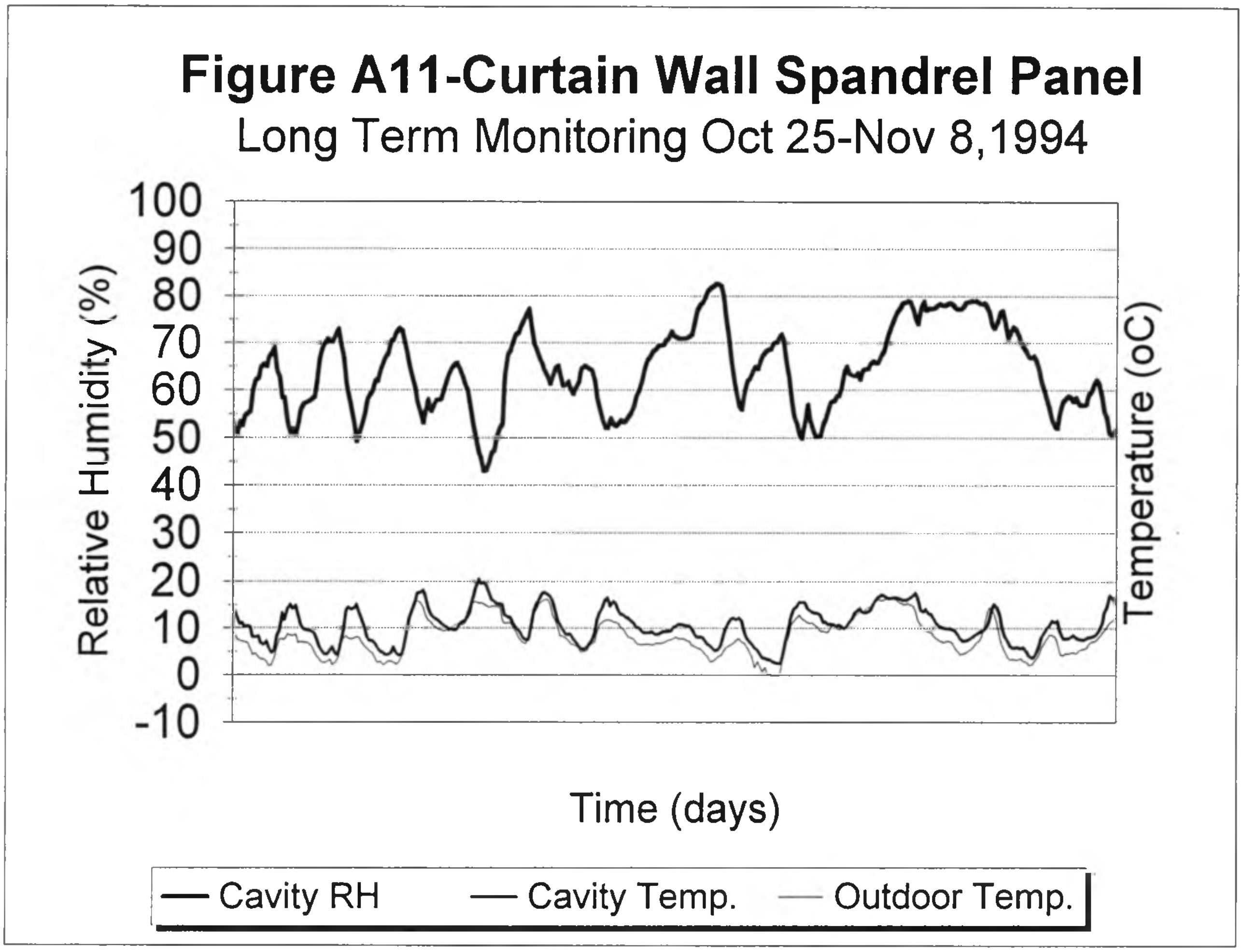


Figure A11-Curtain Wall Spandrel Panel
Long Term Monitoring Oct 25-Nov 8,1994
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
-10
Temperature (oC)
Time (days)
Cavity RH
Cavity Temp.
Outdoor Temp.

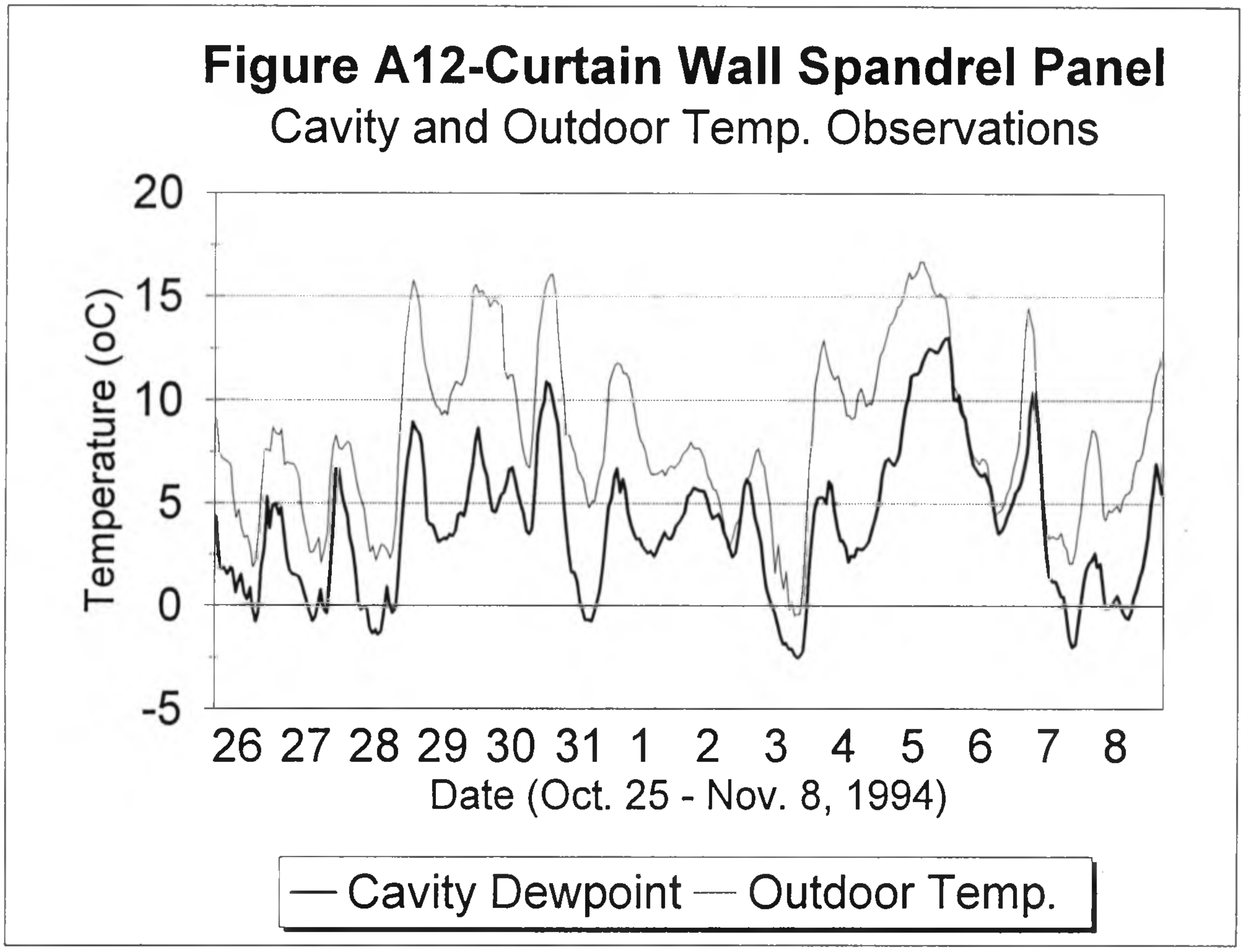


Figure A12-Curtain Wall Spandrel Panel
Cavity and Outdoor Temp. Observations
Temperature (oC)
20
15
10
5
0
-5
26 27 28 29 30 31 1 2 3 4 5 6 7 8
Date (Oct. 25 - Nov. 8, 1994)
Cavity Dewpoint
Outdoor Temp.

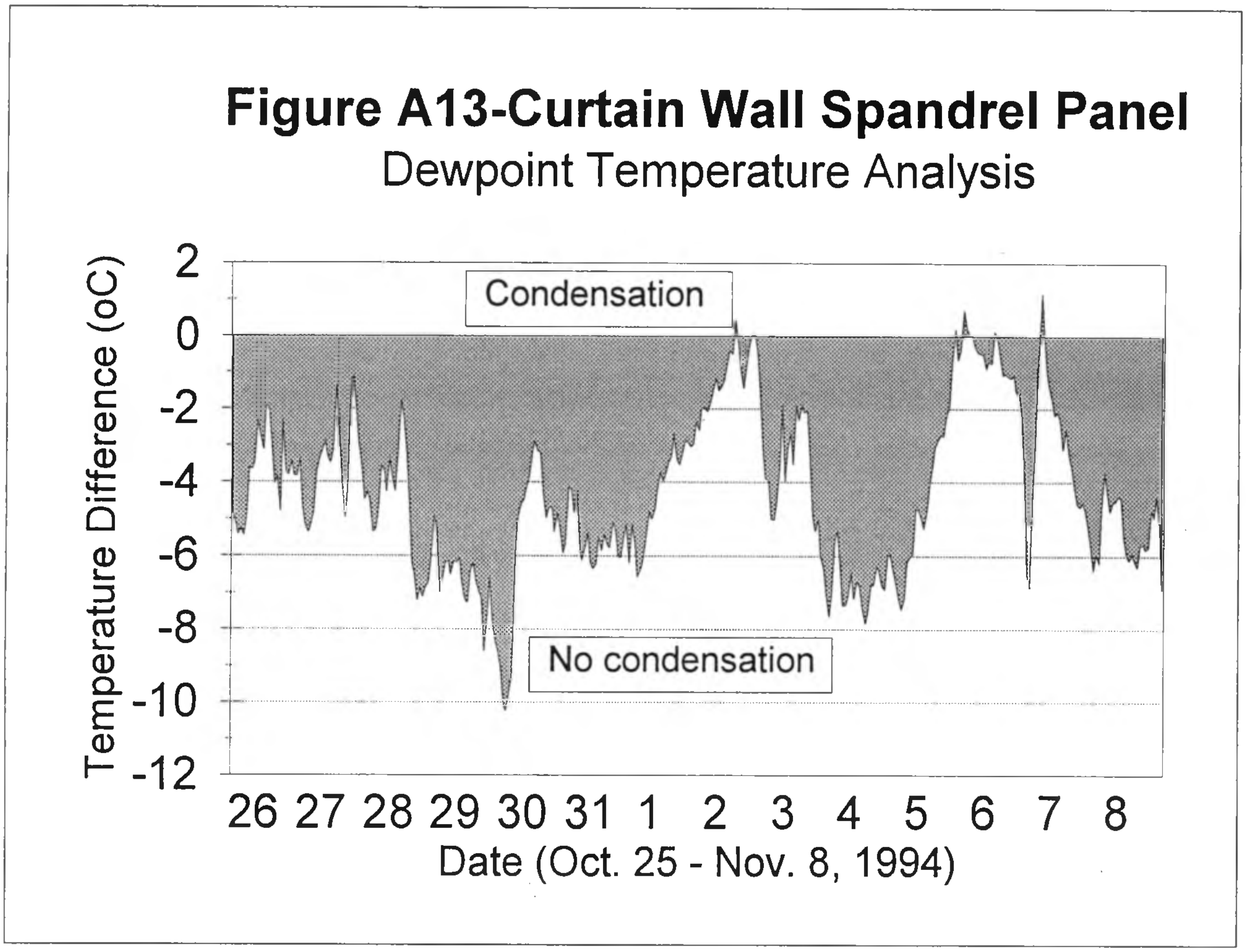


Figure A13-Curtain Wall Spandrel Panel
Dewpoint Temperature Analysis
Condensation
No condensation
Temperature Difference (oC)
2
0
-2
-4
-6
-8
-10
-12
26 27 28 29 30 31 1 2 3 4 5 6 7 8
Date (Oct. 25 - Nov. 8, 1994)

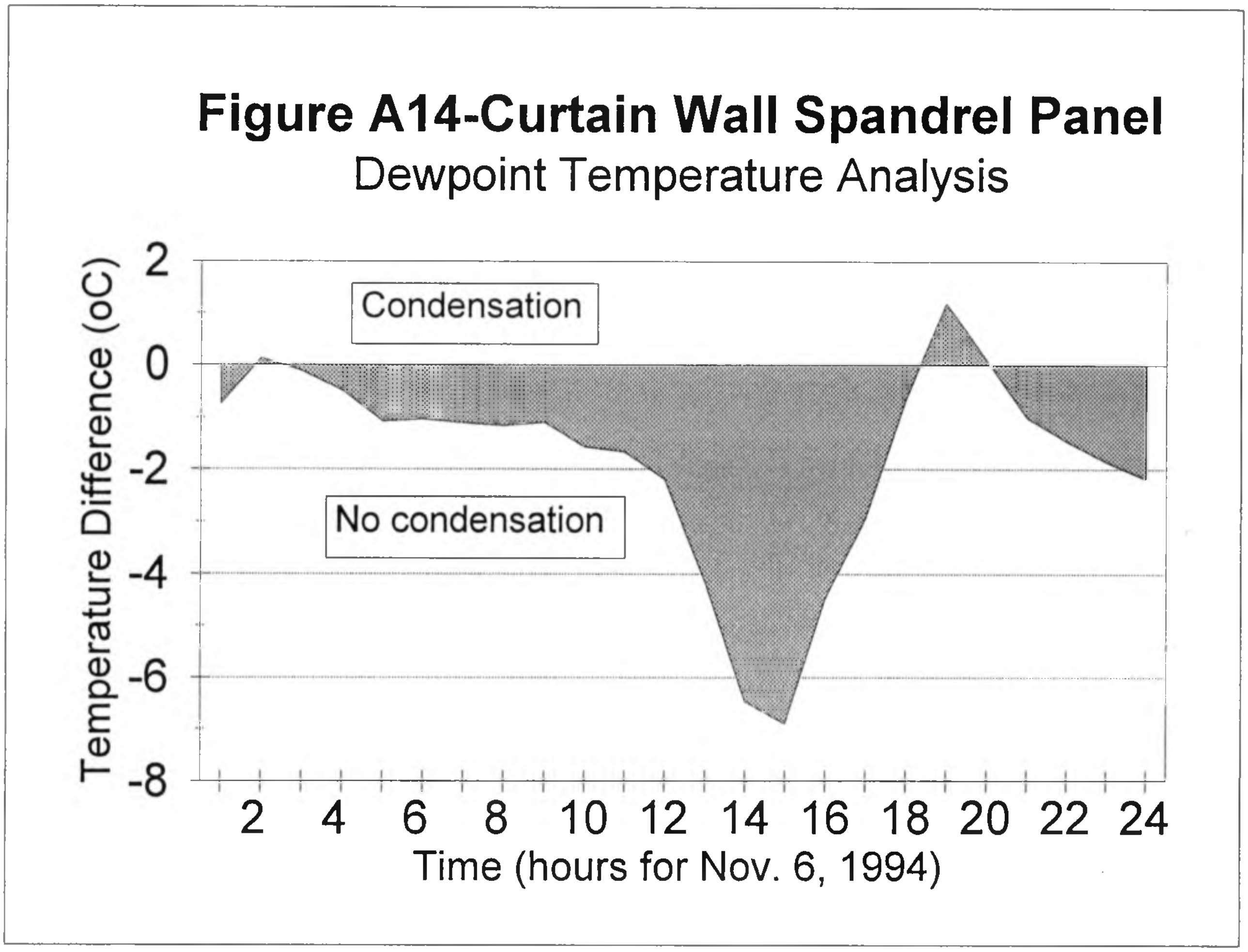
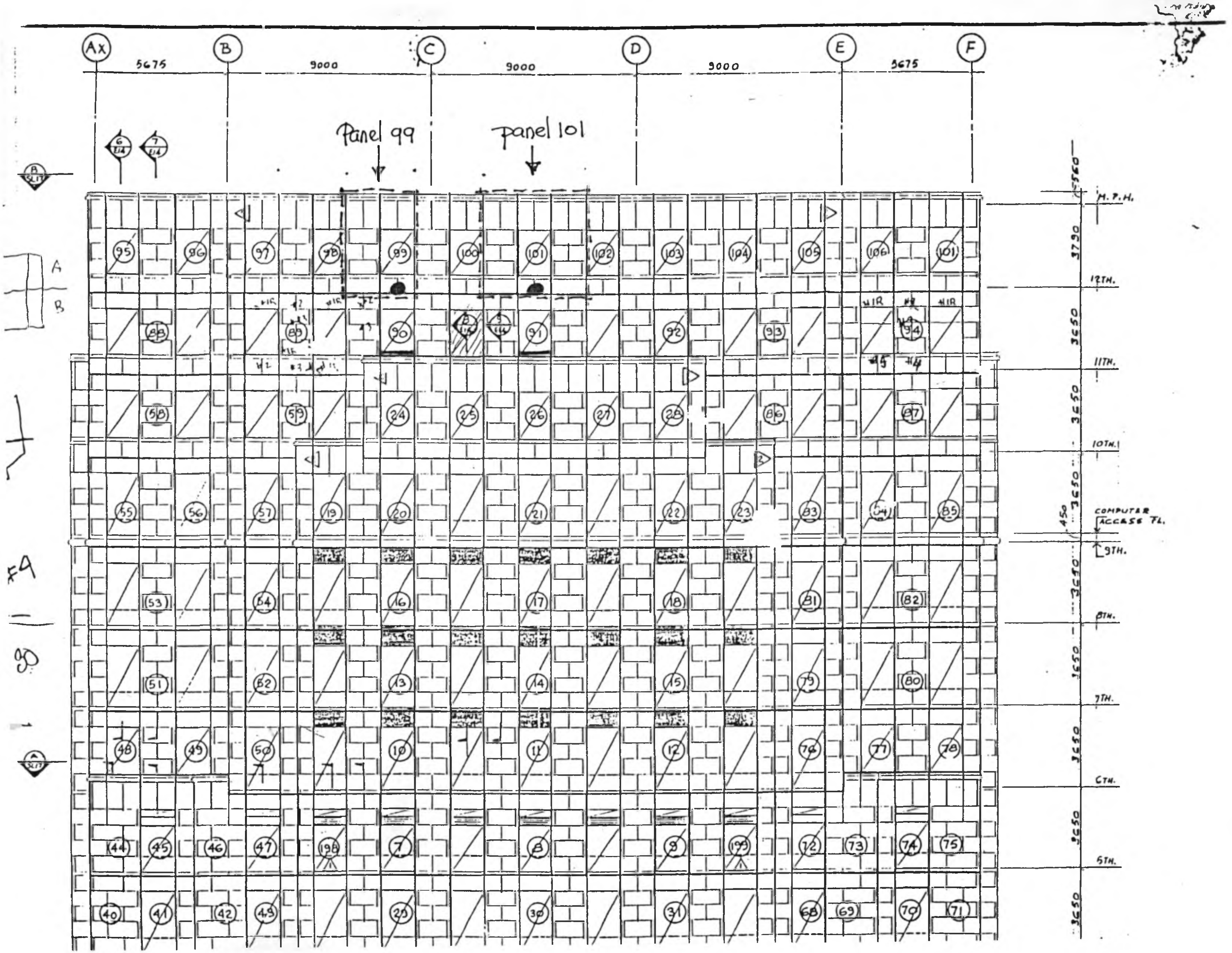


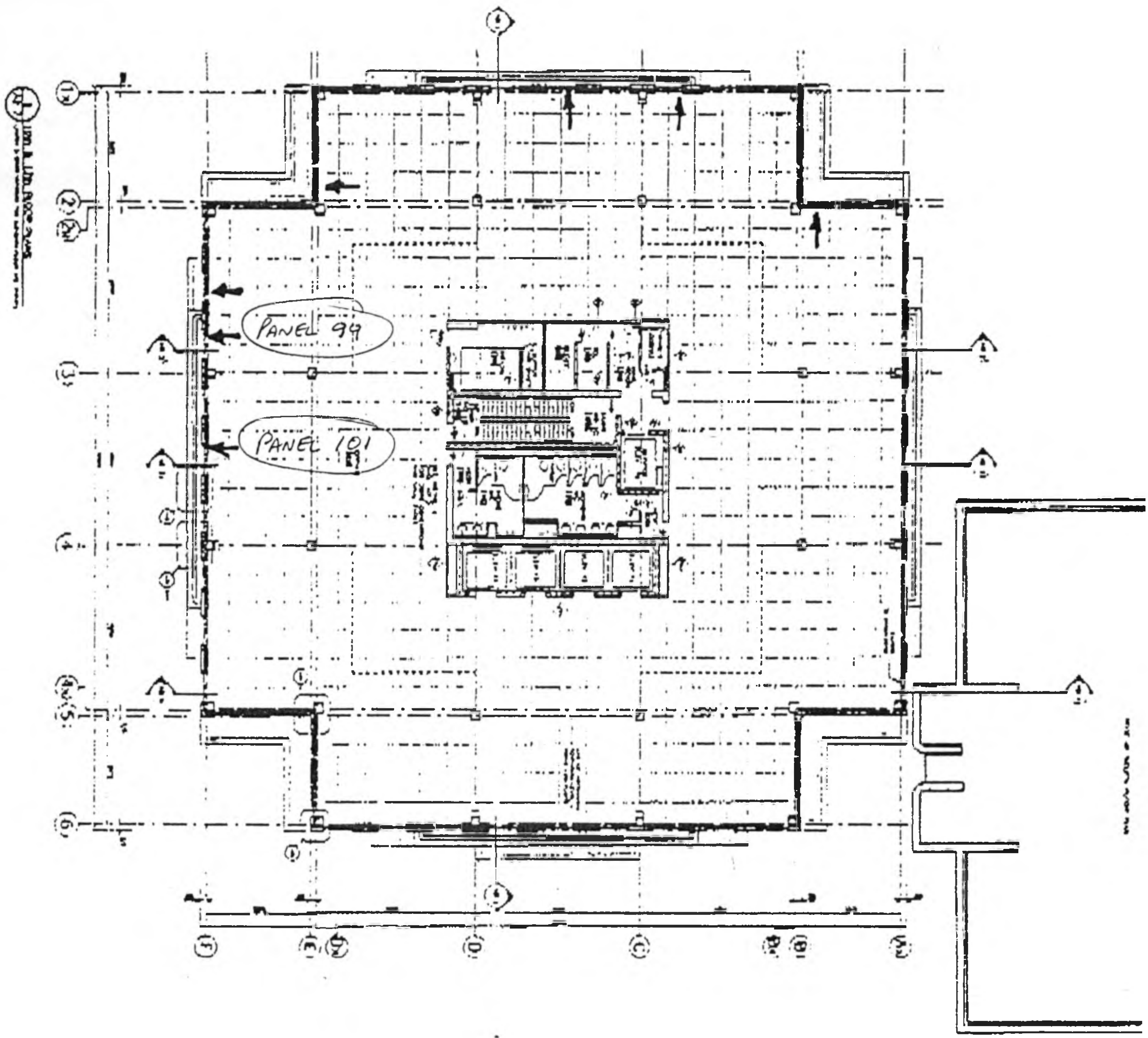
Figure A14-Curtain Wall Spandrel Panel
Dewpoint Temperature Analysis
Condensation
No condensation
Temperature Difference (oC)
2
0
-2
-4
-6
-8
2
4
6
8
10
12
14
16
18
20
22
24
Time (hours for Nov. 6, 1994)

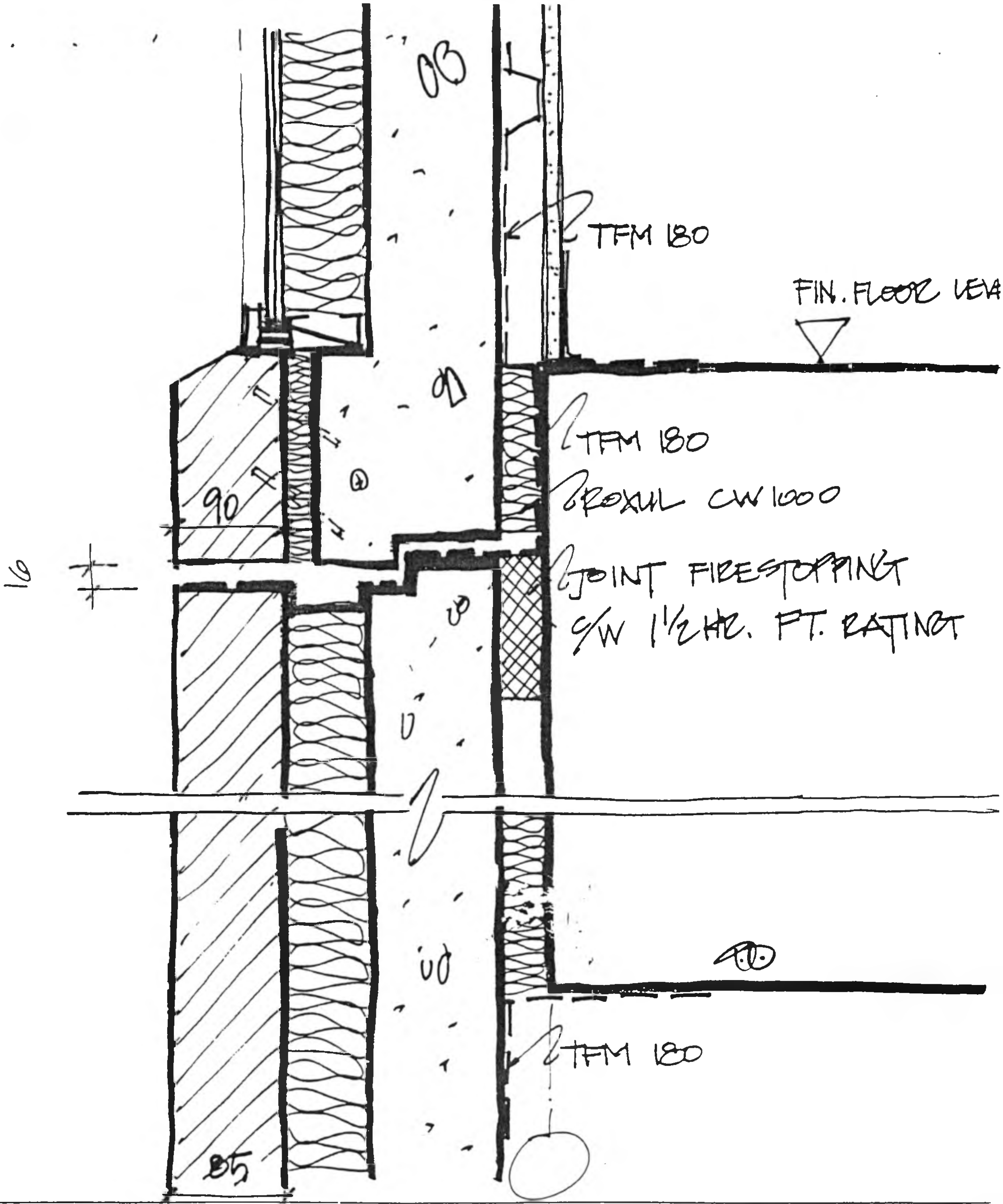
Appendix
"C"

Field Monitoring,
Canada Life Building.



Ax
B
C
D
E
F
5675
9000
9000
9000
5675
Panel 99
Panel 101
M.P.H.
12TH.
11TH.
10TH.
COMPUTER ACCESS FL.
9TH.
8TH.
7TH.
6TH.
5TH.
560
3790
3650
450
A
B


PANEL 99
PANEL 101



ADASON PROPERTIES LIMITED ADDITION TO 190 SIMCOE STREET TORONTO ONTARIO	SECTION @ HORIZONTAL PANEL TO PANEL JOINT Scale NTS Drawn by T.T. Date Aug. 13/92 Revision	ARCHITECTS ENGINEERS SHORE TILBE IRWIN & PARTNERS	9027 Drawing SK-2

Pressure Equalization at Canada Life Panel 89

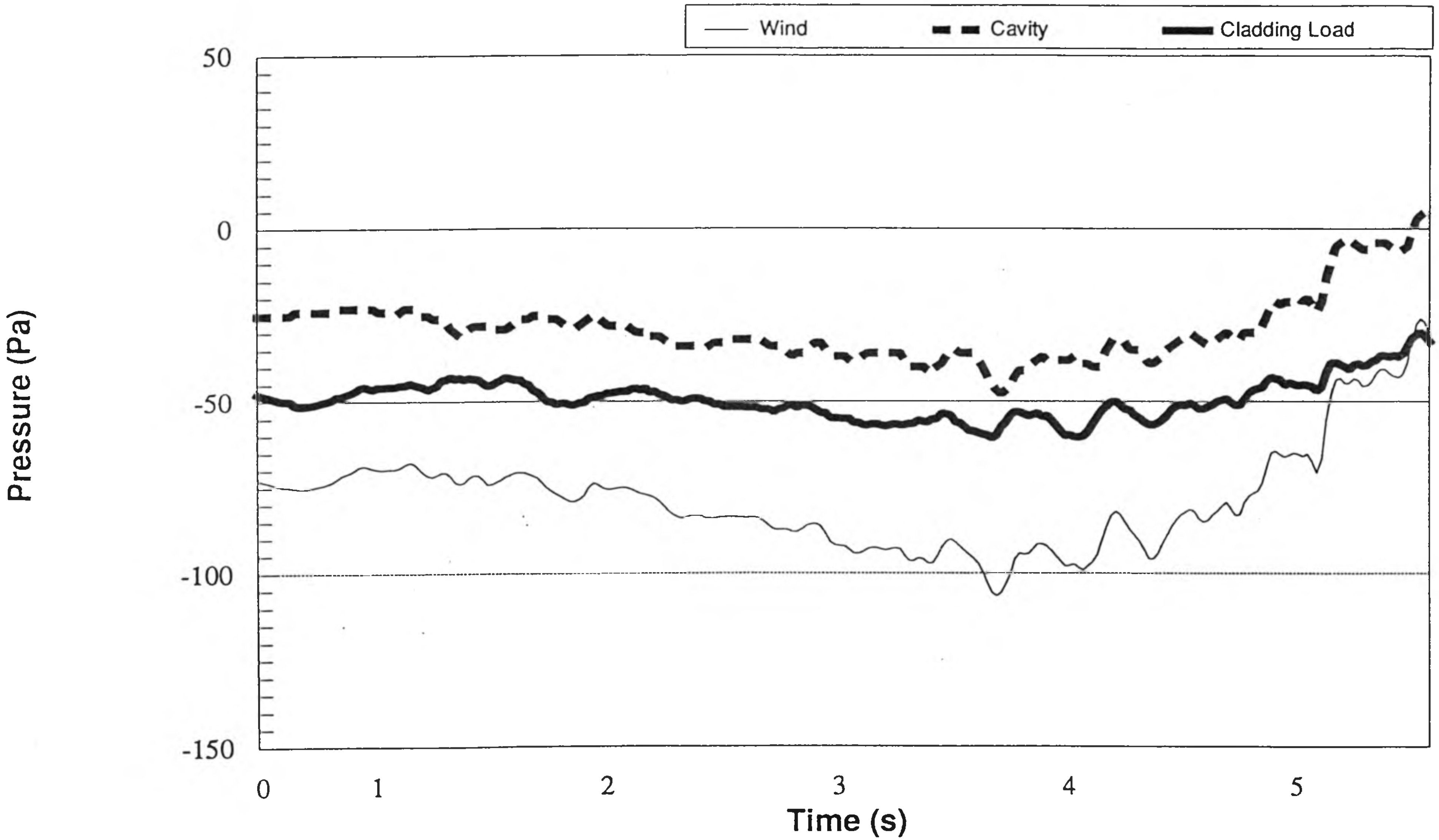


Figure B1

Figure (1): Relative Humidity Inside and Outside Wall Cavity
Canada Life Building, 12th Floor, West Elevation
Centre Panel #101

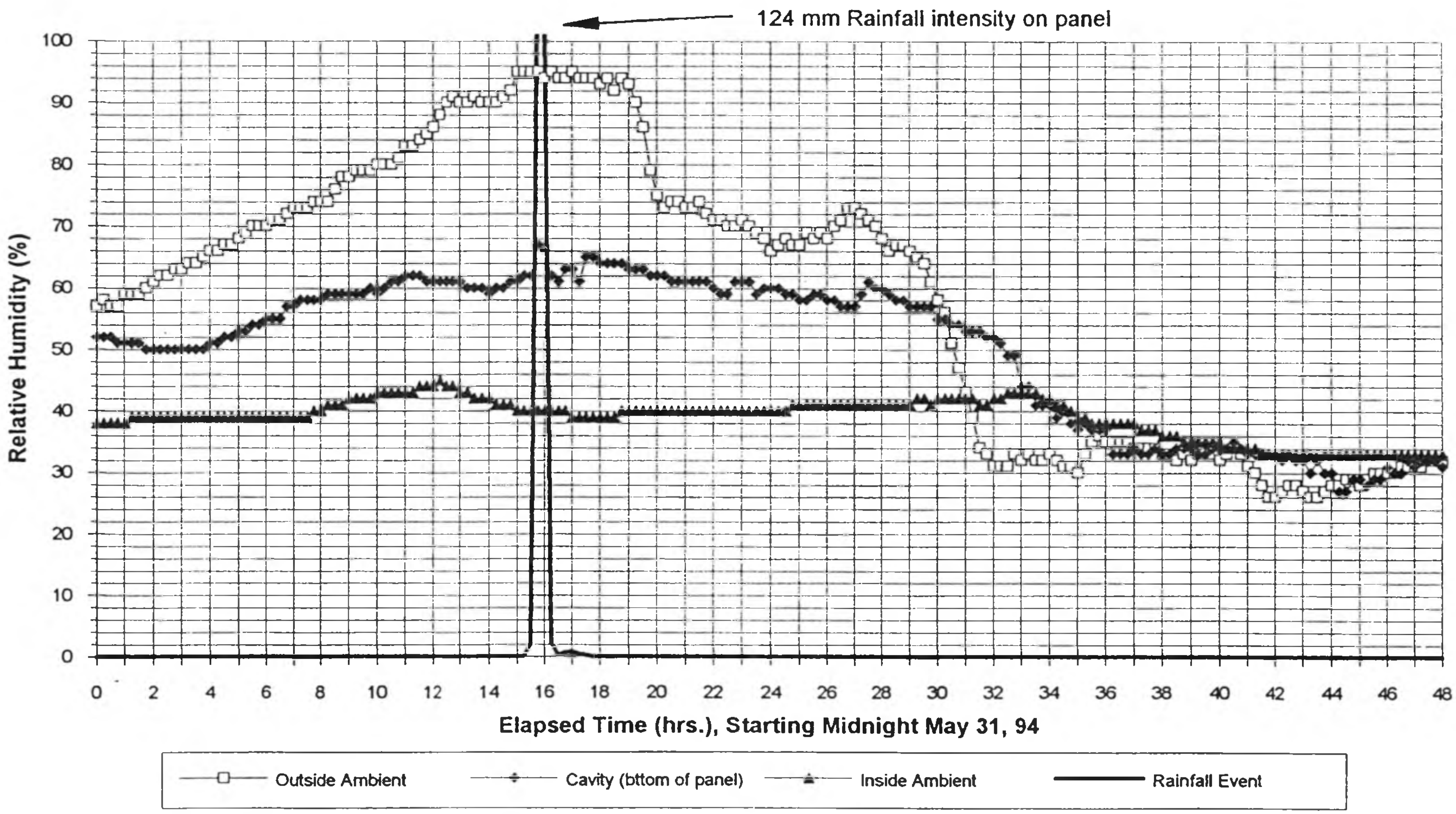


Figure B2

CMHC.XLS Chart 6

Figure (2): Relative Humidity Inside and Outside Wall Cavity
Canada Life Building, 12th Floor, West Elevation
Panel #99

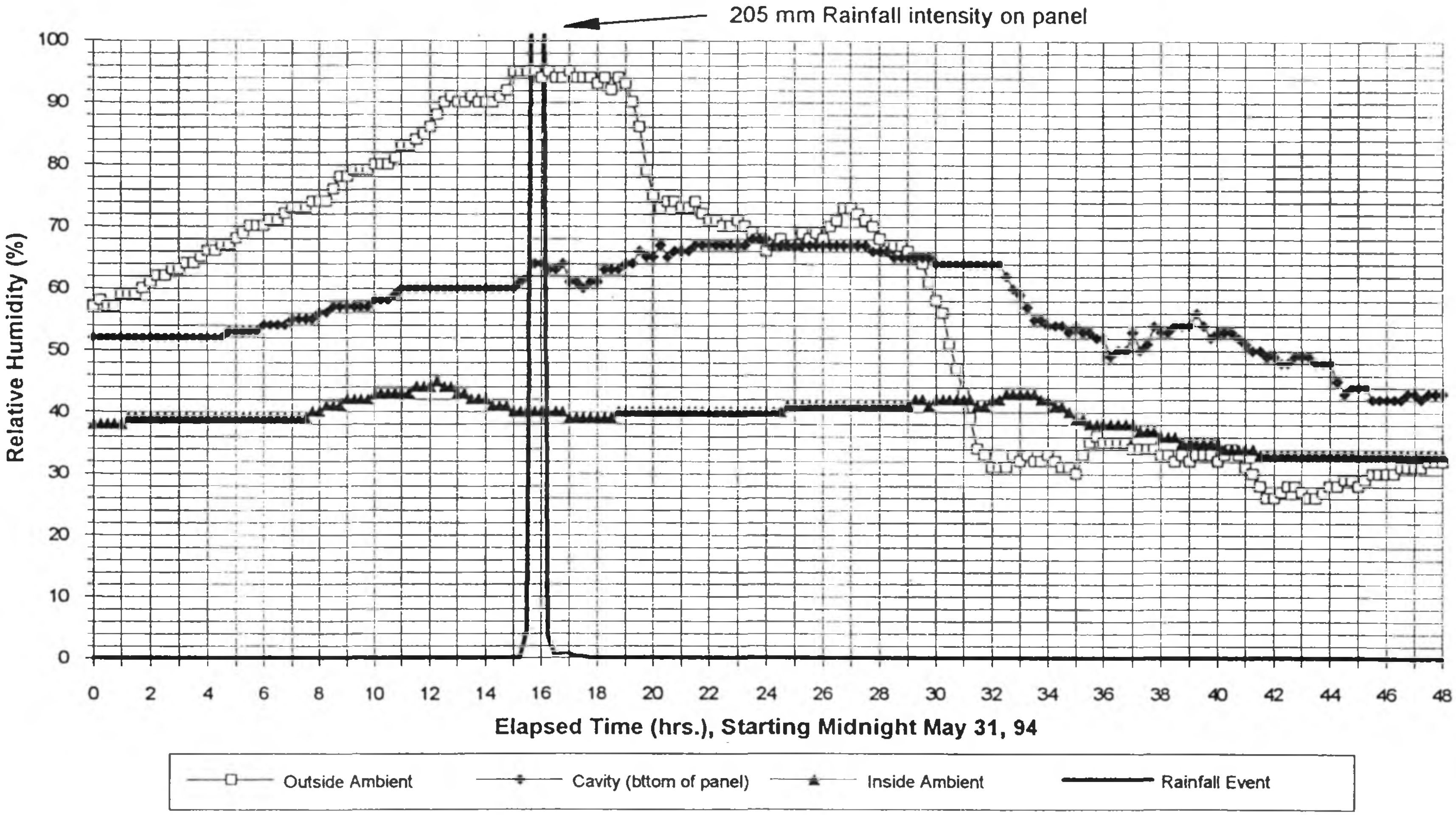


Figure B3

Figure (3): Air Humidity Ratio Inside and Outside Wall Cavity
Canada Life Building, 12th Floor, West Elevation
Centre Panel #101

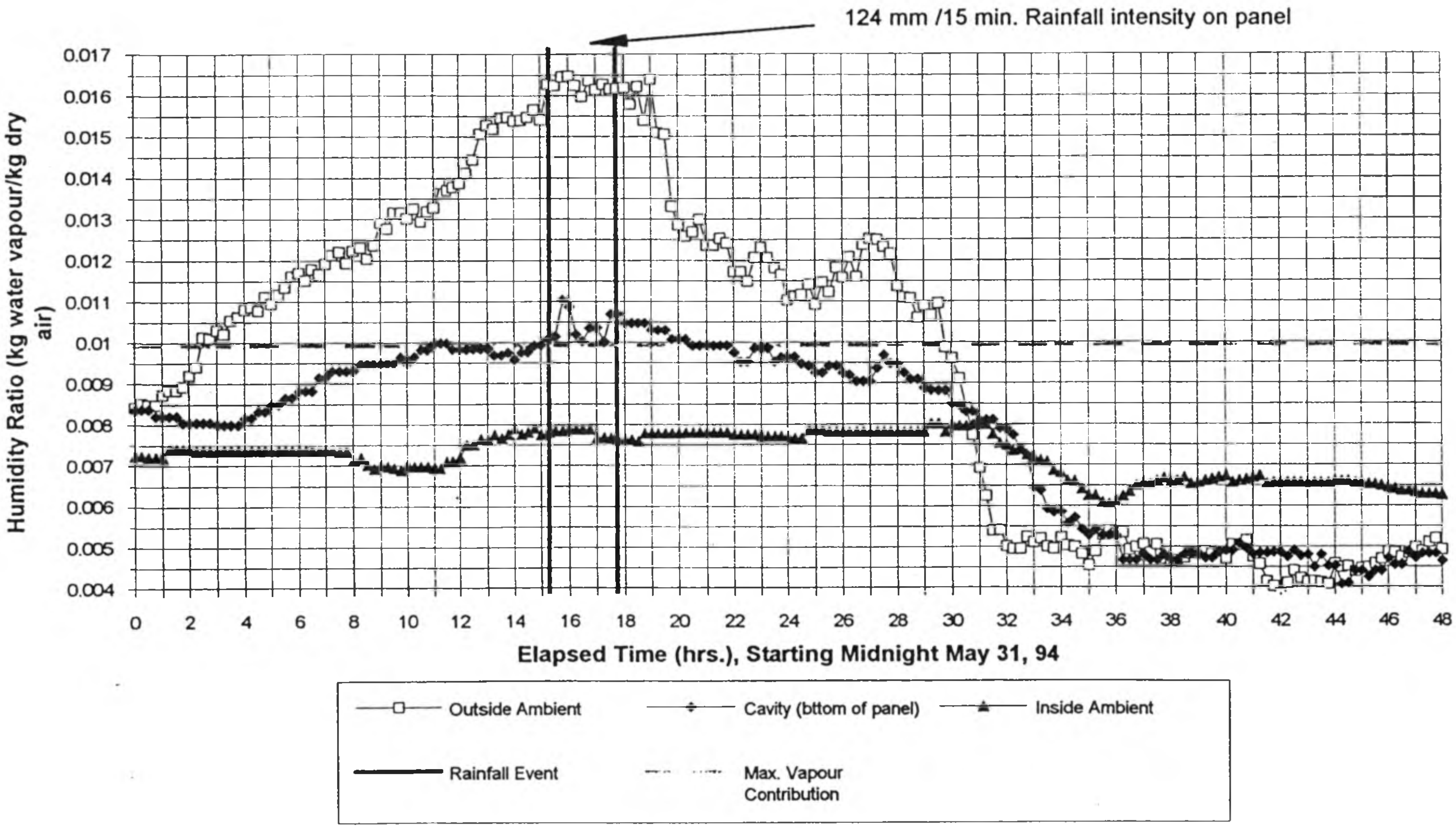
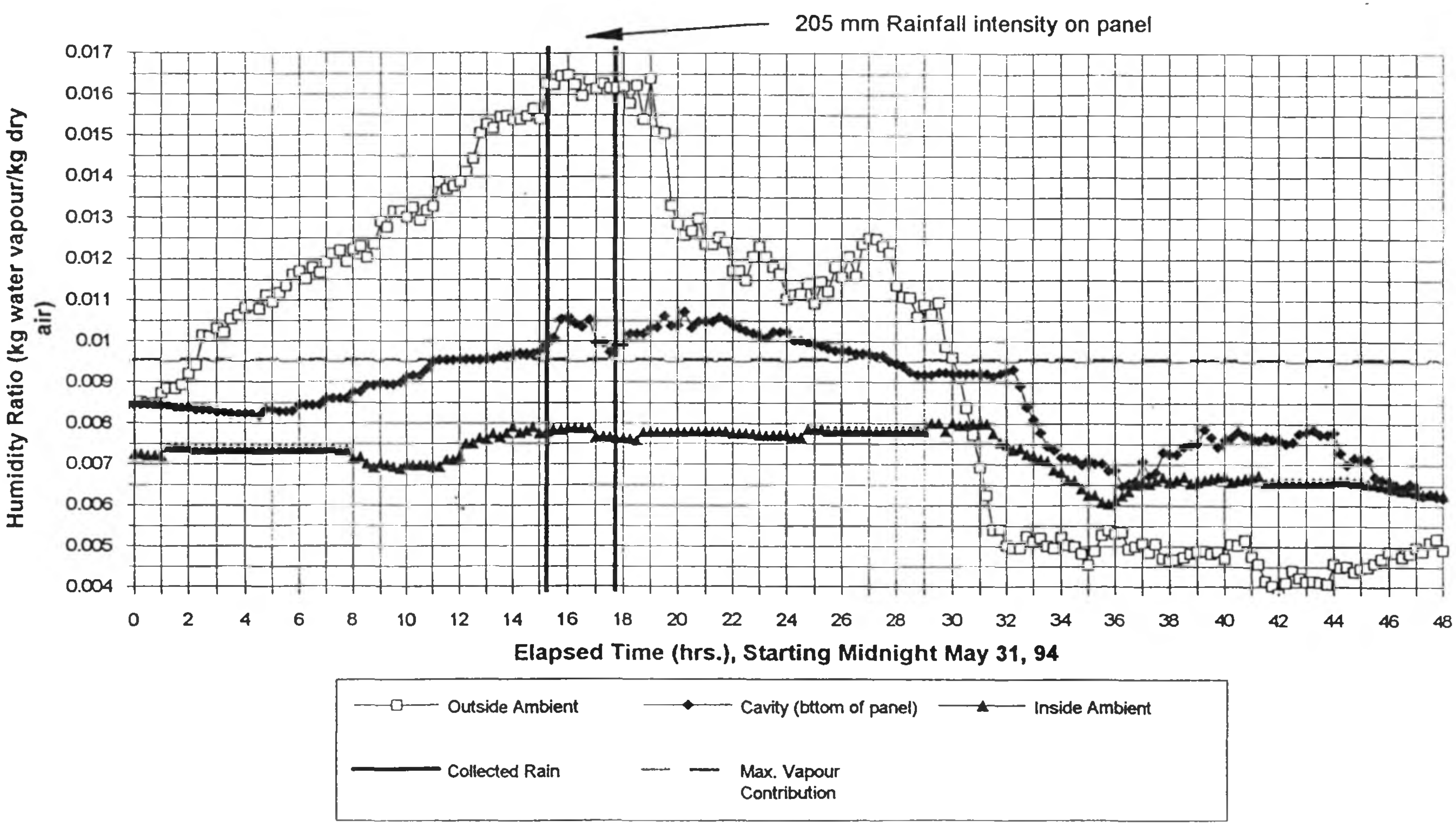


Figure B4

CMHC.XLS Chart 9

Figure (4): Air Humidity Ratio Inside and Outside Wall Cavity
Canada Life Building, 12th Floor, West Elevation
Panel #99



CMHC.XLS Chart 10

Figure B5